Total factor productivity and convergence of China's textile industry

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ABSTRACT – REZUMAT

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The scale of China's textile industry has grown to be the largest in the world with massive factor input. There is a strong demand China's textile industry, and as a traditional industry, should improve total factor productivity (TFP) to realize technology-driven and sustainable development. TFP is a commonly used indicator to measure the level of technological progress. But regional textile industry development in China is seriously unbalanced and regional TFP is quite different from each other. It is worthwhile to estimate the textile industry TFP of China and different regions, analyse the changing trend and test for their convergences. This paper firstly uses the nonparametric DEA-Malmquist index method to measure and analyse the TFP and its evolution of China's textile industry during 2007–2018 at the nation, region and province levels. Then it uses the coefficient of variation to test for σ-convergence of China's and regional textile industry TFP. It also constructs an absolute β-convergence regression equation and panel data model, respectively to test for absolute β-convergence and conditional β-convergence and determine whether the TFP of each region will also converge to its own steady-state or not. The research results help explore the future development model of China's textile industry and provide corresponding policy suggestions for the upgrading and sustainable development of the industry.

Keywords: *China's textile industry, convergence, DEA-Malmquist index method, efficiency-driven development, total factor productivity*

Productivitatea totală a factorilor și convergența industriei textile din China

Industria textilă din China a devenit cea mai mare din lume, cu aport masiv de factori. Există o cerere puternică în industria textilă din China și în calitate de industrie tradițională, ar trebui să-și îmbunătățească productivitatea totală a factorilor (TFP), pentru a realiza o dezvoltare sustenabilă și bazată pe tehnologie. TFP este un indicator utilizat frecvent pentru a măsura nivelul progresului tehnologic. Dar dezvoltarea regională a industriei textile din China este serios dezechilibrată, iar TFP regională este destul de diferită. Merită să estimăm TFP industriei textile din China și din diferite regiuni, să analizăm tendința în schimbare și să testăm convergențele acestora. Această lucrare utilizează în primul rând metoda neparametrică a indicelui DEA-Malmquist pentru a măsura și analiza TFP și evoluția acesteia în industria textilă din China în perioada 2007–2018 la nivel de țară, regiune și provincie. Apoi folosește coeficientul de variație pentru a testa convergența σ a TFP din China și industria textilă regională. De asemenea, construiește o ecuație de regresie a convergenței β absolute și un model de date panou, respectiv pentru a testa convergența β absolută și convergența β condiționată și pentru a determina dacă TFP fiecărei regiuni va converge, de asemenea, la propria sa stare de echilibru sau nu. Rezultatele cercetării ajută la explorarea modelului de dezvoltare viitor al industriei textile din China și oferă sugestii de politici corespunzătoare pentru modernizarea și dezvoltarea durabilă a industriei.

Cuvinte-cheie*: industria textilă din China, convergență, metoda indicelui DEA-Malmquist, dezvoltare bazată pe eficiență, productivitate totală a factorilor*

INTRODUCTION

After decades of development, the scale of China's textile industry has grown to be the largest in the world, with a share exceeding 1/2 of the global market, making an important contribution to China's economic growth. Traditionally, factor input is considered the main driving force of economic growth. The growth of China's textile industry, like other industries, mainly relies on large-scale investment and cheap factor input. However, factor input will be difficult to sustain as the marginal productivity decreases. At present, China's textile industry dominated by labour-intensive enterprises is facing a series of production and operation pressures. The prices of raw materials, electricity, water and other factors are constantly rising, and the supply of industrial land is becoming increasingly tight, which severely limits the sustainable profitability and development of China textile industry.

The endogenous growth theory considers technological progress as the main contributor to economic growth and can maintain the sustainable development of an industry. In the face of the challenges above, there is little doubt China's textile industry will transform from a factor-input development model to a technology-driven model and keep sustainable development by improving total factor productivity (TFP). Due to different economic foundations, industrial

foundations and regional environmental conditions, the textile industry development of different regions in China is seriously unbalanced and regional TFP is also quite different from each other. How will the regional textile industry TFP change with time? Will the regional gap gradually narrow until it tends towards convergence? If there is convergence, which convergence mode is it? Hence, it is worthwhile to estimate the textile industry TFP of China and different regions, analyse the changing trend and test for their convergences.

TFP is a commonly used indicator to measure the level of technological progress in academics, which refers to the contribution of technological and non-technological factors to economic growth after labour and capital inputs are ruled out, which includes technological progress, management improvement and institutional innovation. Since the concept of total factor productivity was put forward, TFP has always been a hotspot of academia and there are fruitful research results in this field. Based on Baumol [1] and Robert's [2, 3] research on the convergence of economic growth, Stephen [4] systematically proposed an analytical framework of TFP convergence and tested TFP convergence for OECD countries. Then the academia has carried out various researches on TFP convergence at the nation level [5, 6] and industry level [7, 8] with this framework. By contrast, the research on TFP of China's textile industry is relatively limited and no literature on TFP convergence has been retrieved. Feng [9] measured and analysed the TFP and its change in the provincial textile industry in China during 2004–2014. Fu [10] found that both export and FDI have positive technology spillover effects on the TFP of China's textile and garment industry. Xie [11] suggested that the supply-side structural reforms could also improve the TFP of China's textile and garment industry. But there are some issues in the current research, such as the failure to distinguish the textile industry from the garment industry, the missing of research at the regional level and the lack of study on convergence of the textile industry TFP.

Given the shortcomings and limitations of the previous research, this article divides China into four regions: eastern, central, western and north-eastern according to the region classification standards of the National Bureau of Statistics of China. This paper firstly uses the nonparametric DEA-Malmquist index method to measure and analyse the TFP and its evolution of China's textile industry during 2007–2018 at the nation, region and province level. Then, it tests for σ-convergence and β-convergence of TFP in China and various regions. The results will help explore the future development model of China's textile industry and provide corresponding policy suggestions for upgrading and sustainable development of the textile industry. The textile industry studied in this paper refers to the textile industry (double-digit industry code: 17) by the national economy classification standard (GB/T 4754-2011), excluding the textile and garment industry (18).

MEASUREMENT METHODOLOGY OF TFP

This paper uses the nonparametric DEA-Malmquist method to measure the TFP of China's textile industry. At a given technology frontier, TFP change is measured by calculating the ratio of the Shephard distance function of two production units. To avoid the arbitrary selection of technology frontier, Fare [12] constructed the TFP Malmquist index (TFP index) from t to t+1 period:

$$M_0(x_t, y_t, x_{t+1}, y_{t+1}) = \left[\frac{D_0^{t+1}(x_{t+1}, y_{t+1})}{D_0^{t+1}(x_t, y_t)} \times \frac{D_0^{t}(x_{t+1}, y_{t+1})}{D_0^{t}(x_t, y_t)}\right]^{1/2} \quad (1)$$

TFP index is the ratio of TFP in period t+1 and period t. If $M_0(x_t, y_t, x_{t+1}, y_{t+1}) > 1$, it indicates that TFP increases from period t to period t+1, otherwise decreases.

TFP index can be decomposed into the product of technological efficiency index (TE) and technological progress index (TP), representing the technological efficiency change and technological change respectively. TP reflects a frontier shift trend at different periods. TE can be further decomposed into pure technological efficiency index (PE) and scale efficiency index (SE). So, the decomposition of the TFP index can be expressed as:

$$TFPch = TEch \times TPch = PEch \times SEch \times TPch \quad (2)$$

Two sets of input data (labour and capital) and one set of output data (effective output) are collected to calculate the TFP index. Gross industrial output value represents the effective output. An average number of regional textile industry workers is used to represent the labour factor. Capital stock represents the capital factor and is calculated by the perpetual inventory method.

TFP OF CHINA'S TEXTILE INDUSTRY

After calculation, this paper obtains the TFP index and its composition of China's textile industry at the nation, region and province levels during 2007–2018 (table 1). Due to space limitations, table 1 only lists the average TFP index and its composition.

The mean TFP indexes of China's textile industry at the nation, region and province levels are all greater than 1 (table 1), showing that China's textile industry TFP has maintained a steady growth. At the national level, the mean TFP index, TP index and TE index of China's textile industry are 1.216, 1.233 and 0.988, which indicates the average growth rates (AGRs) of TFP, TP and TE are 21.6%, 23.3% and –1.2% respectively. It can be concluded that the major contributor to China's textile industry TFP growth is technological progress and the TFP growth is technology-driven. The average annual contribution of technological efficiency to TFP growth is negative, which implies that the textile industry still has a long way ahead before shifting into efficiency-driven development mode.

Table 1

MEAN TFP INDEX AND ITS COMPOSITION OF CHINA'S TEXTILE INDUSTRY DURING 2007–2018

Area	TE	TP	PE	SE	TFP	Area	TE	TP	PE	SE	TFP
China	0.988	1.233	1.000	0.988	1.216	Hainan	0.845	1.512	0.844	0.998	1.219
Eastern	1.000	1.186	1.000	1.000	1.186	Western	0.983	1.290	0.967	1.012	1.254
Beijing	1.000	1.362	1.000	1.000	1.362	Inner Mongolia	1.024	1.511	1.053	0.974	1.506
Tianjin	0.971	1.488	0.965	1.000	1.374	Guangxi	0.835	1.512	0.840	0.994	1.204
Hebei	0.914	1.495	0.942	0.972	1.303	Chongqing	0.958	1.482	0.955	1.007	1.363
Fujian	0.812	1.520	0.848	0.957	1.185	Sichuan	0.874	1.503	0.879	0.992	1.256
Guangdong	0.866	1.459	0.990	0.880	1.244	Guizhou	0.863	1.517	0.901	0.957	1.262
Hainan	1.136	1.475	1.158	0.969	1.597	Yunnan	0.899	1.509	0.959	0.937	1.279
Jiangsu	0.861	1.519	0.999	0.862	1.255	Tibet	0.852	1.494	1.000	0.852	1.285
Shanghai	0.977	1.379	1.000	0.977	1.339	Shaanxi	0.912	1.503	0.904	0.999	1.309
Zhejiang	0.860	1.519	1.000	0.860	1.257	Gansu	0.954	1.492	0.967	0.985	1.352
Shandong	0.907	1.502	1.028	0.878	1.301	Qinghai	1.030	1.487	1.092	0.945	1.481
Central	0.946	1.280	0.946	1.000	1.204	Ningxia	0.821	1.504	0.827	0.992	1.172
Shanxi	0.975	1.504	0.980	0.994	1.385	Xinjiang	0.839	1.497	0.826	1.017	1.196
Anhui	0.837	1.509	0.858	0.972	1.206	Northeastern	1.021	1.330	1.000	1.021	1.352
Jiangxi	0.830	1.497	0.818	1.014	1.197	Liaoning	0.982	1.512	1.003	0.975	1.436
Henan	0.853	1.503	0.882	0.966	1.220	Jilin	1.274	1.499	1.284	0.994	1.806
Hubei	0.837	1.506	0.861	0.968	1.195	Heilongjiang	1.027	1.496	1.021	1.007	1.445

At the region level, textile industry TFP growth in each region has a negative correlation with its economic development. The AGRs of north-eastern, western, central and eastern textile industry TFP are 35.2%, 25.4%, 20.4% and 18.6% respectively. Those of the north-eastern and western regions are both greater than that of the entire nation (21.6%), followed by the central region. As the most developed region, the AGR of the eastern region has lagged behind the nation and is the smallest of all the regions. The AGRs of SE in eastern and central regions are 0% and –0.05%, indicating that in the context of backward overcapacity and rising factor cost, it will hinder TFP growth to some extent if continuing to improve industrial agglomeration level in these regions.

At the province level, technological progress is also the major source of TFP growth, consistent with the overall trend of China. The mean TP indexes of all provinces are also greater than 1, while TE indexes of only six provinces are greater than 1. The mean TFP indexes of Shandong, Jiangsu, Zhejiang, Henan and Guangdong (the five most developed provinces in the textile industry) are 1.301, 1.255, 1.257, 1.220 and 1.244 respectively, higher than that of the nation (1.216). It shows that the technological progress of these provinces still plays an important role in promoting China's textile industry TFP growth.

CONVERGENCE TEST OF CHINA'S TEXTILE INDUSTRY TFP

Interestingly as a leader, the eastern textile industry is the most developed, but its TFP growth is the least as shown in table 1 and is closely followed by other regions, especially the western region. Does this mean the regional gap of the textile industry TFP will gradually narrow? Is there a possibility of convergence in regional textile industry TFP? If there is convergence, what's the mode of convergence? To answer these questions, referring to the analysis framework of TFP convergence proposed by Stephen [4], this paper studies the TFP convergence of China's textile industry. Convergence denotes that in a closed and effective economic environment, there is a negative correlation between the initial static indicators and economic growth rates of different economies (such as a country, a region, or a certain family). There are two types of convergence: σ-convergence and β-convergence. According to whether the economies converge at the same stable state, β-convergence falls under two categories: absolute β-convergence and conditional β-convergence. The absolute β-convergence takes other economies' steady state as the reference frame, each economy will reach the same growth rate and growth level over time. While the conditional β-convergence takes its steady-state as the reference frame.

σ-convergence

This paper uses the coefficient of variation to test for σ-convergence of China's and regional textile industry TFP. The coefficient of variation is calculated as follows:

$$CV_{i,t} = \frac{\sigma_{i,t}}{\overline{TFP}_{i,t}} \quad (3)$$

$CV_{i,t}$, $\sigma_{i,t}$ and $\overline{TFP}_{i,t}$ are the coefficient of variation, standard deviation and mean value of textile industry TFP index in region *i* at period *t* respectively.

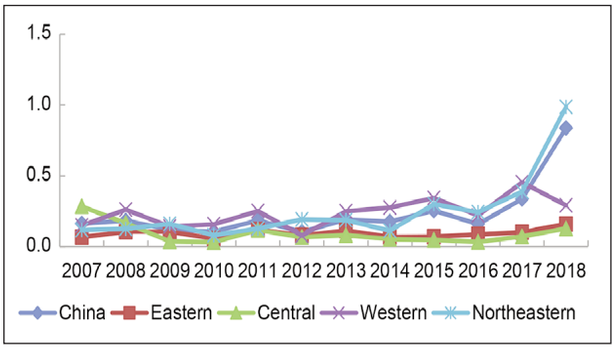

Fig. 1. The coefficient of variation of China's and regional textile industry TFP index

Figure 1 presents that the CV of China's and regional textile industry TFP index are in the fluctuating growth trend and the CV of 2018 is the largest. So, it can be concluded that China's and regional textile industry TFP during 2007–2018 don't show significant σ-convergence and there are complicated changes and restructuring within China's textile industry during that period. The evolutions of CV in eastern and central regions have remained the same, indicating that textile industry restructuring in these two neighbouring regions has been keeping close linkage and coordination. The CV in the western region fluctuates greatly, which may be related to the rapid development of the western textile industry, especially in Xinjiang. However, the CV of the north-eastern region displays greater time-varying volatility and its change trend is also different from the others. This could be attributed to the fact that there are only three provinces in the north-eastern region and the sample is too small.

Absolute β-convergence

Absolute β-convergence tests whether China's and regional textile industry TFP will converge towards the same steady-state. That is, whether the TFP growth rate is negatively correlated with its initial level and whether there is the "catch-up effect" between the backward and developed regions. This paper constructs the absolute β-convergence regression equation as below:

$$\ln\left(\frac{TFP_{i,t+T}}{TFP_{i,t}}\right) / T = \alpha + \beta \ln TFP_{i,t} + \varepsilon_{i,t} \qquad (4)$$

$TFP_{i,t}$ and $TFP_{i,t+T}$ are the textile industry TFP index in province *i* at period *t* and *t+T* respectively. *T* is the time span. α is the constant, β is the convergence coefficient and $\varepsilon_{i,t}$ is the random disturbance. If the $\beta<0$, it indicates evidence of absolute β-convergence. As the absolute β-convergence analysis method is cross-sectional regression at only one period, it may not be able to explain the continuity of convergence and its regression results are highly sensitive to the time span. Therefore, this paper divides the sample time span into two periods (2007–2012 and 2013–2018) and tests for absolute β-convergence of the two periods respectively. At the same time, in order to reduce the influence of outliers, this paper equally divides the sample time span (2007–2018) into six periods and takes the average value of every two years' TFP index as the TFP index of each period. Then it tests for absolute β-convergence. The convergence results are shown in table 2. The absolute β-convergence coefficients of China, eastern, central and western regions are –0.117, –0.113, –0.098 and –0.209 respectively (table 2). They're all negative and have passed the significance test at the corresponding level, indicating evidence of absolute β-convergence in the textile industry TFP index among China and these three regions. This means that the textile industry TFP growth rate of each province is negatively correlated with its initial level. Provinces with low TFP demonstrate a significant "catch-up effect" towards high TFP provinces. The provincial TFP gap will gradually decrease and eventually converge towards the same steady-state. Convergence test results in different periods also confirm this conclusion, except for the result of the central region in 2013–2018. At the same time, it can also be discovered that the absolute β-convergence coefficients of China, eastern, central and western regions in 2013–2018 are bigger than those in 2007–2012, revealing that the "catch-up effect" of the provincial textile industry TFP in 2013–2018 is greater than that in 2007–2012 and TFP of backward

Table 2

THE ABSOLUTE β-CONVERGENCE TEST RESULTS

	2007–2018		2007–2012		2013–2018	
	β	Adj-R^2	β	Adj-R^2	β	Adj-R^2
China	–0.117***	0.385	–0.174***	0.669	–0.374***	0.477
Eastern	–0.113***	0.919	–0.190**	0.422	–0.288***	0.650
Central	–0.098***	0.853	–0.143***	0.909	–0.176	0.160
North-eastern	0.738	0.895	–0.397	0.865	–1.085	0.461
Western	–0.209**	0.426	–0.149***	0.745	–0.239***	0.542

Note: ***, **, * represent significance levels of 1%, 5% and 10%, respectively.

Table 3

THE CONDITIONAL β-CONVERGENCE TEST RESULTS					
	China	**Eastern**	**Central**	**North-eastern**	**Western**
β	–0.919***	–0.476***	–0.466***	–0.764**	–1.072***
Adj-R^2	0.318	0.234	0.285	0.099	0.527
F-statistics	6.118	34.356	25.552	4.502	11.044
Model	RE	RE	RE	RE	FE

Note: ***, **, * represent significance levels of 1%, 5% and 10%, respectively.

provinces grows faster during this period. In addition, the north-eastern region does not exhibit evidence of absolute β-convergence.

Conditional β-convergence

After studying absolute β-convergence, this paper constructs the following panel data model to test for conditional β-convergence of China's and regional textile industry TFP and determine whether it will also converge to its own steady-state or not. The panel data model has the advantages of a large sample size, more reliable parameter estimation and reduced multicollinearity. This paper first uses the Durbin-Wu-Hausman test to examine the fixed effect and random effect of textile industry TFP of China and each region, then determine which estimation model is more appropriate, the fixed-effect model (FE) or random effect model (RE). The results are shown in table 3.

$$\ln\left(\frac{TFP_{i,t+1}}{TFP_{i,t}}\right) / T = \alpha + \beta \ln TFP_{i,t} + \varepsilon_{i,t} \qquad (5)$$

$TFP_{i,t}$ and $TFP_{i,t+1}$ are the textile industry TFP index in province i at period t and t+1 respectively. α is the constant, β is the convergence coefficient and $\varepsilon_{i,t}$ is the random disturbance. If $\beta<0$, conditional β-convergence occurs.

The conditional β-convergence coefficients of China and the eastern, central, north-eastern and western regions are –0.919, –0.476, –0.466, –0.764 and –1.072 respectively (table 3). They're all negative and all of them have passed the significance test at the corresponding level, indicating that there are conditional β-convergence in the textile industry TFP index of China and all four regions. When a region has the higher textile industry TFP in the former period, its latter TFP growth rate will gradually slow down. Textile industry TFP index in China and all four regions will ultimately converge to their own steady state.

CONCLUSIONS

This paper estimates and analyses the TFP and its evolution of China's textile industry during 2007–2018 by using the nonparametric DEA-Malmquist index method at the nation, region and province levels respectively. Then, it tests for σ-convergence and β-convergence of TFP at the nation and region level. The research results are as follows: Textile industry TFP of the entire country, each region and each province have maintained a steady growth. The major contributor of TFP growth is technological progress and the contribution of technological efficiency to TFP growth is basically negative. Textile industry TFP growth in each region has a negative correlation with its economic development. The TFP growth rates of north-eastern and western regions are both greater than that of the nation, followed by the central region. As the most developed region, the growth rate of the eastern region has lagged behind the nation.

Convergence test results show that there are absolute β-convergence and conditional β-convergence, but no σ-convergence in textile industry TFP of China, eastern, central and western regions. The provincial TFP gap will gradually decrease and will not only converge towards their own steady-state but will eventually converge towards the same steady-state. Convergence test results at different periods provide evidence that the absolute β-convergence coefficients of these regions in 2013–2018 are greater than those in 2007–2012, which indicates that the "catch-up effect" of provincial textile industry TFP in 2013–2018 is greater than that in 2007–2012 and the textile industry TFP of backward provinces grow faster at this period. It also concludes there is only conditional β-convergence in the north-eastern region.

The above research results suggest that China should continue to promote the technological progress of the textile industry, improve its TFP to drive it to transfer to the efficiency-driven and sustainable development at last.

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