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Measurement of Technological Progress in China's Manufacturing Industry and Analysis on its Influencing Factors

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ABSTRACT

As the biggest manufacturing country, China's manufacturing industry still didn't change the situation of "big but not strong". Whether can China realize the transformation from "made in China" to "Chinese creation" and "Chinese wisdom made" successfully in the future, technological progress is the key factor. Through the method of DEA-Malmquist and system GMM, this paper measures the technological progress situation of China's manufacturing industries, and empirically tests its influencing factors based on panel data of 20 manufacturing industries in China during 2001-2011. The result shows that, research personnel investment and enterprise scale are key factors on promoting TFP of China's manufacturing industry, but enterprise scale expansion also brings the loss of technical efficiency. Industry agglomeration has significantly positive impact on technological progress index. However, research fund investment has significantly negative impact on technological progress index, which means that there exists inefficient use of scientific research funds. In order to improve manufacturing industry upgrade, further increase research personnel input is necessary. At the same time, it needs to optimize the allocation of scientific research funds, guide the agglomeration of high-tech manufacturing, as well as to increase the guidance and support of technical innovation on small and medium enterprises.

Keywords: China's manufacturing industry; TFP; technological progress; technical efficiency; influencing factors

INTRODUCTION

Since joining the WTO in 2001, China has made great progress in the field of manufacturing. According to the data of the United Nations Industrial Development Organization (UNIDO), China's manufacturing industry added value attained 10.39 trillion US dollars in 2010, accounting for 18.69% of the global manufacturing sector, exceeded the United States which accounting for 17.7% and became the first in the world. The global proportion of China's manufacturing industry has further increased to 23.84% in 2015, exceeding 7.3 percent of that of the United States. Obviously, China's manufacturing industry firmly ranked first in the world in the production scale. However, China's manufacturing industry is still not out of the embarrassing situation of "big but not strong". To enhance the development level of its manufacturing industry, Chinese government formally launched the "Made in China 2025" in May 2015, sketching out a grand blueprint for building a manufacturing power.

The key to industrial upgrading or industrial structure optimization lies in technological progress(Fu et al.,2014; Liang and Zhan, 2005). One question that arises from this is whether China's manufacturing industry has the technical conditions for upgrading from "made in China" to "created in China" or "Chinese wisdom made". This is critical to the success of the upgrade, not only depend on the future innovation capacity of the manufacturing sector, but also has closely relation to the level of technological progress and its key influencing factors of China's manufacturing industry in the past at a large degree. In view of this, and also taking account of total factor productivity (TFP) is a commonly used indicator to measure technology level, the second section will use DEA-Malmquist method to measure TFP and its decomposition of China's manufacturing industry on the basis of using provincial data of 20 major manufacturing industries of China. And the third section will use the system GMM estimation method to carry on the empirical analysis of influencing factors on TFP, so as to discover the key factors to promote the technological progress of China's manufacturing industry.

MEASUREMENT OF TFP OF CHINA'S MANUFACTURING INDUSTRY

The common methods of calculating total factor productivity are Solow residual (Fu et al., 2014) and Data Envelopment Analysis(Xu et al., 2013).This paper uses input-angle DEA to measure TFP of manufacturing industries， and decompose it into technical efficiency and technical progress.

Input and output are essential variables for total factor productivity measurement .In this paper, Output(Y) is gross industrial output value and main business revenue (this index are represented by product sales revenue before 2004，Because the main business of manufacturing industry is selling products, these two indicators are not much difference). Labor input (L) is the annual average number of employees in each industry，capital input(K) is fixed assets investment. We use DEAP2.1 to measure TFP and its decomposition.

The Malmquist productivity index reflects the change of TFP from this year to the next year, but it can't reflect the change from the base period to the reporting period, in other words, this index reflects the relative change between the annual TFP and did not reflect the absolute status of each annual period in total factor productivity, so we construct a total factor productivity index, the total factor productivity index of base period is 1, the total factor productivity index(TFPI) of reporting period = TFP of this period * TFP of previous period, the calculation results are shown in table 1. The definition and calculation formula of the EFFCH index (EFFCHI) and TECH index(TECHI) are the same, and the calculation results are shown in table 2-3.

Table1. *TFPI of China's manufacturing industry during 2001-2011*

Industry Code	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
M13	1	1.105	1.266	1.412	1.569	1.619	1.846	1.958	1.903	2.014	2.316
M14	1	1.072	1.204	1.256	1.434	1.583	1.819	1.892	1.977	2.133	2.389
M15	1	1.103	1.224	1.390	1.620	1.901	2.155	2.104	2.438	2.592	3.017
M16	1	1.227	1.440	1.701	1.839	2.089	1.999	2.599	2.630	2.678	2.929
M17	1	1.059	1.111	1.273	1.428	1.544	1.671	1.691	1.784	1.994	2.210
M22	1	1.118	1.298	1.455	1.598	1.773	2.082	2.219	2.144	2.423	2.696
M25	1	1.113	1.348	1.675	1.995	2.285	2.493	2.866	2.715	3.382	4.059
M26	1	1.138	1.405	1.817	1.984	2.109	2.413	2.524	2.305	2.595	3.080
M27	1	1.009	1.083	1.129	1.285	1.411	1.662	1.762	1.896	2.114	2.526
M28	1	1.129	1.508	1.677	1.991	2.329	2.721	2.661	2.669	3.240	3.732
M31	1	1.083	1.217	1.323	1.477	1.740	2.053	2.248	2.277	2.473	2.888
M32	1	1.151	1.617	2.296	2.482	2.472	2.977	3.367	2.946	3.347	4.069
M33	1	1.096	1.379	1.867	2.171	3.085	3.440	3.079	2.719	3.222	3.863
M34	1	1.116	1.264	1.404	1.524	1.678	1.826	1.760	1.640	1.734	1.867
M35	1	1.152	1.400	1.694	1.858	2.033	2.201	2.239	2.160	2.234	2.582
M36	1	1.169	1.174	1.414	1.493	1.658	1.850	1.874	1.938	2.087	2.289
M37	1	1.231	1.491	1.600	1.646	1.862	2.117	2.049	2.225	2.541	2.701
M40	1	1.074	1.252	1.463	1.537	1.771	1.960	1.878	1.756	1.842	1.964
M41	1	1.083	1.323	1.338	1.385	1.491	1.488	1.407	1.401	1.280	1.668
M42	1	1.088	1.266	1.463	1.562	1.706	1.800	1.719	1.593	1.604	1.853

Table2. *EFFCHI of China's manufacturing industry during 2001-2011*

Industry Code	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
M13	1	1.024	0.968	1.077	1.145	1.098	1.245	1.295	1.295	1.295	1.295
M14	1	0.993	0.920	0.956	1.045	1.073	1.230	1.245	1.346	1.377	1.362
M15	1	0.976	0.919	1.000	1.098	1.188	1.341	1.205	1.406	1.464	1.479
M16	1	1.000	1.000	1.000	0.970	1.000	0.902	1.000	1.000	1.000	1.000
M17	1	0.981	0.849	0.971	1.043	1.048	1.038	1.102	1.259	1.336	1.320
M22	1	0.997	0.980	1.053	1.084	1.104	1.290	1.230	1.215	1.369	1.368
M25	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
M26	1	0.994	1.047	1.278	1.304	1.267	1.442	1.344	1.226	1.434	1.542
M27	1	0.922	0.832	0.840	0.900	0.910	1.068	1.039	1.149	1.241	1.287
M28	1	0.936	1.090	1.085	1.182	1.254	1.457	1.233	1.230	1.557	1.618
M31	1	1.003	0.930	1.008	1.075	1.178	1.385	1.435	1.492	1.570	1.609
M32	1	0.973	1.164	1.486	1.464	1.335	1.565	1.558	1.354	1.486	1.673
M33	1	0.958	1.018	1.290	1.396	1.811	2.004	1.594	1.393	1.744	1.902
M34	1	1.035	0.967	1.071	1.113	1.138	1.132	1.145	1.146	1.153	1.115
M35	1	1.067	1.069	1.290	1.355	1.378	1.390	1.429	1.444	1.418	1.459
M36	1	1.083	0.897	1.078	1.090	1.125	1.204	1.218	1.311	1.342	1.296
M37	1	1.141	1.139	1.204	1.176	1.229	1.392	1.250	1.367	1.532	1.415
M40	1	0.996	0.958	1.117	1.124	1.203	1.211	1.211	1.211	1.211	1.164
M41	1	1.000	1.000	1.000	1.000	1.000	1.000	0.953	0.999	0.867	1.000
M42	1	1.028	0.967	1.115	1.142	1.159	1.128	1.152	1.161	1.110	1.148

Table3. *TECHI of China's manufacturing industry during 2001-2011*

Industry Code	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
M13	1	1.079	1.309	1.311	1.370	1.475	1.482	1.512	1.469	1.555	1.788
M14	1	1.079	1.309	1.311	1.370	1.472	1.475	1.515	1.465	1.545	1.749
M15	1	1.13	1.332	1.391	1.477	1.601	1.611	1.748	1.735	1.772	2.043
M16	1	1.227	1.440	1.701	1.895	2.088	2.216	2.597	2.628	2.675	2.927
M17	1	1.079	1.309	1.311	1.370	1.475	1.610	1.536	1.418	1.494	1.677
M22	1	1.121	1.324	1.382	1.473	1.607	1.614	1.804	1.763	1.768	1.971
M25	1	1.113	1.348	1.675	1.995	2.285	2.493	2.866	2.715	3.382	4.059
M26	1	1.145	1.343	1.422	1.523	1.665	1.675	1.879	1.883	1.813	2.002
M27	1	1.094	1.301	1.344	1.427	1.550	1.556	1.696	1.650	1.703	1.964
M28	1	1.207	1.386	1.546	1.686	1.859	1.868	2.160	2.171	2.082	2.309
M31	1	1.079	1.309	1.311	1.372	1.476	1.480	1.565	1.526	1.575	1.795
M32	1	1.182	1.388	1.543	1.693	1.849	1.898	2.155	2.168	2.243	2.423
M33	1	1.144	1.353	1.447	1.555	1.703	1.717	1.933	1.952	1.849	2.034
M34	1	1.079	1.309	1.311	1.370	1.475	1.613	1.536	1.430	1.503	1.673
M35	1	1.079	1.309	1.311	1.370	1.475	1.582	1.566	1.496	1.575	1.769
M36	1	1.079	1.309	1.311	1.370	1.475	1.537	1.540	1.478	1.556	1.768
M37	1	1.079	1.309	1.330	1.402	1.518	1.524	1.643	1.631	1.661	1.911
M40	1	1.079	1.309	1.311	1.370	1.475	1.621	1.553	1.452	1.523	1.690
M41	1	1.083	1.323	1.338	1.385	1.491	1.488	1.477	1.403	1.477	1.669
M42	1	1.058	1.309	1.311	1.368	1.472	1.597	1.493	1.372	1.446	1.615

Note: *industries corresponding to the industries code can been seen in appendix*

EMPIRICAL ANALYSIS

Model and Data

According to the relevant theory and the purpose of this paper, we set the basic measurement model as follows:

$$TFPI_{it} = \alpha_0 + \alpha_1 Fund_{it} + \alpha_2 Personal_{it} + \alpha_3 EG_{it} + \alpha_4 Scale_{it} + \varepsilon_{it} \quad (1)$$

$$EFFCHI_{it} = \alpha_0 + \alpha_1 Fund_{it} + \alpha_2 Personal_{it} + \alpha_3 EG_{it} + \alpha_4 Scale_{it} + \varepsilon_{it} \quad (2)$$

$$TECHI_{it} = \alpha_0 + \alpha_1 Fund_{it} + \alpha_2 Personal_{it} + \alpha_3 EG_{it} + \alpha_4 Scale_{it} + \varepsilon_{it} \quad (3)$$

Among them, TFPI, EFFCHI and TECHI are explanatory variables, the measured value of them are given in table 1-3; α_0 is constant term, ε_{it} is random error term; i and t represents the i manufacturing industry and the t year respectively. The rest of the variables will be described in detail as below:

[1] Degree of industrial agglomeration, measured by EG index, which is calculated by the following formula based on Ellision & Glaeser (1997):

$$EG = \frac{G_i - (1 - \sum_{j=1}^{r} x_j^2) \cdot H_i}{(1 - \sum_{j=1}^{r} x_j^2)(1 - H_i)} \quad (4)$$

$$G_i = \sum_{j=1}^{r} (x_j - s_{ij})^2, \quad H_i = \sum_{k=1}^{N} z_k^2 \quad (5)$$

Where, i, j, k stand for industry, region and enterprise respectively; x_j represents the proportion of gross output of all industries in j region in gross output of all industries throughout the country; sij denotes the proportion of i-industry output in j region in the output of this industry throughout the country; z_k means the proportion of k-enterprise output in total i-industry output value. In addition, G_i is the spatial Gini coefficient of i industry. The bigger the G_i value is, the higher the agglomeration degree in geography for i industry is. Hi is Herfindahl coefficient of i industry, and it reflects enterprise scale and distribution in industries; the greater this coefficient, the higher the degree of market monopoly of the industry. EG index is involved in industrial and enterprise distributions, and it can provide a referenced unified measuring standard.

Nevertheless, as the detailed data at the corporate level are obtained difficultly currently, it is impossible for calculation by above formula. For this reason, it is necessary to improve the formula. According to Wu and Li (2009), supposing all i -industry enterprises in each region have the same total industrial output, then, the Herfindahl index formula is available as follows:

$$H_i = \sum_{j=1}^{r} n_{ij} \left(\frac{output_{ij} / n_{ij}}{output_i}\right)^2 = \sum_{j=1}^{r} \frac{1}{n_{ij}} \left(\frac{output_{ij}}{output_i}\right)^2 = \sum_{j=1}^{r} \frac{1}{n_{ij}} s_{ij}^2 \quad (6)$$

Where, i, j, r and s have the same meanings as above mentioned. n_{ij} is the enterprise number in i industry in j region; $output_i$ is total national output value of i industry, and $output_{ij}$ is total national output of i industry in j region. The EG is available as follows:

$$EG = \frac{\sum_{j=1}^{r} (x_j - s_{ij})^2 - (1 - \sum_{j=1}^{r} x_j^2) \cdot \sum_{j=1}^{r} \frac{1}{n_{ij}} s_{ij}^2}{(1 - \sum_{j=1}^{r} x_j^2)(1 - \sum_{j=1}^{r} \frac{1}{n_{ij}} s_{ij}^2)} \quad (7)$$

Although the EG index calculated by Formula (7) is not more accurate than the formula given by Ellision & Glaeser (1997), it reflects the core idea in EG index constructing procedure, and the similar processing is available for all industries. So this doesn't hamper at all evaluation and comparison of industry agglomeration. The appendix shows EG indices of agglomeration of 20 main industries in China's manufacturing during 2001-2011 worked out based on this formula.

[2] Input of scientific and technological factors, including research fund intensity (Fund) and research personnel intensity (Personal), the former is measured by the proportion of internal expenditure on science and technology funds to GDP, and the latter is measured by the proportion of scientific research personnel to the total employees.

[3] The average size of the industry enterprises(Scale), measured by industrial output divided by the number of enterprises.

The data used by the empirical study includes 20 China's manufacturing industries during 2001-2011. All original data for above variables are from China Industry Economy Statistical Yearbook and China Statistical Yearbook.

REGRESSION RESULTS AND ANALYSIS

We use system GMM method to estimate the model (1), (2), (3), and the results are given in Table 4. The first and second columns are the estimated results of which the total factor productivity index is the explanatory variables. Without adding other control variables, coefficient of industrial agglomeration is 2.388, and significantly positively correlated with TFPI under the 1% level, but it is not enough to indicate the relationship between the both, it is necessary to add other control variables for further analysis. According to the second column Table 4，we found that, after controlling research funding, research personnel investment and enterprise scale, the EG coefficient is still positive, but its absolute value is greatly reduced, and did not pass the significance test, which shows that industrial agglomeration does not significantly promote the increase of total factor productivity.

The third and fourth columns of table 4 are the estimated results of which the technical efficiency index is the explanatory variables. without adding the control variables, the coefficient of EG is -0.4488, and pass the 1% significant test, after adding the control variables, the coefficient of EG is still negative, but not significate.

The fifth and sixth columns of table 4 are the estimated results of which the technological progress index is the explanatory variables. Without adding the control variables, the coefficient of EG was 0.7234, after adding the control variables, the EG coefficient is still very significant (0.5515). Overall, although the industrial agglomeration didn't have significant impact on total factor productivity and technical efficiency, but it can have positive impact on technological progress, the hypothesis that industrial agglomeration promote technological progress is established, the degree of industrial agglomeration increase of 1% will promote the technological progress index rose 0.5515%.

Table4. *Regression results of the influencing factors of TFP and its Decomposition*

Variable	TFPI		EFFCHI		TECHI	
	（1）	（2）	（3）	（4）	（5）	（6）
L.TFPI	0.6198*** （0.000）	0.5062*** （0.000）				
L.EFFCHI			-0.0219 （0.661）	0.0381 （0.675）		

L.TECHI					0.2582*** （0.000）	0.1698*** （0.000）
EG	2.3883*** （0.000）	0.8396 （0.419）	-0.4488*** （0.000）	-0.2419 （0.369）	0.7234*** （0.000）	0.5515*** （0.009）
Fund		-0.2893 （0.102）		-0.1027*** （0.000）		-0.3046*** （0.000）
Personal		0.1402*** （0.001）		0.0351*** （0.000）		0.0817*** （0.000）
Scale		0.0114*** （0.001）		-0.0128*** （0.000）		0.0321*** （0.000）
constant term	0.5616*** （0.000）	0.6188*** （0.004）	1.1781*** （0.000）	1.1246*** （0.000）	1.1251*** （0.000）	1.2122*** （0.000）

Note: ****, **, * represent that the results are significant at 1%, 5% and 10% respectively and numbers in the bracket are t values; L.TFPI, L.EFFCHI, L.TECHI represent the delay term of TFPI，EFFCHI and TECHI respectively.*

Among the control variables, the impact of research funding on the total factor is not significant, and its impact on technical efficiency and technical progress is significantly negative, there are two reasons, one is related to the 'time lag' of R & D investment, on the other hand, China's market mechanism is not mature and the distortion of elements. Li and Zhu (2006) believed that the market mechanism and structure of China is in a gradually perfecting stage, and R&D investment, as with traditional capital investment，also need competitive market mechanism to guide enterprises to reduce costs when using new technologies. The imperfect market mechanism makes R & D investment can't be used in an efficient way, R&D input-output rate of return is low, so it leads to the result that research has no significant or even negative effects on the total factor productivity

CONCLUSION

The input of scientific research personnel has significantly positive impact on TFP, technical efficiency and technical progress. Since researchers are the most important human capital, the result means that human capital plays an important role in promoting TFP and its decomposition index of China's manufacturing industry.

The enterprise scale has positively correlation with TFP and technological progress, means that expanding the scale of enterprises can promote technological progress. However, it has a significant negative correlation with technical efficiency, this may because that, with the expansion of enterprise scale, the difficulty and cost of internal coordination increase significantly, and resulting in the loss of efficiency.

In terms of industrial agglomeration, the result shows that each 1% increase of manufacturing industry agglomeration will promote 0.5515% growth of technological progress index, means that "technical progress effect" of industrial agglomeration exists in China's manufacturing industry.

The above conclusions indicate that technological progress in China's manufacturing industry is mainly promoted by increasing the number of scientific research personnel, and unleashing technology spillover effect of industrial agglomeration, the research funding does not play an effective supporting role. In the future, to speed up the technological upgrading of China's manufacturing industry, the basic approaches are: further increase the input of scientific research personnel, optimize the investment and allocation system of scientific research funds, accelerate agglomeration development of high-tech manufacturing, and increase the guidance and support to technological innovation of small and medium-sized enterprises.

APPENDIX

Code	2001	2002	2003	2004	2005	2006
M13	0.026	0.030	0.034	0.037	0.044	0.043
M14	0.011	0.011	0.010	0.011	0.015	0.017
M15	0.008	0.008	0.008	0.006	0.010	0.011
M16	0.067	0.060	0.054	0.047	0.048	0.044
M17	0.049	0.056	0.055	0.067	0.066	0.066
M22	0.016	0.019	0.024	0.028	0.028	0.027
M25	0.023	0.025	0.025	0.024	0.022	0.022
M26	0.014	0.014	0.013	0.015	0.018	0.020
M27	0.006	0.006	0.005	0.004	0.007	0.006
M28	0.066	0.077	0.115	0.143	0.160	0.177
M31	0.005	0.006	0.009	0.009	0.014	0.014
M32	0.025	0.023	0.025	0.026	0.028	0.028
M33	0.011	0.011	0.010	0.009	0.011	0.012
M34	0.038	0.040	0.042	0.041	0.032	0.033
M35	0.037	0.038	0.037	0.034	0.032	0.032
M36	0.027	0.025	0.018	0.013	0.013	0.012
M37	0.028	0.027	0.028	0.020	0.015	0.015
M40	0.042	0.043	0.047	0.048	0.043	0.041
M41	0.094	0.103	0.112	0.114	0.104	0.099
M42	0.089	0.090	0.098	0.093	0.074	0.064
average	**0.034**	**0.036**	**0.038**	**0.039**	**0.039**	**0.039**
Code	2007	2008	2009	2010	2011	annual averages
M13	0.041	0.034	0.034	0.028	0.024	0.034
M14	0.020	0.019	0.020	0.016	0.015	0.015
M15	0.012	0.012	0.014	0.018	0.021	0.012
M16	0.043	0.038	0.037	0.034	0.034	0.046
M17	0.065	0.062	0.058	0.052	0.046	0.058
M22	0.025	0.022	0.021	0.018	0.017	0.022
M25	0.020	0.020	0.019	0.024	0.016	0.022
M26	0.019	0.020	0.024	0.020	0.020	0.018
M27	0.007	0.007	0.008	0.007	0.009	0.007
M28	0.168	0.184	0.185	0.187	0.198	0.151
M31	0.015	0.014	0.015	0.012	0.013	0.011
M32	0.028	0.031	0.032	0.030	0.030	0.028
M33	0.013	0.015	0.014	0.014	0.017	0.013
M34	0.032	0.027	0.029	0.023	0.019	0.032
M35	0.030	0.028	0.029	0.026	0.023	0.032
M36	0.011	0.012	0.013	0.014	0.016	0.016
M37	0.014	0.013	0.012	0.012	0.013	0.018
M40	0.040	0.037	0.032	0.033	0.035	0.040
M41	0.094	0.102	0.103	0.103	0.094	0.102
M42	0.063	0.059	0.053	0.057	0.074	0.074
average	0.038	0.038	0.038	0.036	0.037	0.037

Note: *M13:Food processing; M14:Food Manufacturing; M15:Beverage manufacturing; M16:Tobacco manufacturing; M17:Textile manufacturing; M22:Paper and Paper Products manufacturing; M25: Petroleum, Coking, Processing of Nuclear Fuel processing; M26:Chemical Raw Materials manufacturing; M27: Medicines manufacturing;M28:Chemical Fiber manufacturing;M31: Nonmetallic Mineral Products manufacturing; M32: Smelting of Ferrous Metals and Manufacture of Alloys M33: Smelting of Non-Ferrous Metals and Manufacture of Alloys; M34:Metal Products manufacturing; M35: General Purpose Machinery manufacturing; M36:Special Purpose Machinery manufacturing; M37: Transport Equipment manufacturing; M40:Electrical Machinery and Equipment manufacturing; M41: Communication Equipment, Computer and Other Electronic Equipment manufacturing; M42: Measuring Instrument and Machinery for Cultural Activity & Office Work manufacturing.*

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