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Characteristics of Export-oriented Technological Progress and Total Factor Productivity of China's Manufacturing Industry

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Abstract: *Since the reform and opening up, it is an important means of industrial technology innovation in China to realize technology upgrading by introducing and imitating innovation. The characteristics of the supply of technical elements and the demand of technical products "both ends are outside" constitute the export-oriented technological progress mode of China's industrial technological innovation .In this paper, the export-oriented technology progress of China's manufacturing industry from 1992 to 2020 is divided into three stages, and the DEA-Malmquist method is used to measure the total factor productivity changes of 26 manufacturing industries in China during this period. The results show that from 1992 to 2000, the total factor productivity index of China's manufacturing industry showed a fluctuating trend during the period of high economic growth driven by accelerated export expansion. During the period of optimizing commodity structure and promoting industrial upgrading from 2001 to 2011, the total factor productivity index of China's manufacturing industry first increased steadily, and then decreased from 2008 to 2011. Since 2012, in the stage of building a trade powerful country and promoting innovation, the total factor productivity of China's manufacturing industry has entered the growth stage again in 2016 after a period of decline. Finally, this paper puts forward some suggestions.*

Keywords: *Chinese manufacturing industry, Export-oriented technological progress, Total factor productivity*

1. Introduction

Export-oriented technological progress is a way of technological progress in developing countries under the condition of open economy. Total factor productivity is an index to measure the actual effect of this way of technological progress. The history of technological change in the world shows that first-mover countries often improve their technological level by relying on independent innovation, while latecomer countries mainly rely on technology introduction and imitation to achieve technological upgrading (Lin Yifu and Zhang Pengfei, 2005)[1]. The path and mode of China's technological progress are inherent in its economic growth mode and foreign trade strategy choice. The deepening of China's opening to the outside world and the high-quality development of foreign trade make the industry need to rely on technological progress to meet the requirements of upgrading the structure of export products and the continuous expansion of export. This feature of the supply of technological factors and the demand for technological products "both ends are outside" constitutes the export-oriented technological progress mode of China's industrial technological innovation.

With the establishment and evolution of the export-oriented economic growth model, China's export of goods increased from $84.9 billion in 1992 to $2,590.6 billion in 2020, a 30-fold increase. Imports of goods increased 25-fold from $80.5 billion in 1992 to $2,055.6 billion in 2020. During this period, China's GDP increased from $426.9 billion in 1992 to $14.73 trillion in 2020. During this period, foreign trade gives full play to the function of driving economic growth, realizes the upgrading of export product structure and sustained export growth through different ways of embodied technology import, and at the same time improves China's industrial technology level by means of imitation and innovation, that is, in the repeated cycle of exporting final products and importing embodied technology, it achieves the accumulation of technical knowledge and the enhancement of technical ability, which provide impetus for long-term economic growth. In exploring the path and mechanism of

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the influence of import and export trade on technological progress, Chen Aizhen and Liu Zhibiao (2015) [2] drew on the CH model and used the panel data of China's manufacturing industry from 2002 to 2012, at the same time ,they classified imports into capital goods, intermediate goods and consumer goods. It is found that capital goods and intermediate goods have significant influence on the total factor productivity of China's manufacturing industry, mainly on the technical efficiency. Similar to Chen Aizhen's conclusion, Yang Junling (2019) [3] used the data of the world input-output table from 1996 to 2009 through the dynamic panel model for empirical analysis and argued that the import trade of final consumer goods and intermediary goods of agent processing can significantly promote technological progress, while the import trade of non-intermediary goods of agent processing has a hindering effect to a certain extent. Wang Jianxiu and Han Lu et al. (2018) [4] used the threshold effect model to study the panel data of 26 provincial levels in China from 2004 to 2012 and found that export has a significant threshold effect on total factor productivity. Within a certain range of foreign direct investment and R&D level, export of processing trade can promote the improvement of total factor productivity.

The export-oriented technological progress has greatly narrowed the technological gap between China and developed countries, and also promoted China's industrial technological innovation and industrial structure upgrading. However, with the continuous improvement of China's industrial technology level, the space of embodied technology import and technology imitation is gradually narrowed. The inevitable choice of China's technological progress is to promote the further transformation and upgrading of industries, achieve high-quality economic development, improve China's absorption capacity of foreign advanced technologies, increase the accumulation level of China's technical knowledge, realize a higher level of imitation innovation, and promote China's transformation from imitation innovation to independent innovation. It is of great theoretical and practical significance to study the technological progress level of China's manufacturing industry and explore its characteristics and causes under the economic growth target and foreign trade development target.

2. Progress and development of China's export-oriented technology

In different periods, the level of national economic development and strategic objectives determine the strategic objectives of foreign trade and the means to achieve these objectives, and once the foreign trade strategy is established, it will be an important factor to participate in shaping the way of national economic development, including the way of technological progress. From the perspective of development history, the evolution of China's technological progress mode can be generally divided into three periods.

2.1. 1992-2000: Accelerated export expansion and drove high economic growth

This stage is the rapid formation stage of China's export-oriented technological progress mode. At this stage, China's economic development was confronted with such problems as unreasonable industrial structure, a large backlog of finished products, poor economic returns, serious losses of enterprises and financial difficulties. But in response to the complicated international and domestic political and economic situation in the early 1990s, the 14th National Congress of the Communist Party of China proposed that the economic growth rate "could be faster". Subsequently, the GDP target was raised to an average annual growth rate of about 8%. This determines that the strategic goal of China's foreign trade is to support high GDP growth with high export growth. The main measures are to expand the scope of opening-up, form a "multi-level, multi-channel and all-dimensional" opening-up pattern, attract foreign investment with cheap labor and "super national treatment", develop processing trade, abolish import substitution requirements, and reduce average tariff rates to further expand exports. A series of strategic changes and policy adjustments have promoted China's export growth and the formation of China's export-oriented economic development model. Since 1994, China's foreign trade has steadily turned into surplus. From the perspective of industrial development, on the one hand, the economic growth driven by export will inevitably lead to the instability of industrial development due to the instability of external demand. On the other hand, with the increase of exports, labor-intensive products in developing countries will face the problem of price deterioration of the terms of trade, and the cost of export products will continue to rise as employment approaches the level of full employment. Therefore, the development of China's foreign trade urgently needs technological progress to promote the upgrading of industrial structure and export product structure. During this period, in order to break the shackles of labor-intensive industries and encourage the development of

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capital-intensive industries and technology-intensive industries, the state did not hesitate to exchange market for technology to attract foreign investment and advanced technologies.

2.2. 2001-2011: Optimized commodity structure and promoted industrial upgrading

This stage is the progressive stage of China's export-oriented technological progress. The rapid development of foreign trade has enabled China's economy to achieve rapid growth. On December 11, 2001, China formally joined the WTO, and the development of China's foreign trade has entered a new stage. However, in the process of development, there are problems such as environmental deterioration, widening gap between the rich and the poor, insufficient consumption of residents, and intensifying trade frictions. Therefore, the transformation of economic growth mode becomes the main task of economic development at this stage. In order to promote the strategic adjustment of economic structure, the focus of China's foreign trade strategy has changed from promoting the growth of foreign trade quantity to promoting the upgrading of export commodity structure, promoting the development of high-tech industries, thus driving the upgrading of industrial structure and promoting the strategic adjustment of economic structure. The landmark measures is the Action Plan for Revitalizing Trade through Science and Technology formulated in 1999. Its connotation is to vigorously promote the export of high-tech products, and at the same time, transform traditional export industries by using high-tech technologies to improve the technological content and added value of export products. The primary purpose of exports is no longer to generate more foreign exchange, but increasingly to promote the transformation of domestic price advantage. With the favorable situation of joining WTO and the adjustment of policy measures, China became the world's largest exporter in 2009.The excess money supply brought about by the huge gains in foreign exchange reduced the rent of capital, while the prices of imported capital goods and intermediate goods were falling as a result of lower tariffs, creating conditions for sustained growth in domestic investment. Under the condition of abundant capital supply, enterprises in the industry can make use of cheap capital to purchase advanced technology and equipment and import intermediate goods in large quantities, which can effectively improve labor productivity, improve product quality, accelerate the introduction and production of new products, and produce dry effect. This process improves the structure of China's export commodities. However, on the other hand, the capital-intensive products exported by China account for a high proportion of foreign value added. The upgrading of export product structure is still based on a large amount of imported capital goods and intermediate goods input, and the technological progress lacks momentum.

2.3. From 2012 to 2020: Build a trade powerful country and promote innovative development

This stage is the evolution and development stage of China's export-oriented technological progress mode. Affected by the world financial crisis, China's export growth began to decline year by year after 2012.In the face of the new situation, China has comprehensively deepened economic structural reform and promoted innovative economic development. The 13th Five-Year Plan calls for strengthening basic research, strengthening original innovation, integrated innovation and re-innovation through introduction, digestion and absorption, and strengthening the capacity for independent innovation, so as to provide lasting impetus for economic and social development. China's foreign trade strategy is to foster new export competitive advantages by promoting innovation, further optimize the structure of export commodities, and speed up the construction of a trade powerful country. In terms of measures, we will vigorously develop trade in services, strengthen economic and trade cooperation with countries along the Belt and Road, implement the management system of pre-establishment national treatment & negative list for foreign investment, and take a package of measures to build China into a foreign trade powerhouse. A series of measures to achieve steady growth of foreign trade targets. In this process, China's foreign trade is in the stage of "weakened traditional comparative advantages, but the new competitive advantages have not been fully formed". The foreign trade industry is mainly in the middle and low-end links of the global industrial chain and value chain, with low technological content and added value, and the problem of insufficient technological capability of Chinese export enterprises still exists.

3. Total factor productivity of China's manufacturing industry

In order to deeply explore the characteristics of China's industrial technological progress under macroeconomic conditions at different stages, this paper measured the total factor productivity of China's manufacturing industry from 1992 to 2020.Total factor productivity, also known as system

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productivity, is the comprehensive result of all production factors in the system, reflecting the output level of the production unit system itself. For the measurement of total factor productivity, this paper adopts the DEA-Malmquist index method of data envelopment analysis, regards each industry as a decision-making unit, constructs the optimal frontier of each industry in each period by using input-based DEA method, and compares the actual production and optimal production frontier of each industry. Measure changes in technological efficiency and technological progress [5].

$$\text{TFPCH} = \left[\frac{d^t(x_{t+1},y_{t+1})}{d^t(x_t,y_t)} * \frac{d^{t+1}(x_{t+1},y_{t+1})}{d^{t+1}(x_t,y_t)}\right]^{\frac{1}{2}} = TECHCH * EFFCH \quad (1)$$

Technology Change Index (TECHCH) measures the movement of technology boundary between two time periods, and Technology Efficiency index (EFFCH) measures the catch-up degree of each decision object relative to the best practice boundary.

3.1. Data source and arrangement

Data source. This paper uses the panel data of manufacturing sector under two codes from 1992 to 2020. The data used in the calculation of TFPCH and the subsequent empirical analysis are mainly from China Economic Census Yearbook (2004, 2008, 2013, 2018), China Statistical Yearbook (1991-2021), China Industrial Statistics Yearbook (1991-2021), and China Economic Boom Month (2008-2021) Journal, China Science and Technology Statistical Yearbook from 1991 to 2021, China Price Statistical Yearbook. From 1978 to 1990, some important data are missing, so this paper will not consider temporarily.

Industry merging. The industry classification of China's national economy has gone through 5 versions. In this paper, the industry classification standard is GB/T 4754-2017，which named and classified according to the pertinence, timeliness and data availability of the research questions. The industry classification standard of national economy in 2017 was released in June 2017, among which there are 31 categories under the category of manufacturing industry. In order to better integrate the data of different periods, this paper tries to follow the following four principles in data processing: 1. Reduce data merging and splitting as much as possible to reduce errors; 2. Reflect the basic characteristics of the industry as much as possible; 3. Adopt the newer industry classification standards as far as possible; 4. Industry name in the year before and after the basic unchanged as the same industry. The resulting merger selected 26 industries.

Statistical caliber adjustment. When constructing industry panel data, it is necessary to ensure the consistency of statistical caliber before and after statistical data. The inconsistency of statistical caliber in the statistical yearbook makes it unable to be directly used in the composition of panel data. In order to solve this problem, this paper adopts the methods of Chen Shiyi(2011) [6] and Wang Jijia(2019) [7], and uses the ratio before and after the adjustment of the caliber of the national total industrial output value to unify the caliber. Based on the full-bore data in China Statistical Yearbook 1998, China Economic Census Yearbook 2004, China Economic Census Yearbook 2008, China Economic Census Yearbook 2013, and China Economic Census Yearbook 2018, the assumption that the ratio of the two industrial censuses is linear function is adopted. The caliber adjustment ratio of each year between the two industrial censuses is constructed. The caliber adjustment results are shown in Table 1.

Table 1: Caliber adjustment table

1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
0.830	0.801	0.820	0.732	0.621	0.629	0.601	0.552	0.611	0.670
2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
0.730	0.789	0.848	0.907	0.919	0.925	0.930	0.933	0.912	0.891
2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
0.870	0.849	0.828	0.828	0.828	0.828	0.828	0.828	0.828	0.828

Price index and exchange rate adjustment. Since the statistical data of each yearbook report the price of the current year, in order to enable the added value, capital stock, import and export, etc. between each year can be compared, so as to reflect the nature of manufacturing production capacity, this paper takes 1990 as the base year to adjust the price of each year.

Other data. Value added, China Industrial Statistics Yearbook directly provides the annual value added data of each industry from 1992 to 2007, but the value added data yearbook for 2008 and later is not reported. In order to calculate the value added data of 2008 and after, this paper uses the growth rate of value added of each industry from 2008 to 2020 (cumulative number of the current period)

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provided by China Economic Prosperity Monthly Report to calculate the value added data of 2008 and after each year, and makes the adjustment and reduction according to the ex-factory price index of each industry by year. In this paper, the annual average number of all employees in the manufacturing industry is used to reflect the labor input of each industry in that year. Capital stock, this paper uses the method of perpetual inventory to calculate the capital stock of manufacturing industries in each year. The net value of fixed assets in 1990 is selected as the base period of capital stock and the difference of the original value of fixed assets in two consecutive years is used as the added fixed assets.

3.2. Analysis of calculation results

In terms of years, the total factor productivity of the manufacturing industry during 1992-2020 are shown in Figure 1.

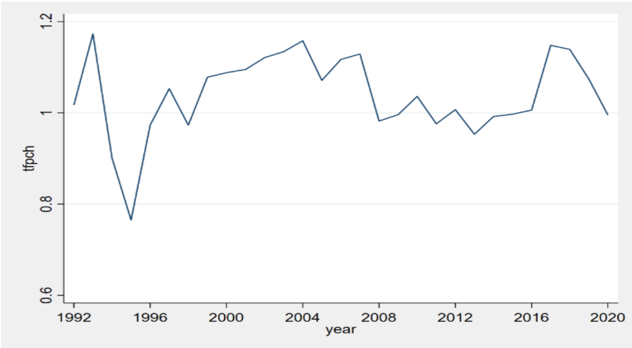

Figure 1: TFPCH of manufacturing industry from 1992 to 2020

Table 2: Total factor productivity and its decomposition in China's manufacturing industry during 1992-2020

Year	TECHCH	EFFCH	TFPCH
1992	0.872	1.165	1.017
1993	0.927	1.265	1.173
1994	1.203	0.749	0.901
1995	0.827	0.925	0.765
1996	0.776	1.253	0.973
1997	1.163	0.906	1.053
1998	0.952	1.022	0.973
1999	0.852	1.266	1.078
2000	1.211	0.899	1.088
Average value from 1992 to 2000	0.976	1.050	1.002
2001	1.003	1.092	1.095
2002	1.162	0.965	1.121
2003	1.24	0.914	1.134
2004	1.100	1.053	1.158
2005	1.091	0.981	1.071
2006	1.126	0.992	1.117
2007	1.036	1.09	1.129
2008	1.059	0.927	0.982
2009	0.995	1.001	0.996
2010	1.033	1.002	1.036
Average value from 2001 to 2010	1.085	1.002	1.084
2011	1.028	0.949	0.976
2012	1.049	0.96	1.007
2013	0.959	0.994	0.953
2014	1.053	0.942	0.992
2015	0.967	1.030	0.997
2016	0.887	1.135	1.006
2017	1.067	1.076	1.000
2018	1.082	1.052	1.139
2019	1.049	1.023	1.074
2020	0.974	1.022	0.995
Average value from 2011 to 2020	1.012	1.018	1.014
Average value from 1992 to 2020	1.019	1.016	1.036

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As can be seen from Figure 1, the total factor productivity index (TFPCH) of China's manufacturing industry showed a fluctuating trend from 1992 to 1998.After 1999, especially after 2001, the total factor productivity index of China's manufacturing industry was significantly more than 1, indicating that the total factor productivity of China's manufacturing industry was rising steadily during this period. However, from 2008 to 2015, the total factor productivity of China's manufacturing industry was less than 1 in most years, which reflected that the productivity of manufacturing enterprises showed a fluctuating downward trend in terms of actual production. Since 2016, the total factor productivity index of China's manufacturing industry has entered the growth stage again, which is more than 1, but the growth momentum has fallen, indicating that there is insufficient driving force for the growth of total factor productivity of China's manufacturing industry.

Further observe the decomposition of China's manufacturing total factor productivity from Table 2. Before 2001, the Technology Change Index and the Technical Efficiency index of China's manufacturing industry showed a staggered trend. After 2001, the Technology Change Index was significantly greater than the Technology Efficiency index in most years, indicating that in China's TFP growth, the contribution of technology change was greater than that of technology efficiency, and it was the fastest growing factor among the components of productivity, while the growth of technology change lagged behind the total factor productivity. This indicates that China's technological frontier has improved a lot in the past 20 years, but the increase of technological efficiency is not very fast. The average index of pure technical efficiency is 1.007, and the average index of scale efficiency is 1.009, both of which have been declining in recent years. From the average point of view, the mean of total factor productivity from 1992 to 2000 is 1.002, the mean of total factor productivity from 2001 to 2011 is 1.084, and that from 2012 to 2020 is 1.014. The period of greatest growth in technological change was from 2001 to 2011.

4. Conclusion

Based on China's economic growth target and foreign trade target, this paper divides the characteristics of export-oriented technological progress of China's manufacturing industry from 1992 to 2020 into three stages, and measures the total factor productivity of each year, and draws the following conclusions through analysis.

The period from 1992 to 2000 was a period of high economic growth driven by the acceleration of export expansion. During this period, the rapid expansion of export brought huge foreign market space to the domestic foreign trade industry. In order to cope with the increasingly fierce competition among industries and the gradual improvement of the requirements of the foreign market on the variety and quality of products. The domestic foreign trade industry has changed from a large amount of technology import to independent innovation, which is reflected in export-driven technological progress. 2001-2011 was the stage of optimizing commodity structure and promoting industrial upgrading. In this stage, in order to solve the many problems left by China's rapid development in the early stage, Chinese industry actively optimized product structure and promoted industrial upgrading. The accumulation of industrial technology in the early stage combined with the import of a large amount of embodied technology promoted the independent research and development ability of Chinese industry and improved the level of industrial technology innovation in China. From 2012 to now, it is the stage of promoting innovation and development to build a trade powerhouse. In this stage, China's industrial technology level approaches the world frontier due to the rapid development of its economy and foreign trade and technology accumulation. At this time, due to various reasons such as foreign technology protection and monopoly, it is less and less possible to rely on imported embodied technology to improve the domestic technological level. On the contrary, relying on the international market, through adjusting structure, innovative development and improving the position of Chinese industries in the global value chain, the level of industrial technology innovation in China has maintained a certain positive growth driven by exports.

Since the reform and opening up, China has imported a large number of commodities, among which capital goods and "processed intermediate goods" contain a large number of embodied technologies. After this kind of embodied technology is imported into China, the domestic industry can quickly improve the technical efficiency of the industry through imitation, digestion and absorption. However, due to the influence of market conditions, gap in basic technology level and other factors, imported embodied technology has not significantly improved China's technological frontier. This shows that the import of embodied technology does not directly stimulate the independent innovation power of Chinese industries. From the influence of export-oriented technological progress mode, Chinese

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industries have been more "imitation" than "innovation" in the past 30 years. Therefore, China should persist in opening up to the outside world in a wider scope, in a wider field and at a deeper level, promote international cooperation and achieve mutual benefit and win-win situation by relying on its advantages of a large domestic market, strengthen basic research, promote industrial optimization and upgrading, enhance the technological innovation capacity of enterprises, train a team of high-level talents, encourage them to play a better role and optimize the structure of scientific and technological innovation by adjusting the mode of technological progress in manufacturing industry.

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