Research on the Impact of Artificial Intelligence on Green Total Factor Productivity in Manufacturing

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ABSTRACT
This paper measures the green total factor productivity of manufacturing in China's provinces from 2003 to 2017 and its decomposition indicators, empirically analyzes the impact of artificial intelligence on the green total factor productivity of manufacturing, and draws the following conclusion: Artificial intelligence helps promote the improvement of green total factor productivity in China's manufacturing industry. This improvement mainly comes from technological progress, and the impact of technological efficiency is not significant. Further inspection found that artificial intelligence has improved the pure technical efficiency of China's manufacturing industry. This paper puts forward the following policy suggestions: In order to further improve the green total factor productivity of the manufacturing industry, efforts can be made in the direction of improving technical efficiency, and the focus of improvement is on how to improve scale efficiency. Manufacturing enterprises should recognize the role and role of artificial intelligence as a "general purpose technology", and the government needs to play a leading role, provide necessary public goods, and guide complementary innovation and investment.

Keywords: *Artificial intelligence, Green total factor productivity in manufacturing, Technological progress, Technological efficiency.*

1. INTRODUCTION

As the main body of the national economy, the manufacturing industry has strongly promoted the process of China's industrialization and modernization, and contributed enormously to China's economic development and national economic growth. However, the rapid development of China's manufacturing industry is based on a large amount of input of factors, accompanied by huge energy consumption and serious environmental pollution. Improving green total factor productivity and promoting green growth are the core of realizing green development of manufacturing industry [1]. Seizing the opportunity of a new round of industrial revolution and using artificial intelligence and the deep integration of manufacturing as a means to promote the manufacturing industry towards the mid-to-high end is the key to the high-quality development of the manufacturing industry [2]. To comprehensively improve the quality and level of China's manufacturing industry and promote the green development of the manufacturing industry, artificial intelligence will be promising.

Studies on the influencing factors of manufacturing green total factor productivity have shown that environmental regulation, innovation input and market competition, industrial agglomeration, input servitization, degree and position of embeddedness in global value chains have positive effects on manufacturing green total factor productivity. There are certain industry heterogeneity. As an emerging technology, the current research on artificial intelligence mainly focuses on the analysis of the role of artificial intelligence, such as affecting enterprise management, promoting the transformation and upgrading of industrial structure, and coping with the problems of aging and the disappearance of demographic dividends and the substantial increase in labor costs. The research topics closely related to this paper mainly include the connotation and performance of manufacturing intelligence, how information technologies such as artificial intelligence affect the transformation and upgrading of the manufacturing industry, improve the total factor productivity of the manufacturing industry, and achieve high-quality development of the manufacturing industry.

From the perspective of artificial intelligence, this paper discusses the impact of artificial intelligence on the green total factor productivity of manufacturing industry, enriches the theoretical research on the integrated development of artificial intelligence and industry, and supplements the research on the green development of manufacturing industry characterized by the improvement of manufacturing green total factor productivity. The study provides empirical evidence that artificial intelligence affects the green total factor productivity of China's manufacturing industry.

2. THEORETICAL BASIS AND RESEARCH ASSUMPTIONS

2.1. The impact of artificial intelligence on green total factor productivity in manufacturing

In the manufacturing process, artificial intelligence can replace human labor as virtual labor, realize "intelligent automation" of complex and dangerous tasks, and directly improve manufacturing productivity. Machines can achieve precise control and real-time monitoring in the production process, thereby reducing energy consumption and pollution. In order to reduce production costs and reduce energy consumption, green production technologies will continue to be updated, iterated and diffused. With the expansion of artificial intelligence capital, new tasks that are knowledge- and intelligence-intensive are gradually generated, resulting in a relative increase in the demand for high-skilled labor, manifested in higher manufacturing productivity. In addition, unlike previous automation technologies, artificial intelligence at this stage seeks not only to replace manual labor, but also to replace mental labor. "Innovation of innovative methods" and "Invention of inventive methods" often have more potential value than any single innovation[3], thereby contributing to profound technological progress and value creation. From the perspective of artificial intelligence-related technologies, information technology and Internet of Things can strengthen the connection between enterprises and enterprises, and enhance the convenience of knowledge spillover; machine learning technology can improve the enterprise's ability to absorb knowledge and technology; big data analysis technology help enterprises to create new knowledge from massive data and information; neural network algorithms can realize the explicit expression of "tacit knowledge", and promote the exchange and absorption of technology and experience between enterprises; Internet of things technology and facilities will make the production organization of enterprises more organized, the means of resource allocation are better, and more effective forms of organization, specialization or management can be produced. In conclusion, the revolutionary technology of artificial intelligence helps to promote technological progress, increase total factor productivity, and reduce energy consumption and environmental pollution in the high-consumption industry of manufacturing. Based on this, this paper proposes:

Hypothesis 1: Artificial intelligence can improve green total factor productivity in manufacturing.

2.2. The impact of artificial intelligence on technological progress and technical efficiency in manufacturing

First, the boosting effect of general-purpose technology on productivity is not automatically realized, and needs to be matched by complementary technologies, infrastructure, and personnel quality [4]. The effect of artificial intelligence on productivity improvement requires a large amount of investment and new capital stock, and requires production and deployment of tangible and intangible supplementary capital. In the short term, the technical efficiency of artificial intelligence cannot be brought into full play. Secondly, the rent dissipation theory holds that the value (or rent) of the originally valuable resources or property will decrease or even disappear completely due to the arrangement of property rights. The control of the data that artificial intelligence relies on for “deep learning” will lead to the “Balkanization” of data and the “rent dissipation” of artificial intelligence technology overflow, hindering the improvement of technical efficiency. In order to initially explore the inherent driving force of artificial intelligence affecting green total factor productivity in manufacturing, this paper selects the Malmquist-Luenberger index method based on the directional distance function (DDF) in the nonparametric method, and selects three input indicators (Capital, Labor, Energy) , one expected output indicator (Industrial added value) and three undesired output index (Discharge of three industrial wastes) is measured and calculated by MAXDEA software to obtain the green total factor productivity (GTFP) of the manufacturing industry in 30 provinces, municipalities and autonomous regions of China except Tibet, Hong Kong, Macau and Taiwan, and its decomposition indicators technical efficiency EC and technical progress TC. After the arithmetic mean processing, it is found that the overall green total factor productivity of my country's manufacturing industry has improved during the sample period, and this improvement comes from technological progress, and technical efficiency has dragged down the improvement of green total factor productivity to a certain extent, as shown in Figure 1. Based on this, this paper proposes:

Hypothesis 2: At this stage, the role of artificial intelligence in improving green total factor productivity in manufacturing is mainly through technological progress, and the role of technical efficiency has not yet been clearly manifested.

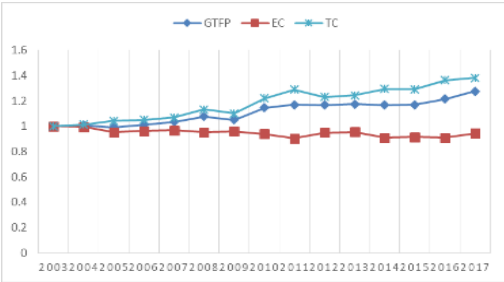

Figure 1 Changes in green total factor productivity and its decomposition indicators of China's manufacturing industry from 2003 to 2017.

3. EMPIRICAL ANALYSIS

3.1. Model settings

This article refers to the empirical research on artificial intelligence development and industrial total factor productivity by Sun Zao and Hou Yulin[5], and constructs the following basic model:

$$Y_{it} = \alpha_0 + \alpha_1 AI_{it} + \alpha_2 Z_{it} + \lambda_i + \varepsilon_{it} \quad (1)$$

Among them, i represents the province, t represents the year, Y is the explained variable, that is, the manufacturing green total factor productivity (GTFP) and its decomposition index calculated above. AI is the explanatory variable, representing the development and application level of artificial intelligence, and Z represents a series of control variables, λ is an individual fixed effect, and ε is a random disturbance term.

Table 1. The regression results of artificial intelligence affecting green total factor productivity of China's manufacturing industry

Variable	*GTFP*	*EC*	*TC*	*PEC*	*SEC*
AI	9.245*	2.722	10.194**	9.821***	-5.776**
	(1.83)	(0.85)	(2.04)	(3.70)	(-2.34)
RD	2.183	-2.956	7.190**	-0.234	-2.819*
	(0.69)	(-1.48)	(2.30)	(-0.14)	(-1.83)
FDI	0.288*	-0.137	0.594***	0.144*	-0.271***
	(1.87)	(-1.40)	(3.89)	(1.77)	(-3.60)
URBAN	1.372***	-0.094	1.615***	0.074	-0.109
	(4.95)	(-0.54)	(5.89)	(0.51)	(-0.81)
Constant	-0.937	1.586***	-2.357***	0.243	2.260***
	(-1.51)	(4.04)	(-3.85)	(0.75)	(7.49)
Observations	450	450	450	450	450
Number of province	30	30	30	30	30
R-squared	0.330	0.092	0.518	0.036	0.113

Notes:***, **, * indicate that the estimated results are significant at the 1%, 5%, and 10% levels, respectively.

3.2. Variable settings and data sources

Explained variable. The 30 provinces, municipalities and autonomous regions manufacturing green total factor productivity (GTFP) and its decomposition indicators technical efficiency EC, technological progress TC, and EC's decomposition indicators pure technical efficiency PEC and scale efficiency SEC are used as explained variables respectively.

Explanatory variables. Referring to the practice of Borland and Coelli [6] and Shen Shang [7], this paper uses the proportion of the total social fixed asset investment in the provincial information transmission, computer services and software industries to the gross domestic product to represent the level of artificial intelligence technology use.

Control variables. According to the existing research conclusions, this paper adds the level of R&D investment (the proportion of R&D investment in each province in GDP), the degree of opening to the outside world (the foreign direct investment FDI in each province) and the urbanization process (the proportion of the urban population in each province to the total population at the end of the year) as control variables.

Data sources. The data used in this paper come from China Statistical Yearbook, China Energy Statistical Yearbook and China Environment Statistical Yearbook.

3.3. Benchmark regression analysis

In this paper, the static panel fixed-effect model was used for basic regression analysis.

Table 1 shows that with GTFP as the explained variable, the regression coefficient of the core explanatory variable AI is 9.245, the sign is positive and significant at the 10% significance level, indicating that artificial intelligence has a promoting effect on the green total factor productivity of China's manufacturing industry. Taking EC as the explained variable, the regression coefficient of AI is positive but not significant. Taking TC as the explained variable, the regression coefficient of AI is 10.194, the sign is positive, and it is significant at the 1% significance level, indicating that artificial intelligence helps to improve the technological progress of China's manufacturing industry. The above results show that artificial intelligence helps promote the improvement of green total factor productivity in China's manufacturing industry, and this improvement mainly comes from technological progress, which verifies the research hypothesis of this paper. Further taking PEC and SEC as explained variables, it is found that artificial intelligence has a positive promoting effect on PEC, which is significant at the 1% significance level, with a coefficient of 9.821, and has a negative effect on SEC at the 5% significance level. Significant, with a coefficient of -5.776. This suggests that AI is beneficial for increasing the efficiency of green technologies, but this improvement is temporarily weighed down by efficiencies of scale. This paper passes the robustness and endogeneity tests of replacing the core explanatory variable measurement method, adjusting the sample period, and adding possible missing control variables.

4. CONCLUSIONS

This paper draws the following main conclusion: Artificial intelligence helps to improve the green total factor productivity of China's manufacturing industry. This improvement mainly comes from technological progress, and the impact of artificial intelligence on the technical efficiency of manufacturing is not significant. Further analysis found that artificial intelligence is beneficial to improve the pure technical efficiency of China's manufacturing industry, but the improvement of technical efficiency is temporarily dragged down by scale efficiency. This paper puts forward the following countermeasures and suggestions: In order to further promote the green development of China's manufacturing industry, efforts can be made in the direction of improving technical efficiency, and enterprises below the "frontier" are encouraged to catch up with those on the "frontier". Taking the smart factory considering environmental construction and energy improvement as the goal orientation, accelerate the construction of the system and model of smart manufacturing. Manufacturing enterprises should recognize the role of artificial intelligence as a "general purpose technology", and actively promote the application of artificial intelligence technology in all aspects of manufacturing product design, manufacturing, and intelligent supply chains to achieve green development. The government needs to play a guiding role, provide public goods necessary for the application of artificial intelligence technology, reduce the cost of using new technologies, solve the problem of "Curse of Knowledge", and guide complementary innovation and investment.

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