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Research on the Impact of Digital Economy on Green Total factor productivity of Enterprises

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Abstract

Based on the city level Panel data of China from 2011 to 2019, this paper explores the impact of digital economy development on green Total factor productivity (GTFP) of Chinese enterprises. Research has found that the digital economy has a significant driving effect on the growth of GTFP in Chinese enterprises, and there are differences in this driving effect, with a greater promoting effect on high-tech and non dual employment enterprises. Through this article's analysis, we hope to assist in the better development of China's digital economy and create greater possibilities for the improvement of enterprise GTFP.

Keywords

Digital economy; Green Total factor productivity; Artificial intelligence.

1. Introduction

Compared to previous development models, high-quality development focuses more on optimizing and protecting resources. The digital economy, as an important driving force for development, also provides important driving force for promoting green economy development. According to statistics, by the end of 2020, the scale of China's digital economy had reached 39.2 trillion yuan (CCID Consulting Digital Economy Industry Research Center, 2021). With the rapid development of digital information technology and artificial intelligence, the digital economy, as a supplement to the Traditional economy, has penetrated into all aspects of the economy, deeply integrated with many fields, and become an important driving force for economic development, effectively promoting the transformation of economic growth mode from production factor driven to innovation driven. In the new era, exploring the role of digital economy in green Total factor productivity (GTFP) of enterprises is of great significance for how to grasp the new opportunities brought by the digital industrial revolution in China and promote the sustainable and green development of enterprise economy.

The digital economy is an economic model nurtured by a new round of scientific and technological revolution. It takes data as the key production factor, modern information network as the important carrier of digital economy and green Total factor productivity, and the Internet and artificial intelligence to promote economic development. In recent years, the digital economy has become a major trend in global economic development, and China attaches great importance to the development of the digital economy. In 2021, 7 of the top 10 global market capitalization companies are located in the United States, 2 are located in China, and 7 are all internet technology companies; At present, due to the repeated COVID-19 and the downturn of the global economy, China is faced with multiple impacts such as diminishing marginal investment returns and the gradual disappearance of Demographic dividend. It is urgent to shift from factor driven and investment driven to innovation driven and Total factor productivity driven. The important embodiment of high-quality economic development is the improvement of efficiency, which is to achieve additional production efficiency, that is, the improvement of Total factor productivity. However, because China's economic development is

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restricted by serious environmental pollution and inefficient energy utilization, green development has become a strategic choice for high-quality development of China's economy. Compared with the traditional Total factor productivity, it is more scientific to use green Total factor productivity to measure and evaluate the growth of enterprises. Therefore, as an integrated economy, whether the digital economy can break through the shackles of traditional production factors, become a new driving force for economic growth, and play an important role in promoting green Total factor productivity of enterprises and promoting green development is worth further exploring.

In view of this, on the basis of relevant theories, this paper uses the digital economy index of 288 Prefecture-level city in China from 2011 to 2019 to empirically test the impact of digital economy on enterprise green Total factor productivity and its mechanism, starting from enterprise green Total factor productivity, using artificial intelligence as an intermediary variable.

2. Journals reviewed

In terms of employment, Daron and Pascual's research found that the development of the digital economy can provide more employment options for the workforce, thereby effectively improving the efficiency of labor allocation. In terms of innovation, Xiong Li and Cai Xuelian analyzed the relationship between the digital economy and regional innovation, and found that the digital economy has a significant promoting effect on regional innovation. In terms of trading markets, Erik and Loran pointed out that the strong development of digital economies such as the Internet has greatly improved trade efficiency; Lv Mingyuan and Miao Xiaodong found that the digital economy can significantly improve transaction efficiency on the one hand, and also play a positive role in promoting the rationalization and advancement of industrial structure on the other hand, which has a significant impact on value distribution.

The report of the 19th National Congress of the Communist Party of China pointed out the direction for China's high-quality green development in the new era, that is, to establish a sound green circular economic development system. Digital economy and green development will become inevitable requirements for building a new development system in China in the future. The digital economy has become the key force for China to implement this major strategy. Song Yang analyzed the impact of the digital economy on the quality of economic development from two dimensions: "external performance" and "endogenous motivation". The results showed that the digital economy promotes the improvement of economic development quality at multiple levels and dimensions. Zhang Hong et al. pointed out that the digital economy promotes three major transformations - economic development quality, economic growth efficiency, and economic growth momentum - to drive the economy towards a high-quality level of development. Jiang Jinhe proposed that the digital economy is a necessary way to help China achieve the dual carbon goals, promote the transformation of green economy, and achieve green and high-quality development. Liu Li and Ding Tao pointed out that the development of the digital economy can improve resource utilization efficiency, reduce carbon emissions and pollution, and achieve the goal of promoting green and high-quality economic development. Therefore, it can be considered that the digital economy is becoming an important driving force for promoting the green and high-quality development of China's economy.

3. Theoretical analysis and hypothesis formulation

3.1. The impact of digital economy on green Total factor productivity of enterprises

The digital economy can alleviate the financing pressure of enterprises in the process of technological innovation. Enterprise innovation and research and development often have a long cycle and large capital investment, and traditional financial institutions are unwilling to provide financing to avoid risks. As an expansion of the Traditional economy, the digital economy can use Big data and cloud computing technology to effectively evaluate financing companies, promote accurate matching of capital supply and demand, thus expanding the boundaries of financial services, easing financing constraints, and achieving inclusive economic growth. Green industries generally have advanced environmental protection technologies, high technical requirements, and financial needs. Obtaining financial support from the digital economy can promote technological innovation in green industries, expand production scale, and increase green output. The digital economy plays its convenient credit and mobile payment functions, which can promote the expansion of consumption scale and to some extent incentivize producers to expand production and improve production efficiency. In addition, the digital economy can revitalize private capital, effectively guide funds to invest in industries currently encouraged by the state, and serve the real economy. Due to information asymmetry and other reasons, the development of green finance is limited to some extent. But the digital economy can link human behavior with green transactions, and digital economy services such as online credit and digital payments have inherent green attributes, which can effectively promote green development. Based on the above analysis, this article proposes the first hypothesis.

H1: The development of digital economy can promote the improvement of green Total factor productivity of enterprises.

3.2. Indirect effect of digital economy on green Total factor productivity of enterprises

The digital economy further improves green Total factor productivity through the indirect effect of artificial intelligence, which is mainly reflected in the following points: First, the technology spillover effect brought by the digital economy not only expands the production scale of each industry, but also increases the proportion of high-tech in the industry, and improves green Total factor productivity through optimizing the industrial structure by building an intelligent ecological industrial chain and combining it with traditional industries, Assist in high-quality economic growth (Zhou Jianjun, 2021). Secondly, the promotion effect of the digital economy on artificial intelligence is mainly reflected in three aspects: firstly, related technologies such as the digital economy directly promote the economic development of the internet industry, software industry, and information technology service industry; Secondly, the technological spillover effect of digital economy related technologies can re empower traditional industries, significantly improving the production scale and efficiency of industries, and promoting industrial digitization; Third, the development and application of technologies such as digital economy have penetrated into all areas of the economy and society, thus driving the development of the real economy (Luo Yihong, 2019), and further promoting the improvement of green Total factor productivity by stimulating innovation efficiency, optimizing factor allocation and other ways. Finally, the continuous progress of the digital economy has promoted the speed of information circulation, effectively reduced the access threshold and R&D costs for innovative enterprises to carry out R&D, provided new vitality for economic development, and ultimately effectively improved green Total factor productivity.

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H2: The digital economy improves the green Total factor productivity of enterprises through the technology spillover effect of artificial intelligence.

4. Research Design

4.1. Variable Definition

The dependent variable (gtfp). In order to enhance the rationality and accuracy of the research as much as possible, after comparing existing green all factor measurement methods, this article selects the SBM directional distance function and GML index based on non expected output for actual measurement. The advantages of this measurement method are: on the one hand, the directional distance function can measure the distance between the expected output of enterprises and the front line of maximizing positive efficiency, The distance between negative non expected output and the forefront of negative minimization can be measured, fully reflecting the new concept of green development at present (Chen Chaofan, 2016). On the other hand, compared with M index and ML index, GML index can not only consider the problem of unexpected output, but also avoid the situation that the enterprise Linear programming has no solution.

Explanatory variable (Dige). In empirical analysis, the measurement indicators for the digital economy include Tencent Research Institute's Digital China Index and some scholars' self constructed digital economy indicator measurement indicators. Zhao Tao and others combined urban finance with Internet development, used the level of urban financial development to symbolize the degree of digital transactions, and used the level of Internet development as the degree of digital application to build a measurement system of digital economy index for Prefecture-level city. This paper selects data from 288 Prefecture-level city with reference to Zhao Tao and other practices. Based on the two dimensions of Internet and digital transactions, it will reflect five indicators of Internet development level - the number of Internet users per 100 people, the proportion of computer services and software practitioners, the total amount of telecommunications services per capita The per capita postal service is combined with the number of mobile phone users per 100 people and the digital HP financial index, which reflects the level of digital transactions in the city. The principal component analysis method is used to calculate the city's digital economy index.

Mediating variables. The artificial intelligence measurement indicators refer to the processing method of artificial intelligence measurement indicators by Acemoglu&Restrepo (2020), Kangxi et al. (2021), and are measured using the density of industrial robots. The specific approach is to first match the industry category in the China Labor Statistics Yearbook with the usage of Chinese robots published by the International Federation of Robots (IFR), and then calculate the AI development level index using the Bartik Instrumental variables estimation method, and take logarithmic processing. The data comes from the Robot Alliance database and EPS database.

Control variables. (1) Environmental regulations. The intensity of environmental regulation can directly reflect the energy consumption and environmental pollution status of a region. This article refers to the approach of Tian Jie et al. (2021) and uses the entropy method to fit five indicators, including sulfur dioxide removal rate and domestic sewage treatment rate, to obtain environmental regulation measurement indicators. At the same time, logarithmic processing is performed. (2) Regional openness level. Select the total investment amount of foreign-invested enterprises to measure the level of openness in the region, and take logarithmic processing. (3) Distorted allocation of capital factors. This indicator can measure the degree of deviation between the actual use of capital elements and the optimal allocation of capital elements. The calculation method is based on Zhou Xiaohui's (2021) processing method. (4) Urban infrastructure construction. Urban infrastructure construction is closely related to

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environmental pollution, which affects the level of green Total factor productivity. The length of optical cable per capita is used to measure urban infrastructure construction, and logarithmic treatment is taken. (5) Advanced industrial structure. It is expressed by the ratio of the total output value of the Tertiary sector of the economy to the sum of the total output value of the Primary sector of the economy and Secondary sector of the economy. The above data is sourced from the China Statistical Yearbook.

4.2. Model Building

$$\mathrm{Gtfp}_{i,t} = \alpha_0 + \alpha_1 \mathrm{Dige}_{j,t} + \sum \alpha_i \times \mathrm{Controls}_{i,t} + \sum \mathrm{Year} + \sum \mathrm{Industry} + \varepsilon \tag{1}$$

Gtfpi, t stands for green Total factor productivity of enterprises, Digej, t stands for digital economy index, $\sum \mathrm{controls}_{i,t}$represents the control variables that may be affected, $\sum$ Year is a time fixed effect, $\sum$ Industry is an industry fixed effect, and ε is a random interference term.

5. Empirical Results and Analysis

5.1. Basic regression

Based on the Hausman test results, a fixed effects model was selected. The benchmark regression results are shown in Table 1, from which it can be observed that the coefficient of the development level of the explanatory variable digital economy is positive and passes the test at a significant level of 1%, which indicates that the digital economy can significantly improve the green Total factor productivity of enterprises. Hypothesis 1 is valid

Table 1 Benchmark Regression Results

	(1) Gtfp	(2) Gtfp
Dige	0.095***	0.152***
	(9.135)	(15.286)
lnep		1.069***
		(20.276)
lnopen		-0.115***
		(-10.447)
lninf		0.050***
		(3.402)
abstauk		-0.651
		(-1.064)
ind		0.390***
		(7.165)
		(6.910)
YEAR	control	control
Industry	control	control
Constant	0.490***	-0.689***
	(4.397)	(-4.255)
N	17188	17188
R2	0.127	0.222

5.2. Mesomeric effect

The basic regression results have significantly proved that the development of the digital economy can promote the green Total factor productivity of enterprises, but the mechanism between the two has not been shown. This paper introduces artificial intelligence variables to explore the mechanism of digital economy affecting green Total factor productivity of enterprises.

Table 2 shows the verification results of green Total factor productivity of enterprises driven by the digital economy. The coefficient of 0.152 between the digital economy index (Dige) and the green Total factor productivity of enterprises in column (1) is significantly positive correlation at the level of 1%, which is consistent with the basic regression results; The correlation coefficient between the Digital Economy Index (Dige) and artificial intelligence in column (2) is 0.008, which is significantly positively correlated at the 1% level, indicating that the better the development level of the digital economy, the more it can promote the development of artificial intelligence. In column (3), the regression coefficient is 0.151, which is significantly positive at the level of 1%, indicating that enterprises can promote the upgrading of artificial intelligence technology and thus improve green Total factor productivity under the development of the digital economy.

Table 2 Impact Mechanism Testing

	(1)	(2)	(3)
	Gtfp	lnrobot	Gtfp
Dige	0.152***	0.008***	0.138***
	(15.286)	(-5.495)	(14.340)
lnep	1.069***	-0.274***	0.566***
	(20.276)	(-36.874)	(10.697)
lnopen	-0.115***	-0.002	-0.119***
	(-10.447)	(-1.501)	(-11.216)
lninf	0.050***	-0.090***	-0.115***
	(3.402)	(-43.222)	(-7.649)
abstauk	-0.651	0.352***	-0.004
	(-1.064)	(4.090)	(-0.006)
ind	0.390***	-0.111***	0.186***
	(7.165)	(-14.483)	(3.516)
lnrobot			0.151***
			(5.656)
_cons	-0.689***	1.275***	1.656***
	(-4.255)	(55.973)	(9.735)
N	17188	17188	17188
r2_a	0.222	0.640	0.274
Year	control	control	control
Industry	control	control	control
Industry	control	control	control

5.3. Robust Test

In order to verify the reliability of the above results, the following robustness tests were also conducted in this article:

Firstly, considering the continuity of the impact of digital economy development on enterprise innovation performance, the explanatory variable Digital Economy Index (Dige) lags behind by one period and lags behind by two periods, respectively. The regression results are shown in columns (1) and (2) of Table 3. The coefficients of lag are 0.178 and 0.185, which are significantly positively correlated at the 1% level, confirming the robustness of the article's conclusions.

Secondly, to eliminate industry characteristics that change over time, this article controls the industry × The joint fixed effect of years is shown in column (3) of Table 3.

Third, since other industries such as computer and Telecommunications engineering are closely related to digitalization, only the sample regression of manufacturing industry is retained, as shown in Table 3 (4). Overall, the regression coefficients of the above methods are significantly positively correlated at the 1% level, consistent with the benchmark regression results.

Table 3 Robustness Test

	(1) Gtfp	(2) Gtfp	(3) Gtfp	(4) Gtfp
Dige			0.152***	0.165***
			(15.255)	(14.759)
L.Dige	0.178***			
	(14.864)			
L2.Dige		0.185***		
		(13.227)		
lnep	1.076***	1.042***	1.068***	1.150***
	(18.045)	(15.308)	(20.124)	(19.086)
lnopen	-0.102***	-0.098***	-0.118***	-0.130***
	(-8.462)	(-7.497)	(-10.474)	(-10.156)
lninf	0.081***	0.091***	0.050***	0.028
	(4.123)	(3.562)	(3.375)	(1.635)
abstauk	-0.653	-0.541	-0.587	0.393
	(-0.959)	(-0.717)	(-0.952)	(0.505)
ind	0.365***	0.335***	0.387***	0.410***
	(5.949)	(4.876)	(7.081)	(6.479)
Year	control	control		control
Industry	control	control		control
Industry * Year Joint Fixed Effect			control	
_cons	-0.526***	-0.455**	-1.134**	-0.454***
	(-2.880)	(-2.212)	(-2.513)	(-2.873)
N	17188.000	17188.000	17188.000	17188.000
r2_a	0.215	0.204	0.220	0.210

5.4. Heterogeneity test

5.4.1. High tech enterprises

Enterprises need to improve their core competitiveness to cope with the increasingly fierce competition in science and technology, while enterprises' efforts to improve green Total factor productivity are also faced with complexity, uncertainty of external factors and other problems,

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which require the government to play a role. The recognition policy for high-tech enterprises has become an important tool, which can motivate enterprises to attach importance to scientific research activities and increase research and development investment. Enterprises that have been recognized can also obtain more production resources based on their own popularity. This paper considers the relationship between digital economy and green Total factor productivity among different types of enterprises with the high-tech enterprise identification (Tec). It takes 1 for high-tech enterprises, and 0 for non high-tech enterprises. In the column (4) of Table 4, the coefficient of the interactive term identified by the digital economy and high-tech enterprises is -0.077, which is significantly negative at the level of 1%. This indicates that compared with non high-tech enterprises, high-tech enterprises themselves have a large R&D investment, and the development of the digital economy may lead to a decrease in the proportion of production and R&D funds of high-tech enterprises, which cannot promote the improvement of green Total factor productivity.

5.4.2. Integration of two positions

In order to measure the relationship between management decisions on the enterprise's digital economy and green Total factor productivity, this paper describes whether the chairman and general manager are the same person to describe the dual role of the enterprise. As shown in Column (5) of Table 4, the coefficient of the interaction term between the digital economy and the integration of two positions is -0.054, which means that when the chairman and general manager of an enterprise are the same person, the digital economy will inhibit the green Total factor productivity of the enterprise. This is because the business strategy formulated by the company is not effective due to the fact that the chairman and general manager are both held by one person.

Table 4 Heterogeneity Test

	(4) Gtfp	(5) Gtfp
Dige	0.172***	0.156***
	(13.297)	(13.888)
Tec	0.328***	
	(11.979)	
Dige* Tec	-0.077***	
	(-4.853)	
Dual		0.081***
		(2.624)
Dige* Dual		-0.054***
		(-3.147)
lnrobot	1.873***	1.845***
	(-35.837)	(-35.076)
lnep	0.549***	0.548***
	(10.407)	(10.310)
lnopen	-0.122***	-0.117***
	(-11.522)	(-10.967)
lninf	-0.111***	-0.116***
	(-7.410)	(-7.631)
abstauk	0.160	0.031
	(0.272)	(0.052)
ind	0.199***	0.208***

	(3.771)	(3.889)
_cons	1.525***	1.583***
	(8.989)	(9.216)
N	17188	17028
r2_a	0.280	0.274
Year	Yes	Yes
Industry	Yes	Yes

6. Inspiration

This paper selects the city level digital economy development index from 2011 to 2019 to empirically study the impact of digital economy on green Total factor productivity of enterprises, and analyzes the mechanism of its impact from the perspective of AI technology spillover. The results show that: first, the digital economy significantly improves the green Total factor productivity of enterprises; Second, the digital economy further strengthens the positive effect on green Total factor productivity by improving enterprise AI technology; Third, the heterogeneity analysis results show that the impact of AI on green Total factor productivity is more significant for high-tech enterprises and non dual role enterprises.

Research enlightenment: First of all, data has become an indispensable part of enterprises' green Total factor productivity. We should actively promote the integration of the Internet and other network economies with the real economy, further expand the infrastructure of the digital economy, combine Chinese wisdom with the digital economy, and better build a Socialism with Chinese characteristics digital economy. Secondly, optimize artificial intelligence to alleviate technological problems in enterprises. Finally, follow the steps of the digital era to fully release the dividend of the digital economy, and vigorously develop the digital economy to maximize the promotion of green Total factor productivity.

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