

Study on the Impact of Digital Transformation on Green Total Factor Productivity

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Abstract: This paper discusses the theoretical application mechanism of digital transformation to total factor productivity from the direct and indirect effects, and constructs enterprise digital transformation indicators based on the data of A-share listed companies from 2010 to 2022 for empirical analysis. The findings are as follows: First, enterprise digital transformation significantly promotes the increase of total factor productivity, and this conclusion passes multiple robustness tests. Secondly, the digital transformation of enterprises mainly enables the improvement of total factor productivity through direct effects and indirect effects of reducing internal control costs and external transaction costs. Finally, the empowering effect of enterprise digital transformation on total factor productivity is more obvious in service industries, technology-intensive, capital-intensive, competitive industries, large-scale enterprises, and emerging enterprises.

Keywords: Digital transformation, Total factor productivity, Text analysis, Enabling effect.

1. Introduction

With the continuous development and wide application of digital technology, the digital economy has become a new engine to promote high-quality economic development. Among them, the digital transformation of enterprises has become the micro foundation for the rapid development of the digital economy, an important part of the high-quality development strategy system of China's economy, and an important driving force for the improvement of the total factor productivity of micro-enterprises in the deep integration of the digital economy and the real economy. At the same time, China's economy has entered a new development pattern and is faced with difficulties such as tight factor endowment, lower production efficiency, less room for value appreciation and serious environmental pollution. Enterprises have realized that the rugged development mode can no longer meet the requirements of sustainable development, and it is urgent to change the development mode, change the growth momentum, and improve the total factor productivity. Enterprise digital transformation refers to the use of data, information, algorithms and other digital technologies in production, trading, management and other aspects of the transformation of traditional production and life style and business model, in order to promote high-quality development of enterprises. In fact, the digital transformation of enterprises is leading many difficulties, completely different scenarios bring transformation pressure to traditional enterprises, and enterprises with different characteristics are significantly different. Leading enterprises in the industry are easy to realize digitalization by virtue of their strong capital and technical advantages, but most small and medium-sized enterprises are reluctant to turn and unable to turn due to practical constraints such as their own development scale and insufficient management experience. Therefore, it is of great practical significance and theoretical value to deeply explore the productivity effect of enterprise digital transformation. Although the existing researches have accumulated a lot of valuable results, there is still room for improvement due to the complex impact mechanism of digital

transformation on total factor productivity and the inconsistency of measurement indicators. On the one hand, there are different academic views on the relationship between the two. On the one hand, there is the "enabling effect", which believes that the digital transformation of enterprises significantly improves the total factor productivity; the second is "negative energy effect", which believes that the digital transformation of enterprises has a inhibiting effect on total factor productivity due to resource misallocation and management ability. On the other hand, the definition and measurement of enterprise digital transformation are flawed. In terms of its connotation, most of the existing scholars define digital transformation from one or several aspects in actual research, and it is difficult to get a full picture, including the application of digital technology, the innovative value of data elements and the utility of data management. As for its measurement, because it is a frontier problem, there are some difficulties, but the existing research has carried out some exploration in the macro and micro levels. At the macro level, we mainly use the national and civil economic accounting method and the entropy method to build the digital economy development index to measure the digitalization level of a certain region. The micro level mainly includes the construction of digital intangible assets, ICT-related indicators based on tracking survey data, and digital word frequency indicators. Among them, the first method is easy to obtain data but difficult to reflect the overall picture of digitalization; the second method is subject to large sample limitations and poor representation; and the third method is more widely used. Based on this, on the basis of improving enterprise digital transformation, this paper constructs a digital dictionary and uses text analysis method to measure digital transformation indicators to explore its enabling effect on total factor productivity. Major marginal contributions: At the theoretical level, it enriches and expands the research boundaries of digital economy empowerment, systematically analyzes the impact of digital transformation on total factor productivity from the perspective of micro enterprises, and deeply explores its direct impact mechanism and indirect impact mechanism through reducing enterprises' internal

control costs and external transaction costs. At the method level, based on the digital dictionary and the use of text analysis method to measure digital comprehensive indicators, improve the measurement of enterprise digital level, and lay a good foundation for the subsequent evaluation of the economic effect of digital economy at the micro level. At the practical level, enterprise digital transformation is the concrete embodiment of the integrated development of digital economy and micro real economy. Clarifying its enabling effect and differentiated impact will help the government to guide different enterprises scientifically.

2. Literature Review

The relevant research involved in this paper is mainly carried out from the following three aspects. The first is the research on enterprise digital transformation. Under the big wave of digital economy, the relevant researches on enterprise digital transformation have shown explosive growth, and their research levels and perspectives are rich and colorful. At the micro level, they can be roughly classified into three categories: driving factors, process mechanism and impact results of enterprise digital transformation. As far as driving factors are concerned, one is driven by the ability of data element management, information technology application, organization management, digital literacy of employees, CEO's composite functional background, leadership characteristics, etc. The other is policy guidance such as direct government subsidies, indirect tax incentives, and special industrial support for the digital industry [1]. As far as the process mechanism is concerned, it is manifested as the construction process of enterprise digital capability and value acquisition capability, and the transformation is realized through the technology-environment leading path. In terms of influencing the results, the digital transformation of enterprises is conducive to enhancing the competitiveness of enterprises and promoting the high-quality development of enterprises. The second is about the driving factors of enterprise total factor productivity. It can be divided into macro-economic factors outside the enterprise and micro-economic factors inside the enterprise. In terms of external macro factors, including economic policy support, environmental protection policies, government behavior, digital finance and digital infrastructure construction and other factors; internal micro factors include R&D investment, executive pay gap and human capital structure adjustment [2]. With the development and promotion of digital technology, digital transformation has become an important driving force to improve the total factor productivity of enterprises. The third is related research on the impact of enterprise digital transformation on total factor productivity. Since the "IT production paradox" was put forward, most researches focus more on how to play the potential of IT and control the measurement error to solve the production paradox.

3. Theoretical Analysis and Research Hypothesis

Next, this paper explores the impact mechanism of enterprise digital transformation on green total factor productivity from two dimensions of direct effect and indirect effect.

3.1. The Direct Effect of Enterprise Digital Transformation on Green Total Factor Productivity

The digital transformation of enterprises has exerted many influences on the production efficiency, product circulation and management mode of enterprises, and its direct effects are mainly reflected in the following aspects: First of all, digitalization changes the traditional time and space restrictions on enterprise development, makes market liberalization and government macro-control more convenient [3], optimizes all aspects of enterprise production, facilitates the structural adjustment of production factors, accelerates the digitalization and intelligent transformation of enterprises in various industries, and improves the utilization efficiency of factors [4]. Secondly, enterprise digitalization and digital enterprise "double linkage", accelerate the construction of a diversified digital innovation platform and digital management platform, improve the efficiency of internal information query, transmission, communication and management, and then optimize the enterprise management organization structure, simplify the approval process, effectively avoid the distortion and distortion of information in the transmission process, and help improve production efficiency.

Based on this, hypothesis 1 is proposed: enterprise digital transformation is conducive to the improvement of total factor productivity.

3.2. Indirect Effects of Enterprise Digital Transformation on Green Total Factor Productivity

In the era of digital economy, digital transformation is a compulsory course for enterprises to keep up with the trend, which can not only have a direct impact on the production efficiency of enterprises, but also its indirect driving effect cannot be ignored. Therefore, this paper further explores the indirect effects of external transaction cost reduction and internal control cost [5]. The external transaction cost reduction mechanism is mainly reflected as follows: First, enterprises constantly integrate digital technology in production and management operation, which is conducive to alleviating information asymmetry between enterprises and society, effectively reducing search and matching costs, expanding the spatial scope of transactions, and improving the success rate of transactions [6]. Second, enterprises make full use of digital platforms to strengthen information inquiry and exchange, making the quality, standards and prices of products on the market relatively open and transparent, so as to avoid malicious competition between enterprises and reduce market research costs.

In terms of internal control cost reduction mechanism, the adoption of digital information management system within enterprises is conducive to the cooperation and linkage of information communication, event tracking, task transmission and emergency handling among various departments of enterprises, reducing the approval process, reducing the coordination cost between departments, and improving the efficiency of enterprise management decision-making.

Based on this, hypothesis 2 is proposed: enterprise digital transformation directly improves total factor productivity by reducing external transaction costs.

4. Research Design

4.1. Sample Selection and Data Source

Since the trend of rapid development of China's digital economy and increasing attention to digital application is reflected after 2010, the sample interval of this paper is finally selected from 2010 to 2022, taking China's A-share listed companies as the research object, and excluding samples with missing data of financial industry, ST, PT and main variables.

$$TFP_{it} = \alpha_0 + \alpha_1 DIG_{it} + \sum Controls + \sum Firm + \sum Ind + \sum Pro + \sum Year + \varepsilon_{it} \quad (1)$$

Where, TFP_{it} represents the total factor productivity of enterprise i in year t , and DIG_{it} represents the degree of digital transformation of enterprise i in year t . Controls is the control variable, Firm, Ind, Pro and Year respectively represent the fixed effect of enterprise, industry, province and year, ε_{it} is the random error term.

4.3. Measurement of Variables

Total factor productivity (TFP). The mainstream calculation method for TFP is the two-step estimation method proposed by Olley and pakes (1996) (OP method). However, OP method has the shortcoming of losing a large number of samples, so Levinsohn and petrin (2003) improved it (LP method). Since the index used by LP method is easier to obtain, can effectively reduce sample loss, and avoid endogeneity when OP method is used to estimate, the total factor productivity estimated by LP method is widely used in academia. In this paper, LP method is used to calculate total factor productivity as the explained variable.

5. Empirical Results and Economic Interpretation

5.1. Baseline Regression

Table 1 reports the results of baseline regression, where result (1) does not add the fixed effects of control variables and individuals, provinces, industries and time; result (2) does not add the fixed effects of individuals, provinces, industries and time; result (3) adds the fixed effects of control variables but does not add the fixed effects of individuals, provinces, industries and time. Result (4) Control variables and fixed effects of individual, province, industry, and time were added. All four results show that enterprise digital transformation can improve total factor productivity, which verifies hypothesis 1 of this paper. In addition, with the addition of fixed effects and control variables, the goodness of fit of the model gradually increases, which indicates the rationality of the model setting and the robustness of the regression results.

Table 1. Results of baseline regression

Variable	(1)	(2)	(3)	(4)
	TFP	TFP	TFP	TFP
DIG	0.954*** (42.63)	0.310*** (7.84)	0.051*** (3.43)	0.072*** (2.97)
Control variable	no	no	yes	yes
Fixed effect	no	yes	no	yes
Observed value	28710	28710	28710	28710
Adj.R ²	0.066	0.349	0.641	0.661

In the end, 28,710 enterprise-annual observations of 3,004 enterprises were obtained. The data was sourced from the Wind database, and 1% and 99% indentation were done for the continuity variables.

4.2. Model Setting

In order to verify the direct impact effect, this paper draws on the research of Shi Bingzhan and Li Jiantong (2020) and builds the following benchmark model:

Note: The t statistic is in parentheses, where ***, ** and * are significant at the 1%, 5% and 10% levels, respectively.

5.2. Robustness Test

This paper uses the method of instrumental variables to solve the possible endogenous problems in the empirical study. By referring to the practice of Huang Qunhui et al. (2019), this paper defines the data of posts and telecommunications in each city in 1984 as instrumental variables for the digital transformation of enterprises, and refers to the practice of Zhang Hu et al. (2023) in the empirical analysis. It is measured by the product of the number of post offices in each prefecture-level city and the number of Internet users in the country in 1984. The results of the two-stage regression are shown in Table 3: First, the selection of instrumental variables is reasonable, because LM statistics are significant at the level of 1%, rejecting the hypothesis of insufficient identification of instrumental variables; while F statistics are larger than the critical value of Stock-Yogo weak instrumental variable identification, rejecting the hypothesis of weak instrumental variables. Secondly, the results of the first stage show that digital transformation and instrumental variables are significantly positively correlated at the level of 1%, which meets the premise expectations. The results of the second stage show that the coefficient of digital transformation is still significantly positive, which indicates that the basic conclusion of this paper is robust and reliable.

6. Conclusions and Enlightenments

Through mechanism analysis and empirical test, this paper finds that: First, enterprise digital transformation significantly improves total factor productivity, and this conclusion passes the robustness test of IV, replacement of core variables and replacement of samples. Second, mechanism analysis shows that enterprises' digital transformation can enhance total factor productivity mainly through direct effects and reducing internal control costs and external transaction costs [7]. Third, heterogeneity analysis finds that the empowering effect of digital transformation on enterprise digital transformation is more obvious in the service industry, technology-intensive, capital-intensive, competitive industries, large-scale enterprises and emerging enterprises. According to the previous analysis, this paper has obtained the following policy implications: First, the government should take multiple measures and attach importance to the role of enterprises' digital transformation in enabling total factor productivity [8]. Governments at all levels should not only conform to the trend of rapid development of the digital economy, establish incentive mechanisms to promote enterprises' digital transformation, accelerate the construction

of new infrastructure [9], lay a solid foundation for enterprises' digital transformation and create a good environment for digital transformation, but also guide enterprises to implement macro digital economic policies, pay attention to digital application, and avoid digital concept hype. The real realization of digitalization improves the quality and efficiency of enterprises' total factor productivity. Second, enterprises should have the awareness of digital transformation, and use digital technology to reduce internal control costs and external transaction costs, so as to improve total factor productivity [10]. Aware of the digital economy era, opportunities and challenges coexist, we should pay attention to long-term benefits, maintain strategic focus, and make full use of data elements. In the face of practical challenges such as shortage of digital transformation talents and capital constraints [11], on the one hand, actively develop the digital talent introduction plan, increase the expenditure on the introduction and training of senior digital talents, and form a "reservoir" effect of digital transformation talents. On the other hand, traditional financing methods, the implementation of digital inclusive financial model, the use of supply chain finance and other open source methods to obtain financial support, in order to establish a special fund for digital transformation, and continue to expand the "capital pool" of digital transformation.

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