

Retraction

Retracted: Digital Transformation and Corporate Total Factor Productivity: Empirical Evidence Based on Listed Enterprises

Discrete Dynamics in Nature and Society

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

- (1) Discrepancies in scope
- (2) Discrepancies in the description of the research reported
- (3) Discrepancies between the availability of data and the research described
- (4) Inappropriate citations
- (5) Incoherent, meaningless and/or irrelevant content included in the article
- (6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

- [1] G. Zeng and L. Lei, "Digital Transformation and Corporate Total Factor Productivity: Empirical Evidence Based on Listed Enterprises," *Discrete Dynamics in Nature and Society*, vol. 2021, Article ID 9155861, 6 pages, 2021.

Research Article

Digital Transformation and Corporate Total Factor Productivity: Empirical Evidence Based on Listed Enterprises

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This paper mainly attempts to disclose the action mechanism of corporate digital transformation on total factor productivity (TFP). Based on the data on listed enterprises in 2007–2019, the influence of corporate digital transformation on TFP was analyzed empirically. The results show that corporate digital transformation can significantly promote TFP. Heterogeneity analysis reveals that the promoting effect of digital transformation on TFP only exists in small and medium high-tech enterprises, suggesting that corporate digital transform enhances TFP by improving the management efficiency and technical level of enterprises. The research provides theoretical basis and empirical evidence for improving corporate TFP from the perspective of digital transformation.

1. Introduction

With the continuous expansion of economic globalization, new economic forms are taking shape, thanks to the rapid development of information technology, laying the foundation for the growth of digital economy. Digital economy is an economic model formed through the informatization and networking of the environment, by virtue of modern information technology. As the core of digital economy, corporate digital transformation means enterprises rely on information technology to improve the efficiency of business handling and resource allocation. Existing studies have shown that corporate digital transformation helps to reduce corporate costs, increase corporate management efficiency, and promote corporate technological progress [1]. All these consequences contribute to the total factor productivity (TFP) of enterprises. Therefore, it is of practical significance to study how digital transformation influences corporate TFP.

There is not yet a consensus on the connotations of digital transformation. Lee et al. [2] considered corporate digital transformation as the application of digital technology in certain business links. Hininga et al. [3] believed that digital transformation has a comprehensive innovation

effect and brings new actors, structures, and values. Vial [4] viewed digital transformation as a process, in which digital technology triggers organizations to create new strategies for value creation. Verhoef et al. [5] divided digital transformation into three stages: converting analog information into digital information, streamlining the current business flows (e.g., communication, distribution, and business relationship management) with digital information, and strategic changes of the business model. This paper holds that China belongs to the second stage of digital transformation defined by Liu et al.

Many scholars have explored the influencing factors of corporate productivity. Syverson [6] and Marchese et al. [7] concluded that corporate productivity is affected by both internal and external factors. The internal factors include management skills, management practices, information and communication technology (ICT), and digitalization; the external factors include the degree of competition, agglomeration economy, and the degree of specialization. Similar to our topic, they studied the influence of ICT, software application, and digital economic growth on productivity. The early literature regards ICT investment as a production factor and discusses its influence on productivity. Mittal and Nault [8] classified the effects of ICT on

business performance into direct and indirect categories. The direct effect refers to the impact of ICT as a production element on output, and the indirect effect refers to the impact of ICT on output by changing the input efficiency of other elements. Relich [9] analyzed how labor productivity is affected by different components of ICT, namely, enterprise resource planning (ERP) and e-commerce and found that ICT software application always promotes labor productivity. In addition, previous studies have learned that digital transformation requires complementary investments to increase productivity. Brynjolfsson and Hitt [10] proved that the contribution of digitalization needs many complementary investments, e.g., human capital. This complementary mechanism was demonstrated empirically in the recent literature. For example, Pieri et al. [11] noticed the joint effects of research and development (R&D) and ICT on productivity.

Domestic scholars have investigated the evolutionary features, governance mechanism, and positive influence of corporate digital transformation [12] and concluded that corporate digital transformation improves financial performance [1], boosts innovation efficiency and performance [13, 14], and bolsters corporate export [15] and input-output efficiency [16]. Existing studies have shown that corporate TFP can be elevated by improving technological progress and management efficiency [17]. Relying on new technologies like blockchain, big data, cloud computing, artificial intelligence (AI), and the Internet of things (IoT) [18–20], digital technology can improve the technical level and management efficiency of enterprises from various aspects, namely, technology, information, and platforms, thereby removing the obstacles to corporate TFP growth. Therefore, TFP can be enhanced by the corporate digital transformation driven by digital technology. However, there are very few reports on the relationship between corporate digital transformation and TFP. Liu [21] was the only researcher who examined the impact of corporate digital transformation on productivity based on the data of listed enterprise. The researcher pointed out that corporate digital investment does not directly affect productivity but promotes the productivity of other elements [21]. Contrary to Liu Fei's conclusions, the authors noticed that the promoting effect of corporate digital transformation on TFP mainly concentrates in small and medium high-tech enterprises.

Taking China's A-share listed enterprises as samples, this paper discusses the influence of corporate digital transformation on TFP and discovers that corporate digital transformation helps to promote TFP, especially in small and medium high-tech enterprises. The possible marginal contribution of this work is enriching the research results on the relationship between corporate digital transformation and TFP. Many researchers have studied how corporate digital transformation influences TFP but failed to clarify the mechanism of that influence. In this paper, a heterogeneity analysis is carried out from the angles of enterprise type (whether it is a high-tech enterprise) and enterprise scale. It was found that corporate digital transformation significantly promotes the corporate TFP of small and medium high-tech enterprises. This indicates that corporate digital

transformation enhances TFP by improving the management efficiency and technical level.

The remainder of this paper is organized as follows: Section 2 performs theoretical analysis and presents a hypothesis; Section 3 explains the data sources and gives the empirical model; Section 4 analyzes the test results; Section 5 puts forward the conclusions and suggestions.

2. Theoretical Analysis and Hypothesis

The influence of corporate digital transformation on TFP can be summarized in two aspects:

- (1) Corporate digital transform helps to reduce management costs and increase management efficiency, thereby enhancing TFP. The management efficiency of an enterprise involves the utilization and arrangement of various resources (e.g., human, finance, materials, and information) in the enterprise, as well as the management of human, finance, and materials in society. ICT can improve TFP by transforming and upgrading the traditional industrial sectors [17]. An enterprise is composed of multiple business units, each of which performs its own duties. Many management issues will surface as the enterprise expands and the number of employees grows. These management issues, as well as business operation problems, can be effectively solved by management software systems. Through the software systems, standard processes, management systems, and best practices could be fully embedded in business operations. For example, the ERP system enables manufacturing enterprises to realize scientific and efficient production. Centering on systematic management, the system fully integrates information technology with advanced management philosophy and provides employees and the management with useful decision-making tools. Similarly, the warehouse management system (WMS) helps large warehouses achieve efficient management and operations. This real-time computer software system can perfectly manage information, resources, behaviors, inventory, and distribution according to business and computing rules. Furthermore, the consumer service system makes it possible for enterprises to effectively handle the complaints raised by consumers. In summary, corporate digital transform plays a critical role in improving corporate management efficiency.
- (2) Digital transformation enhances TFP by promoting the technical level of enterprises. With the deepening of the new technological revolution, the digital economy, which centers in new technologies like 5G, cloud computing, and IoT, drives the continuous upgrading of technology applications and directly acts on the operation and development of enterprises. Digital transformation improves the technical level through two main paths. First, digital transformation increases the technical level of people

(technology users). In the context of digital economy, enterprises need new people who can master, understand, and accept new technologies. Therefore, technology users are forced to improve their technical level by learning new technologies, enhancing professional competence and keeping sensitive to new tech trends [21]. Second, digital transformation increases the technical level of things. The technical level, manifested as work efficiency, directly affects the efficiency of enterprises. With the infiltration of new technologies, enterprises cannot satisfy their needs of production and operation unless they upgrade and update the existing things. The entry of new technologies like intelligence and digitization not only simplifies operations and reduces error rates but also improves the efficiency of simple and repeated operations. Thanks to these new technologies, enterprises are empowered to reach the standards for high-quality enterprises in the new economic era: large scale, standardized, automated, and intelligent. The above two paths run through the entire process of technology application and facilitate the improvement of TFP by digital transformation from different angles [16]. On this basis, the following hypothesis was put forward.

Hypothesis 1. Corporate digital transformation improves TFP.

3. Data Sources and Empirical Model

3.1. Model Setting. To test the influence of corporate digital transformation on TFP, the benchmark model was constructed as follows:

$$TFP_{it} = c + \beta_1 \text{transform}_{it} + \sum_j \beta_j \text{control}_{it} + \mu_i + u_t + \varepsilon_{it}, \quad (1)$$

where TFP_{it} is TFP; transform_{it} is the level of digital transformation; control_{it} is a series of control variables that affect corporate TFP; β_j is the parameter to be estimated; μ_i is individual fixed effects; u_t is time-fixed effects; and ε_{it} is the residual term. To control the effects of macroenvironment and industry on TFP, both time and industry fixed effects are controlled in the regressions in this paper. To eliminate heteroscedasticity and autocorrelation problems, the standard errors were adjusted by clustering at the enterprise level.

The variables were configured as follows.

3.1.1. Explained Variable: TFP. Referring to Lu and Lian [19], the corporate TFP was estimated by the Levinsohn–Petri (LP) method.

3.1.2. Core Explanatory Variable: Digital Transformation. Following the ideas of Zhang et al. [22], the digital transformation level of each enterprise was treated as the digital

level of business management and operation. The level was calculated by the following formula: digital transformation = (office software + network application + platform management system + new technology R&D)/total intangible assets. The greater the calculated value, the higher the digital transformation level of the enterprise.

3.1.3. Control Variables. To control the other factors affecting corporate TFP, the control variables were selected in the light of Chen et al. [17]: enterprise age, enterprise scale, number of employees, debt-assets ratio, net profit margin of total assets, export intensity, and technological innovation.

The above variables are defined and described in Table 1.

3.2. Data Sources. The samples are enterprise listed in the A-share market of Shanghai and Shenzhen Stock Exchanges. The relevant data were collected from China Stock Market and Accounting Research (CSMAR) Database and prepared into the panel data of 2007–2019. The original samples were processed to obtain 8,134 effective enterprise-year observations through five steps: (1) removing financial enterprises; (2) removing enterprises receiving special treatment (ST); (3) removing the observations that last shorter than three consecutive years; (4) removing the data whose digital transformation index falls outside [0, 1]; and (5) winsorizing all continuous variables at the 1% and 99% levels. The mean and variance of corporate digital transformation were 0.128 and 0.232, respectively. The results indicate a significant difference between enterprises in the degree of digital transformation.

4. Test Results and Analysis

4.1. Benchmark Regression. Formula (1) was called to test the influence of corporate digital transform on corporate TFP. The test results are listed in Table 2, where column (1) only controls individual and time-fixed effects; column (2) also considers enterprise-level control variables.

In column (1), the coefficient of digital transformation was not significant because some variables are missing. In column (2), the coefficient of digital transformation was significantly positive at the 1% level, indicating that digital transformation has a significant positive impact on corporate TFP, after the other factors affecting corporate TFP have been controlled. Therefore, corporate digital transformation, e.g., handling businesses with office software and platform management systems, helps improve the working efficiency of employees, which in turn enhances corporate TFP. Hence, Hypothesis 1 was proved valid.

The regression results of the control variables show that the corporate TFP increases with enterprise scale, enterprise age, debt-assets ratio, and net profit margin of total assets and decreases with the growth of export intensity. The stronger the export intensity, the lower the corporate TFP. A possible reason is that many export enterprises in China are locked in the low end of the value chain and has a lower productivity than nonexport enterprises. The results are consistent with our expectation.

TABLE 1: Definition and descriptive statistics of variables.

Name	Definition	Sample size	Mean	Standard deviation
TFP	Lu Xiaodong and Lian Yujun (2012)	8,134	3.507	0.883
Digital transformation	Zhang Yongshen et al. (2021)	8,134	0.128	0.232
Enterprise age	Log of enterprise age	8,134	2.745	0.404
Enterprise scale	Log of total assets	8,134	7.641	1.270
Number of employees	Log of number of employees	8,134	8.597	9.669
Debt-assets ratio	Total liabilities/total assets	8,134	0.423	0.213
Net profit margin of total assets	Net profit/mean total assets	8,134	0.039	0.077
Export intensity	Export amount/operating income	8,134	0.121	0.208
Technological innovation	Log of number of patent applications	8,134	3.466	4.844

TABLE 2: Benchmark regression results.

Explanatory variables	Corporate TFP	
	(1)	(2)
Digital transformation	0.040 (1.17)	0.146*** (2.89)
Enterprise age		0.073** (2.19)
Enterprise scale		0.058*** (11.37)
Number of employees		0.012 (1.21)
Debt-assets ratio		0.282*** (2.95)
Net profit margin of total assets		1.677*** (5.74)
Export intensity		-0.121 (-0.70)
Technological innovation		0.033 (0.25)
Individual, time, industry, and city fixed effects	Yes	Yes
Constant term	3.814*** (874.11)	1.803*** (7.73)
N	8,134	8,134
Within R-sq	0.046	0.054

Note. ***, **, and * represent the significance at the levels of 1%, 5%, and 10%, respectively; the bracketed values are the Z-scores adjusted by robust clustered standard errors.

4.2. Robustness Test. The benchmark regression results confirm that digital transformation enhances corporate TFP. This paper uses formula (1) to test the influence of digital transformation (the mean digital transformation level of all enterprises in a region in the sample period) on regional TFP (the mean TFP of all enterprises in a region in the sample period). The regression results are listed in Table 3. For the other control variables that affect the regional TFP, the regional mean of each control variable was adopted. In Column (1), the coefficients of regional digital transformation were all significantly positive, suggesting that regional digital transformation significantly promotes regional TFP. From the macroscale, the results confirm the significant promoting effect of regional digital transformation on corporate TFP. That is, the core conclusion of this paper is robust.

4.3. Heterogeneity Analysis

4.3.1. Heterogeneity Analysis Based on Enterprise Type (Whether It Is a High-Tech Enterprise). Studies have shown that high-tech enterprises are more likely to increase corporate TFP with digital transformation than non-high-tech enterprises [17]. High-tech enterprises generally refer to the knowledge- and technical-intensive economic entities defined in Key High and New Technology Fields with National Supports. These enterprises continuously implement R&D and transform technological results and form core-

TABLE 3: Robustness analysis.

Explanatory variable	Regional TFP (LP method) (1)
Regional digital transformation	0.498** (2.43)
Control variables	Yes
Time, industry, and city fixed effects	Yes
_Cons	1.849*** (7.78)
N	2,663
adj. R-sq	0.062

independent intellectual property rights. On this basis, high-tech enterprises carry out business activities as resident enterprises. Theoretical analysis suggests that the digital transformation of enterprises can enhance corporate TFP by improving the technological level. Objectively speaking, high-tech enterprises boast a large room for technological improvement. Thus, the promoting effect of digital transformation on corporate TFP should be greater in high-tech enterprises than other enterprises. As a result, this paper divides all sample enterprises into high-tech enterprises and non-high-tech enterprises and regresses the two groups separately. The results of the two groups are recorded in columns (1) and (2) of Table 3, respectively. The coefficient of digital transformation was significantly positive in column (1) but insignificant in column (2). This means digital transformation only has a significant promoting effect of corporate TFP in high-tech enterprises.

TABLE 4: Regression results of heterogeneity analysis.

Explained variable: TFP	High-tech enterprises (1)	Non-high-tech enterprises (2)	Large high-tech enterprises (3)	Small and medium high-tech enterprises (4)
Digital transformation	0.146*** (2.89)	-0.048 (-0.99)	-0.019 (-0.22)	0.224*** (3.00)
Enterprise age	0.058*** (11.37)	0.058*** (14.83)	0.042*** (6.21)	0.062*** (6.96)
Enterprise scale	0.073** (2.19)	-0.065** (-2.55)	0.215*** (2.96)	0.055 (0.58)
Number of employees	0.012 (1.21)	0.013*** (2.64)	-0.033 (-0.43)	0.035 (0.19)
Debt-assets ratio	0.282*** (2.95)	0.241** (2.51)	0.000 (0.00)	0.304** (2.30)
Net profit margin of total assets	1.677*** (5.74)	1.384*** (5.85)	0.877** (1.98)	1.903*** (5.47)
Export intensity	-0.121 (-0.70)	-0.096 (-0.94)	-0.093 (-0.40)	-0.182 (-0.64)
Technological innovation	0.033 (0.25)	0.036 (0.76)	-0.056 (-0.68)	0.053 (0.94)
_Cons	1.803***	3.311*** (18.15)	1.058* (1.83)	1.766*** (3.16)
N	2663	5471	1328	1335
Within R-sq	0.044	0.050	0.056	0.051

4.3.2. Heterogeneity Analysis Based on Enterprise Scale.

The heterogeneity analysis based on enterprise type confirms that digital transformation only has a significant promoting effect of corporate TFP in high-tech enterprises. Furthermore, high-tech enterprises were divided into large high-tech enterprises and small and medium high-tech enterprises, and the two groups were regressed separately. The results of the two groups are recorded in columns (3) and (4) of Table 4, respectively. The coefficient of digital transformation was insignificant in column (3) and significantly positive in column (4), indicating that digital transformation only has a significant promoting effect of corporate TFP in small and medium high-tech enterprises. The reason is that, compared with large high-tech enterprises, small and medium enterprises are low in management efficiency: a large portion of their operating income is used to cover transaction cost, labor cost, and daily nonoperating consumption. Through digital transformation, small and medium enterprises can save management cost and improve management efficiency. The result also confirms that digital transformation enhances corporate TFP by improving management efficiency.

5. Conclusions

Targeting listed enterprises, this paper discusses the influence of corporate digital transformation on TFP. Two main conclusions were drawn through the research: (1) digital transformation promotes corporate TFP; (2) the promoting effect of digital transformation on corporate TFP only exists in small and medium high-tech enterprises, which suggests that corporate digital transformation enhances TFP by improving management efficiency and technical level. Based on these conclusions, several suggestions were put forward.

First, the digital transformation of traditional enterprises is promoted.

The core conclusion of our research is that corporate digital transformation can improve TFP. To promote corporate digital transformation, it is necessary to guide enterprises to understand digitization. While adapting to the latest technologies, the traditional enterprises should pursue

precise development and improve operating efficiency through digitization. In addition, the enterprises during the digital transformation should be supported with a suitable amount of policy subsidies.

Second, policy support is provided to the digital transformation of high-tech enterprises.

Heterogeneity analysis shows that digital transformation only has a significant promoting effect of corporate TFP in high-tech enterprises. High-tech enterprises have few physical assets. Most of their assets are immeasurable and intangible. The cost of constructing these intangible assets is even higher than the cost of asset acquisition of many traditional industries. What is worse, the property rights of these intangible assets are more susceptible to infringement, and the associated losses are usually greater. Therefore, it is necessary to step up the policy incentives for the digital transformation of high-tech enterprises.

Third, the digital transformation of small and medium enterprises is encouraged.

Heterogeneity analysis also shows that digital transformation only has a significant promoting effect of corporate TFP in small and medium high-tech enterprises, rather than in large high-tech enterprises. For small and medium enterprises, resource waste and inefficient management bottleneck their transformation and development. Through digital transformation, the enterprises can improve their resource management and reduce the misapplication of funds, thereby enhancing corporate TFP. The government should provide policy supports to small and medium enterprises and stimulate their enthusiasm for digital transformation.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding the publication of this paper.

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