

Digitalization Enables High-Quality Development of Enterprises--The Example of Listed Companies

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Abstract. In the digital era, the rapid development and popularization of information technology has brought unprecedented opportunities for enterprises, and digital transformation has become the key to achieve high-quality development of enterprises. Using panel data of Chinese A-share listed companies from 2011-2021, this paper investigates the impact of enterprise digital transformation on the high-quality development of enterprises and its mechanism through a fixed-effects regression model. The study finds that (1) digital transformation can enhance firms' total factor productivity, thus empowering high-quality development; (2) digitalization empowers firms in terms of promoting the level of innovation, improving operational efficiency, and enhancing growth capabilities; and (3) differences in firms' regional distributions, types of firms, and adoption of AI technologies significantly affect digitalization's empowerment of firms' high-quality development. This study reveals the intrinsic influence mechanism of total factor productivity of digitally-enabled enterprises from a novel perspective, and provides an important empirical basis for the "China Solution" for high-quality development of enterprises.

Keywords: Digital transformation; enterprise total factor productivity; high-quality enterprise development.

1. Introduction and Literature Review

With the rapid development of information technology and the global wave of digitization, digital transformation has become a key driver of high-quality development for enterprises. The wide application of digital technology provides enterprises with more efficient operations, innovative business models and broader market space. In today's highly competitive business environment, enterprises must adapt to the wave of digital transformation to maintain their competitive edge and achieve sustainable development.

Numerous scholars have conducted extensive research on the factors affecting enterprise digital transformation. You and Yi(2021) use the theory of strategic consistency to study the "psychological" factors affecting the decision-making level of enterprise digital transformation from the perspectives of cognitive psychology and cognitive linguistics. Zeng(2022) found that the market competition mechanism significantly promotes the digital transformation of enterprises, which is mainly realized by enhancing the effectiveness of management incentives, improving the level of enterprise management decision-making, and strengthening the entrepreneurial orientation of enterprises. Tang et al. (2022) found that digital transformation is negatively related to the age heterogeneity of the corporate executive team, which is influenced by the quality of information disclosure, financial liability leverage, and innovation willingness and ability. Ren et al. (2022) found that the digital transformation of enterprises in specific regions is significantly affected by the institutional dividend of the pilot free trade zone. Mao et al. (2022) examined for the first time the impact of transportation infrastructure on the development of digital transformation of enterprises by taking China's high-speed railway as an example. The results show that high-speed rail proximity significantly improves entrepreneurs' digital technology exposure and enhances cooperation with digital technology platforms, which in turn facilitates enterprise digital transformation.

In the academic world, the impact of digital transformation on enterprise development has also attracted much attention, and some scholars have launched analyses from various angles. Xiao et al. (2022) suggest that digital transformation will optimize the human capital structure of enterprises,

thus greatly increasing the share of labor income. Chen and Wang(2022) examine the realization mechanism and its boundary conditions of the strategic diffusion of enterprise digital transformation based on executive linkage. Wang et al. (2022) find that corporate digital transformation can improve their ESG performance, which provides a new research perspective for the implementation of the "dual-carbon" goal. Tang et al. (2022) demonstrated that digital mergers and acquisitions (M&A) can enhance the market power of traditional manufacturing enterprises in a long-term and sustainable manner, and the economic significance is significant. Xu and Wang(2022) empirically analyze that the digital transformation of enterprises will increase the total employee compensation, the number of employees, and the average compensation of employees, but at the same time, it will also increase the internal inequity of employee compensation. Yang et al. (2022) found that customer digital transformation has a spillover effect and significantly increases the level of supplier innovation. Li et al. (2022) showed that enterprise digital transformation empowers enterprise development by enhancing the core competitiveness of products, expanding the strategic layout of the market, and improving the efficiency of operation and management, and greatly improves the level of industrial investment of enterprises.

In recent years, the country has been steadfastly promoting high-quality development in order to achieve Chinese-style modernization. At the micro level, the high-quality development of enterprises has become a hot topic of discussion in academia. Many scholars construct various ways to measure the high-quality development of enterprises, probe deeply into their influence mechanisms and paths, and make targeted suggestions and recommendations. Jin (2018) launched a more comprehensive study on the economics of "high-quality development" from the perspective of theoretical research. Wang and Shi(2022) launched a study on the measurement of the level of high-quality development of China's manufacturing industry and the factors affecting it from the perspectives of internal factor supply and external environmental factors. A part of scholars introduce enterprise digital transformation and study its impact on enterprise total factor productivity, so as to explore the enabling path of digital transformation on enterprise high-quality development, which provides a lot of references to the ideas of this paper. Digital transformation can promote enterprise total factor productivity from the perspectives of driving innovation (Zhao et al., 2021), accelerating inter-firm knowledge spillover (Tu & Yan, 2022), reducing resource mismatch (Huang & Wang, 2022), and optimizing the efficiency of the allocation of capital and labor factors (Dan & Sun, 2022).

However, despite the fact that digital transformation is widely recognized for its potential value, there are still many issues and challenges that need to be addressed (Zhu et al., 2021). For example, enterprises face technical difficulties, challenges of organizational change, and issues of data security and privacy protection during digital transformation (Peter et al., 2021). Therefore, it is necessary to deeply study how digital transformation affects the high-quality development of enterprises and propose corresponding strategies and measures to help enterprises overcome the challenges and realize the successful empowerment of digital transformation.

This study aims to explore how digital transformation empowers high-quality development of enterprises. First, this study initially reveals the impact and influence of digital transformation on enterprises by reviewing and analyzing related literature. Then, by constructing a fixed-effects regression model based on the panel data of China's A-share listed companies from 2011 to 2021, the mechanism of digital transformation on the total factor productivity improvement of enterprises is further explored. In addition, this study will provide guidance and reference for enterprises on how to better cope with the challenges in the process of digital transformation, and provide an important empirical basis for realizing the "China Solution" for high-quality development of enterprises.

2. Theoretical mechanisms and research hypotheses

2.1 Digital transformation and high-quality enterprise development

Digital transformation of an enterprise refers to the use of digital technology and ICT to change its business model, processes and operations to meet the needs and challenges of the digital era. This

transformation involves all aspects of the enterprise, including internal organizational structure, business operations, product and service innovation, and marketing (Zeng, 2022). The goal of digital transformation is to achieve higher-quality development of enterprises through the application of digital technologies. It can involve the application of technologies such as cloud computing, big data analytics, the Internet of Things (IoT) and artificial intelligence, as well as the construction of related digital tools and platforms. Enterprise digital transformation has a positive impact on the total factor productivity improvement of enterprises. Through the introduction of digital technology and ICT, enterprises can increase production efficiency, improve resource allocation and management, and promote innovation capacity, thereby realizing a higher level of total factor productivity and ultimately empowering enterprises to achieve high-quality development. Based on the above analysis, this paper puts forward the following hypotheses:

H1: Digital transformation of firms contributes to their total factor productivity.

2.2 Level of digital transformation and innovation

The digital transformation of enterprises will not only lead to increased investment in R&D and enhanced innovation, but will also increase the total factor productivity of enterprises through this enhanced innovation (Zhao et al., 2021).

Digital transformation provides a broader space and opportunities for business innovation. Through the application of digital technology, enterprises are able to acquire, analyze and utilize big data more effectively and discover new business opportunities and market demands. Digital transformation can help enterprises achieve personalization and precision marketing, improve customer satisfaction and loyalty, and drive business growth. At the same time, digital transformation can also accelerate an enterprise's R&D and innovation process and increase the speed of launching new products and services. Enterprise digital transformation provides more opportunities and tools for R&D and innovation, thus guiding enterprises to increase R&D investment and improve innovation.

Increasing R&D investment and upgrading the level of innovation by enterprises will directly promote the total factor productivity of enterprises. R&D investment is a key factor for enterprises to realize technological progress and innovation, and has a positive impact on their total factor productivity. By increasing R&D investment, enterprises are able to raise the level of technology and promote the continuous updating and improvement of products and services. This leads to higher-quality products and more efficient production processes, thereby increasing the total factor productivity of enterprises.

In addition, raising the level of innovation can bring benefits in other areas and further enhance the total factor productivity of enterprises. Innovation can help enterprises reduce production costs, improve the production process and increase the efficiency of resource utilization. Innovation can also improve product quality and functionality, increase the added value of products and enhance market competitiveness. The improvement of these aspects will further enhance the total factor productivity of enterprises. Based on the above analysis, this paper puts forward the following hypotheses:

H2: The digital transformation of enterprises will lead them to increase their level of innovation and thus total factor productivity.

2.3 Digital transformation and operational efficiency

The process of digital transformation empowering enterprises often achieves cost reduction and efficiency gains. One of the manifestations of efficiency gains is the ability of digitalization to optimize a firm's operational efficiency, which further contributes to the firm's total factor productivity (Shi & Sun, 2022).

Through the application of digital technologies, enterprises can automate, optimize and innovate their business processes, thereby improving operational efficiency. Digital transformation can improve an organization's financial management system, enable real-time financial data analysis and forecasting, and help enterprises better manage capital flows and risks. Digital transformation can

also provide more accurate data analysis and decision support to help companies optimize inventory management, supply chain distribution and sales forecasting, thus reducing inventory backlogs and lowering the cost of capital employed. Enhancements in these areas will help optimize the operational efficiency of enterprises, especially capital turnover.

Capital turnover is one of the most important indicators of enterprise operation, which reflects the efficiency and profitability of enterprise capital utilization. Optimizing an enterprise's operational efficiency through digital transformation can result in faster capital turnover, lower capital occupancy costs, and improved profitability. Optimizing capital turnover frees up capital and provides more liquidity, enabling enterprises to better invest in key R&D, production and marketing activities, thereby increasing total factor productivity. In addition, optimizing operational efficiency reduces waste and unnecessary costs, improves resource utilization efficiency, and further enhances an enterprise's total factor productivity.

Based on the above analysis, the following hypotheses are proposed in this paper:

H3: Digital transformation empowers high-quality growth by optimizing the operational efficiency of enterprises.

2.4 Digital Transformation and Growth Capabilities

Digital transformation also accelerates business growth, which often leads to an increase in the total factor productivity of a company.

With the help of digital transformation, enterprises can identify and explore new market opportunities and realize growth in business scale and operating income. Through the application of digital technology, enterprises can better understand and analyze market demand and discover new business opportunities and customer groups. Digital transformation can help enterprises achieve personalization, precision marketing, and improve customer satisfaction and loyalty, thus promoting sales growth. Digital transformation can also leverage e-commerce and online channels to expand an enterprise's market coverage, develop new sales channels, and promote business expansion.

Operating revenue growth rate is one of the key indicators of an enterprise's growth capacity, which reflects its performance in market competition and growth potential. Enhancing an enterprise's growth capacity through digital transformation can lead to more resources and capital investment, thus promoting technological innovation and R&D investment. This will improve the technological level and product quality of enterprises, and promote the continuous updating and improvement of products and services. At the same time, enhancing growth capacity can also improve the brand awareness and market share of the enterprise and increase market competitiveness. Based on the above analysis, this paper puts forward the following hypotheses:

H4: Digital transformation enhances the ability of companies to grow and achieve total factor productivity.

3. Data sources and measurement models

3.1 Sample Selection

This paper selects all A-share listed companies in China from 2011 to 2021 as the initial research sample, and uses annual data for the study. At the same time, in order to ensure the scientific accuracy of the research results, this paper excludes the samples in the financial industry, excludes the samples in the ST, SST, *ST and PT categories, and excludes the samples in which there are missing values and outliers in the relevant variables. The final unbalanced panel data consists of 28,469 "firm-year" observations, which has a large sample capacity and ensures the credibility of the findings of this paper.

3.2 Data sources

The relevant data used in this paper are obtained from the Cathay Pacific (CSMAR) database. Before starting the empirical analysis, all continuous variables at the firm level in this paper are subjected to shrinking tails (Winsorize) of less than 1% and more than 99% in sub-years, as a way to

mitigate the possible impact of outliers on the regression results. At the same time, in order to eliminate the possible clustering characteristics of the sample data, this paper also adjusts the standard errors of the regression coefficients for clustering (cluster) at the enterprise level. The data analysis and processing work in this paper is mainly done by Stata17.0.

3.3 Selection of indicators and description of variables

3.3.1 Explained Variables

The assessment of the level of high-quality development of enterprises has been a hotly debated topic in academic circles, and a commonly used measure is the total factor productivity of enterprises as a proxy variable. Total Factor Productivity (TFP) is a measure of an enterprise's comprehensive production efficiency, which reflects the level of output achieved by an enterprise with a certain amount of resources. TFP is often used to indicate the degree of improvement in an enterprise's productivity, i.e., the increase in production efficiency brought about by technological advancement, management innovation, etc., relative to the inputs of factors of production such as capital and labor. the improvement of production efficiency. In this study, TFP is mainly calculated using the LP method, and the OP method is introduced in the robustness analysis. The difference between the LP method and the OP method is that the LP method uses the demand function for intermediate inputs instead of the investment demand function.

3.3.2 Explanatory variables

Digital transformation is the process by which a business or organization uses digital technologies and innovations to change its business model, processes and value creation. It covers a wide range of applications of digital technologies, including but not limited to artificial intelligence, big data analytics, cloud computing, and the Internet of Things. In this study, digital transformation is measured in two ways:

(1) Logarithm of the frequency of digitized words of enterprises: this paper uses the logarithm of the frequency of digitized words of enterprises provided by the Cathay Pacific database as the indicator of the base regression. This indicator analyzes the frequency of digitization-related keywords appearing in the public documents of enterprises (e.g., annual reports, announcements, etc.), and then takes the logarithmic processing, so as to reflect the magnitude of the degree of digital transformation of enterprises.

(2) Comprehensive evaluation index of enterprise digitalization: this paper adopts the newly launched comprehensive evaluation index of enterprise digitalization for robustness testing. The index takes into account the performance of enterprises in terms of digital technology application, digital capability, digital strategy, etc., and comprehensively assesses the digital transformation level of enterprises through the weighted combination of multiple indicators.

Intended relationship

3.3.3 Control variables

Referring to related studies, this paper selects firm size (Size), firm age (Age), equity concentration (Top1), gearing ratio (Lev), profitability (ROA) and net cash flow (CFO) as control variables, which are defined in the following table.

Table 1 Definition of variables

characteristic	variant	variable name	way of measuring
core variable	TFP_lp	Total factor productivity of enterprises	Calculated using the LP method
	TFP_op		Calculated using the OP method
	Digit	Degree of digital transformation	Digitized word frequency measure of annual reports of listed companies
	Digit2		Measured by a comprehensive enterprise digital transformation index
intermediary variable	RD	Enterprise innovation level	R&D investment
	CTurnover	Operational efficiency of enterprises	Funding turnover rate
	Growth	Enterprise growth rate	Revenue growth rate
Control variables (Basic Characteristics)	Size	Enterprise size	Logarithm of total business assets
	Age	Age of business	Logarithm of the year of establishment of the listed company
	Top1	shareholding concentration	Shareholding ratio of the largest shareholder
Control variables (financial characteristics)	Lev	gearing	Ratio of liabilities to total assets of the enterprise
	ROA	Profitability	return on assets
	CFO	Net cash flow	Free cash flow as a percentage

3.4 Modeling

Since the two-way fixed-effects model with fixed enterprise individuals and years can solve the endogeneity problem caused by omitted variables on the one hand, and exclude the effects brought about by different macro-environments in different years on the other hand, this paper mainly uses the fixed-effects model to analyze, and the specific model formulas are shown as follows:

$$TFP_{lp_{i,t}} = \beta_0 + \beta_1 Digit_{i,t} + \sum \emptyset_i Controls_{i,t} + \mu_i + \mu_{year} + \varepsilon_{i,t} \quad (1)$$

In the above model, subscript *i* and subscript *t* denote individual firms and years, respectively; β_0 represents the intercept term, β_1 denotes the regression coefficients of the explanatory variables and $\emptyset_i$ denotes the regression coefficients of the control variables; μ_i and μ_{year} denote fixed effects at the firm and year levels, respectively; $\varepsilon_{i,t}$ denotes the residual term.

4. Empirical analysis

4.1 Benchmark regression analysis

The results of the underlying regression of the impact of digital transformation on firms' total factor productivity are shown in Table 3. Among them, column (1) shows that the regression coefficient of digitization index (Digit) on total factor productivity (TFP_lp) under fixed effects is 0.2273 and is significantly positively correlated at the 1% level, while column (2) shows that the regression coefficient of Digit on TFP_lp after adding various control variables is 0.0315 and is significant at the 1% level. The above results indicate that digital transformation can significantly enhance the total factor productivity of enterprises, thus empowering their high-quality development, which confirms the research hypothesis H1.

Table 3 Main effects regression results

	(1) TFP_lp	(2) TFP_lp
Digit	0.2273*** (29.69)	0.0315*** (6.23)
Size		0.5929*** (43.55)
Lev		0.3618*** (7.56)
Age		0.2306*** (3.72)
ROA		1.2415*** (16.03)
Top1		-0.0103 (-0.14)
CFO		0.6391*** (11.70)
_cons	8.7746*** (834.53)	-4.9740*** (-15.36)
Firm	Yes	Yes
Year	No	Yes
N	28469	28469
adj. R ²	0.143	0.592

Note: *, **, and *** indicate significance at the 10%, 5%, and 1% significance levels, respectively (two-tailed tests); t-test values adjusted for clustering at the firm level are in parentheses.

4.2 Mechanism testing

4.2.1 Promoting levels of innovation

From the analysis in Table 4, the regression coefficient of the digital transformation indicator (Digit) without considering the mediator variable (RD input) is 0.0315 and it is significant at 1% level of significance. In column (2), the regression coefficient of digital transformation indicator (Digit) on total factor productivity (TFP_{lp}) becomes 0.0346 after adding research and development investment (RD) as a mediating variable and remains significant at 1% significance level. Meanwhile, the regression coefficient of research and development investment (RD) on total factor productivity (TFP_{lp}) is 0.1704, which is significant at 1% level. This indicates that the mediating role of R&D inputs is valid, i.e., research hypothesis 2 is valid. Digital transformation positively affects total factor productivity by increasing the R&D investment of firms, which in turn enhances the level of innovation.

When companies undergo digital transformation, their R&D investments tend to increase. This is because the adoption of digital technologies provides companies with more R&D opportunities and room for innovation. Increased practice of innovation activities can improve existing products and services, develop new product lines, and even lead to entirely new business models. These innovations can in turn increase the total factor productivity of enterprises, including improving productivity, product quality, market competitiveness and other aspects.

Table 4 Mediation effect regression results for R&D investment

	(1) TFP _{lp}	(2) RD	(3) TFP _{lp}
Digit	0.0315*** (6.23)	0.0346*** (4.26)	0.0256*** (5.27)
RD			0.1704*** (11.94)
Control variable	(-15.36)	(-0.56)	(-15.05)
Firm	Yes	Yes	Yes
Year	Yes	Yes	Yes
N	28469	28469	28469
adj. R ²	0.592	0.079	0.609

Note: Same table as above.

4.2.2 Improved operational efficiency

In this study, capital turnover is used as a proxy variable for enterprise operational efficiency, and the mediating role of operational efficiency is proved by the following empirical regression. As can be seen from Table 5, the regression coefficients of digital transformation indicators on total factor productivity of enterprises are significant at 1% level, both without the mediator variable and with the inclusion of capital turnover (CTurnover) as a mediator variable. In addition, the effect of capital turnover on total factor productivity also holds significantly. The three-step mediation effect holds, indicating that capital turnover plays a mediating role between digital transformation and total factor productivity, and research hypothesis 3 is proved.

Digital transformation further contributes to total factor productivity by optimizing the operational efficiency of enterprises and improving capital turnover. Digital transformation enables enterprises to manage and utilize capital more efficiently and optimize business processes, supply chains and customer relationships, thereby accelerating capital turnover and improving resource efficiency. By increasing capital turnover, companies are able to better utilize limited resources and accelerate the flow of capital. This reduces idle and wasted resources and improves productivity and business performance. Optimized capital turnover further contributes to the improvement of total factor productivity in terms of increased productivity, cost reduction and faster time-to-market.

Table 5 Mediation effect regression results for financial turnover ratio

	(1) TFP _{lp}	(2) CTurnover	(3) TFP _{lp}
Digit	0.0315*** (6.23)	0.0121*** (3.75)	0.0178*** (5.39)
CTurnover			1.1293*** (53.32)
Control variable	Yes	Yes	Yes
Firm	Yes	Yes	Yes
Year	Yes	Yes	Yes
N	28469	28469	28469
adj. R ²	0.592	0.133	0.810

Note: Same table as above.

4.2.3 Enhanced capacity for growth

This paper adopts the operating revenue growth rate, as a measure of corporate growth, i.e., an increase in operating revenue growth rate will accelerate corporate growth. As seen in column (2) of Table 6, the regression coefficient is 0.0107 when adding the mediator variable (operating revenue growth rate), and it is significant at the 5% level, and the mediation effect of the three-step method is established. This suggests that digital transformation further contributes to total factor productivity by enhancing firms' ability to grow and increase operating revenue growth rate, and Hypothesis 4 is valid.

Digital transformation enables enterprises to better utilize digital technologies and innovative practices to expand their markets, increase their customer base and provide more value-added services, thereby achieving faster operating income growth. By increasing the rate of revenue growth, companies are able to access more economic resources and invest more capital and human resources, which in turn contributes to the total factor productivity of the company. A higher rate of revenue growth usually means that an enterprise is better able to meet market demand, provide competitive products and services, and have a better market share and growth potential.

Table 6 Mediation effect regression results of operating income growth rate

	(1) TFP _{lp}	(2) Growth	(3) TFP _{lp}
Digit	0.0315*** (6.23)	0.0107** (2.34)	0.0294*** (5.99)
Growth			0.1940*** (24.38)
Control variable	Yes	Yes	Yes
Firm	Yes	Yes	Yes
Year	Yes	Yes	Yes
N	28469	28469	28469
adj. R ²	0.592	0.115	0.618

Note: Same table as above.

4.3 Heterogeneity analysis

4.3.1 Results of geographic heterogeneity analysis

To analyze the geographical heterogeneity for the impact of enterprise digital transformation on enterprise total factor productivity, this paper divides the region into east, central and west..According to the regression results in Table 7, it can be concluded that digital transformation has a significant positive impact on total factor productivity in all three regions of East, Central and West. This indicates that enterprise digitalization has a positive enabling effect on high-quality development in all regions. However, at the same time, there may be differences in the degree of impact of digital transformation across different regions. This paper observes that the regression results in the western region are significant only at the 5% significance level, which suggests that the impact of enterprise digital transformation on high-quality development is relatively weak in the western region.

This may be due to the fact that the eastern part of China has a clear advantage in terms of digitization level and economic development over the central and western parts of the country. The

eastern region is more economically developed, has more innovative resources and technology-intensive industries, and has also started the process of digital transformation earlier. Compared with the eastern region, the central and western regions are relatively lagging behind in terms of digitalization level and economic development. As a result, the impact of digital transformation on total factor productivity is more significant among firms in the eastern region.

However, despite the relative lag in digital transformation, the central and western regions are gradually strengthening their digitalization and promoting the development of the digital economy with policy support and investment guidance from the Chinese government. Therefore, this paper speculates that digital transformation in the central and western regions may further accelerate over time, and the impact on total factor productivity will gradually emerge.

Table 7 Regression results by region

	the east TFP lp	central section TFP lp	western part TFP lp
Digit	0.0294*** (4.89)	0.0333*** (2.89)	0.0351** (2.46)
Control variable	Yes	Yes	Yes
Firm	Yes	Yes	Yes
Year	Yes	Yes	Yes
<i>N</i>	20455	4040	3974
adj. <i>R</i> ²	0.594	0.631	0.578

Note: Same table as above.

4.3.2 Results of technology heterogeneity analysis

In this section, companies are categorized into two groups of adopting AI technology and not adopting AI technology for heterogeneity analysis, in order to explore the role of technological differences in empowering digital transformation. The data in this section comes from Cathay Pacific's digitized word frequency database of listed companies, which is defined as 1 if the sample adopts AI technology and 0 otherwise.

From the regression results, it can be observed that digital transformation has a positive effect on total factor productivity among firms adopting AI technology and is significant at the 1% significance level. This indicates that firms adopting AI technology have achieved better results in digital transformation and are able to increase total factor productivity more effectively. Meanwhile, in enterprises that do not adopt AI technology, digital transformation has the same positive effect on total factor productivity and is significant at the 5% significance level. Although firms that do not adopt AI technologies are relatively weaker in terms of digital transformation, digital transformation still has a positive impact on their total factor productivity.

These results show that the impact of digital transformation on firms' total factor productivity is positive regardless of whether firms adopt AI technologies or not. However, firms adopting AI technologies are better able to fully utilize the potential of digital transformation and achieve more significant total factor productivity gains. This may be due to the fact that AI technologies have a higher level of automation and intelligence and are better able to respond to market changes and optimize business processes, thus improving productivity and quality.

Table 8 Regression results with and without AI techniques

	Adoption of artificial intelligence technology TFP lp	No artificial intelligence technology TFP lp
Digit	0.0261*** (5.08)	0.0252** (2.17)
Control variable	Yes	Yes
Firm	Yes	Yes
Year	Yes	Yes
<i>N</i>	22011	6458
adj. <i>R</i> ²	0.548	0.506

Note: Same table as above.

4.3.3 Results of the nature heterogeneity analysis

In order to explore the different roles of the differences in the nature of enterprises on the empowerment of digital transformation, this section analyzes the heterogeneity of the enterprises by dividing them into two groups: high-tech enterprises and non-high-tech enterprises. Among them, high-tech enterprises are defined as those belonging to the pharmaceutical manufacturing industry, instrument and meter manufacturing industry, transportation equipment manufacturing industry, chemical raw materials and products manufacturing industry, electronic equipment manufacturing industry, etc. The rest are defined as non-high-tech enterprises.

The results in Table 9 show that in high-tech enterprises, digital transformation has a positive effect on total factor productivity at the 1% significance level. This indicates that high-tech enterprises have achieved better results in digital transformation and contributed to the improvement of total factor productivity. In contrast, among non-high-tech enterprises, the positive effect of digital transformation on total factor productivity holds, but the significance level is 5%, which means that non-high-tech enterprises are relatively weak in the empowerment of digital transformation for high-quality development.

This may be due to the fact that high-tech enterprises have advanced technological capabilities and innovation capabilities, pay more attention to technology research and development and innovation investment, and are better able to cope with the challenges of digital transformation and realize the increase in total factor productivity through the introduction of advanced digital technologies, upgraded business models and innovative products.

Table 9 Regression results by whether high-tech enterprises

	High-tech enterprises	Non-high-tech enterprises
	TFP _{lp}	TFP _{lp}
Digit	0.0203*** (3.52)	0.0395*** (4.87)
Control variable	Yes	Yes
Firm	Yes	Yes
Year	Yes	Yes
N	14071	14398
adj. R ²	0.661	0.516

Note: Same table as above.

4.4 Robustness Tests

In order to ensure the reliability of the results, this paper conducts a robustness test and an endogeneity test. The results show that the digital transformation indicator positively affects the total factor productivity of enterprises, whether it is measured by replacing the explanatory variables or by replacing the explanatory variables, and this effect is robust. At the same time, we also conducted the lagged effect test and the second-order regression test of instrumental variable method, and the significant establishment of the results further validates the conclusion that digital transformation can promote the high-quality development of enterprises.

5. Conclusions and recommendations

5.1 Conclusions of the study

Through the above empirical analysis in this paper, the following conclusions are drawn: ① Overall, enterprise digital transformation can effectively promote the improvement of total factor productivity, thus empowering the high-quality development of enterprises. The above results have been tested for robustness and endogeneity, and all of them hold significantly; ② From the analysis of the impact mechanism, enterprise digital transformation can significantly promote the level of innovation, improve operational efficiency, enhance the growth capacity, and thus improve the total factor productivity of enterprises. The innovation level of enterprises is mainly reflected in the growth of R&D investment, operational efficiency is mainly reflected in the optimization of capital turnover, and the enhancement of growth capacity is mainly reflected in the improvement of revenue growth

rate; ③ Heterogeneity study shows that the enhancement effect of digital transformation is more significant for the enterprises in the east (the higher level of digitization geography), and the digital transformation effect is more significant for the enterprises that use AI technology and the high-tech enterprise, the digital transformation promotes total factor productivity. For enterprises using artificial intelligence technology and high-tech enterprises, the impact of digital transformation on total factor productivity is relatively larger.

5.2 Policy recommendations

Governments and relevant organizations should take proactive measures to provide comprehensive support to enterprises in order to accelerate the process of digital transformation. In order to improve the innovation capacity of enterprises, governments can formulate innovation policies to encourage enterprises to increase their R&D investment. By providing innovation subsidies and tax incentives, it can reduce the burden on enterprises and stimulate them to increase their R&D expenditures. In addition, public R&D platforms and joint research projects should be established to promote cooperation among enterprises and between enterprises and scientific research institutions to jointly tackle major scientific and technological challenges.

The Government can promote financial reforms to provide more flexible and diversified financing channels, thereby improving the liquidity of enterprises. For example, it should develop science and technology finance and supply chain finance to provide enterprises with low-cost and high-efficiency financing services. At the same time, it has established a credit collection system and strengthened enterprise credit ratings to reduce financial risks and promote better financing conditions for enterprises.

In assisting enterprises to accelerate their growth, the Government should formulate differentiated support policies. First, it should provide preferential tax policies for growing enterprises to reduce their burden and enhance their competitiveness. Second, it should strengthen training and consulting services for growing enterprises to help them solve management and operational problems and upgrade their overall level. Thirdly, growth enterprises are encouraged to cooperate with large enterprises and transnational corporations to promote resource sharing and technology transfer and to enhance their innovation and competitiveness.

In view of the characteristics and development needs of enterprises in different regions, the Government should formulate differentiated policies on digital transformation. For enterprises in the eastern part of the country, the advantages brought about by their high level of digital development should be maintained and sustained; for enterprises in the central and western parts of the country, investment in digital infrastructure should be increased, network speed and stability should be improved, and the digital environment should be enhanced.

For enterprises using AI technology and high-tech enterprises, the Government should increase its support for technological innovation and talent training, provide technical advice and support to enterprises, and promote their innovative development in the field of AI and high-tech.

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