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Broadband infrastructure and enterprise digital transformation: Evidence from China

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ABSTRACT

Broadband infrastructure, as a basis of digital economic development, plays an important role in accelerating the enterprise digital transformation. Using the "Broadband China" strategy as a quasi-natural experiment, this paper investigates whether and how the broadband infrastructure affects enterprise digital transformation. We find that the construction of broadband infrastructure significantly increases enterprise digital transformation. The underlying mechanism is that the broadband infrastructure mitigates transformation costs and facilitates competition among peers within the same industry, thereby promoting enterprise digital transformation from both active and passive aspects. The effect is magnified when enterprises are small-scale, non-SOEs and in high-tech or technology-intensive sectors. Under the rapid development of the digital economy, this paper contributes to the economic consequences of the broadband infrastructure and offers empirical support for enterprise digital transformation.

1. Introduction

Digital transformation can enable enterprises to enhance their performance and competitiveness by integrating digital technologies (Nambisan, 2017; Vial, 2019; Troise et al., 2022). Revealing the drivers of enterprise digital transformation holds significant research value. Literature has indicated that high transformation costs are a significant barrier to enterprise digital transformation, while the construction and development of broadband infrastructure during the societal digital transformation process can significantly reduce enterprise digital transformation costs (Bharadwaj et al., 2013; Mandviwalla and Flanagan, 2021). The Chinese government, based on a vast market size, abundant data resources, and diverse application scenarios, has gradually established a digital economy development pattern. This paper uses the "Broadband China" strategy practice as an identification tool, focusing on the economic impact of broadband infrastructure in the process of enterprise digital transformation.

Theoretically, broadband infrastructure can reduce digital technology costs and facilitate the information sharing, thereby alleviating the shortage of technological resources that enterprises face during digital transformation (Goldfarb and Tucker, 2019; Staab and Thiel, 2022). Simultaneously, broadband infrastructure can improve digital skills within the labor market, diminishing talent training expenses. Furthermore, the development of digital finance, spurred by broadband infrastructure, not only broadens the corporate debt financing channels but also introduces financing products with lower costs. It reduces the debt financing expenses directly and solves the financial issues faced by enterprises during the process of digital transformation.

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By 2023, the total volume of China's digital economy ranked second globally, with the added value of the digital economy's core industries accounting for 10 % of GDP, where broadband infrastructure construction plays a significant strategic role. In 2013, the State Council of China announced *the Broadband China Strategy and Implementation Plan*, aiming to deeply integrate broadband applications into production and daily life by addressing broadband network access speed, coverage, and popularization issues. To implement this strategy, China approved 117 pilot cities in three waves from 2014 to 2016. The selection of "Broadband China" pilot cities is exogenous, unaffected by enterprise intervention, and the "Broadband China" strategy has promoted the enhancement of broadband infrastructure construction in these pilot cities.

This paper is based on data from Chinese A-share listed companies from 2007 to 2019, regarding the "Broadband China" strategy as a quasi-natural experiment. A staggered DID model is used to explore the impact of broadband infrastructure on enterprise digital transformation. We find that the construction of broadband infrastructure significantly promotes enterprise digital transformation. On the one hand, the "Broadband China" strategy reduces the transformation costs by promoting information sharing, increasing the demand for digital skills in the labor market, and decreasing enterprise financing costs, thereby lowering the costs of innovation, labor, and finance. On the other hand, the "Broadband China" strategy intensifies market competition and forces enterprises to transform passively. Furthermore, the heterogeneity analysis reveals that the impact of broadband infrastructure on enterprise digital transformation is more significant for small-scale enterprises, non-state-owned enterprises, and those in high-tech and technology-intensive industries.

The main contributions of this paper can be summarized in three aspects. Firstly, this paper enriches the research findings related to enterprise digital transformation. With the rapid development of the digital economy, enterprise digital transformation has raised a series of focus. While prior literature has focused on the impact factors and the economic effects of enterprise digital transformation (Pan et al., 2022; Zhang et al., 2023; Luo et al., 2024; Zhao et al., 2024), little attention has been paid to the external drivers of enterprise digital transformation. This paper analyzes the motivation for enterprise digital transformation from the perspective of broadband infrastructure, providing theoretical experience and concrete approaches for enterprise digital transformation.

Secondly, the results expand on the meaning of the "Broadband China" strategy. More and more studies have proved the effect on enterprises brought by the digital economy (Zhang et al., 2023; Zhou et al., 2024). Countries around the world have introduced a range of digital economy policies, with the "Broadband China" strategy being one of them. In this paper, we utilize the "Broadband China" strategy and further analyze the economic consequences of broadband infrastructure. Prior literature has discussed the economic effects of broadband infrastructure at the regional level, our findings support the broadband infrastructure impact on enterprises. Hence, we extend the study of the "Broadband China" strategy from the household to the enterprise.

Thirdly, this paper deepens the mechanisms of broadband infrastructure construction affecting enterprise digital transformation. We focus on transformation cost and industry competition from active and passive transformation, offering a more comprehensive analysis of how broadband infrastructure affects enterprise digital transformation. This provides practical approaches for enterprise digital transformation and offers theoretical evidence for implementing digital economy policies in the future.

The rest of the paper is structured as follows. Section 2 provides the literature review of this paper and formulates the hypothesis. Section 3 describes the model setting, variables selection and data description. Section 4 reports regression results, mechanism analysis and heterogeneity analysis. Section 5 conducts endogeneity and robustness testing. Section 6 presents our conclusions and recommendations.

2. Literature review and hypothesis development

Broadband infrastructure plays a crucial role in the development of the digital economy and has positive impacts on socio-economic development. These include fostering economic growth (Pradhan et al., 2018), enhancing regional labor productivity (Oliner and Sichel, 2000; Jorgenson, 2001), promoting geographical concentration of industries (Hong and Fu, 2011), advancing financial development (Pradhan et al., 2015), and contributing to human development (Acheampong et al., 2022). Although existing researches have thoroughly discussed the economic effects of broadband infrastructure at the regional level, a limited number of scholars have examined its impact on enterprises.

Enterprise digital transformation alters traditional patterns and subsequently influences enterprise development. Scholars have investigated the economic effects of enterprise digital transformation. Pan et al. (2022) and Cheng et al. (2023) show that digital transformation enhances firms' Total Factor Productivity (TFP). Loebbecke and Picot (2015) and Peng and Tao (2022) argue that digital transformation improves enterprise performance. Moreover, various studies have indicated that enterprise digital transformation significantly affects international trade (Feliciano-Cestero et al., 2023), enterprise productivity (Bharadwaj et al., 2013), labor income share (Yang et al., 2023), capital structure adjustment (Niu et al., 2023) and so on. Internal factors, such as management background characteristics (Porfírio et al., 2021), flexibility and sensitivity of organization (AlNuaimi et al., 2022; Nguyen et al., 2023), employee digital literacy (Cetindamar Kozanoglu and Abedin, 2020), and profitability expectations (Grover and Kohli., 2013) affect enterprise digital transformation. Extensive research has focused on the internal drivers of enterprise digital transformation. However, there is not sufficient research on the external factors that drive digital transformation.

The "Broadband China" strategy can improve enterprise digital transformation in two ways, including cost effect and competition effect. On the one hand, it reduces high transformation costs, thereby facilitating enterprise digital transformation. Firstly, it decreases the expenses associated with digital technology innovation and promotes information-sharing knowledge. This helps address the lack of technological resources during enterprise digital transformation and reduces uncertainty in R&D processes (Tether, 2002). Secondly, it mitigates the expenditure on internal technical training. The construction of broadband infrastructure leads to higher standards for digital skills required in employment (Van Laar et al., 2018). The subsequent enhancement of digital skills among the workforce fosters a reservoir of technical personnel, thereby diminishing expenses related to the training and recruitment of technical personnel. Thirdly, it reduces the cost of enterprise financing. Due to the construction of broadband infrastructure, digital finance is developing rapidly (Niu et al., 2022). Compared with traditional financial services, digital finance can not only expand the enterprise debt financing channels (Liu et al., 2021) but also provide lower-cost debt financing products, which reduces the debt financing costs and solves the financial problems in the enterprise digital transformation (Guo et al., 2023; Tang and Geng, 2024).

On the other hand, the "Broadband China" strategy influences the willingness for digital transformation by enhancing market competitiveness. Firstly, broadband infrastructure is a quasi-public good with a limited amount and may be overused. Consequently, enterprises must generate new competitive advantages to access the limited broadband infrastructure, thereby accelerating their digital transformation processes. Secondly, the digital transformation of traditional industries and innovative digital businesses have emerged with the implementation of the "Broadband China" strategy. Market competition propels technological evolution in conventional sectors, elevating the barriers to market entry. This implies that pioneers in digital transformation will gain access to digital resources and opportunities. Simultaneously, enterprises can derive superior solutions from digital development (Teece, 2018), suggesting that digital transformation is a crucial element in capturing a significant market share. Thirdly, the evolution of the digital economy has led to an increase in digital service models and the formation of digital network relationships. Adopting non-digital operational methods implies that enterprises give up the conveniences offered by digital services and are excluded from participation in digital network relationships.

Based on this, we propose the hypothesis: Broadband infrastructure construction fosters enterprise digital transformation, accelerating the process by reducing associated costs and intensifying competition.

3. Data and empirical design

3.1. Data and samples

The sample for this paper consists of Chinese A-share listed companies from 2007 to 2019. Several considerations are taken into account in handling the original data to ensure the validity of the sample data. Firstly, listed financial industry companies are not included in this paper. Secondly, during the study period, ST category firms are not included. Thirdly, firms lacking information on key variables are not included. Fourthly, we tail continuous variables at the 1 % and 99 % percentiles.

We use corporate-level data from the CSMAR database and regional-level data from the China City Statistical Yearbook and the EPS database. The listed companies' annual report data we used is collected from the official websites of the stock exchanges. The information regarding the pilot cities for the "Broadband China" strategy is sourced from the official website of the MIIT.

3.2. Definition of variables

3.2.1. Enterprise digital transformation

According to Wu et al. (2021) and Xiao et al. (2022), we use the frequency of digital transformation-related words in the annual report to measure their level of digital transformation. Specifically, we collect the Management Discussion and Analysis (MD&A) section in annual reports disclosed by A-share listed from 2007 to 2019, and determine whether each word is associated with digital transformation. The words are shown in Table A1. To overcome the distribution problem of the length of the MD&A section, we divide the length of the MD&A section by the frequency of keywords and multiply it by 100 as an index for digital transformation (*DIGITAL*). In brief, the higher value of *DIGITAL* indicates a higher degree of digital transformation. According to Liu et al. (2023) and Chen and Zhang (2024), we use the proportion of intangible assets connected to the digital economy (*DIGITAL1*), as well as the natural logarithm of the number of keywords in whole annual reports as alternative dependent variables (*DIGITAL2*) in the robustness test.

3.2.2. The "Broadband China" strategy

The degree of digitalization has been frequently used to measure broadband infrastructure construction (Zhou et al., 2024). However, it is difficult to fully assess its effect using indicators, such as the regional broadband penetration rates and the number of

Table 1
Descriptive statistics of variables.

Variables	Observation	Mean	Std. Dev.	Minimum	Maximum
DIGITAL	28,162	0.7327	0.8421	0.0000	5.6151
POLICY	28,162	0.4118	0.4922	0.0000	1.0000
SIZE	28,162	22.0246	1.2777	19.7007	26.0585
LEV	28,162	0.4260	0.2080	0.0492	0.8821
CASHFLOW	28,162	0.0448	0.0719	−0.1770	0.2447
TOP5	28,162	0.5364	0.1538	0.1959	0.8764
TOBINQ	27,588	2.0366	1.2713	0.8879	8.3914
LISTAGE	28,162	2.0123	0.9135	0.0000	3.2581
BOARD	28,160	2.1416	0.2010	1.6094	2.7081
ECONOMY	25,695	9.3858	3.0600	3.2000	17.5000
EXPENSE	27,938	0.1565	0.0914	0.0437	2.3488

Internet users. Hence, we set a dummy variable named *POLICY* to represent the implementation of the “Broadband China” strategy, aiming to measure regional broadband infrastructure development status. Specifically, if the firm is located in a city participating in the “Broadband China” strategy within the specified timeframe, the variable *POLICY* is set to 1. Otherwise, it is set to 0. In this paper, 117 pilot cities are used as policy impact samples for broadband infrastructure construction.

3.2.3. Control variables

Following Jiang et al. (2024) and Wang et al. (2024), we add control variables at both the regional and enterprise levels in the regression model, including *SIZE*, *LEV*, *CASHFLOW*, *TOP5*, *TOBINQ*, *LISTAGE*, *BOARD*, *ECONOMY*, *EXPENSE*. The primary variables and definitions are shown in Table A2.

Table 1 shows the descriptive statistics of the variables. The value of *DIGITAL* ranges from 0 to 5.6151, suggesting significant variation in the level of digital transformation among enterprises. The main explanatory variable (*POLICY*) has two values, 0 and 1, which aligns with the variable setting in this paper. This paper finally contains 3401 listed companies, which belong to 248 prefecture-level cities in China, including 103 “Broadband China” pilot cities. These pilot cities were approved in the years 2014 (36 cities), 2015 (35 cities), and 2016 (32 cities), respectively. We detail the ten words that received the most enterprise attention after implementing the “Broadband China” strategy in Fig. A1.

3.3. Empirical model

3.3.1. Baseline model

Since the “Broadband China” strategy was implemented in three batches from 2014 to 2016, a staggered DID model is employed to investigate the effect of broadband infrastructure on enterprise digital transformation. To evaluate the impact of the “Broadband China” strategy on enterprise digital transformation, we consider the implementation of the “Broadband China” strategy as a quasi-natural experiment. We compare pre-post changes in digital transformation among enterprises that are influenced by the “Broadband China” strategy (the treatment group) and firms that are not (the control group). The baseline model is as follows:

$$DIGITAL_{i,t} = \alpha_0 + \alpha_1 POLICY_{i,j,t} + \varphi X_{i,j,t} + \mu_i + \gamma_t + \varepsilon_{i,t} \tag{1}$$

In the equation, $DIGITAL_{i,t}$ represents the digital transformation level of firm i in year t. $POLICY_{i,j,t}$ is a dummy variable indicating whether the city j, where the firm i is located, has adopted the “Broadband China” strategy in year t. It equals 1 if city j implemented the “Broadband China” strategy in year t, and 0 otherwise. $X_{i,j,t}$ denotes a vector of control variables that may influence enterprise digital transformation. Additionally, we incorporate firm and year fixed effects into our model to account for potential confounding factors. The coefficient in Eq. (1) is α_1, which measures how the enterprise digital transformation level changes in response to the “Broadband China” strategy.

Table 2
The impact of the “Broadband China” strategy on the enterprise digital transformation.

Variable	(1) *DIGITAL*	(2) *DIGITAL*
POLICY	0.0569*** (0.0104)	0.0516*** (0.0108)
SIZE		0.1350*** (0.0072)
LEV		-0.1752*** (0.0276)
CASHFLOW		-0.0758* (0.0445)
TOP5		-0.3579*** (0.0407)
TOBINQ		0.0253*** (0.0034)
LISTAGE		0.0558*** (0.0100)
BOARD		0.0982*** (0.0252)
ECONOMY		0.0020 (0.0018)
EXPENSE		0.0532 (0.0532)
Controls	No	Yes
Firm FE	Yes	Yes
Year FE	Yes	Yes
N	28,162	25,210
R-squared	0.2381	0.2644

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; standard errors are in parentheses.

3.3.2. Dynamic effect model

The DID method provides a solution to overcome endogeneity concerns in assessing the effects of policies. However, some assumptions are required to use this method, among which the parallel trend assumption is fundamental. Specifically, before the implementation of the "Broadband China" strategy, the level of enterprise digital transformation in the treatment and control groups should remain parallel. Following Beck et al. (2010) and Tao et al. (2024), we establish a dynamic DID model to examine the parallel trends assumption.

$$DIGITAL_{i,t} = \beta_0 + \sum_{n=-6,n\neq-1}^{5} \beta_n POLICY_{i,j,t+n} + \theta X_{i,j,t} + \mu_i + \gamma_t + \varepsilon_{i,t} \quad (2)$$

In this equation, $POLICY_{i,j,t+n}$ represents the *n-th* year in relation to the year when the "Broadband China" strategy was implemented. For $n < 0$, it refers to the *n-th* year before the "Broadband China" strategy implementation, whereas $n > 0$ represents the *n-th* year following this strategy. We select a value for n from the interval [-6, 5] and exclude $n = -1$ from the regression analysis. All other variables are consistent with those described in Eq. (1). The parallel trend assumption is satisfied if the regression coefficient β_n is insignificant where $n < 0$.

4. Empirical results

4.1. Baseline results

Table 2 reports the effect of the "Broadband China" strategy on the enterprise digital transformation. Column (1) presents results without control variables, and column (2) simultaneously includes control variables and fixed effects. The results indicate that regardless of the inclusion of control variables, the regression coefficient of *POLICY* is significant at the 1 % level. This suggests that the "Broadband China" strategy enhances enterprise digital transformation. In column (2), the coefficient of *POLICY* is 0.0516. The "Broadband China" strategy raises the level of enterprise digital transformation by approximately 5 %.

Considering control variables, the coefficients generally remain consistent with previous studies (Cai et al., 2024; Chen and Zhang, 2024; Jiang et al., 2024). For example, the coefficient of *SIZE* is significantly positive, indicating that larger firms are more likely to participate in digital transformation. The coefficient of *LEV* is significantly negative at the 1 % level, suggesting that companies tend to pursue digital transformation when they face greater financial risk and higher financing costs. Furthermore, the coefficient of *TOBINQ* is significantly positive, indicating that the progress of digitalization is promoted when investors have confidence in the firm's prospects.

4.2. Mechanism analysis

4.2.1. The active transformation

A series of challenges, including the shortages of digital technology and digital talent, severely hinder enterprise digital transformation. In the early stages of digital transformation, substantial initial investments and the uncertainty of returns make the transformation costs a critical factor affecting the enterprise digital transformation. We examine the transformation cost from two levels: city and firm. Firstly, the technology cost (*TC*) is calculated by the proportion of digital patent applications at the city level in the total number of patent applications in that city. Secondly, the labor cost (*LC*) is computed using the ratio of the number of technical professionals at the city level to the total number of professionals. Thirdly, the absolute value of the SA index is used to evaluate the financing cost (*SA*), which measures the financing constraints of firms.

The results of the cost effects mechanism are shown in Table 3, incorporating all results with control variables and fixed effects. The coefficient of *POLICY* in column (1) is positive, indicating that the "Broadband China" strategy has increased digital patent applications. It has promoted the generation of regional-level digital innovation outcomes, and enhanced the adoption of digital technology

Table 3
Mechanism test: the cost effect of active transformation.

Variable	(1) *TC*	(2) *LC*	(3) *SA*
POLICY	0.0043**	0.0039***	-0.0046***
	(0.0018)	(0.0005)	(0.0016)
Controls	Yes	Yes	Yes
Firm FE	No	No	Yes
Year FE	Yes	Yes	Yes
City FE	Yes	Yes	No
N	2,622	2,631	25,210
R-squared	0.8143	0.7000	0.8534

Notes: This table displays the regression results of the cost effects mechanism at various analytical levels. Column (1) and column (2) show the city-level regression results, including city fixed effects and year fixed effects. Column (3) shows the firm-level regression results, including the firm fixed effects and year fixed effects. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; standard errors are in parentheses.

innovation outcomes by enterprises, thereby lowering the technical expenses associated with digital transformation. The coefficient of *POLICY* in column (2) is positive at the 1 % significance level, indicating that the “Broadband China” strategy propels the digital talent aggregate, making the regional labor structure more in line with the digital era and decreasing the labor expenses of enterprise digital transformation. Based on the results from column (3), it can be inferred that the “Broadband China” strategy reduces firms’ financing costs, thereby alleviating the funding constraints in digital transformation.

In general, on the one hand, the “Broadband China” strategy reduces the cost of enterprise digital transformation by increasing regional digital innovation output and strengthening digital talent reserve. On the other hand, the policy implementation directly alleviates the issue of capital shortages. Enterprises actively use the resources in their regions for digital transformation, aligning with the trend of enterprise digital transformation.

4.2.2. The passive transformation

We investigate the effect of the “Broadband China” strategy on industry rivalry and firm competitiveness. Firstly, we use the measuring method developed by Cremers et al. (2008) to determine the number of enterprises in each industry (*ICP*) in the sample for various years. The level of industry competitiveness is inversely related to the increase in *ICP*. Utilizing the annual median of the industry, we categorize the enterprise conditions into two classes: those in industries with intense competition and those with moderate competition. Secondly, industry concentration (*ICC*) is measured by the market shares of the top four enterprises in the industry (Xu et al., 2023a, 2023b). We split our samples into two groups according to the industry concentration’s yearly median. If an enterprise is in an industry where the industry concentration is greater than the median, it is considered to be in an industry with high concentration and low competition intensity; otherwise, it is considered to be in an industry with low concentration and high competition intensity (Saeed et al., 2023). Thirdly, taking into account the impact of the enterprise’s internal state, the Individual Lerner Index is employed to characterize enterprise competitiveness (*ECP*). The level of enterprise rivalry decreases as the *ECP* increases. The yearly median is utilized to separate the firms into two categories.

The results of the group regression are presented in Table 4. Columns (1) - (4) provide the results at industry competition levels. The results indicate that the coefficient of *POLICY* remains consistently significant and positive, suggesting that regardless of the industry competition level, the “Broadband China” strategy is advantageous for enterprise digital transformation. However, the coefficients indicate a more substantial positive impact for enterprises in industries with intense competition and low concentration. Columns (5) and (6) present the results at enterprise competitiveness levels. Both coefficients in column (5) and (6) are significantly positive, with the coefficient in column (6) being higher than that in column (5). This indicates that compared to other enterprises in the same industry, the “Broadband China” strategy is greater for enterprises with weaker competitiveness. This highlights that the improvement in broadband accessibility is advantageous for enterprises with relatively weaker competitiveness to seize policy opportunities, thus narrowing the gap with larger enterprises. In general, the results in Table 4 indicate that the “Broadband China” strategy has a more substantial impact on enterprises in intense industry competition and weaker internal competitiveness. Consequently, enterprises will undergo digital transformation passively due to pressure from other companies in the field.

4.3. Heterogeneity analysis

The previous sections of this paper show that the “Broadband China” strategy plays a facilitating role in enterprise digital transformation. This section examines the heterogeneous impact by analyzing both micro characteristics and macro environment. Specifically, the heterogeneity investigations examine how property rights, firm size, industries’ technological level and industries’ factor intensity influence the relationship between the “Broadband China” strategy and the enterprise digital transformation.

4.3.1. Nature of corporate property rights

With the deepening of market-oriented reforms, there are many differences between enterprises with different ownership in terms of resource advantages, government-enterprise relations, and business objectives. Therefore, the “Broadband China” strategy may have various effects on different enterprises. We categorize the overall sample into state-owned enterprises and non-state-owned

Table 4
Mechanism test: the competitive effect of passive transformation.

Variable	*ICP*		*ICC*		*ECP*	
	(1) *High*	(2) *Low*	(3) *Low*	(4) *High*	(5) *High*	(6) *Low*
POLICY	0.0779***	0.0216*	0.0627***	0.0258*	0.0300*	0.0644***
	(0.0183)	(0.0125)	(0.0192)	(0.0136)	(0.0158)	(0.0162)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	11,982	13,228	11,303	12,343	12,636	12,574
R-squared	0.2534	0.2419	0.2422	0.2498	0.2725	0.2466
Empirical p-values	0.0000		0.0000		0.0169	

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; standard errors are in parentheses.

enterprises (SOEs and non-SOEs) based on enterprise property rights. In Table 5, columns (1) and (2) report the results of group regressions for SOEs and non-SOEs. The coefficients are all significantly positive, indicating that the "Broadband China" strategy improves the digital transformation of both SOEs and non-SOEs. Furthermore, the "Broadband China" strategy improves the enterprise digital transformation more in non-SOEs. A possible explanation is that, unlike SOEs, which are subject to strict official supervision and bear more social responsibilities, non-SOEs are more targeted at maximizing benefits and more sensitive to policy change. Hence, non-SOEs can adjust their strategy according to the policy direction and environmental changes in time, and maximize the policy dividends brought by the "Broadband China" strategy.

4.3.2. Firm size

The sensitivity of enterprises to the "Broadband China" strategy is also different because there are differences in the production structure and business model among enterprises of varying sizes. We divide the samples into large-scale enterprises and small-scale enterprises based on the median natural logarithm of enterprise asset size for group regression. Table 5 reports the results based on firm size in columns (3) and (4). The coefficient of *POLICY* in column (4) is larger and more significant than that in column (3), indicating that the "Broadband China" strategy has a more potent impact on the digital transformation of small-scale enterprises. Firstly, large-scale enterprises possess advanced market departments, intense research and superior digital foundations. The primary motivation for their digital transformation is based on internal growth requirements, with less sensitivity to the implementation of external policies and changes in the external environment. Secondly, small-scale enterprises have inadequate internal organization, relying on external sources for information transfer and knowledge exchange. The broadband infrastructure increases regional digital supply and optimizes the digital environment, providing small-scale enterprises with more digital information and knowledge. Simultaneously, small-scale enterprises rely more heavily on the external environment to overcome the challenges they face in digital transformation.

4.3.3. The technical level of industry

Digital technology plays a crucial role in driving enterprise digital transformation. Enterprises in different industries with various levels of technological advancement have different needs for digital transformation. The "Broadband China" strategy may have various degrees of impact on enterprise digital transformation based on the technical levels of industries. This paper categorizes enterprises into high-tech enterprises and non-high-tech enterprises based on the *Classification of High-Tech Industries (Services) 2018* and *Classification of High-Tech Industries (Manufacturing) 2017* published by NBS. The results are shown in Columns (1) and (2) of Table 6. Both coefficients of *POLICY* are statistically significant and positive, with a larger value in Column (1). This indicates that the "Broadband China" strategy promotes enterprise digital transformation at different technical levels of industries, with a stronger effect on the digital transformation of high-tech enterprises.

On the one hand, core operations of high-tech enterprises often directly rely on digital technologies such as AI, IoT and cloud computing. This implies that high-tech enterprises can respond to the broadband infrastructure quickly and grasp the opportunities. On the other hand, the effectiveness of broadband infrastructure relies on the initial digitalization levels. Enterprises with higher digitalization levels can better utilize the broadband infrastructure. High-tech enterprises have a competitive edge over non-high-tech enterprises in terms of digitalization levels. Consequently, high-tech enterprises exhibit greater adaptability and transformation capabilities after the broadband infrastructure construction.

4.3.4. The factor intensity of industry

Based on the discussion above regarding enterprise digital transformation at technical levels of industries, this section divides enterprises into three categories: labor-intensive, capital-intensive and technology-intensive.

Table 6 reports the results of group regressions in columns (3) - (5). The coefficient of *POLICY* in Column (3) is not statistically significant, while the coefficients in Columns (4) and (5) are both statistically significant and positive. Furthermore, the coefficient in Column (5) is larger and more significant. This indicates that the "Broadband China" strategy promotes enterprise digital transformation in capital-intensive and technology-intensive industries, with a particularly pronounced effect on technology-intensive

Table 5
Heterogeneity analysis of the micro characters.

Variable	Property rights		Firm size	
	(1) *SOEs*	(2) *non-SOEs*	(3) *Large-scale*	(4) *Small-scale*
POLICY	0.0429***	0.0765***	0.0250*	0.0711***
	(0.0137)	(0.0155)	(0.0140)	(0.0169)
Controls	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	10,094	15,116	12,510	12,700
R-squared	0.2492	0.2794	0.2113	0.2438
Empirical p-value	0.0000		0.0001	

Notes: *** p < 0.01, ** p < 0.05, * p < 0.1; standard errors are in parentheses.

Table 6
Heterogeneity analysis of the macro-environment.

Variable	The technical level of industries		The factor intensity of industries		
	(1) *High-tech*	(2) *Non-high-tech*	(3) *Labor-intensive*	(4) *Capital-intensive*	(5) *Technology-intensive*
POLICY	0.1051***	0.0234**	0.0235	0.0342**	0.0889***
	(0.0197)	(0.0107)	(0.0145)	(0.0142)	(0.0210)
Controls	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	No	No	Yes	Yes	Yes
N	11,824	13,386	7,001	6,694	11,143
R-squared	0.2710	0.2841	0.2914	0.2463	0.2880
Empirical p-value	0.0000			0.0000	

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; standard errors are in parentheses.

enterprises. Capital-intensive and technology-intensive industries, whose core productive force lies in advanced technology, have a closer connection with the digital economy. In contrast, labor-intensive industries, which rely more heavily on labor, are not significantly impacted in their core operations by broadband infrastructure. In addition, we provide a detailed list of the words that capture the attention of enterprises across various industries in Table A3.

5. Robustness tests

5.1. Dynamic effect test

We provide Fig. 1 utilizing Eq. (2) as the foundation, which shows the time trend of enterprise digital transformation with 95 % confidence intervals. Before the implementation of the policy, the regression coefficient fluctuates around 0, indicating no significant difference in the level of enterprise digital transformation between the treatment and control groups. In the year the "Broadband China" strategy is implemented, a noticeable positive effect is observed. Moreover, the coefficient shows a gradual increase after the policy, suggesting a growing difference in the level of digital transformation between the treatment and control groups. The results pass the parallel trend assumption test.

5.2. PSM-DID method

To further test the validity of DID estimations and reduce any estimation bias due to sample selection, such as the city's resource endowments and the economic foundation of enterprises, we utilize propensity score matching (PSM) in conjunction with DID to choose the control group. The propensity score and "nearest neighbor matching with a caliper" method are used in this paper. We use

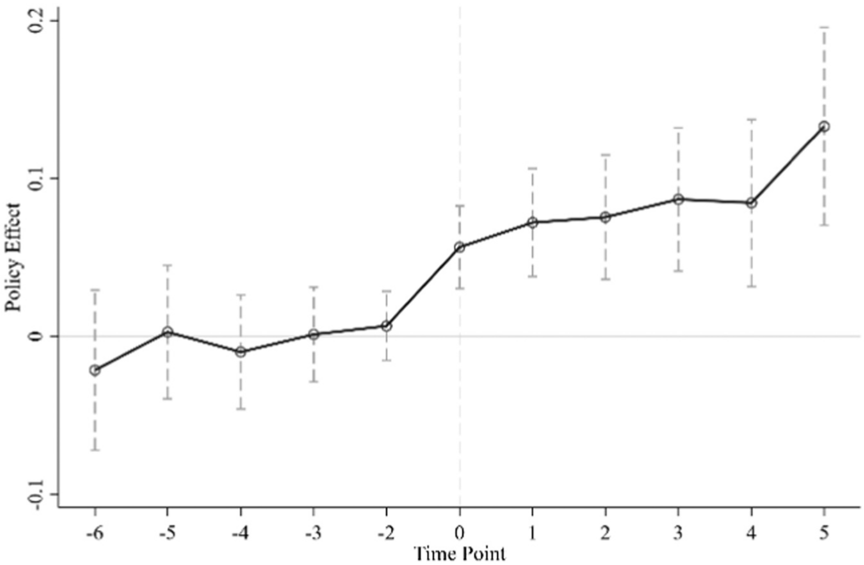

Fig. 1. Parallel trends test.
Notes: The graph displays the outcomes of the parallel trends analysis using *DIGITAL* as the explained variable. The confidence interval is at 95 %.

the matched samples and the base model in Eq. (1) to estimate.

The PSM-DID estimate result is presented in Table 7. Regardless of whether control variables are included, the results indicate that the coefficient of *POLICY* is positive. The estimation results show consistency with the baseline results, indicating that the conclusions remain valid after eliminating selective errors.

5.3. Instrumental variable method

The preceding analysis indicates that broadband infrastructure is conducive to enterprise digital transformation. However, this impact may be subject to endogeneity issues such as reverse causality. Considering that "Broadband China" pilot cities are not randomly established, we address the endogeneity problem by identifying the net effect of broadband infrastructure on digital transformation through an instrumental variable approach. Following Tian and Lu (2023), we utilize the number of fixed telephone lines per hundred people in 1984 (*IV*).

The selection of the instrumental variable needs to satisfy two aspects. Firstly, the fixed telephone service was the most effective inter-regional communication in 1984, which would affect the selection of pilot cities for the "Broadband China" strategy. The choice of this variable satisfies the relevance requirement of the instrumental variable. Secondly, the construction of telephone facilities in 1984 would not impact enterprise digital transformation over three decades later. Thus, it also satisfies the exogeneity requirement of the instrumental variable. Given that the number of fixed telephone lines in 1984 is a cross-sectional variable, we introduce a time-varying variable (Nunn and Qian, 2014; Wang and Shao, 2024). Specifically, following Tian and Lu (2023) and Xu et al., (2023a); (2023b), we multiply the *IV* by a year dummy variable to serve as an instrumental variable for broadband infrastructure (*TELE*), thereby conducting a two-stage least squares (2SLS) estimation.

The results are presented in Table 8. The *POLICY* coefficient in column (2) remains significantly positive, aligning with the baseline results. This suggests that the "Broadband China" strategy significantly promotes enterprise digital transformation, even after accounting for potential endogeneity.

5.4. Placebo test

To address the concern that our results might be driven by some unobservable shocks rather than the"Broadband China" strategy, we further conduct a placebo test. Specifically, we randomly assign firms affected by the "Broadband China" strategy and then construct a false variable *POLICY_placebo*. We repeat this procedure 500 times to generate a distribution of coefficient estimates. Fig. 2 displays the distribution of coefficients and their associated p-values. The distribution of these coefficients is approximately normal, with centers around zero. Besides, most of the estimated p-values are greater than 0.1. This result indicates that our findings are not driven by some unobservable characteristics.

5.5. Other robustness tests

Replace the indicators of the explanatory variables. We substitute the variable representing the corporate digital transformation in the primary regression with two other variables. The first measures the enterprise digital transformation (*DIGITAL1*) using the proportion of intangible assets connected to the digital economy disclosed in the year-end detailed items in financial reports. This paper also uses the natural logarithm of the number of keywords in the annual reports of listed companies after adding one as the second way to assess the enterprise digital transformation (*DIGITAL2*). Table 9 shows the robustness test results. The coefficients of *POLICY* in columns (1) and (2) are significantly positive, suggesting that even when the measurement method of the explained variable is altered, the conclusion remains robust.

Change the sample. Municipalities have enhanced geographical and political advantages above typical prefecture-level cities due to being directly administered and controlled by the central government. To mitigate the influence of this factor, we exclude the samples of enterprises located in Beijing, Tianjin, Shanghai, and Chongqing. Column (3) of Table 9 reports the results after excluding these samples. The coefficient of *POLICY* is consistent with our main findings. It shows that the "Broadband China" strategy has a notably good impact, indicating that our benchmark result is robust.

Table 7
Results of PSM-DID estimates.

Variable	(1) *DIGITAL*	(2) *DIGITAL*
POLICY	0.0571***	0.0509***
	(0.0104)	(0.0108)
Controls	No	Yes
Firm FE	Yes	Yes
Year FE	Yes	Yes
N	28,128	25,176
R-squared	0.2383	0.2646

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; standard errors are in parentheses.

Table 8
Results of IV method.

Variable	(1) First-stage	(2) Second-stage
POLICY		0.2328*** (0.0423)
TELE	0.0201*** (0.0025)	
Firm FE	No	Yes
City FE	Yes	No
Year FE	Yes	Yes
N	2,117	23,675

Notes: *** p < 0.01, ** p < 0.05, * p < 0.1; the Cragg-Donald Wald F statistic for the weak identification test is 1604.379.

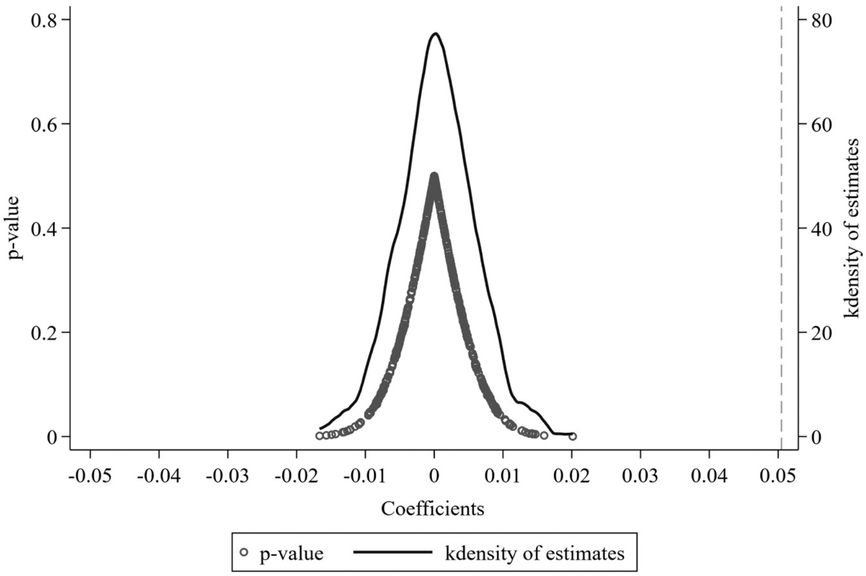

Fig. 2. Distribution of coefficients in placebo test.
Notes: This figure shows the results of a placebo test that randomly assigns firms affected by the "Broadband China" strategy. This procedure is repeated 500 times. The vertical dashed line represents the estimated coefficient of the baseline regression.

Table 9
Results of robustness tests.

Variable	(1) *DIGITAL1*	(2) *DIGITAL2*	(3) Excluding municipalities	(4) Excluding provincial factors	(5) Excluding industrial factors
POLICY	0.0059* (0.0033)	0.0980*** (0.0182)	0.0615*** (0.0113)	0.0457*** (0.0139)	0.0322*** (0.0107)
Controls	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Province FE×Year FE	No	No	No	Yes	No
Industry FE×Year FE	No	No	No	No	Yes
N	22,574	25,210	19,526	25,020	25,012
R-squared	0.0020	0.3799	0.2743	0.8100	0.8204

Notes: *** p < 0.01, ** p < 0.05, * p < 0.1; standard errors are in parentheses.

Change the clustering method. Regions with superior economic growth have advantages in adopting the digital economy, and there are notable variations in digital maturity among different industries. Based on benchmark regression models, we further cluster the data at the "province-year" and "industry-year" levels to assess the reliability of the results. In columns (4) and (5), the coefficients of *POLICY* are significantly positive, and all results are robust.

6. Conclusions and recommendations

Using data from Chinese A-share listed companies from 2007 to 2019, we regard the "Broadband China" strategy as a quasi-natural experiment and use a staggered DID approach to explore how broadband infrastructure affects enterprise digital transformation. We hope this paper can offer empirical evidence for improving broadband infrastructure and accelerating enterprise digital transformation. The primary research findings are as follows. Firstly, broadband infrastructure can significantly accelerate enterprise digital transformation. Specifically, the baseline results remain valid after a series of robustness tests. Secondly, mechanism analysis indicates that broadband infrastructure facilitates the active digital transformation of enterprises by reducing costs associated with innovation, labor, and finance. It also compels a passive digital transformation through the intensification of industry competition. Furthermore, this impact is more significant for small-scale enterprises, non-SOEs, and those enterprises in high-tech and technology-intensive industries.

Our study explains how digital economy policies affect enterprise strategies, which is based on an analytical framework characterized as "urban-industry-firm". Enterprise transformation and government guidance are critical to the digital economy. By using digital technologies such as artificial intelligence, big data, and cloud computing, which are facilitated by advanced broadband infrastructure, enterprises can effectively utilize vast data resources. This strategy is especially advantageous for multinational corporations, equipping them with comprehensive tools to gather and analyze market information. This includes understanding the market landscape and the growth trends of competitors, as well as gauging customer demand.

Moreover, governments should prioritize the continuous construction of broadband infrastructure. This strategic focus ensures that the benefits of digital economy, including technological innovations and digital talents, are accessible to a broader range of regions and enterprises. In the era of widespread digitization, there is a necessity for developing countries and emerging economies to take action. They should emphasize the strengthening of broadband infrastructure, fostering international collaboration, and establishing a solid foundation for the digital economy's prosperity.

CRediT authorship contribution statement

Zhengqi Wang: Writing – original draft, Conceptualization. **Meng Li:** Writing – review & editing. **Haoyu Gao:** Writing – review & editing. **Linhan Shu:** Writing – original draft, Data curation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix

Table A1
Word dictionary.

Dimension	Word Segmentation Dictionary
Digital Technology Applications	Big Data, Data, Digitalization, Data Center, Data Application, Digital Economy, Data Sharing, Database, Data Security, Data Analysis, Data Platform, Information Repository, Data Collection, Data Openness, Massive Data, Data Processing, Data Services, Data-Driven, Data Science, Data Integration, Network Poverty Alleviation, Resource Element Data, Data Information, Data Mining, Predictive Warning, Data Set, Data Management, Data Barriers, Digital Technology, Digital Talent, Open Sharing, Resource Sharing, Electronic Certificate, Information Island, Electronic Medical Records, Open Source Community, Digital Dividends, Traceable Information, Digital Education, High-End Software, Artificial Intelligence, Intelligent Terminals, Smart Cities, Intelligence, Collective Intelligence, Smart Grid, Identity Authentication, Intelligent Services, Intelligent Computing, Intelligent Technology, Intelligent Economy, Intelligent Society, Natural Language Processing, Machine Learning, Deep Learning, Voice Technology, Smart Agriculture, Intelligent Control, Information Collection, Autonomous Driving, Wearable Devices, Monitoring and Early Warning, Smart Home, Digital Television, Medical Imaging, Drones, Satellite Remote Sensing, Correlation Analysis, Data Storage, Dynamic Monitoring, Augmented Intelligence, Blockchain, Virtual Reality, Automatic Control Systems
Internet Business Models	Internet, Internet Plus, E-commerce, Online, On the Web, Information Platform, Sharing Economy, Network Culture, Online Presence, Internet Access, New Media, Social Networking, Interconnected Sharing, Real-Time, Logistics Information, Energy Network, Information Sharing, Information Services, Information Economy, Cyberspace, One-Stop Internet Service, E-Government, Network Philanthropy, Network Economy, Network System, Telemedicine, Distance Education, Information Dissemination, Access Services, Knowledge Services, Innovative Networks
Intelligent Manufacturing	Intelligent Manufacturing, Intelligentization, Intelligence, Intelligent Products, Robots, Smart Factories, Visualization, Autonomous Unmanned Systems, Virtualization, Intelligent Equipment, 3D Printing, Intelligent Decision-Making, Intelligent Perception, Brain-Like Intelligence, Smart Energy Use, Automation, Testing Technology, Deep Integration, Dynamic Monitoring, System Integration, Software and Hardware, Operating Systems, Wireless Technology, Cross-Media, Shared Exchange, Industrial Software, Basic Software, Application Software, Additive Manufacturing, Autonomous Learning, Augmented Reality, Autonomous Collaboration, Internet of Things, Chips, Sensors, Numerical Control Machine Tools, Semiconductors, Intelligent Monitoring, Radio Frequency Identification, Environmental Monitoring, Cloud Computing, Cloud Platform, Cloud Services, Industrial Cloud

(*continued on next page*)

Table A1 (*continued*)

Dimension	Word Segmentation Dictionary
Modern Information Technologies	Information Technology, Integrated Circuits, Informatization, Networking, Network Security, Information Security, Networked Systems, Information Systems, Broadband, Software, Information, Telecommunications, Fiber Optics, Information for Public Welfare, Broadband Networks, 5 G, Credit Information, Core Technology, Mobile Communications, IP, Information and Communication, Triple Play Convergence, Interconnectivity, Information Consumption, Network Construction, Servers, Satellite Systems, Information Interoperability, Integration and Convergence, Network Architecture, Network Infrastructure, Public Information, Information Management, Fiber Optic Cables, 4 G, Processors, Electronic Information, Network Technology, Network Information, Network Devices, Communication Equipment, Communication Systems, Network Services, Beidou Navigation System, Satellite Navigation, Communication Networks, Network Acceleration

Table A2
Description of the primary variables.

Type	Variables	Definition
Explained variables	*DIGITAL*	The word frequency is divided by the length of MD&A segments multiplied by 100 in the annual reports of listed companies
	DIGITAL1	The proportion of digital intangible assets
	DIGITAL2	The natural logarithmic of the number of keywords after adding 1
Explanatory variable	*POLICY*	Policy dummy variables
Control variables	*SIZE*	The natural logarithm of the firm's total assets
	LEV	The ratio of total liabilities to total assets at the end of the year
	CASHFLOW	The ratio of the firm's net cash flow to the average balance of total assets
	TOP5	The proportion of the top five shareholders to the total number of shares
	TOBINQ	The ratio of the market value to total assets at the end of the year
	LISTAGE	The natural logarithm of company age plus 1
	BOARD	The natural logarithm of the number of board of directors
	ECONOMY	The regional GDP growth rate
	EXPENSE	The ratio of fiscal expenditure share to GDP

Table A3
Changes about the words in different industries.

Industries	Top Ten Words
High-tech	Intelligence, Data, Intelligentization, Big Data, Internet of Things, Information, Internet, Artificial Intelligence, Informatization, Intelligent Manufacturing
Non-high-tech	Data, Information, Intelligence, Digitalization, Online, Intelligentization, Informatization, Internet, Big Data, E-commerce
Labor-intensive	Data, Information, Online, Digitalization, Intelligence, E-commerce, Informatization, Intelligentization, Internet, Big Data
Capital-intensive	Data, Information, Intelligentization, Intelligence, Informatization, Digitalization, Internet, Automation, Intelligent Manufacturing, Online
Technology-intensive	Intelligence, Data, Intelligentization, Big Data, Internet of Things, Information, Internet, Artificial Intelligence, Intelligent Manufacturing, Digitalization

Notes: This table displays the top ten words for enterprises across different industries. We calculate the annual average change in word frequency for each firm, obtain the average change in word frequency for each industry category, and rank them from highest to lowest. It can be observed that there are disparities in various industries and the digital transformation process aligning with the characteristics of their own industry. For example, high-tech and technology-intensive industries tend to concentrate on words representing technologies, such as the *Internet of Things* and *Artificial Intelligence*, while non-high-tech and labor-intensive industries are more likely to focus on words like *E-commerce*.

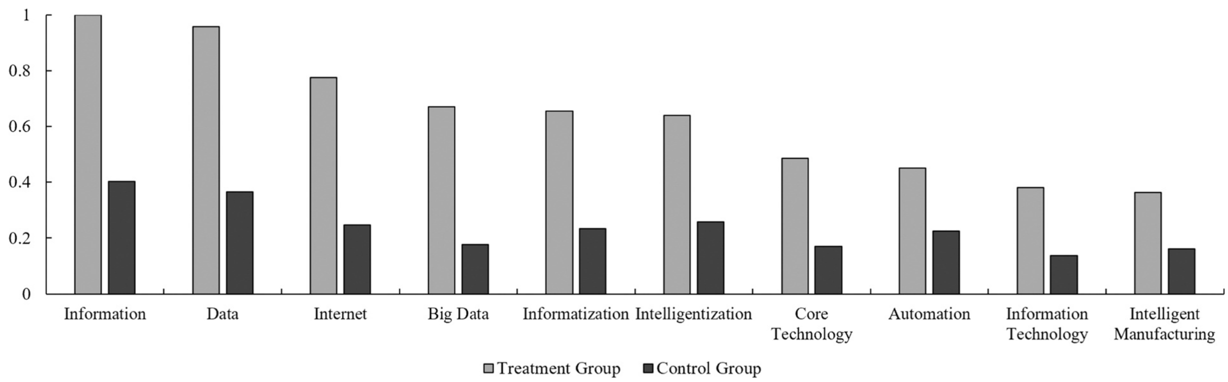

Fig. A1. Changes about the words.
Notes: To visually present the changes about the words after the implementation of the "Broadband China" strategy, we calculate the number of enterprises that experienced positive keyword changes one year before and after the policy in the treatment group and control group, respectively.

The degree of enterprise attention to each keyword is represented by the ratio of this number to the total number of enterprises in the corresponding group. This figure displays the top ten keywords and their corresponding proportions. On one hand, the treatment and control groups show high attention to these ten words. On the other hand, the changes in the treatment group are more pronounced than those in the control group.

Data Availability

Data will be made available on request.

References

Acheampong, A.O., Opoku, E.E., Dzator, J., Kufuor, N.K., 2022. Enhancing human development in developing regions: Do ICT and transport infrastructure matter? Technol. Forecast Soc. Change 180, 121725.
AlNuaimi, B.K., Singh, S.K., Ren, S., Budhwar, P., Vorobyev, D., 2022. Mastering digital transformation: The nexus between leadership, agility, and digital strategy. J. Bus. Res. 145, 636–648.
Beck, T., Levine, R., Levkov, A., 2010. Big bad banks? The winners and losers from bank deregulation in the United States. J. Financ. 65, 1637–1667.
Bharadwaj, A.S., Sawy, O.E., Pavlou, P.A., Venkatraman, N., 2013. Digital business strategy: toward a next generation of insights. Mis. Q. 37, 471–482.
Cai, Y., Luo, N., Xie, X., Gong, Y., 2024. Chairman's IT background and enterprise digital transformation: evidence from China. Pac. -Basin Financ. J. 83, 102220.
Cetindamar Kozanoglu, D., Abedin, B., 2020. Understanding the role of employees in digital transformation: conceptualization of digital literacy of employees as a multi-dimensional organizational affordance. J. Enterp. Inf. Manag. 34, 1649–1672.
Chen, K., Zhang, S., 2024. How does open public data impact enterprise digital transformation? Econ. Anal. Policy 83, 178–190.
Cheng, Y., Zhou, X., Li, Y., 2023. The effect of digital transformation on real economy enterprises' total factor productivity. Int. Rev. Econ. Financ. 85, 488–501.
Cremers, M., Nair, V.B., Peyer, U., 2008. Takeover defenses and competition: the role of stakeholders. J. Empir. Leg. Stud. 5, 791–818.
Feliciano-Cestero, M.M., Ameen, N., Kotabe, M., Paul, J., Signoret, M., 2023. Is digital transformation threatened? A systematic literature review of the factors influencing firms' digital transformation and internationalization. J. Bus. Res. 157, 113546.
Goldfarb, A., Tucker, C., 2019. Digital economics. J. Econ. Lit. 57 (1), 3–43.
Grover, V., Kohli, R., 2013. Revealing your hand: caveats in implementing digital business strategy. Mis. Q. 37, 655–662.
Guo, B., Feng, Y., Lin, J., 2023. Digital inclusive finance and digital transformation of enterprises. Financ. Res. Lett. 57, 104270.
Hong, J., Fu, S., 2011. Information and communication technologies and the geographical concentration of manufacturing industries: evidence from China. Urban Stud. 48 (1), 2339–2354.
Jiang, Y., Wang, J., Huang, Y., 2024. Does religious atmosphere affect enterprise digital transformation? Evidence from China. Res. Int. Bus. Financ. 70, 102389.
Jorgenson, D.W., 2001. Information technology and the U.S. economy. Am. Econ. Rev. 91 (1), 1–32.
Liu, S., Zhao, H., Kong, G., 2023. Enterprise digital transformation, breadth of ownership and stock price volatility. Int. Rev. Financ. Anal. 89, 102713.
Liu, Y., Luan, L., Wu, W., Zhang, Z., Hsu, Y., 2021. Can digital financial inclusion promote China's economic growth? Int. Rev. Financ. Anal. 78, 101889.
Loebbecke, C., Picot, A., 2015. Reflections on societal and business model transformation arising from digitization and big data analytics: a research agenda. J. Strateg. 24, 149–157.
Luo, W., Yu, Y., Deng, M., 2024. The impact of enterprise digital transformation on risk-taking: evidence from China. Res. Int. Bus. Financ. 69, 102285.
Mandviwalla, M., Flanagan, R., 2021. Small business digital transformation in the context of the pandemic. Eur. J. Inform. Syst. 30, 359–375.
Nambisan, S., 2017. Digital entrepreneurship: Toward a digital technology perspective of entrepreneurship. Entrep. Theory Pract. 41, 1029–1055.
Nguyen, D.K., Broekhuizen, T.L., Dong, J.Q., Verhoef, P.C., 2023. Leveraging synergy to drive digital transformation: a systems-theoretic perspective. Inf. Manag. 60, 103836.
Niu, G., Jin, X., Wang, Q., Zhou, Y., 2022. Broadband infrastructure and digital financial inclusion in rural China. China Econ. Rev. 76, 101853.
Niu, Y., Wang, S., Wen, W., Li, S., 2023. Does digital transformation speed up dynamic capital structure adjustment? Evidence from China. Pac. -Basin Financ. J. 79, 102016.
Nunn, N., Qian, N., 2014. US food aid and civil conflict. Am. Econ. Rev. 104 (6), 1630–1666.
Oliner, S.D., Sichel, D.E., 2000. The resurgence of growth in the late 1990s: is information technology the story? J. Econ. Perspect. 14 (4), 3–22.
Pan, W., Xie, T., Wang, Z., Ma, L., 2022. Digital economy: An innovation driver for total factor productivity. J. Bus. Res. 139, 303–311.
Peng, Y.C., Tao, C., 2022. Can digital transformation promote enterprise performance? —From the perspective of public policy and innovation. J. Innov. Knowl. 7 (3), 100198.
Porfírio, J.A., Carrilho, T., Felício, J.A., Jardim, J., 2021. Leadership characteristics and digital transformation. J. Bus. Res. 124, 610–619.
Pradhan, R.P., Arvin, M.B., Norman, N.R., 2015. The dynamics of information and communications technologies infrastructure, economic growth, and financial development: evidence from Asian countries. Technol. Soc. 42, 135–149.
Pradhan, R.P., Mallik, G., Bagchi, T.P., 2018. Information communication technology (ICT) infrastructure and economic growth: a causality evinced by cross-country panel data. IIMB Manag. Rev. 30, 91–103.
Saeed, A., Alnori, F., Yaqoob, G., 2023. Corporate social responsibility, industry concentration, and firm performance: evidence from emerging Asian economies. Res. Int. Bus. Financ. 64, 101864.
Staab, P., Thiel, T., 2022. Social media and the digital structural transformation of the public sphere. Theory Cult. Soc. 39, 129–143.
Tang, Y., Geng, B., 2024. Digital finance development level and corporate debt financing cost. Financ. Res. Lett. 4, 104825.
Tao, Y., Kong, D., Sun, N., Li, X., 2024. Social credit and corporate risk-taking: evidence from China. Res. Int. Bus. Financ. 69, 102206.
Teece, D.J., 2018. Profiting from innovation in the digital economy: enabling technologies, standards, and licensing models in the wireless world. Res. Policy 47 (8), 1367–1387.
Tether, B.S., 2002. Who co-operates for innovation, and why: an empirical analysis. Res. Policy 31 (6), 947–967.
Tian, X., Lu, H., 2023. Digital infrastructure and cross-regional collaborative innovation in enterprises. Financ. Res. Lett. 58, 104635.
Troise, C., Corvello, V., Ghobadian, A., O'Regan, N., 2022. How can SMEs successfully navigate VUCA environment: the role of agility in the digital transformation era. Technol. Forecast Soc. Change 174, 121227.
Van Laar, E., Van Deursen, A.J.M., Van Dijk, J.A.M., De Haan, J., 2018. 21st-century digital skills instrument aimed at working professionals: conceptual development and empirical validation. Telemat 35, 2184–2200.
Vial, G., 2019. Understanding digital transformation: a review and a research agenda. J. Strateg. Inf. Syst. 28, 118–144.
Wang, L., Shao, J., 2024. The energy saving effects of digital infrastructure construction: empirical evidence from Chinese industry. Energy 294, 130778.
Wang, S., Song, Y., Du, A., Liang, J., 2024. The digital economy and entrepreneurial dynamics: an empirical analysis of urban regions in China. Res. Int. Bus. Financ. 71, 102459.
Wu, F., Hu, H., Lin, H., Ren, X., 2021. Enterprise digital transformation and capital market performance: empirical evidence from stock liquidity. J. Manag. World 37 (07), 130–144.
Xiao, T., Sun, R., Yuan, C., Sun, J., 2022. Digital transformation, human capital structure adjustment and labor income share. J. Manag. World 38 (12), 220–237.
Xu, L., Xu, T., Zhu, S., 2023a. Common ownership and executive pay-for-performance sensitivity: evidence from China. Res. Int. Bus. Financ. 65, 101947.

Xu, S., Chen, H., Dong, S., Guo, Z., 2023b. Can upgrading information infrastructure improve the innovation ability of companies? Empirical evidence from China. Telecommun. Policy 47, 102569.
Yang, G., Si, D., Ning, G., 2023. Does digital transformation reduce the labor income share in enterprises? Econ. Anal. Policy 80, 1526–1538.
Zhang, Y., Ma, X., Pang, J., Xing, H., Wang, J., 2023. The impact of digital transformation of manufacturing on corporate performance — the mediating effect of business model innovation and the moderating effect of innovation capability. Res. Int. Bus. Financ. 64, 101890.
Zhao, S., Zhang, L., Peng, L., Zhou, H., Hu, F., 2024. Enterprise pollution reduction through digital transformation? Evidence from Chinese manufacturing enterprises. Technol. Soc. 77, 102520.
Zhou, K., Wang, Q., Tao, Y., Li, X., 2024. Information infrastructure construction and firm export performance in China. Res. Int. Bus. Financ. 70, 102311.