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Does the Opening of High-Speed Railway Promote Corporate Digital Transformation?

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Abstract: As China's economy enters the digital era, guiding enterprises to conduct better digital transformations has become an urgent problem to be solved. In this regard, this paper builds a multiperiod DID model to empirically examine the impact of opening a high-speed railway (HSR) on corporate digital transformation by matching the data of HSR with the data of Shanghai and Shenzhen A-share listed companies from 2008 to 2019. It was found that (1) the opening of an HSR can significantly improve corporate digital transformation, and this finding still held after considering endogeneity issues and various robustness tests. (2) A heterogeneity analysis showed that the promoting effect of opening an HSR on corporate digital transformation was mainly found in nonstate enterprises, high-tech enterprises, and enterprises located in cities with low initial transportation endowment. (3) A mechanistic analysis found that opening an HSR can promote corporate digital transformation by promoting senior staff mobility, increasing industry competition, and enhancing financial agglomeration. This paper not only enriches the research related to the economic consequences of opening an HSR, but it also has important implications for guiding enterprises to successfully conduct corporate digital transformations.

Keywords: the opening of high-speed rail; digital transformation; text analysis; mechanism analysis

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1. Introduction

With the extensive penetration of digital technologies such as artificial intelligence, big data, cloud computing, and the Internet of Things, the world today has entered the era of digital economies. By 2022, China's digital economy reached 48.9 trillion yuan, which accounted for 38.6% of the GDP. The digital economy has become a new engine that is driving the development of the national economy. The development of the digital economy cannot be separated from the support of corporate digital transformation at the micro level. Theoretically, corporate digital transformation refers to the process where enterprises reform their production methods, organizational structure, and business logic by employing digital technologies so as to cultivate their core competitiveness [1,2]. Existing studies have shown that corporate digital transformation can drive business performance and total factor productivity improvement by enhancing the management efficiency [3], promoting specialized division [4], stimulating innovation potential [5], and reducing production costs [6–8]. However, as a systematic project involving all-round changes in enterprises, corporate digital transformation is characterized by high technical thresholds, a high volume of resource inputs, and uncertain transformation results, which thus makes enterprises generally face the dilemma of "won't transform", "don't want to transform", and "afraid to transform" [3]. In this context, actively exploring the factors that affect corporate digital transformation and guiding enterprises to successfully implement digital transformation has become the focus of attention in the academic and practical fields.

New economic geography theory points out that changes in companies' geographic environment can have an important impact on their decision making. The vast territory

of China and the great geographical distances between different regions make the development of transportation infrastructure profoundly intrinsic and connected to corporate decision making. In particular, since China entered the era of high-speed rail, the HSR's impact of the "time-space compression" effect on corporate decision making has become the focus of scholars. Specifically, the existing literature has investigated the effects of opening an HSR on firm innovation [9,10], corporate relocation [11,12], financial performance [13,14], and corporate financialization [15]. However, there is no literature directly focusing on the relationship between opening an HSR and corporate digital transformations, and the relationship between the two can only be indirectly speculated from the existing literature. For example, the opening of an HSR has broken the spatial–temporal constraint of geographical distance and enhanced intercity accessibility, which removed obstacles to the cross-regional movement of production factors [16] and promoted the concentration of capital, technology, talent, and information [11,17–19]. In this regard, opening an HSR can alleviate the problems of "won't transform" due to a high technological threshold, "do not want to transform" due to high resource investments, and "afraid to transform" due to the uncertainty of the transformation results. Furthermore, Figure 1 also provides us with intuitive evidence that the degree of digital transformation is generally higher in enterprises with access to HSR services compared with those without access to HSR services, and the degree of digital transformation tends to follow the HSR's growth, which indicates that there may be a positive correlation between the two. Therefore, to directly examine the relationship between the opening of an HSR and corporate digital transformations, we set to answer the following research questions from a theoretical perspective: (1) Does the opening of an HSR affect corporate digital transformation? (2) What is the mechanism between the two? (3) Does the impact of opening an HSR on corporate digital transformation vary with the change in the external environment? The answers to the above questions not only provide direct evidence for the relationship between the opening of an HSR and corporate digital transformations, but they also provide useful references to guide enterprises to successfully implement corporate digital transformations to enhance their core competitiveness.

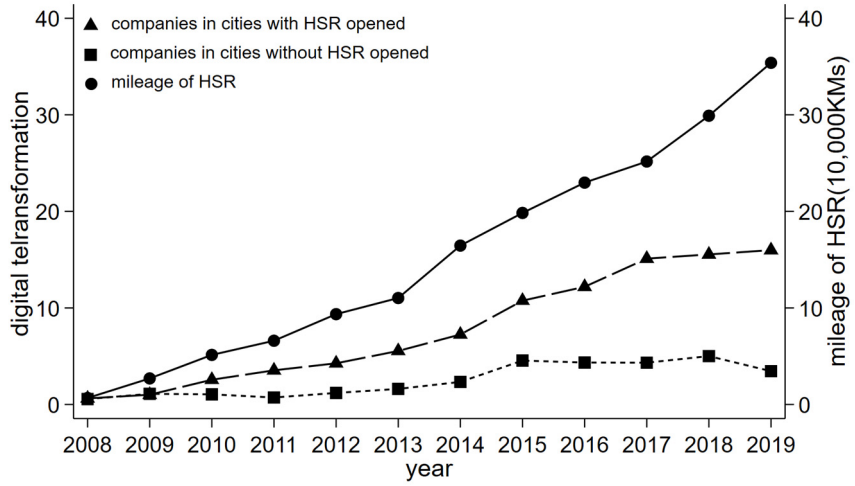

Figure 1. Growth trends of HSR and corporate digital transformation.

On this basis, taking the Shanghai and Shenzhen A-share listed enterprises as a sample, this paper empirically examines the impact of opening an HSR on corporate digital transformations and carefully explores the possible transmission mechanisms at the levels of enterprises, industries, and cities, which not only helps to assess the impact of opening an HSR on the business decisions of micro enterprises, but it also provides useful references for enterprises to successfully conduct corporate digital transformations.

The marginal contributions of this paper are as follows: in terms of the research angle, it innovatively links the large-scale high-speed railway construction in China with corporate

digital transformations and deeply analyzes the relationship between opening a high-speed railway and corporate digital transformations, which not only expands the research scope in this branch but also provides useful implications for enterprises to successfully conduct corporate digital transformations. In terms of the research methods, this study uses Python text analysis technology to construct indicators for measuring digital transformations based on corporate annual reports and decomposes them into transformation decisions and transformation intensity for empirical testing, which can reflect the role of high-speed rail in different stages of digital transformation in enterprises. In terms of the research content, we construct a theoretical framework from the levels of firms, industries, and cities, which opens the "mechanism black box" of the two. At the end of this paper, we also provide useful references for the government to guide enterprises in successfully conducting corporate digital transformations.

2. Literature Review and Theoretical Analysis

2.1. Literature

2.1.1. Research on Corporate Digital Transformation

Currently, there is no consensus among academics on the definition of corporate digital transformation. Specifically, scholars have focused on the following two aspects of the definition of corporate digital transformation: First, companies use digital technology to upgrade their current production technology so as to improve their corporate performance [20]. This definition does not capture the essence of digital transformations and only treats transformation as the application of new technologies. Second, companies use digital technologies to improve existing business models [21,22]. This definition, although interested in involving changes to business models, still fails to capture the full scope of corporate digital transformations. We believe that a digital transformation is multilayered and multifaceted, whereby not only are the existing production methods upgraded by using digital technology (digital empowerment), but also an all-around change is made to the organizational structure and business logic to create new business models and form new profit growth points (digital enablement) so as to enhance the core competitiveness of the enterprises [1,2].

Regarding the driving factors of corporate digital transformation, scholars have focused on the following aspects: technology, organization, and environment. First, from the technology perspective, corporate digital transformations are driven by the development of digital technologies such as big data, cloud computing, and the Internet of Things, and they need to undergo a highly dynamic transformation between technology acquisition and technology implementation [23]. In this process, companies generate dynamic capabilities by changing, extending, and adapting their existing resources, processes and values as a way to drive their digital development [24]. Second, at the organizational level, a company's organizational resources, organizational culture, and organizational strategy affect the propensity and effectiveness of their digital transformation. For example, executives' decision-making logic, perceptual ability, academic experience, and learning ability are all important factors in determining the success of corporate digital transformations [25]. Also, the intensity of communication and cooperation among the executive team also increases the probability of a corporate digital transformation occurring in an organization by enhancing information exchange and business collaboration [26]. Furthermore, the organization's own technological reserve, the organizational culture that is receptive to new things, and an adequate strategic execution also influence the effectiveness of digital transformations in enterprises [27]. Third, at the environmental level, corporate digital transformations have obvious spillover effects and positive externalities, and if conducting corporate digital transformation only relies on the enterprises themselves, it will most likely lead to insufficient incentives. As a result, corporate digital transformations also need to be driven by institutional changes, industry competition, and the regional business environment. For example, the improvement in the external environment, such as the opening of the capital market, the establishment of the pilot-free trade zone, and the

increase in financial technologization (fin-tech) helps to establish a sound digital economy system [28–30]; customers' demands changing, the competitive environment intensifying, and the industrial structure upgrading will all prompt enterprises to seek creative solutions through digital transformation [31].

The economic consequences of corporate digital transformations have been extensively discussed in academia, and the existing literature mainly focuses on the following aspects: (1) Corporate digital transformations and enterprise performance. He and Liu [6] found that corporate digital transformations can significantly improve enterprise performance through the paths of "cost reduction", "efficiency improvement" [32], and "innovation promotion" [7]. Ardito [33], using a sample of North American SMEs, also found that digital strategic positioning has a positive and significant effect on product and innovation performance. (2) Corporate digital transformation and companies' total factor productivity. Some scholars found that corporate digital transformation drives total factor productivity growth by improving innovation capabilities [34], optimizing the human capital structure, promoting the integration of advanced manufacturing, and reducing operational costs [8]. Tu and Yan [35] also found that corporate digital transformations can increase the total factor productivity by accelerating and expanding the knowledge spillover effect among firms. (3) Corporate digital transformation and risk control. Wang et al. [36] argue that corporate digital transformations can lower the risk of debt default by reducing operational risks, easing financing constraints, and reducing agency costs. However, some scholars point out that the rapid iteration of digital technology may shorten the life cycle of new products so that firms have to continuously increase R&D expenditures to maintain their competitive advantage [37], which exacerbates the financial burden of firms and exposes them to higher operational risks. (4) Corporate digital transformation and capital market performance. Wu et al. [5] found that corporate digital transformations significantly increased the level of stock liquidity and had a more significant impact on non-state-owned enterprises. Wu et al. [38] found that corporate digital transformation can significantly reduce the risk of stock price collapse.

2.1.2. Research on Economic Consequences of HSR

Transportation infrastructure is a leading variable for economic development [39]. The economic consequences of opening an HSR have been well discussed by scholars. Specifically, existing studies have explored the economic effects of an HSR at the macro and micro levels.

Macrolevel studies focus on the urban spatial structure [40], regional innovation, and regional economic growth [40,41]. First, regarding the impact of an HSR on the urban spatial structure, the opening of an HSR can break the balance of the centripetal and centrifugal forces in the region and break through administrative boundaries and single-centered development, which can reshape the spatial structure of cities and urban clusters. For example, Wang et al. [42] showed that the construction of an HSR can promote the spatial reallocation of production, guide the trend of population and industry agglomeration, and have a significant impact on the reorganization of urban spatial structures in China. Second, the impact of opening an HSR on regional innovation and industrial structure upgrading. The opening of an HSR reduces the cost of production factor movement and improves total factor productivity allocation, which has become an important engine to promote industrial structure upgrading and technological innovation [43]. Deng et al. [44] pointed out that HSRs significantly promoted the flow of factors between cities and promoted industrial structure upgrading through the of economy of scale effect, technological innovation effect, and capital–labor allocation optimization. He and Tao [45] showed that opening an HSR enhances the knowledge spillover effect of regional central cities along the HSR route, which can in turn stimulate the innovation in non-node cities. Third, the impact of opening an HSR and economic growth. The impact of opening an HSR and regional economic growth has received widespread attention, but scholars have not reached a unanimous conclusion so far. On the one hand, some scholars believe that opening an HSR can weaken

the traditional market segmentation [16] and trigger economic agglomeration in cities along the route [43], which can promote regional economic growth. On the other hand, some studies have shown that the impact of an HSR on regional economies is heterogeneous, and the "siphon effect" of an HSR may cause factors of production and advantageous resources to flow from small cities to big cities, which makes big cities gain while small cities lose, which thus exacerbates unbalanced regional economic development [46].

In recent years, studies assessing the economic effects of HSRs have gradually shifted from the macro perspective on the region to the micro perspective on enterprises. Specifically, the existing studies mainly focus on the following aspects: First, the opening of an HSR and enterprise innovation [47]. The research in this direction mainly focuses on two mechanisms: the knowledge spillover effect and the competition escape effect. From the knowledge spillover perspective, high-value-added innovation activities often rely on face-to-face contact, and the opening of an HSR accelerates the flow of innovation factors such as talents and technologies, which strengthens the role of the knowledge spillover effect and technology externalities and thus enhances enterprise innovation [10]. From the perspective of competition avoidance, the increased market integration brought about by the opening of an HSR enhances the degree of market competition, which will lead to the competitive avoidance effect of enterprises and thus enhance innovation incentives [9]. Second, the opening of an HSR and the location of firms. The opening of an HSR helps promote cooperation over longer distances, which can trigger changes in firms' location selection strategies. For example, Wang et al. [12] found that the opening of an HSR promoted market integration, which can reduce the information cost and supervision cost of firms establishing subsidiaries in remote locations. Third, HSR opening and firm productivity. On the one hand, the opening of an HSR enables firms to search for capital, labor, and suppliers at lower costs, which optimizes the allocation of production factors among firms and thus increases firm productivity [13]. On the other hand, the opening of an HSR enables firms to sell more products to a wider market with lower transportation costs, which allows them to enjoy greater economies of scale and thereby increase productivity [14]. Fourth, the impact of opening an HSR on the capital market. The opening of an HSR will affect the performance of enterprises in the capital market through information mechanisms, supervision mechanisms, and governance mechanisms. For example, Zhao et al. [48] found that the opening of an HSR facilitates the flow of information and improves corporate governance and thus reduces companies' stock price crash risks. In addition, several studies have analyzed the impact of HSRs on corporate behaviors from the perspectives of corporate senior personnel employment [18], corporate cost management [16], enterprise high-quality development [49], and corporate financialization [15].

2.1.3. Summary of Relevant Literature

By reviewing the related literature, we found there is still room for further research. First, the research on "HSR opening–corporate digital transformation" is still in its initial stage. Although Mao et al. [50] examined the impact of the proximity of HSRs on the digital transformation of private enterprises using survey data, the 2022 Employment Trends Report stated that the trend of digital transformation was more pronounced in large listed enterprises, and the pace of digital transformation in private enterprises was slightly slower. Therefore, it is not representative to analyze the relationship between "HSR opening and corporate digital transformation" by only using the data of private enterprises. Second, the existing literature has made useful discussions on how to quantitatively measure corporate digitalization, but there are still some problems. For example, some scholars use the 0–1 variable of "whether the enterprise has carried out digital transformation in the current year" as a measurement indicator [6], which makes it difficult to measure the intensity of corporate digital transformation. Some scholars also use survey data to measure corporate digital transformation [50], but the survey data inevitably have various forms of measurement errors, which make the data less reliable [51]. In view of this, this paper innovatively places the opening of an HSR and digital transformations under the

same analytical framework and examines the impact of opening an HSR on the digital transformations of listed companies, which fills a gap in the current research field. In addition, we construct corporate digital transformation indexes by using the Python text analysis method, which can be used to accurately measure the degree of enterprise digital transformation and thus enhance the reliability of the conclusion.

2.2. Theoretical Analysis

We believe that opening an HSR can promote corporate digital transformation through tree tunnels: enhancing the movement of the senior labor force, increasing industry competition, and generating financial agglomeration.

The opening of an HSR can promote digital transformation by enhancing the movement of senior labor forces. Schumpeter's growth theory argues that the risk-taking spirit, innovation ability, and competitive consciousness play an important role in the transformation and upgrading of enterprises. A large-scale HSR construction can significantly reduce the mobility cost of labor, which can expand the range of senior labor movements. This can help companies recruit technical staff and provide technical reserves for digital transformation [17,18]. Specifically, on the one hand, the opening of an HSR enhances the accessibility of cities, promotes economic clustering, and boosts the local economy. A good urban living environment is an important factor in attracting an inflow of senior workers. At the same time, for enterprises, the opening of an HSR can improve their profitability by reducing their inventories, connecting their supply chains, and reducing their trade costs [13,52], which enables them to pay higher wages, invest in R&D, and attract more senior talents. On the other hand, human capital has the quality of "profitability", and senior talents tend to make multifaceted cost-benefit considerations when choosing employment locations, such as career prospects, the cost of living, and family emotions. The improvement of urban location advantages brought by an HSR can stimulate urban development potential and enhance living comfort and thus attract more highly skilled talents to cities opened by an HSR. In other words, the high-speed rail network breaks the labor market segmentation to a certain extent and improves the matching efficiency between highly skilled talents and corporate positions [10]. As an important carrier of information, technology, and knowledge, the flow of senior talent can not only provide technology reserves for corporate digital transformation but can also enhance the awareness of incumbent managers to actively conduct corporate digital transformation. Therefore, the following hypotheses are proposed:

H1. *The opening of an HSR can promote corporate digital transformations.*

H2. *The opening of an HSR can promote corporate digital transformation by enhancing the movement of senior labor forces.*

The opening of an HSR will "accelerate" the corporate digital transformation through its competitive effect. The digital transformation decision of an enterprise does not depend entirely on its own development needs but is also influenced by the behavior of its competitors [31]. On the one hand, the opening of an HSR expands the competitive scope of enterprises. Before opening HSRs, firms have to pay extra transportation costs and transaction fees for cross-regional transactions, which in effect provides competition protection for local firms. After opening an HSR, the linkage between the local and external markets is enhanced, and producers and consumers are able to purchase better-quality products and services from more distant firms and cities at lower costs [13]. That is, the scope of firms' competition is no longer confined to the local area [43], and they will be impacted by cross-regional competitors. On the other hand, the opening of an HSR also intensifies firms' local market competition. Specifically, the opening of an HSR can stimulate market potential and eliminate the constraints for firms to expand their business in other places. Companies located in peripheral cities can freely move to the center cities, which indeed

intensifies the degree of competition among the firms located in central cities [12]. As a result, companies have no choice but to actively conduct digital transformations to keep their competitiveness; that is, the opening of HSRs makes firms face severe competition, and to keep their competitiveness, companies have no choice but to learn advanced technology, enhance their information access, and reduce their production costs to maintain a competitive advantage while undergoing high-quality digital transformations. Therefore, the following hypotheses are proposed:

H3. *The opening of an HSR can promote corporate digital transformations by enhancing the degree of companies' competition*.

The opening of an HSR can promote corporate digital transformation by generating financial agglomerations. Since digital transformation is characterized by high investments, high risk, and long cycles, it is often difficult for enterprises to meet all their capital needs with their internal funds, so the availability of sufficient external financial support becomes the key to the success of digital transformations [30]. According to the relevant theories of financial geography theory, geographical distance and the spatial costs significantly affect the supply of financial resources [53].This causes HSRs to play an important role in the aggregation process of financial resources. Specifically, the "temporal-spatial compression effect" brought by the opening of an HSR can enable investors to obtain more "soft information", which can avoid the problem of preinvestment adverse selection and postinvestment moral hazard. As a result, the venture capital is more likely to flow to the cities where an HSR has opened, which provides the capital reserves for local enterprises [19]. Second, the high efficiency of an HSR greatly broadens the service range of financial institutions; that is, since the opening of an HSR improves the accessibility of remote cities, financial resources can freely flow to the peripheral cities, which improves the possibility of local enterprises in peripheral cities obtaining valuable financial resources [54]. Finally, HSR construction can also drive economic growth through the multiplier effect and industrial linkage effect, which results in more demand for financial services, which in turn leads to the formation of a more efficient "capital incubation pool" in cities. As a result, the above changes brought about by an HSR can promote the concentration of financial resources in the city. This will increase the probability of local enterprises obtaining external financial resources, which can support the conduct of corporate digital transformation. Therefore, the following hypotheses are proposed:

H4. *The opening of an HSR can promote corporate digital transformation by generating financial agglomerations*.

3. Data and Methodology

3.1. Data Sources and Sample Selections

This research selects A-share listed companies in Shanghai and Shenzhen from 2008 to 2019 as samples. To clean the data, the following processes were performed: eliminating sample companies in ST, *ST, IPO, and delisting stages; eliminating sample companies in financial industries; and eliminating sample companies with missing values. After the above process, we finally obtained 21776 observations. In terms of the data source, the financial data came from the CSMAR database, and the data on the opening of HSRs were manfully collected from the official website of the National Railway Group Co., Ltd., China. The other city-level data came from the China Urban Statistics Yearbook. To eliminate the influence of outliers, all the continuous variables were winsorized at 1%.

3.2. Variable Specifications

3.2.1. Dependent Variable

The dependent variable in this paper is corporate digital transformation (DT), which is represented by two key indicators: the digital transformation decision (DTde) and digital

transformation intensity (Dtin). The Dtde is a dummy variable, and it reflects companies' willingness for digital transformation; that is, if the sample company is conducting digital transformation, it is one, and otherwise it is 0.

The DTin was constructed by using text analysis technology, and the steps used to construct it are as follows: Firstly, we collected the annual reports of the sample companies from 2008–2019 from the official websites of the Shanghai and Shenzhen stock exchanges using Python crawler technology and extracted the "Management Discussion and Analysis" (MD&A) section of the annual reports as a corpus for subsequent feature word screening. Secondly, a series of classical literature on digital transformation [5,8,26] was referenced to summarize the keywords related to digital transformation, and a digital key word corpus was initially constructed. On this basis, the dictionary of digital transformation keywords was expanded according to some important policy documents and research reports, such as the Notice on Accelerating the Digital Transformation of State-owned Enterprises, the Digital Economy Development Plan of the 14th Five-Year Plan, and the Digital Transformation Index Report 2022. Third, we used text analysis technology to eliminate keywords with negative meanings, such as "not", "no", "failed", etc., and invalid keyword expressions (including keywords but not about the company). Fourth, the corpus constructed in the previous section was compared with the digital transformation keyword lexicon using text analysis techniques, and the number of disclosures of digital transformation keywords appearing in the corpus was counted. We logarithmized it and took it as the proxy for corporate digital transformation, whereby the higher the indicator, the higher the degree of digital transformation that the sample companies conducted.

3.2.2. Independent Variable

The independent variable in this paper is the dummy variable for HSR opening (Hsr), which is set to 1 when the firm's city opens an HSR and 0 otherwise. Considering that an HSR opening may not have an immediate impact, we set one-period lags of the Hsr based on the practice of Zhang et al. [52].

3.2.3. Control Variables

Referring to the existing literature [28–30], this paper introduces a series of control variables, including firm size (Size), firm age (Age), return on total assets (Roa), gearing (Lev), EBIT (Ebit), firm growth (Toq), equity concentration (Eqd), capital intensity (Den), type of audit opinion (Aud), and degree of financing constraints (Abs).

3.2.4. Mediator Variables

Based on the theoretical analysis, we selected three levels of mediating variables: (1) Firm level: senior talent (Phd). Referring to the study of Du and Peng [18], the number of PhD senior managers hired by each listed company was used to represent the senior talents owned by the company. (2) Industry level: industry competitiveness (HHI), referring to the study of Zhu et al. [9], who used the city–industry level Herfindahl index to measure the degree of competition in the industry in which the firm is located; the larger the index, the less competitive the industry is. (3) City level: financial agglomeration (Fina), referring to the study of Lin et al. [17], who used the loan balances of local financial institutions/local GDP to measure the level of financial agglomeration in cities. The specific definitions of the relevant variables are shown in Table 1.

Table 1. Variable definition.

Variable Symbol	Variable Definitions
DTde	Sample conduct dig is 1 or 0
DTin	Ln(the frequency of dig keyword + 1)
Hsr	Cities with HSR opened is 1, otherwise is 0
Station	The number of HSR stations
Size	The nature log of total assets
Age	Ln(years of establishment + 1)
Roa	Net profit/total asset
Lev	Total debts/total assets
Ebit	Ln(income before interests and tax)
Toq	Market value/total asset
Eqd	The Shareholding ratio of the largest shareholders
Den	Total asset/income
Aud	Standard unqualified opinion is 1, otherwise is 0
Abs	The absolute value of SA index
Phd	Ln(managers with PhD + 1)
HHI	HHI index
Fina	The loan balance of local financial institutions/the local GDP

3.3. Model Settings

3.3.1. Benchmark Regression Model

To capture the net effect of opening an HSR on the digital transformation of enterprises, this paper treats an HSR opening as a quasinatural experiment, divides the sample into the treated group (HSR opened) and control groups (HSR not opened), and employs a time-varying DID model to test H1:

$$DT_{i,t} = \alpha_0 + \alpha_1 Hsr_{i,t-1} + \sum_{j=2}^{11} \alpha_j CVs_{i,t,j} + \mu_t + \nu_i + \varepsilon_{it} \quad (1)$$

where the subscripts i and t represent individual enterprises and years, respectively. DT is the digital transformation of enterprises, represented by the transformation decision (DTde) and transformation intensity (DTin). Hsr is the independent variable. CVs is the set of the control variables. μ, ν, and ε are the time fixed effect, industry fixed effect, and random disturbance term, respectively. To ensure the accuracy of the results, we also adjusted the t statistics by clustering the standard errors and clustering at the firm level.

3.3.2. Mediating Effect Model

In order to further open the black box between corporate digital transformation and the opening of an HSR, we also set up a mediating effect model:

$$MED_{i,t} = \beta_0 + \beta_1 Dig_{i,t-1} + \sum_{j=2}^{11} \beta_j CVs_{i,t,j} + \mu_t + \nu_i + \varepsilon_{it} \quad (2)$$

$$DT_{i,t+1} = \gamma_0 + \gamma_1 Hsr_{i,t-1} + \gamma_2 MED_{i,t} + \sum_{j=3}^{12} \gamma_j CVs_{i,t,j} + \mu_t + \nu_i + \varepsilon_{it} \quad (3)$$

where *MED* is the mediating variable, which includes the senior talent (Phd), industry competition (HHI) and financial agglomeration (Fina), and other variables have the same meaning as the model (1). In order to overcome the reverse causality to a certain extent, we set the following data structure: "Hsr_{t-1} (at the $t-1$ period) $\rightarrow$ mediating variable $_t$ (at the t period) $\rightarrow$ digital transformation $_{t+1}$ (at the $t+1$ period)".

4. Empirical Results

4.1. Descriptive Statistics

Table 2 reports the results of the descriptive statistics of the main variables. Regarding corporate digital transformations, the mean and standard deviation of the DTde was

0.5346 and 0.4988, respectively, indicating that 53.46% of the enterprises chose to carry out digital transformation activities during the sample period. Furthermore, the median of the DTin was smaller than the mean, indicating that the distribution of the DTin was significantly right skewed. Additionally, the DTin varied significantly across the enterprises since the minimum and maximum were 0 and 4.8112, respectively. The mean of the DTin was only 1.0084, implying that most enterprises were at a low level of digital transformation. Regarding opening the HSR, the mean and standard deviation of Hsr was 0.7455 and 0.4356, respectively, indicating that 74.55% of sample companies were in cities with an opened HSR. And, the control variables also had a reasonable data structure. More details are shown in Table 2.

Table 2. Descriptive statistics.

Variable	Obs	Mean	Std.Dev.	Minimum	Median	Maximum
DTde	21,774	0.5346	0.4988	0.0000	1.0000	1.0000
DTin	21,774	1.0884	1.3165	0.0000	0.6931	4.8122
Hsr	21,774	0.7455	0.4356	0.0000	1.0000	1.0000
Station	21,774	4.5453	4.3479	0.0000	4.0000	25.0000
Size	21,774	22.1792	1.3014	19.2306	22.0052	26.0543
Age	21,774	3.1997	0.2126	2.6391	3.2189	3.6376
Roa	21,774	0.0490	0.0401	−0.0741	0.0401	0.2033
Lev	21,774	0.4296	0.2039	0.0485	0.4258	0.9796
Ebit	21,774	19.2246	1.4859	15.7114	19.1241	23.3742
Toq	21,774	2.0044	1.2653	0.8874	1.5970	9.3058
Eqd	21,774	0.3566	0.1508	0.0888	0.3385	0.7510
Den	21,774	2.4476	2.1228	0.3872	1.8552	16.8216
Aud	21,774	0.6522	0.4763	0.0000	1.0000	1.0000
Abs	21,774	3.7410	0.2642	2.1126	3.7492	5.2368
Phd	15,148	0.8702	0.5783	0.0000	0.6931	2.1972
HHI	21,754	0.6662	0.3182	0.0543	0.6651	1.0000
Fina	21,565	1.5199	0.6282	0.3988	1.5098	3.3530

4.2. Benchmark Regression Results

To verify the impact of opening an HSR on corporate digital transformations, this paper adopts a progressive regression strategy, and the results are shown in Table 3. Columns (1) and (3) show the univariate test results, and the coefficients of Hsr_{t-1} were 0.039 and 0.086, respectively, which were significant at the 1% level. Columns (2) and (4) report the results after controlling a series of control variables. The absolute value of the HSR's estimated coefficients was lower than that in columns (1) and (3), but they were still significant at the 5% level, implying that although some effects were absorbed by the control variables, the HSR's impact still existed. The results suggest that opening an HSR can promote corporate digital transformations, which supports H1.

Table 3. Benchmark regression results.

	$DTde_{t+1}$		$DTin_{t+1}$	
	(1)	(2)	(3)	(4)
Hsr_{t-1}	0.039 ***	0.032 **	0.086 ***	0.068 **
	(2.97)	(2.52)	(3.09)	(2.51)
Size		0.045 ***		0.166 ***
		(3.87)		(5.65)
Age		−0.073		−0.547 ***
		(−1.52)		(−4.17)

Table 3. *Cont.*

	$DTde_{t+1}$		$DTin_{t+1}$	
	(1)	**(2)**	**(3)**	**(4)**
Roa		0.145 (0.66)		−0.366 (−0.65)
Lev		−0.046 (−1.39)		−0.221 *** (−2.63)
Ebit		0.008 (0.74)		0.014 (0.54)
Toq		0.010 ** (2.24)		0.064 *** (5.21)
Eqd		−0.032 (−0.97)		−0.215 ** (−2.39)
Den		−0.007 ** (−2.46)		−0.026 *** (−4.03)
Aud		−0.002 (−0.27)		−0.058 *** (−3.02)
Abs		0.027 (0.65)		0.396 *** (3.82)
constant	0.506 *** (46.19)	−0.483 *** (−3.25)	1.024 *** (42.64)	−2.477 *** (−6.08)
Year/Industry FE	YES	YES	YES	YES
Adjusted R^2	0.329	0.341	0.478	0.494
Obs	21,774	21,774	21,774	21,774

Notes: ***, ** indicate the estimated coefficients are significant at the 1% and 5% level, respectively. t-statistics are reported in parentheses.

4.3. Robustness Tests

4.3.1. Parallel Trend Test

An important prerequisite for the unbiased estimation results of the time-varying DID model is that the assumption of consistent pretrends is satisfied between the treated and control groups; i.e., the digital transformation trend in the two sample groups should be approximately the same before opening the HSR. To test the parallel trend, we introduced the preterm and post-term dummy variables into the model, which is shown below:

$$DT_{i,t} = \alpha_0 + \alpha_1 Hsr_{i,t} + \sum_{m=1}^{7} \eta_m Hsr\_m_{i,t} + \sum_{n=1}^{7} \theta_n Hsrn_{i,t} + \sum_{j=2}^{11} \alpha_j CVs_{i,t,j} + \mu_t + \nu_i + \varepsilon_{it} \quad (4)$$

where $Hsr\_m_{i,t}$ and $Hsrn_{i,t}$ are the advance term and lag term of the HSR opening, respectively. η_m is used to verify whether the parallel trend hypothesis is met before opening the HSR. If it is not significant, then it is met; otherwise, it can be questioned that the change in corporate digital transformations was not caused by the opening of the HSR.

To visually demonstrate the effect of the parallel trend test, the results are mapped in Figure 2. Specifically, for both the DTde and DTin, the estimated coefficients were not significant before the opening of the HSR, while all the estimated coefficients became significant one year after the opening of the HSR, which implied that the digital transformation in the treated group and the control group had the same trend before the opening of the HSR, which meets the parallel trend hypothesis. Therefore, the results showed that the basic conclusion was robust.

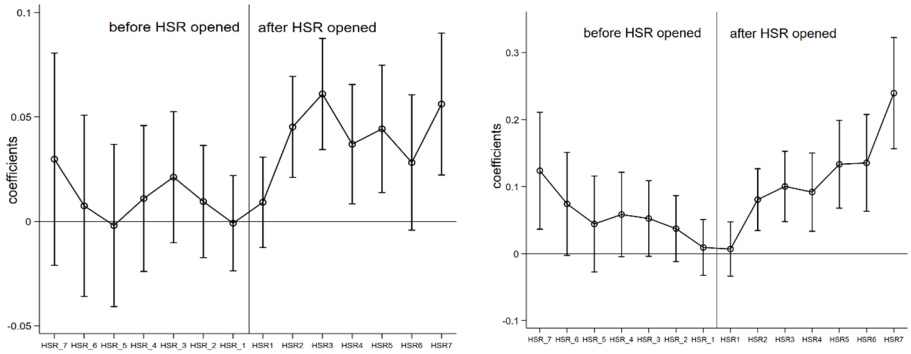

Figure 2. Parallel trend test.

4.3.2. Instrumental Variable Estimation Approach

Usually, the construction of an HSR is not random; it is highly likely affected by the population, local economic development, and political factors, and these factors will also highly likely affect the digital transformation of local firms, which generates severe endogeneity problems. Therefore, it is necessary to further adopt the instrumental variable estimation approach.

In the existing literature, the methods of constructing the instrumental variables for the opening of the HSR mainly include three strategies: constructing instrumental variables based on geographic information, constructing instrumental variables based on historical planning maps or political planning policies, and constructing instrumental variables based on historical route information. We followed the first two strategies and constructed two instrumental variables: IVmc and IVmr. For IVmc, referring to the practice of Zhang et al. [52], we constructed "the minimum spanning tree" based on geographic information such as local water waves, land slope, and topographic relief, etc.; the validity of this variable is that the geographical elements are important factors when deciding to construct an HSR, which meets the relevance requirement, while local geographical elements cannot directly affect the corporate digital transformation of local companies, which meets the exogenous requirement. For IVmr, referring to the practice of He and Tao [45] and Ma et al. [11], we constructed IVmr based on a political planning policy ("Four Vertical and Four Horizontal Railways") that was first introduced in "China's Medium and Long-term Railroad Network Planning" in 2004. Specifically, we calculate the shortest straight-line distance of each sample city from the main railroad lines (defined by the abovementioned policy). If the distance was less than 50 km, IVmr was 1; otherwise, it was 0.

It is worth noting that since the above two variables are cross-sectional data and cannot be directly applied to the panel data model, we converted them into panel data by multiplying the time dummy variables.

Table 4 reports the empirical results of the two-stage regressions of the instrumental variables. Specifically, the estimated coefficients of the instrumental variables in the first stage were all significant at the 1% level; the Kleibergen–Paap Wald rk LM statistics and the Cragg–Donald Wald F-statistics were significantly larger than the Stock–Yogo critical value at all critical levels, which implied that the instrumental variables selected in this paper were technically reasonable and reliable. Most importantly, after controlling the endogeneity, the estimated coefficients of *HSR* for both the DTde and DTin were significant at the 10% level, which implied that after controlling the abovementioned problem, the basic conclusion still held.

Table 4. Instrumental variable estimation approach.

	DTde		DTin	
	(1)	**(2)**	**(4)**	**(5)**
IVmc	0.642 ** (2.03)		3.208 *** (3.56)	
IVmr_t		0.093 * (1.93)		0.384 *** (3.14)
Constant	−1.451 *** (−2.98)	−0.846 *** (−4.64)	−7.159 *** (−5.46)	−3.339 *** (−7.12)
Control variables	YES	YES	YES	YES
Year/Industry FE	YES	YES	YES	YES
Adjusted R^2	0.109	0.341	0.270	0.464
Kleibergen–Paap Wald rk LM	32.96 ***	438.4 ***	32.96 ***	438.4 ***
Cragg–Donald F	61.40 [16.38]	2330 [16.38]	61.40 [16.38]	2330 [16.38]
IV First Stage	0.076 *** (5.74)	0.00002 *** (20.94)	0.076 *** (5.74)	0.00002 *** (20.94)
Obs	2264	16670	2264	16670

Notes: ***, **, * indicate the estimated coefficients are significant at the 1%, 5% and 10% level, respectively. t-statistics are reported in parentheses.

4.3.3. Placebo Test

To exclude the impact of the omitted variables on the estimation results, we also conducted a placebo test. Specifically, we randomly selected some samples and randomly generated a fake open time for them so that we could construct a random treated group and rerun the regression. We repeated the regression 500 times, and the results are mapped in Figure 3. The coefficients of the randomly generated independent variable Hsr_r were centrally distributed at 0 for both the DTde and Dtin. There was only a 0.4% and 0.8% possibility that the estimated coefficients in the benchmark regression were in the distribution of the fake estimated coefficients for the DTde and DTin, respectively. The results suggest that after controlling the abovementioned problems, the basic conclusion still held.

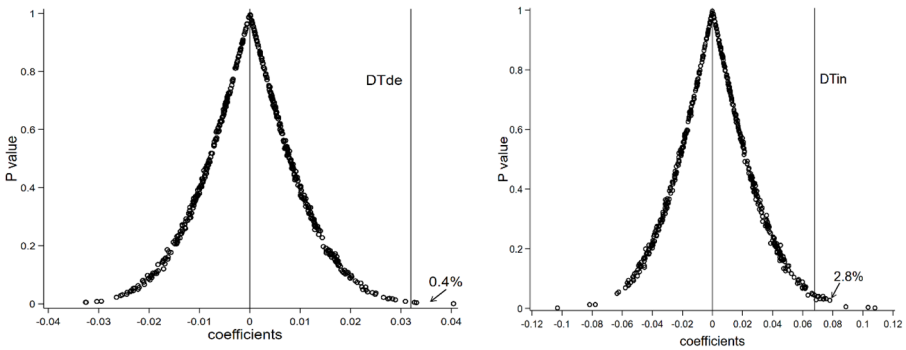

Figure 3. Placebo test.

4.3.4. PSM-DID

To further consider the effects of the differences in the firm characteristics between the treated and control groups on corporate digital transformations, we also used the propensity score matching method (PSM) to reconstruct the control group for analysis. Specifically, referring to the practice of Ji and Qing [10], we selected their operating income (Income), gearing (Lev), capital intensity (Den), firm size (Size), and equity concentration (Eqd) as the matching covariates. Second, a logit model was constructed to estimate the

propensity score of each sample, and we also employed k-nearest-neighbor 1:1 within the caliper to match the treated group with the control group. Based on this, we reran the DID model. We also conducted a balance test to examine matching performance, details are shown in Table A1 Appendix A, the results show that all covariates passed balanced test.

Table 5 reports the results of the PSM-DID. Specifically, the estimated coefficients of Hsr were 0.031 and 0.064, respectively. Compared with the estimated coefficients in the benchmark regression (0.032 and 0.068), they were slightly lower, which implies that the effects of Hsr were indeed absorbed by some missing variables, and if they are not controlled, the results of the benchmark regression will be overestimated. More importantly, the estimated coefficients were all significant at the 5% level in columns (1) and (2), which suggested that after controlling the abovementioned problem, the basic conclusion still held.

Table 5. PSM-DID.

	$\mathbf{DTde_{t+1}}$ **(1)**	$\mathbf{DTin_{t+1}}$ **(2)**
Hsr_{t-1}	0.031 ** (2.33)	0.064 ** (2.49)
Constant	−0.472 *** (−3.11)	−2.500 *** (−5.93)
Control variables	YES	YES
Year/Industry FE	YES	YES
Adjusted R^2	0.331	0.490
Obs	20,614	20,614
ATT	0.623 (32.31)	

Notes: ***, ** indicate the estimated coefficients are significant at the 1% and 5% level, respectively. t-statistics are reported in parentheses.

4.3.5. Other Robustness Tests

We replaced the Hsr core independent variable with *Station* (the number of HSR stations) to rerun the regression, and the results are reported in columns (1) and (4) of Table 6. The estimated coefficients were 0.005 and 0.014, respectively, both significant at the 1% level. Considering the fact that the fake information reported in the annual reports may affect the measurement of Dig, we eliminated the samples with poor information quality (the samples that received "Bad" in the information quality assessment conducted by the Shanghai and Shenzhen stock markets) and reran the regression; the results are reported in columns (2) and (5), and the estimated coefficients were all significant at least at the 10% level. To further control the endogeneity, referring to the practice of Zhang et al. [52], we eliminated the samples located in the central cities and reran the regression; the results are reported in columns (3) and (6), and the estimated coefficients were significant at least at the 5% level. In conclusion, the above results proved that the basic conclusion was robust.

4.4. Mechanism Analysis

According to the previous theoretical analysis, opening an HSR can promote corporate digital transformation through three channels: promoting the flow of senior talents, improving industry competition, and enhancing the financial agglomeration of cities. In this section, we will empirically test the mechanism between the two based on the mediating effect models (Model (2) and (3)).

Table 6. Other robustness tests.

	$DTde_{t+1}$			$DTin_{t+1}$		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Hsr_{t-1}		0.031 *	0.029 **		0.091 **	0.086 ***
		(1.82)	(2.12)		(2.46)	(2.88)
$Station_{t-1}$	0.005 ***			0.014 ***		
	(4.37)			(4.23)		
Constant	−0.465 ***	−0.518 ***	−0.615 ***	−2.426 ***	−2.797 ***	−2.706 ***
	(−3.13)	(−2.94)	(−3.64)	(−5.94)	(−5.60)	(−5.80)
Control variables	YES	YES	YES	YES	YES	YES
Year/Industry FE	YES	YES	YES	YES	YES	YES
Adjusted R^2	0.341	0.332	0.341	0.494	0.494	0.468
Obs	21,774	13,352	17,019	21,774	13,352	17,019

Notes: ***, **, * indicate the estimated coefficients are significant at the 1%, 5% and 10% level, respectively. t-statistics are reported in parentheses.

Table 7 reports the results of the mediating effects of the movement of the senior talents. As the estimated coefficients of Hsr in columns (1) and (2) are significant, further analyses were considered. Column (3) reports the results of the Hsr on the movement of the senior talents; the estimated coefficient of Hsr was 0.109, which was significant at the 1% level and indicated that opening an HSR can promote the movement of senior talents. Columns (4) and (5) report the impact of both the Hsr and Phd on the corporate digital transformation, and the estimated coefficients of Hsr and Phd were significant at the 1% level. It could be preliminarily determined that the mediating effects of the Phd existed. We further conducted the Sobel test to confirm the results; the Sobel Z statistics were all significant at the 1% level, which supports the above results. Therefore, the results showed that opening an HSR can indeed promote corporate digital transformation by enhancing senior labor forces; that is, the path "Opening of HSR → (increase) senior labor forces → (promote) digital transformation "existed, which supports H2.

Table 7. Mechanism analysis: senior labor forces.

	(1) $DTde_{t+1}$	**(2)** $DTin_{t+1}$	**(3)** Phd_t	**(4)** $DTde_{t+1}$	**(5)** $DTin_{t+1}$
Hsr_{t-1}	0.041 ***	0.098 ***	0.109 ***	0.038 ***	0.090 ***
	(4.01)	(3.89)	(7.88)	(3.77)	(3.53)
Phd_t				0.021 ***	0.082 ***
				(3.54)	(5.49)
Constant	−0.473 ***	−3.249 ***	−1.933 ***	0.432 ***	−3.090 ***
	(−4.17)	(−11.48)	(−12.51)	(−3.79)	(−10.87)
Control variables	YES	YES	YES	YES	YES
Year/Industry FE	YES	YES	YES	YES	YES
Sobel Z				0.002 ***	0.009 ***
				(3.23)	(4.51)
Adjusted R^2	0.316	0.510	0.317	0.317	0.511
Obs	15,148	15,148	15,148	15,148	15,148

Notes: *** indicates the estimated coefficients are significant at the 1% level. t-statistics are reported in parentheses.

Table 8 reports the results of the mediating effects of industry competition. Since the estimated coefficients of Hsr in columns (1) and (2) were significant, further analyses were considered. Column (3) reports the results of Hsr on the industry competition. The

estimated coefficient of Hsr was −0.164, which was significant at the 1% level and indicated that opening an HSR can promote industry competition (*HHI* is an inverse indicator; the higher the index, the less severe the competition among the companies.). Columns (4) and (5) report the impact of both Hsr and *HHI* on corporate digital transformations, and the estimated coefficients of Hsr and *HHI* were significant at least at the 10% level. It could be preliminarily determined that the mediating effects of HHI existed. The results of the Sobel test showed that the Sobel Z was significant at least at the 10% level, which implied that the mediating effects of industry competition existed. Therefore, the above results showed that opening an HSR can promote corporate digital transformations by enhancing industry competition; i.e., "opening of HSR → (enhancing) the industry competition → (promoting) Corporate digital transformation", which supports H3.

Table 8. Mechanism analysis: the industry competition.

	(1) $DTde_{t+1}$	(2) $DTin_{t+1}$	(3) HHI_t	(4) $DTde_{t+1}$	(5) $DTin_{t+1}$
Hsr_{t-1}	0.039 *** (4.71)	0.079 *** (3.95)	−0.164 *** (−30.69)	0.036 *** (4.25)	0.058 *** (2.85)
HHI_t				−0.019 * (−1.77)	−0.125 *** (−4.95)
Constant	−0.563 *** (−5.90)	−3.037 *** (−13.21)	0.874 *** (14.17)	−0.547 *** (−5.70)	−2.927 *** (−12.68)
Control variables	YES	YES	YES	YES	YES
Year/Industry FE	YES	YES	YES	YES	YES
Sobel Z				0.003 * (1.77)	0.021 *** (4.89)
Adjusted R^2	0.323	0.492	0.325	0.323	0.493
Obs	21,754	21,754	21,754	21,754	21,754

Notes: ***, * indicate the estimated coefficients are significant at the 1% and 10% level, respectively. t-statistics are reported in parentheses.

Table 9 reports the results of the mediating effects of financial agglomeration. As the estimated coefficients of Hsr in columns (1) and (2) were significant, further analyses were considered. Column (3) reports the results of Hsr on the financial agglomeration. The estimated coefficient of Hsr was 0.320, which was significant at the 1% level and indicated that opening an HSR can generate financial agglomeration. Columns (4) and (5) report the impact of both Hsr and Fina on corporate digital transformations, and the estimated coefficients of Hsr and Fina were significant at the 10% level. It could be preliminarily determined that the mediating effects of Fina existed. The results of the Sobel test showed that the Sobel Z was significant at the 1% level, which implied that the mediating effects of financial agglomeration existed. Therefore, the above results showed that opening an HSR can promote corporate digital transformation by generating financial agglomeration; that is, "Opening of HSR → (generating) financial agglomeration → (promoting) Corporate digital transformation", which supports H4.

4.5. Heterogeneity Analysis

The previous paper mainly verified the impact of opening an HSR on corporate digital transformations based on the full sample, but its effect may vary according to the differences in the enterprise characteristics, industry characteristics, and city characteristics. In this regard, we also conducted heterogeneity analyses from the perspectives of ownership, industry attributes, and initial transportation resources.

Table 9. Mechanism analysis: the financial agglomeration.

	(1) $DTde_{t+1}$	(2) $DTin_{t+1}$	(3) $Fina_t$	(4) $DTde_{t+1}$	(5) $DTin_{t+1}$
Hsr_{t-1}	0.039 *** (4.64)	0.079 *** (3.96)	0.320 *** (29.12)	0.038 *** (4.64)	0.047 ** (2.30)
$Fina_t$				0.018 *** (3.53)	0.101 *** (8.12)
Constant	−0.563 *** (−5.87)	−3.055 *** (−13.25)	1.133 *** (8.94)	−0.583 *** (−6.08)	−3.169 *** (−13.74)
Control variable	YES	YES	YES	YES	YES
Year/Industry FE	YES	YES	YES	YES	YES
Sobel Z				−0.583 *** (−6.08)	0.032 *** (7.82)
Adjusted R^2	0.324	0.493	0.273	0.324	0.494
Obs	21,565	21,565	21,565	21,565	21,565

Notes: ***, ** indicate the estimated coefficients are significant at the 1% and 5% level, respectively. t-statistics are reported in parentheses.

4.5.1. Considering the Corporate Ownership

The existing literature suggests that there are significant differences between state-owned and non-state-owned enterprises in terms of technological innovation capability, business decision-making mechanisms, and the external financing environment [5,30]. Specifically, compared with non-SOEs, SOEs take on more political burdens, including maintaining employment, maintaining social stability, expanding tax revenue, etc. Under this background, SOEs may be less likely to conduct corporate digital transformations since they may lead to many low-skilled workers losing their jobs. Non-SOEs have more economic vitality, and they are more likely to conduct corporate digital transformations if they can enhance their financial performance. But, they may not have enough resources to support the digital transformation. The opening of an HSR expands their resource boundaries, which makes them able to acquire more valuable resources from remote areas and can help them conduct corporate digital transformations more deeply. Therefore, we assume that the driving effect of an HSR opening on corporate digital transformations is more pronounced in non-state enterprises compared to state-owned enterprises.

Table 10 reports the grouped regression results. The coefficients of Hsr were all significant at the 5% level in the non-state-owned enterprises. In contrast, the coefficients of Hsr were not significant in the state-owned enterprises. This indicated that the driving effect of the HSR on corporate digital transformations was mainly reflected in the non-state-owned enterprises, which was consistent with expectations. In addition, we also employed the bootstrap method (we repeated the regression 500 times) to confirm whether the heterogeneity effect of the ownership existed. The results showed that the empirical *p*-value was significant at the 5% level, which implied that the heterogeneity effect of ownership indeed existed; that is, the driving effect of opening an HSR on corporate digital transformation was more pronounced in the non-SOEs, which supports the above assumption.

4.5.2. Considering Industry Attributes

An enterprise digital transformation is the process of applying digital technology for organizational change, and the final effect of the transformation is strongly linked to its own technology reserve. Tech enterprises have more technology reserves, and they can absorb and digest new knowledge more quickly, which means the technical threshold of corporate digital transformations is lower than for nontech companies. Under this context, we assume that the driving effect of the HSR on corporate digital transformations is more pronounced in tech companies.

Table 10. Heterogeneity analysis: ownership.

	DTde		DTin	
	(1) SOEs	**(2) Non-SOEs**	**(3) SOEs**	**(4) Non-SOEs**
Hsr_{t-1}	0.021 (1.14)	0.040 ** (2.26)	0.049 (1.38)	0.086 ** (2.17)
Constant	−0.883 *** (−3.32)	−0.565 *** (−3.02)	−3.131 *** (−4.87)	−3.312 *** (−6.19)
Control variables	YES	YES	YES	YES
Year/Industry FE	YES	YES	YES	YES
Adjusted R^2	0.352	0.322	0.477	0.493
Obs	9148	12,625	9148	12,625
p-value	0.028 **		0.022 **	

Notes: ***, ** indicate the estimated coefficients are significant at the 1% and 5% level, respectively. t-statistics are reported in parentheses.

We divided the sample into tech company samples and nontech company samples for group regression according to the Classification Standard for High-tech Industries issued by the National Bureau of Statistics. The results are shown in Table 11. The coefficients of Hsr in the tech company group were significant at least at 5% while the estimated coefficients of Hsr in the nontech group were not significant. The results of the bootstrapping also confirmed the results as the *p*-value was significant at the 5% level, which implied that the coefficients of Hsr had significant differences between the two groups. Therefore, the above results suggest that the driving effect of HSRs on corporate digital transformations is more pronounced in tech companies.

Table 11. Heterogeneity analysis: industry attributes.

	DTde		DTin	
	(1) Tech	**(2) Non-Tech**	**(3) Tech**	**(4) Non-Tech**
Hsr_{t-1}	0.040 ** (2.45)	0.024 (1.25)	0.111 *** (3.01)	0.018 (0.44)
Constant	−0.452 ** (−2.39)	−0.524 ** (−2.19)	−2.550 *** (−4.71)	−2.220 *** (−3.75)
Control variables	YES	YES	YES	YES
Year/Industry FE	YES	YES	YES	YES
Adjusted R^2	0.354	0.322	0.534	0.387
Obs	12,088	9686	12,088	9686
p-value	0.004 ***		0.000 ***	

Notes: ***, ** indicate the estimated coefficients are significant at the 1% and 5% level, respectively. t-statistics are reported in parentheses.

4.5.3. Considering the Difference in Initial Traffic Resource

It has been shown that transportation resource endowment not only affects companies' information accessibility, production cost, and operational efficiency, but it may even be relevant to their future development [16,52]. Based on this, we argue that the effect of opening an HSR on corporate digital transformations will vary depending on the initial transportation endowment. Specifically, enterprises in cities with lower initial transportation endowments have fewer opportunities to compete with and cooperate with outside economic bodies. The opening of HSRs has significantly improved the accessibility of cities, and enterprises have more opportunities to obtain the talents, technologies, and funds

that can improve their willingness to conduct digital transformations, which means the marginal effects of opening an HSR in cities with poor initial transportation resources are higher. Therefore, we assume that the driving effect of an HSR is more pronounced in cities with low initial transportation resources.

To confirm the above speculation, this paper draws on the study of Zhang et al. [52], which used the mean road area per capita in 2008 as the initial urban traffic endowment and divided the samples into a high initial traffic endowment city group and a low initial traffic endowment city group for grouped regressions. Table 12 reports the results. The coefficients of Hsr were significant in the group with low traffic endowment but not significant in the group with high traffic endowment. The results of the intergroup differences also confirmed the results. In conclusion, the driving effects of an HSR were more pronounced in the cities with low traffic endowments, which supports the above assumption.

Table 12. Heterogeneity analysis: initial traffic endowments.

	DTde		DTin	
	(1) High Traffic Endowments	**(2) Low Traffic Endowments**	**(3) High Traffic Endowments**	**(4) Low Traffic Endowments**
Hsr_{t-1}	0.060 ***	0.012	0.087 **	0.042
	(2.87)	(0.74)	(1.97)	(1.18)
Constant	−0.403	−0.514 ***	−1.899 ***	−2.634 ***
	(−1.62)	(−2.72)	(−2.86)	(−5.08)
Control variables	YES	YES	YES	YES
Year/Industry FE	YES	YES	YES	YES
Adjusted R^2	0.342	0.345	0.541	0.475
Obs	7623	14,070	7623	14,070
p-value	0.000 ***		0.026 **	

Notes: ***, ** indicate the estimated coefficients are significant at the 1% and 5% level, respectively. t-statistics are reported in parentheses.

5. Conclusions

5.1. Discussion

Based on neogeography economics theory, this paper constructed a multiperiod DID model to test the impact of opening an HSR on corporate digital transformations by using a sample of A-share listed companies in Shanghai and Shenzhen from 2008 to 2019. This study's findings are outlined below.

The HSR opening was significantly and positively associated with corporate digital transformations; i.e., the opening of an HSR can significantly facilitate corporate digital transformations, which answers research question (1) of this paper. Specifically, compared with firms without access to HSR services, firms with access to HSR services experienced a simultaneous increase in digital transformation decisions and transformation intensity of 3.2% and 6.8%, respectively, after opening an HSR. This finding still held after running endogeneity treatments such as the parallel trend test, the placebo test, IV estimations, PSM-DID, and a series of other robustness tests. This result is similar to the results of several existing studies (e.g., Zhu et al., 2019; Ji and Yang 2020, Mao et al., 2022) [9,10,50], which demonstrates that the opening of an HSR has a driving effect on corporate transformation and upgrading in the context of the digital economy. Among them, the results of this paper are most similar to the findings of Mao et al. [50]. Mao et al. [50] used survey data to confirm that the proximity of an HSR can significantly contribute to the digital transformation of private enterprises. However, according to the 2022 Employment Relations Trends Report, the trend of digital transformation is more obvious in large listed companies, and the pace of private enterprises carrying out digital transformations is slightly slower. As a result, it may bias the estimations if only private enterprises are selected as samples.

Furthermore, most private enterprises have a smaller geographical scope of operation than listed enterprises, which makes the digital transformation of private enterprises insensitive to the "time-space compression" effect of HSRs, which may also underestimate the effect of opening an HSR. Therefore, we believe that it is more descriptive and representative to select listed enterprises as samples to study the impact of opening HSRs on corporate digital transformations.

The opening of an HSR can promote corporate digital transformations by improving the movement of senior laborers, increasing industry competition, and enhancing financial agglomeration, which answers the research question (2) of this paper. Specifically, for the path "HSR opening → (attracting) senior labors → (promoting) corporate digital transformation", the mediating effect of senior labors accounts for 5.67% and 9.07% of the total effect. The existing literature has also demonstrated that an HSR can promote industrial structure upgrading [55] and improve patent quality [56] by improving the movement of senior laborers. Similar to the mechanism of the above study, this paper argues that the inflow of senior talents after the opening of an HSR can not only solve the problems of talent shortages and a weak awareness of digital transformation, but it can also enhance the diversity of the human capital choices of enterprises so that incumbents can promote digital transformations due to promotion incentives and the elimination of pressure. For the path of "HSR → (strengthening) industry competition → (promoting) corporate digital transformation", the mediating effect of industry competition accounted for 7.86% and 26.16% of the total effect. As previously suggested, industry competition can have a catalytic effect on corporate digital transformations [31]. This paper further extends such research by arguing that more intense industry competition after opening an HSR will lead to a positive "competition avoidance effect" and thus push firms to conduct digital transformations. For the path of "HSR opening → (increased) financial agglomeration → (facilitated) corporate digital transformation", the mediating effects of financial resources accounted for 15.12% and 40.70% of the total effect. As the microcomponent of China's digital economy, the development of corporate digital transformation needs to be supported by a high-quality financial supply [57]. Tang et al. [30] and Dai and Zhai [28] also discussed the impact of fintech and capital market openings, respectively, on corporate digital transformations in terms of alleviating enterprise financing constraints. In this paper, we argue that the opening of an HSR will promote financial agglomeration and increase the probability of firms obtaining external financial support, which will drive their digital transformation. Therefore, we argue that the effect of opening an HSR on enterprises is multilevel; i.e., opening an HSR can affect enterprise digital transformations at the enterprise level, industry level, and city level. Therefore, we analyzed the impact of HSR opening son enterprise digital transformations through three paths: senior talent mobility (enterprise level), increased industry competition (industry level), and the promotion of financial agglomeration (city level).

The effect of HSR openings on the digital transformation of enterprises was significantly asymmetric; i.e., the effect of HSR openings on corporate digital transformations was more significant in nonstate enterprises, high-tech enterprises, and enterprises in cities with poor initial transportation resource endowment. These findings answer the research question (3) of this paper. Regarding firm ownership attributes, the effect of opening an HSR on firms' digital transformation was significant among the nonstate firms but not among the state firms, and the between-group coefficient difference test estimated by using the self-sampling method supported this finding. This was consistent with a series of studies such as those conducted by Du and Peng [18], Ma et al. [11], and Wang et al. [12], where the impact of HSRs on corporate behaviors was mainly reflected in non-SOEs. This paper argues that this difference mainly stemmed from the differences between SOEs and non-SOEs in terms of technological innovation capability, business decision-making mechanisms, and external financing environments; e.g., SOEs may be insensitive to profit-seeking behaviors since they undertake an excessive policy burden [58]. For technological attributes, the impact of opening an HSR on corporate digital transformation has a sig-

nificant impact among high-tech enterprises but not among non-high-tech enterprises, and the between-group coefficient difference test estimated by using the self-sampling method supports this conclusion. According to the previous analysis, the process of digital transformation needs to be driven by different digital technologies [23], so the effect of HSRs on digital transformation is also related to companies' underlying technology levels. We believe that there are significant differences in both the subjective willingness and objective underlying conditions for digital transformation between high-tech and non-high-tech enterprises [5,36], which will result in the digital transformation effect of high-tech enterprises being more profound. Regarding the initial transport endowment, the effect of opening an HSR on corporate digital transformations was significantly positive in cities with low initial transport endowments, but it was not significant in cities with a high initial transport endowment, which was supported by the between-group coefficient difference test. This was because cities with a high initial transportation endowment have a high level of accessibility and can provide sufficient transportation support for the survival and development of enterprises, and even if such cities open a high-speed rail, the marginal effect of the HSR is relatively small, which follows the law of diminishing marginal returns in economics. This has a similar logic to studies such as Yang et al. [16].

5.2. Implications

Based on the above conclusions, the following policy recommendations are made:

First, the government should actively and orderly promote the construction of quality transportation network systems to help enterprises develop in a high-quality manner. Chinese society is full of objections to the construction of HSRs because the operational revenue of high-speed rails cannot cover the construction and operation costs. This paper found that the opening of HSRs has improved corporate digital transformations, which will subsequently lead to substantial improvements in the management efficiency. This suggests that we should consider the effect of "external public goods" caused by high-speed rails when assessing their economic effects.

Second, the regional infrastructure construction and industrial layout should be adjusted to increase the regional welfare of the high-speed rail. Since the driving effect of HSRs on the digital transformation of enterprises is mainly pronounced in non-state enterprises, high-tech enterprises, and enterprises in cities with poor initial transportation endowment, in the future planning of high-speed rails, the construction of high-speed rails should be increased in areas with a dense concentration of nonstate enterprises and high-tech enterprises and in cities with poor transportation resource endowment. For state-owned enterprises, policy constraints should be further relaxed to guide state-owned enterprises to participate in market competition in a more market-oriented way so that they can enjoy the benefits brought by the opening of HSRs.

Third, the government should sort out the painful and difficult points of digital transformation and enable the driving effect of high-speed rails. For enterprises, on the one hand, they should implement the innovation-driven development strategy; use the opportunity of high-speed railway construction to introduce talents, capital, and technology; and cultivate their own R&D capability. On the other hand, they should use the high-speed railway network to strengthen exchanges and cooperation with peer enterprises, competitors, universities, and research institutions and improve their own digital transformation capability by using external knowledge. The government should combine policies to build a policy support system to promote the digital transformation of enterprises, such as talent introduction policies, tax incentives, and innovation subsidies; on the other hand, they should also increase the investment in new-generation information technology infrastructure and strengthen the construction of digital development platforms, which can provide solid basic conditions for enterprises to realize digitalization and intelligent upgrading.

5.3. Limitations and Future Research

Although this paper measured the overall degree of corporate digital transformation using textual analysis, it did not achieve an accurate portrayal of the digitalization of various segments within the enterprise (e.g., R&D and design, manufacturing, marketing, sales, etc.). Future research can be innovative in portraying the measurement of digital transformation indicators to make the indicator more accurate and comprehensive in terms of reflecting the real situation of corporate digital transformation. Due to the limitation of data accessibility in this paper, other transportation modes are not included, and the interactive impact of HSRs and other transportation modes on the digital transformation of enterprises can be further studied in future research. Due to the limitation of data availability, spatial factors were not included in this paper. In the future, we can consider the construction of a spatial multiplicative difference method to study the spillover effects of HSRs on cross-regional corporate digital transformation.

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Appendix A

Table A1. Balance test.

		Mean		Bias (%)	Bias Reduction (%)	*t*-Test	
		Treated	Control			T	$p > \|t\|$
Income	Unmatched	21.591	21.368	15.3	93.2	9.65	0.000
	Matched	21.589	21.574	1.0		0.92	0.356
Lev	Unmatched	0.421	0.456	−17.3	91.3	−11.04	0.000
	Matched	0.421	0.418	1.5		1.36	0.175
Den	Unmatched	2.490	2.322	7.8	88.0	5.10	0.000
	Matched	2.490	2.470	0.9		0.87	0.383
Size	Unmatched	22.259	21.945	24.7	95.7	15.60	0.000
	Matched	22.258	22.244	1.1		0.93	0.351
Eqd	Unmatched	0.353	0.367	−9.0	81.3	−5.77	0.000
	Matched	0.353	0.356	−1.7		−1.49	0.136
Pseudo R^2	Unmatched			0.036			
	Matched			0.000			

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