The Impact of Digital-Physical Convergence on Enterprise Resilience - From the Perspective of External Resources and Internal Capacity

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ABSTRACT

Under the background of profound changes and adjustments in the global economic governance structure, enterprise resilience has become a key strategy to deal with complex shocks. Based on the data of provincial and A-share listed companies in China from 2013 to 2022, this paper constructs an index system of digital-entity integration and enterprise resilience, and verifies the influence of digital-entity integration on enterprise resilience. It is found that digital-entity integration can significantly improve enterprise resilience, and the effect is more obvious in large enterprises, mature enterprises, non-manufacturing industries and fierce competition market environment. The mechanism analysis shows that digital-entity integration can enhance enterprise resilience by relaxing financing constraints and promoting innovation. The conclusion of this paper provides a valuable reference for enterprises to improve their toughness in uncertain environment.

Keywords: Digital-Physical Integration; Corporate Resilience; Financing Constraints; R&D Investment; Financial Support

1. INTRODUCTION

At a time when the global economy is undergoing great changes and crises occur frequently, improving the “resistance” of enterprises to cope with various shocks has become a top priority for stable development. President Xi Jinping emphasized the need to put risk prevention first and ensure that major risks can be resisted. Enterprises are like “small cells” of the social and economic system. Corporate resistance is an important indicator of high-quality social and economic development (Wang Yonggui and Gao Jia, 2020) [24], so in today’s world full of uncertainty, it has become particularly important. At the same time, companies are also enjoying the opportunities brought by digital transformation. The deep integration of digital economy and real economy is an inevitable requirement for building a modern industrial system and achieving high-quality development (Hong Yinxing et al., 2023) [9].Guided by the report of the 20th National Congress of the Communist Party of China, “accelerating the development of the digital economy and promoting the deep integration of the digital economy and the real economy”, this paper studies the impact of this deep integration on corporate resistance and how it functions internally.

Relevant research mainly focuses on three aspects. First, regarding the connotation and measurement of digital-physical integration, it represents system collaboration and joint value creation (Shi Dan and Sun Guanglin, 2023) [17]. There are many measurement methods, including coupling coordination models at the macro level (Zhao Tao et al., 2020) [27], there are meso-level input-output analysis (Xu Yingmei and Li Kun, 2025) [25], and micro-level indicators, such as the integration of digital investment and patents (Wu Fei et al., 2021; Li Yuxin and Jin Xiaoying, 2025) [13] [21]. However, existing micro indicators often fail to reflect deeper integration connotations, such as business process redesign. Secondly, corporate resilience is widely recognized as a dynamic, multi-dimensional concept (Li Ping & Zhu Jiaze, 2021) [14]. It is mainly measured through comprehensive index (Shi Changchun & Zhao Huijuan, 2023) [18] or questionaire based process analysis (Xu Longbing et al., 2020) [15]. Thirdly, the research shows that the combination of numbers and entities can make enterprises more resistant to pressure in several ways: operation optimization (Li Yuxin & Jin Xiaoying, 2025) [13], capacity reorganization and organizational learning (Feng Zheng & Zhong Jian, 2025) [3], and the synergy of open ecosystems (Wang Lin et al., 2025) [22].

Compared with the previous research, this paper has four new contributions: (1) Studying the integration problem from the perspective of macro-regional ecology, instead of just looking at digital technology; (2) A more comprehensive provincial macro-measurement index is established by using the coupling coordination model; (3) Revealing the underlying mechanism from two angles of external “resource acquisition” and internal “capacity building”; (4) The differences of this compressive effect in different company sizes, ages, industries and competitive environments are actually analyzed.The rest of the paper is arranged as follows: Section 2 talks about theoretical mechanism, Section 3 talks about research design, Section 4 shows empirical results, and the last part is conclusions and policy suggestions.

2. ANALYSIS OF THEORETICAL MECHANISMS

2.1 Digital-Physical Convergence and Enterprise Resilience

With the wide application of digital technologies such as AI, blockchain and big data in the real economy, the interaction between them has formed a virtuous circle. At the industrial level, the boundary between digital industry and physical industry is becoming more and more blurred, which lays a theoretical foundation for their integration. At the enterprise level, companies are integrating digital technology and data elements into their daily operations and actively participating in digital transformation.

The combination of numbers and entities makes the company more resilient through four important aspects: technology flow, data flow, resource flow and talent flow. First of all, technologies like big data, IoT and AI can help enterprises collect, store and process vast amounts of information, so that they can better understand the market situation, customer needs and supply chain status. This reduces the uncertainties in operation and improves the flexibility to deal with external shocks. Secondly, the adoption of digital technology requires enterprises to recruit specialized talents, which is helpful to bring new knowledge, optimize the human structure and stimulate the learning and innovation ability of organizations. Finally, digital technology promotes connectivity and enables enterprises to cooperate and communicate. Based on these findings, this paper puts forward hypothesis 1: digital-physical integration can enhance corporate resilience.

Hypothesis 1: Digital-physical integration can enhance corporate resilience

2.2 Impact Mechanism of Digital-Physical Convergence on Enterprise Resilience

Indirect financing mainly by banks is the main way for China enterprises to get money. However, because the information between banks and enterprises is not transparent and the risks are sometimes unclear, it is difficult for many companies to get money from outside when they need capital restructuring, which has fallen into a financing problem. Now, the integration of digital economy and real economy provides a new way to solve the financing problem of enterprises by optimizing the efficiency of resource allocation. On the one hand, the deep application of digital technology in real industries can greatly reduce the information asymmetry between banks and enterprises. By establishing a data monitoring system, financial institutions can track the operation of enterprises in real time and improve the accuracy of credit risk assessment, which is helpful to reduce such problems as “moral hazard” and “adverse selection”. On the other hand, the digital platform is deeply rooted in the real economy, which will produce an “aggregation effect”, which will enable enterprises to obtain more flexible financial support without being restricted by traditional mortgage guarantee. Generally speaking, the combination of digital economy and real economy can reduce financing costs, broaden financing channels, and improve the ability of enterprises to integrate resources, so that they can survive more easily in an uncertain environment.

Digital technology is deeply integrated into the real economy, which can optimize the allocation of innovation elements, promote the development, introduction, improvement and dissemination of new technologies, and thus enhance the innovation ability of enterprises. The improvement of innovation ability can help enterprises to enhance their adaptability, broaden their knowledge and transform and recover faster in the crisis.

Hypothesis 2: The integration of digital entities enhances enterprise resilience by easing financing constraints.

Hypothesis 3: Digital entity integration enhances enterprise resilience by increasing R&D investment.

3. RESEARCH DESIGN

(1) Sample Selection and Data Sources

The sample in this paper is derived from China A-share listed companies from 2013 to 2022. Data for constructing firm resilience and firm-level control variables are sourced from the CSMAR database, while data for constructing data-real integration and province-level control variables are obtained from the China Statistical Yearbook. Referring to Hu Haifeng et al. (2022) [6] and Chen Lei et al. (2025) [1], this paper excludes ST and financial industry firms and tail-trimmed all continuous variables at the 1% and 99% quantiles, respectively.

(2) Variable Construction

1. Explanatory variables

Digital-Real Integration (DR_index). Current research indicates that measuring the level of digital-real integration primarily employs two approaches: micro-level and macro-level. At the micro level, studies mainly rely on corporate patent citation data (Huang Xianhai et al., 2023) [7], identifying the degree of integration between digital technology and real industries through co-occurrence relationships and citation patterns (Fang Meiyan et al., 2025) [4]. At the macro level, coupling evaluation models are predominantly used for measurement. This study adopts the “system-subsystem-coordinated evolution” analytical framework, conceptualizing digital-real integration as a composite ecosystem composed of digital and real economies. The integration level is reflected in the coupled coordination state of mutual adaptation and collaborative development between the two subsystems (Jiang Tianying et al., 2014) [11]. Based on this, we employ the widely used macro-level coupling coordination model for measurement. First, drawing on the definitions of digital economy and real economy, and referencing studies by Shi Dan and Sun Guanglin (2023) [17], Liu Yongwen and Li Rui (2024) [12], we construct comprehensive evaluation index systems for their development levels (as shown in the table). Second, we determine the weights of each indicator using the entropy weight method, calculating the development levels of the digital economy subsystem (DL) and real economy subsystem (RL). Finally, through the coupling coordination model, we establish a comprehensive index system reflecting the overall level of digital-real integration as follows:

Table 1. Indicator System of Digital Economy Development Level and Real Economy Development Level

Primary Indicator	Secondary Indicator	Tertiary Indicator
DL	Digital infrastructure	Optical cable length (km) -
		Mobile phone exchange capacity (10,000 units)
		Internet broadband access ports (in ten thousand)
		Telephone penetration rate includes mobile phones (units per 100 people)
	Digital products	Total telecom service volume (billion yuan)
		Revenue from IT consulting services (in ten thousand yuan)
		Software service revenue (ten thousand yuan)
	Digital finance	Digital Inclusive Finance Index
	Data element	E-commerce transaction share (%)
		Number of websites owned by the enterprise
RL	Agriculture	Value Added of Agriculture, Forestry, Animal Husbandry and Fishery (in billions of yuan)
		Total output value of agriculture, forestry, animal husbandry and fishery (in billions of yuan)
	Industry	Industrial added value (billion yuan)
		Number of industrial enterprises above designated size (units)
		Total assets of industrial enterprises above designated size (in billions of yuan)
		Main business revenue of industrial enterprises above designated size (in billions of yuan)
	Construction business	Construction industry added value (100 million yuan)

Table 1. (continued) Indicator System of Digital Economy Development Level and Real Economy Development Level

Primary Indicator	Secondary Indicator	Tertiary Indicator
	Transport and post industry	Number of construction enterprise units (units)
		Total output value of the construction industry (in ten thousand yuan)
		Value Added of Transportation, Warehousing and Postal Services (in billions of yuan)
		Road distance (km)
		Employment of postal town employees (in ten thousand)
	Wholesale and Retail Trade	Value Added of Wholesale and Retail Trade (Billion Yuan)
		Number of wholesale legal entities
		Total wholesale sales (in billions of yuan)
		Employment in urban wholesale and retail trade (in ten thousand)
	Accommodation and Catering Industry	Value Added of Accommodation and Catering Industry (Billion Yuan)
		Number of legal entities in the accommodation and catering industry
		Turnover of the accommodation industry (in billions of yuan)
		Employment in urban accommodation and catering industry (in ten thousand)

Drawing on the coupling model developed by Wang Zhigang and Xiang Meng (2024) [23], the coupling degree (C) and the degree of real-numerical integration (DR) can be calculated using the following formulas.

$$C = \frac{DL \times RL}{\left(\frac{DL + RL}{2}\right)^2} \tag{1}$$

$$DR = \sqrt{C \times \frac{DL + RL}{2}} \tag{2}$$

2. Dependent Variable

Corporate Resilience (score). There are two main methods to measure the company's anti-risk ability: single index method and index system method. The single index method is to select some specific figures, such as the fluctuation of stock return (Meng Qiankun et al., 2025) [16], the fluctuation of stock price (Wang Na et al., 2024) and the total sales growth (Chen Junhua et al., 2023) [2], to evaluate the company's anti-risk level. In order to make a more comprehensive evaluation, our research refers to the research of Zhang Hongchang and Ding Rui (2024) [29], Yang Yang and Lin Zibo (2024) [26] and Shi Yiming (2025) [19], and selects eight secondary indicators to measure the company's anti-risk ability from three dimensions-defense ability, recovery ability and growth ability. Calculate the weights of these indicators by entropy weight method (see Table 1), and finally get a comprehensive score to represent the company's anti-risk ability.

Table 2. Enterprise Resilience Index System

Primary indicator	Secondary indicator	Indicator description
Defensive capability	Return on equity	Net profit/shareholder equity average balance (%)
	Cash holding level	Total cash held by the enterprise (in yuan)
	Current ratio	Current assets and current liabilities
Recovery capability	Total assets growth rate	Increase in total assets this year / Total assets last year (%)
	Gross profit growth rate	Increase in operating profit this year / Total operating profit last year (%)
Growth potential	Increase rate of business revenue	Year-on-year revenue growth (%)
	Earnings per employee	Net profit/Number of employees (RMB/person)
	Percentage of individuals with a bachelor’s degree or higher	Percentage of people with a bachelor′ s degree or higher

3. Control variables

The selected firm-level control variables include: firm size (measured as the logarithm of total assets), debt-to-asset ratio (Dar, defined as total liabilities divided by total assets), and Tobin's Q (calculated as the sum of market value of tradable shares, book value of non-tradable shares, and book value of liabilities divided by total assets).

The selected provincial-level control variables include: the urban-rural income gap (Gap), measured as the ratio of urban to rural per capita disposable income; population density (Density), calculated as the ratio of year-end permanent residents to land area per 1,000; and fiscal support intensity (FS), [measurement method].

(3) Model Design

To demonstrate how digital-physical integration enhances corporate resilience, this paper establishes Equation (3):

$$Score_{jt} = \alpha_0 + \alpha_1 DR_{index_{it}} + X\gamma + \eta_j + u_t + \epsilon_{it} \quad (3)$$

Here, i, j, and t represent province, firm, and year $Score_{jt} DR_index_{it} X \eta_j u_t \epsilon_{it} \alpha_1$respectively. The dependent variable is, the core explanatory variable is, and the control variables are. The firm fixed term is, the year fixed term is, and the cluster random disturbance term at the provincial level is. The coefficient of interest in this study is, with a positive value indicating that the integration of quantitative and qualitative approaches enhances corporate resilience.

(4) Descriptive Statistics

Table 3 shows the descriptive statistics of key variables. The average value of the explained variable-enterprise Score is 0.17, the standard deviation is 0.102, the minimum value is 0.04, and the maximum value is 0.41, which shows that there are differences in the toughness level of sample enterprises. The average value of the core explanatory variable-number-real fusion index (DR_index) is 0.69, and the standard deviation is 0.177, ranging from 0.35 to 0.94, and the distribution is relatively concentrated. The median (0.73) is slightly higher than the average, indicating that the level of digital-real integration in most provinces is higher than the average, but regional differences still exist.

The fluctuation of control variables is within a reasonable range, which provides a good data base for subsequent regression analysis.

Table 3. Descriptive Statistics

Variable name	Observed value	Average value	Standard error	Least value	Median	Crest value
Score	19555	0.17	0.102	0.04	0.15	0.41

Table 3. (continued) Descriptive Statistics

Variable name	Observed value	Average value	Standard error	Least value	Median	Crest value
Dr_index	19555	0.69	0.177	0.35	0.73	0.94
Size	19555	21.83	0.932	20.38	21.72	23.73
Dar	19555	0.36	0.177	0.09	0.35	0.70
TobinQ	19555	2.11	1.038	1.08	1.75	4.98
Density	19555	0.86	0.896	0.17	0.64	3.92
Gap	19555	2.33	0.215	1.94	2.34	2.67
FS	19555	0.18	0.045	0.12	0.16	0.29

4. EMPIRICAL RESULTS

4.1 Baseline Regression

Table 4 shows the benchmark regression results of Digital-Physical Integration (DR _ Index) on corporate toughness (Score). Column (1) is the regression result with only the core explanatory variables, and then we add the control variables, company fixed effect and year fixed effect step by step. The coefficient of the core explanatory variable (DR_index) has remained remarkably positive at the statistical level of 10%, which shows that after controlling the company's own characteristics, macroeconomic time trends and other related factors, digital-physical integration can significantly improve the company's resilience. We further analyze the economic significance of the explanatory coefficient in column (4), and find that, other things being equal, the company's toughness will increase by 0.01 percentage point (0.0589 × 0.177) on average for every unit of standard deviation increase in the level of digital-physical integration, which accounts for about 5.9% (0.01/0.17) of the sample average.

Table 4. Benchmark Regression

	(1) Score	(2) Score	(3) Score	(4) Score
DR_index	0.0558***	0.1026***	0.1238*	0.0589**
	(7.63)	(13.21)	(1.99)	(2.61)
Size	-	0.0075***	0.0341***	0.0085**
	-	(7.31)	(9.09)	(2.74)
Dar	-	-0.3135***	-0.2797***	-0.2570***
	-	(-61.95)	(-22.44)	(-58.89)
Tobinq	-	-0.0019***	-0.0059***	-0.0026***
	-	(-3.22)	(-7.86)	(-4.48)
Density	-	0.0099***	0.0414***	0.0037
	-	(8.04)	(3.98)	(1.01)
Gap	-	0.0481***	0.2407***	-0.0450***
	-	(10.23)	(5.04)	(-2.92)

Table 4. (continued) Benchmark Regression

	(1) Score	(2) Score	(3) Score	(4) Score
FS	-	0.3563***	0.6285***	0.1715*
	-	(12.93)	(4.06)	(1.86)
Constant term	0.1427***	-0.1221***	-1.2473***	0.0713
	(27.23)	(-4.72)	(-6.16)	(0.74)
Observed value	19555	19555	19555	19555
Adjust R2			0.18	0.67
Enterprise Fixed	Deny	Deny	Yes	Yes
Fixed year	Deny	Deny	Deny	Yes

Note: The values in parentheses represent cluster-robust t-values at the province-year level; *, **, and *** indicate significance at the 10%,5%, and 1% levels, respectively. The same applies below.

4.2 Robustness Test

4.2.1 Endogenous Treatment

In order to reduce the endogenous problems caused by reverse causality or missing variables, we refer to the research of Jiang Ting (2020) [10] and adopt the two-stage least squares method (2SLS). According to Huang Kun Hui's (2019) [8] method, we chose the interactive item of the number of fixed telephones in each province in 1984 and the number of Internet users lagging behind in the whole country as the instrumental variable (IV) of digital-physical integration. This tool variable satisfies the correlation condition, because the popularity of communication infrastructure in history is highly correlated with the current digital economy foundation. At the same time, it also meets the exogenous requirements, because the early layout of communication facilities was determined by historical strategy and geographical conditions, which was earlier than the development of digital-entity integration, and was not directly related to the resilience of current enterprises.

As can be seen from Table 5, the results of the first stage prove that the instrumental variable (IV) is effective, and its influence on integration index is significantly positive at the level of 1%, and the F statistic is much greater than 10, indicating that there is no problem of weak instrumental variables. The results of the second stage show that the estimation coefficient of digital-physical integration for enterprise resilience is 0.3310, which is still significantly positive at the level of 1%. This coefficient is larger than the benchmark result (0.0589), which shows that if the endogeneity is ignored, the real promotion effect may be underestimated, which strongly proves that digital-physical integration can indeed significantly improve the resilience of enterprises.

Table 5. Instrumental Variable Method

	(1) DR_index	(2) Score
IV	0.0186***	-
	(3.01)	-
DR_index	-	0.3310***
	-	(3.49)
Size	0.0036*	0.0073***
	(1.93)	(3.81)

Table 5. (continued) Instrumental Variable Method

	(1)	(2)
	DR_index	Score
Dar	-0.0017	-0.2568***
	(-0.39)	(-36.27)
Tobinq	-0.0000	-0.0027***
	(-0.09)	(-4.46)
Density	0.0597**	-0.0068
	(2.32)	(-0.87)
Gap	0.0244	-0.0451**
	(0.41)	(-2.36)
FS	-0.8169***	0.3661***
	(-6.09)	(5.04)
Constant term	0.6080***	-0.1203
	(3.37)	(-1.43)
Observed value	19555	19555
Adjust R2	0.58	-
F price	60.61	-
Enterprise Fixed	Yes	Yes
Fixed year	Yes	Yes

4.2.2 Other Robustness Tests

In order to further verify the findings of baseline, we have done five additional robustness tests in this study (Table 6). Specifically, we made these adjustments to the model: (1) Remove the sample of COVID-19 in 2020 to avoid abnormal data fluctuation caused by the epidemic; (2) Remove four municipalities directly under the Central Government (Beijing, Shanghai, Tianjin and Chongqing) to prevent their special resource advantages from causing estimation bias; (3) Join the industry-year fixed effect to absorb the systematic differences that cannot be observed in different industries; (4) Change the standard error clustering from the provincial level to the industry level to reduce the correlation within the industry; (5) Change the tail pruning threshold of continuous variables to 5% and 95% quantiles to see if the results are sensitive to extreme values. Under all settings, the coefficient of digital-physical integration is consistently significantly positive at the level of 1% or 5%. These results confirm a robust conclusion: digital-physical integration can significantly improve the resilience of enterprises, whether there is systematic impact, unique geographical resources or switching to different data processing methods.

In conclusion, after a series of endogeneity tests and robustness checks, the data-real integration (DR_index) consistently shows a significant positive effect on corporate resilience (Score), demonstrating the robustness and credibility of the study’s conclusions.

Table 6. Robustness Test

	(1) Remove the 2020 sample	(2) Excluding the municipal sample	(3) High dimensional fixed effect	(4) Change clustering	(5) Change tailing method
DR_index	0.0643**	0.0501**	0.0472**	0.1159***	0.0595***
	(2.50)	(2.28)	(2.61)	(3.47)	(3.04)
Size	0.0071**	0.0091**	0.0069**	0.0015	0.0081***
	(2.35)	(2.56)	(2.45)	(0.88)	(3.39)
Dar	-0.2522***	-0.2517***	-0.2609***	-0.3078***	-0.2517***
	(-50.81)	(-55.91)	(-50.70)	(-13.91)	(-69.49)
Tobinq	-0.0027***	-0.0024***	-0.0023***	0.0062***	-0.0023***
	(-4.84)	(-3.60)	(-4.60)	(7.58)	(-3.72)
Density	0.0032	-0.0128	0.0059*	0.0663	0.0038
	(0.86)	(-0.34)	(1.96)	(1.45)	(1.33)
Gap	-0.0652***	-0.0278*	-0.0324**	0.0228	-0.0212
	(-3.06)	(-1.94)	(-2.59)	(0.85)	(-0.97)
FS	0.2204*	0.1008	0.1378*	0.0290	0.1781*
	(1.97)	(1.33)	(1.82)	(0.67)	(1.91)
Constant term	0.1344	0.0337	0.0788	-0.0266	0.0153
	(1.49)	(0.33)	(0.85)	(-0.28)	(0.15)
Observed value	17179	16263	19555	19555	19555
Adjust R2	0.68	0.67	0.70	0.60	0.70
Enterprise Fixed	Yes	Yes	Yes	Yes	Yes
Industry X Year Fixed	Deny	Deny	Yes	Deny	Deny
Fixed year	Yes	Yes	Deny	Yes	Yes

4.3 Heterogeneity analysis

Regression analysis shows that digital-entity integration has a positive impact on enterprise resilience as a whole. In order to further study the difference of this influence in different situations, we conducted a heterogeneity analysis, covering four dimensions: enterprise scale, enterprise age, industry characteristics and market competition intensity. The results are shown in Table 7.

4.3.1 scale

This study divides companies into large enterprises (column 1) and small enterprises (column 2) according to the median total assets. The results show that the coefficient of Digital-Entity Fusion Index (DR_index) is obviously positive at the significance level of 1%, but the influence on small business groups is not significant statistically. This difference may be due to the inherent advantages of large enterprises: they usually have more capital, more advanced digital infrastructure and stronger ability to integrate resources. Moreover, as BRYNJOLFSSON et al. (2017) [30] pointed out, if digital technology is really used well, it needs supporting systems. Large enterprises are better at absorbing, transforming and applying digital innovation, so they can achieve deeper digital and entity collaboration and establish a stronger anti-risk framework.

4.3.2 enterprise age

According to the median operating years of enterprises, this study divides them into established companies (column 3) and start-ups (column 4). Regression analysis shows that the synergistic effect of digital-entity integration has a significant positive impact on established companies, but the impact on start-up companies is not obvious. This shows that although the established companies face the challenges of organizational inertia and path dependence, they have profound industry experience, stable customer relationship and mature operation framework, which can provide powerful application scenarios for digital transformation, thus more effectively integrating the digital economy and the real economy. In contrast, although startups are more innovative, their business models and systems may not be stable enough. Their integration of digital technology and physical business is still in the exploration stage, and the effect of improving operational resilience has not yet fully appeared in the short term.

4.3.3 Industry characteristics

This study divides the sample area into manufacturing (column 5) and non-manufacturing (column 6). The results show that the coefficient of digital-physical integration is obviously positive in non-manufacturing companies, but it does not show statistical importance in manufacturing enterprises. This difference may come from the characteristics of the industry: non-manufacturing sectors (such as finance, retail, information services) naturally have more digital and intangible products/services, and their business processes are more closely integrated with digital technology. Therefore, digital-physical integration can quickly become efficiency improvement, new business model and stronger risk management ability. On the contrary, digital transformation in manufacturing usually needs to spend a lot of money on hardware, redesign complex production processes, and coordinate the whole supply chain. It takes a long time to see its effect, and it needs to go through a clear cycle from the beginning of use to the complete landing, from “quantitative change” to “qualitative change” (Sun Xiaohua et al., 2025) [20]. In addition, the manufacturing industry may encounter more resistance in the transition, which leads to the short-term improvement of resilience is not obvious in statistics.

4.3.4 degree of market competition

In this study, the Herfindahl-Hirschman Index (HHI) is used to measure the degree of industry competition, and the company is divided into low competition (the seventh column) and high competition (the eighth column) according to the median. The results show that the coefficient of the integration of numbers and entities is obviously positive at the significance level of 1% in the fierce competition environment; But in the case of low competition, they are not statistically significant. This discovery is consistent with the theory of competitive incentive: in a highly competitive market, companies are faced with continuous survival pressure, which urges them to use digital technology to optimize their operations, innovate products and improve efficiency in order to gain competitive advantages. On the contrary, in a low-competitive market, such as a monopoly market, due to the lack of external competitive pressure, the sense of urgency and motivation for companies to carry out deep integration and transformation is reduced, thus weakening the resilience enhancement effect brought by digital entity integration.

Table 7. Heterogeneity Analysis

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Large-scale	Small-scale	Long-established enterprise	New business	Manufacturing industry	Non-manufacturing industry	Low competition	High competition
DR_index	0.0638***	0.0091	0.0423**	0.0122	0.0441	0.1344***	0.0275	0.0779***
	(2.85)	(0.26)	(2.47)	(0.18)	(1.54)	(5.95)	(0.73)	(4.84)

Table 7. (continued) Heterogeneity Analysis

	(1) Large-scale	(2) Small-scale	(3) Long-established enterprise	(4) New business	(5) Manufacturing industry	(6) Non-manufacturing industry	(7) Low competition	(8) High competition
Size	0.0157***	-0.0037	0.0120***	0.0304***	0.0081**	0.0056	0.0029	0.0074**
	(8.49)	(-0.87)	(3.97)	(7.94)	(2.50)	(1.40)	(0.65)	(2.56)
Dar	-0.2090***	-0.2839***	-0.2218***	-0.3134***	-0.2707***	-0.2335***	-0.2636***	-0.2537***
	(-27.89)	(-34.74)	(-34.27)	(-32.56)	(-48.94)	(-17.95)	(-23.54)	(-31.46)
Tobinq	0.0005	-0.0041***	0.0013	-0.0027**	-0.0030***	-0.0022	-0.0037***	-0.0018**
	(0.46)	(-5.21)	(1.50)	(-2.67)	(-5.94)	(-1.63)	(-4.18)	(-2.40)
Density	0.0041	-0.0046	0.0065**	-0.0109	0.0062	-0.0075	0.0027	0.0018
	(1.26)	(-0.93)	(2.22)	(-0.74)	(1.34)	(-1.42)	(0.40)	(0.44)
Gap	-0.0196	-0.0840***	-0.0336**	-0.0416	-0.0053	-0.1189***	-0.0174	-0.0613***
	(-1.52)	(-3.62)	(-2.62)	(-0.88)	(-0.28)	(-5.39)	(-0.67)	(-3.80)
FS	0.1301	0.2751**	0.1374**	0.1319	0.1287	0.2984***	0.3365**	0.0901
	(1.44)	(2.57)	(2.13)	(0.76)	(1.51)	(3.37)	(2.21)	(1.46)
Constant term	-0.1839**	0.4643***	-0.0531	-0.2777	-0.0088	0.2792**	0.1543	0.1423
	(-2.75)	(4.62)	(-0.74)	(-1.51)	(-0.08)	(2.59)	(1.11)	(1.60)
Observed value	9777	9778	10708	8847	14601	4954	7980	11570
Adjust R2	0.69	0.68	0.66	0.71	0.67	0.71	0.69	0.68
Enterprise Fixed	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed year	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

4.4 Mechanism Analysis

Both benchmark regression and robustness test prove that combining quantitative and qualitative data can greatly improve the enterprise’s ability to resist risks. In order to further study the reasons behind this effect, we tested the mechanism through two ways: relaxing financing constraints and increasing R&D investment. Table 8 shows the corresponding regression results.

4.4.1 financing constraint

Capital limitation is a key factor affecting the company's ability to resist risks and sustainable development. In order to see whether the "integration of numbers and entities" can make the company more resilient by reducing the financial constraints, this study uses SA Index (Hadlock & Pierce, 2010) [31] to measure the company's financial constraints. The higher this index, the greater the constraints. Column (1) of Table 8 shows that the coefficient of digital entity integration (DR_index) is significantly negative at the level of 1%, which shows that the better the digital entity integration is, the more effectively it can reduce the company's capital constraints. In the second column, we further analyze the Score and SA Index together, and find that the more difficult the financing of companies is, the greater the negative impact on their ability to resist risks. This shows that the integration of number and reality can enhance the resilience of enterprises by alleviating financing constraints. The reason behind it is that the integration of numbers and facts improves the digitalization and transparency of operations, which can reduce information asymmetry (Guo Xiaoxu et al., 2025) [5], enhance the credit of enterprises, broaden external financing channels, and reduce financing costs. These improvements provide an important financial guarantee for enterprises to cope with external shocks and maintain normal operations and investment activities.

4.4.2 research input

Innovation is the core driving force for companies to adapt to environmental changes and gain long-term competitive advantages. Our research uses the natural logarithm of R&D investment to measure the innovation intensity of the company. In column (3) of Table 8, we can see that the coefficient of digital entity integration (DR_index) to R&D investment is 4.3562, which is significant at the level of 1%, which shows that digital entity integration can significantly enhance the company's innovation activities. Column (4) examines R&D investment as an intermediary variable, and the coefficient is significantly positive (0.0007) at the level of 1%, which proves that innovation investment plays an intermediary role in the process of digital entity integration affecting the company's resilience. This mechanism shows that the integration and development of digital entities can help companies improve the tendency of independent innovation (Zheng Haotian, 2025) [28]. Greater innovation ability enables companies to develop new products, improve production methods or find new markets faster, so that they can find opportunities in difficult times, realize transformation and upgrading, and thus make the company more resilient.

This study found two key micro-paths for the integration of digital and entity to enhance enterprise resilience. The first path is to alleviate external financing constraints by optimizing the information environment and credit qualifications, thus enhancing the resource base for enterprises to cope with risks. The second path is to empower innovative activities and reorganize production factors, stimulate endogenous growth momentum, and enhance their dynamic adaptability and resilience. These two paths systematically explain how the integration of numbers and entities affects enterprise resilience from the perspectives of "resource acquisition" and "capacity building" respectively.

Table 8. Mechanism Testing

	(1)	(2)	(3)	(4)
	SA	Score	R&D	Score
DR_index	-0.0683***		4.3562***	
	(-3.22)		(2.86)	
Size	0.0247***	0.0131***	1.4533***	0.0083***
	(6.47)	(4.47)	(11.77)	(2.96)
Dar	0.0281***	-0.2446***	-1.6284***	-0.2643***
	(3.48)	(-49.55)	(-4.48)	(-74.35)
TobinQ	-0.0098***	-0.0004	0.1815***	-0.0032***
	(-6.95)	(-0.84)	(4.23)	(-4.85)
Density	0.0022	0.0067**	0.2038	0.0045
	(0.61)	(2.65)	(0.86)	(0.83)

Table 8. (continued) Mechanism Testing

	(1)	(2)	(3)	(4)
	SA	Score	R&D	Score
Gap	0.0479***	-0.0329**	-0.2511	-0.0423**
	(2.77)	(-2.32)	(-0.22)	(-2.27)
Fs	-0.1865**	0.1021	2.5319	0.1638*
	(-2.37)	(1.40)	(0.67)	(1.72)
Sa		-0.0739***		
		(-3.94)		
R&d				0.0007***
				(7.15)
Constant term	3.0579***	0.2470**	-33.5883***	0.1136
	(31.30)	(2.55)	(-9.02)	(1.17)
Observed value	17427	17427	18242	18242
Adjust R2	0.86	0.67	0.10	0.68
Enterprise fixed	Yes	Yes	Yes	Yes
Fixed year	Yes	Yes	Yes	Yes

5. CONCLUSION AND POLICY RECOMMENDATIONS

This study uses China A-share listed companies from 2013 to 2022 as samples. Through empirical analysis, it is found that the number-real integration can significantly improve the enterprise's resilience, and the enterprise's resilience can be improved by about 5.9% for each unit standard deviation of the integration index. This core finding is very reliable in all kinds of rigorous robustness tests, including instrumental variable method to deal with endogenous problems and adding high-dimensional fixed effects. The promotion effect of the integration of number and reality is obviously different among different enterprises, especially for larger, longer-established non-manufacturing enterprises and those operating in the fierce competitive market, which shows the key influence of resource endowment and external pressure. From the mechanism point of view, the integration of number and reality can enhance the resilience of enterprises mainly through two ways: one is to indirectly reduce financial pressure by alleviating financing constraints, and the other is to build long-term resilience by encouraging R&D investment and innovation.

In order to make full use of these benefits at the macro level, the government should be a good guide and waiter and formulate different regional integration strategies. Instead of "one size fits all", policies should encourage developed areas to develop industrial Internet ecology, and at the same time provide inclusive public services and technology platforms for small and medium-sized enterprises in traditional industries. In addition, policy makers should establish a new financing support system around "credit data", cooperate with banks, and incorporate the desensitized high-frequency digital footprint into the credit evaluation model to solve the problem of insufficient collateral for SMEs. The government should also set up a special R&D incentive plan and fault-tolerant mechanism to support enterprises to jointly tackle key technical problems and protect their innovation enthusiasm.

In the small world of enterprises, they have to work hard to turn the external digital technology into their own super power. First of all, the company should take management data as a top priority, make good use of those neat operational and financial data, and make everything clearer, so that it can successfully get loans that rely on data. Secondly, enterprises should push the R&D mode to "data-driven", and use timely market feedback, in-depth user understanding and simulation testing to make innovation more accurate, faster and more economical. Finally, the company must build a flexible structure and actively join the open industrial digital ecosystem. By sharing data and cooperating with upstream and downstream partners, enterprises can turn the original supply chain into a network platform, so as to disperse external shocks, share risks and cultivate long-term development ability.

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