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Exploring Regional Economic Resilience: Empirical Evidence from the Digitization of Trade

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Abstract

The development of digital technology has promoted the digital transformation of trade supported by the Internet, and has gradually become a new trend of international trade development and a new driving force to enhance economic resilience. Based on the construction of an indicator system, this paper measures and analyzes the levels of trade digitization and economic resilience in 30 provinces of China from 2010 to 2023. It also explores the mechanisms and impacts through which trade digitization affects regional economic resilience from both theoretical and empirical perspectives. The findings are as follows. First, the levels of trade digitization and economic resilience in China's provincial regions have both shown an upward trend. Second, trade digitization can significantly enhance regional economic resilience. Third, trade digitization strengthens regional economic resilience through pathways such as stimulating technological innovation, promoting industrial upgrading, and temporarily suppressing industrial competitiveness. Fourth, the positive impact of trade digitization on economic resilience is more evident in the central region and southern region, as well as provinces with relatively lower levels of economic development, technological innovation, industrial upgrading, and becomes negative in provinces with lower levels of industrial competitiveness. The conclusions of this paper provides ideas and references for China to promote digital transformation of trade and empower regional economic resilience. It also provides new empirical evidence and valuable references for countries around the world, especially developing countries, to promote trade liberalization and sustainable economic development.

Keywords: *trade digitization, economic resilience, technological innovation, industrial structure upgrading, industrial competitiveness, transmission mechanism, heterogeneity test*

JEL Classification: O11, O44, Q01, Q56

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1 INTRODUCTION

At present, as the world is undergoing accelerated changes unseen in a century, problems such as the rise of trade protectionism, the emergence of anti-globalization trends, and supply chain disruptions have brought huge challenges to the global economy and trade. China's economic development is in a period of coexistence of strategic opportunities and risks and challenges, with an increase in uncertain and unpredictable factors. Moreover, China is facing a complex situation of the transformation of old and new kinetic energy of the economy, as well as the "triple pressure" of demand contraction, supply shocks and weakening expectations. These factors add uncertainty and risks to the stable operation of China's and the world's economies. A high level of economic resilience is undoubtedly an important force for China to cope with external risks, optimize its economic structure and cultivate new driving forces for growth, as well as a basic guarantee for avoiding a "hard landing" and maintaining the country's long-term stable development. In recent years, the development of digital technology has driven the digital transformation of trade supported by the Internet, which has gradually become a new trend in international trade development and a new driving force for enhancing economic resilience. Therefore, leveraging trade digitization to enhance regional economic resilience has become an important approach and focus of China's current and future economic work.

With the deterioration of geopolitical situations, intensified major power competition, and the frequent occurrence of "black swan" events, the global economy is facing numerous challenges and uncertainties. For instance, the outbreak of the COVID-19 pandemic in 2020 dealt a severe blow to global trade and cooperation, but it also accelerated the integration of traditional trade and digital technology. The emergence of digital trade, marked by digital technology and digital transaction methods, significantly mitigated the negative impact of the pandemic on traditional trade (Tolba et al., 2022). The core logic lies in the fact that digital technology endows economies with the ability to sense the dynamics of international markets, thereby greatly enhancing the agility of economic systems. This agility has become a core element in building export resilience and unleashing economic potential (Cao et al., 2024). According to statistics, in 2023, the total import and export volume of China's cross-border e-commerce reached 2.37 trillion yuan, with a year-on-year increase of 15.3%; the scale of trade in digitally deliverable services reached 2.72 trillion yuan, with a year-on-year increase of 8.5%.[1] This fully demonstrates the strong vitality and

[1] Ministry of Commerce of the People's Republic of China. (2024). *China Digital Trade Development Report 2024*. https://fms.mofcom.gov.cn/xxfb/art/2024/art_2af090f44fd44b16b4d281d55dd5a31c.html.

resilience of China's digital trade in recent years. This emerging form of trade, through platform-based operations, digital empowerment, and inclusive services, has restructured the traditional trade chain. Its innovative information screening mechanisms and intelligent matching systems have effectively reduced the information search costs in cross-border transactions, while simplifying trade processes and improving transaction efficiency (Chiappini & Gaglio, 2024).

In 2021, the Chinese government identified digital trade as a strategic fulcrum for optimizing the trade structure, emphasizing the need to enhance economic resilience through institutional innovation and technological empowerment to cultivate new competitive advantages in the international arena.[2] Against this backdrop, the interaction between policy orientation and the innovation and development of digital technologies is gradually creating a resonance effect, continuously driving the digital transformation of trade and stimulating new growth drivers for regional economic development. For example, digital technologies such as 5G, big data, cloud computing, and artificial intelligence are not only promoting the digital transformation of goods trade but also creating new growth spaces through the tradability of services (Yin & Choi, 2025). Traditional services that were once considered non-tradable, such as education and healthcare, are now breaking through geographical boundaries with the help of virtual reality and remote interaction technologies, giving rise to new business forms and models like digital education and telemedicine. Meanwhile, the digital transformation of trade driven by digital technologies is reshaping the development logic of China's economic resilience, with its impact showing a significant dual effect. On the one hand, trade digitization is promoting the transformation and upgrading of China's economic structure, forcing traditional industries to move towards networked, digital, and intelligent development. On the other hand, the rapid development of digital service trade is injecting strong momentum into technological innovation (Wen et al., 2023), driving the growth of strategic emerging industries and shifting China's economic model from scale expansion to value creation.

To sum up, trade digitization is a new form of trade extended from traditional trade in the digital economy era. The essence of its ability to empower economic resilience lies in the dynamic adjustment of the economic system led by new-generation digital technologies and digital platforms. Through digital innovation and digital transformation, new trade forms are created,

[2] Ministry of Commerce of the People's Republic of China. (2021). Notice of the Ministry of Commerce on Issuing the "14th Five-Year Plan for High-Quality Development of Foreign Trade". Chinese Government. https://www.gov.cn/zhengce/zhengceku/2021-11/24/content_5653009.htm.

thereby strengthening regional economic resilience. Therefore, trade digitization is increasingly becoming the core force driving the transformation of traditional trade methods, industrial upgrading, and economic transformation. Against this backdrop, what impact has trade digitization had on China's regional economic resilience? What is the theoretical logic and transmission mechanism of this impact? And, is there a heterogeneous effect of this impact? This paper starts from a new perspective of trade digitization, not only elucidating the mechanisms through which trade digitization affects economic resilience at the theoretical level but also empirically examining the impact, transmission mechanisms, and heterogeneous effects of trade digitization on economic resilience.

2 THEORETICAL ANALYSIS AND RESEARCH HYPOTHESES

2.1 Mechanisms of the Direct Impact of Trade Digitization on Economic Resilience

Economic resilience refers to the resistance recovery ability of the economic system to resist and recover from external shocks, the regulating adaptive capacity to adjust itself to changes in the external environment during shocks, and the innovative transformation capacity to innovate and transform to continue to develop and create new paths of economic development after being impacted. Therefore, this paper focuses on elucidating the direct impact mechanisms of trade digitization on economic resilience from three dimensions: resistance recovery ability, regulating adaptive capacity, and innovative transformation capacity.

First, trade digitization leverages digital platforms and infrastructure to promote the development of e-commerce, facilitating the transformation and upgrading of traditional trade in China and effectively enhancing the resistance recovery ability of the economic system. Digital infrastructure can boost urban economic vitality and resilience by reducing information and communication costs, streamlining redundant processes, and improving economic efficiency (Zhang et al., 2023). On the one hand, the Internet not only transforms the transmission of financing information, enabling seamless interaction between supply and demand (Bollaert et al., 2021), but also fosters knowledge spillovers, aiding workers in learning and knowledge accumulation, thereby promoting human capital development (Santoro et al., 2018). By enabling real-time information sharing and transparent trade processes through Internet platforms, trade digitization significantly reduces search and matching costs in trade (Meng & Lei, 2023; Yin & Choi, 2022). On the other hand, the integration of Internet platforms and digital technologies has established an interconnected

information network, promoting the integration and optimal allocation of resources in traditional industries (Zhang et al., 2024). This convergence drives enhanced information transparency, improved economic efficiency, and refined governance mechanisms, thereby collectively strengthening the resistance recovery ability of urban economies (Hu & Mao, 2023). Such advancements enable rapid resource reorganization during external shocks, shorten industrial recovery cycles, and reinforce the resistance recovery ability of traditional industries. For example, e-commerce platforms integrate marketing, logistics, and settlement processes, not only improving the operational efficiency of traditional industries but also building a rapid response mechanism based on data intelligence analysis (Mabon & Kawabe, 2023). Consequently, when market fluctuations occur, enterprises can adjust their strategies and supply chain layouts in real time to withstand external shocks.

Secondly, trade digitization promotes the deep integration of digital technology and traditional industries, thereby enhancing the regulating adaptive capacity of the real economy. On the one hand, digital trade can leverage digital technology empowerment and digital platform support to form a global digital network. This promotes the effective allocation of global resources and diversifies risk-sharing, thereby enhancing the adaptability, stability, and innovation capacity of the economy (Kong et al., 2024). The platform economy centered on digital technology breaks down barriers caused by geographical distance (Fahmy, 2021), promotes efficient resource allocation and market expansion, and thus provides greater buffering and adaptability in the face of market fluctuations and external shocks (Chen et al., 2024). On the other hand, compared with traditional factors such as land, capital, and labor, data elements can drive the continuous penetration and integration of digital technology with traditional trade industries through their virtual substitutability, renewability, and low-cost advantages. This integration breaks through the barriers between online and offline channels in traditional industries, achieves dynamic and precise matching of supply and demand, and fully releases the industrial upgrading dividends of digital transformation (Feng & Xu, 2022). This deep integration not only strengthens the foundation of the real economy, but also enhances the adaptability of economic entities, effectively cushioning external shocks and maintaining stable economic growth.

Thirdly, trade digitization empowers industrial innovation through digital technology, thereby enhancing the innovative transformation capacity of the real economy. During the process of trade digitization, the iterative development of digital technology driven by actual demand has improved regional innovation levels (Zhang et al., 2024). On the one hand, technologies such as cloud

computing, artificial intelligence, and big data can permeate all aspects of trade, accurately uncovering the heterogeneous needs of customers and dynamically optimizing the matching of products and services. This enables a capability leap from manufacturing to research and development (Luo et al., 2024), thereby opening up new spaces for economic growth. On the other hand, trade digitization relies on new business forms such as smart logistics and e-commerce to drive industries towards networked, digital, and intelligent evolution. This not only gives rise to cross-sector economic forms, but also continuously releases industrial innovation vitality through digital innovation. Moreover, the innovation of digital technology in the financial sector can break through the limitations of time and space, expand the scope of financial services, and provide reliable financial support for cities to cope with external shocks, thereby enhancing economic resilience (Zhang & Yao, 2023).

Thus, the first hypothesis is proposed as follows for empirical testing:

Hypothesis 1: Trade digitization has a positive effect on enhancing regional economic resilience.

2.2 Transmission Mechanisms of Trade Digitization Affecting Economic Resilience

2.2.1 Technology Innovation Effect

On the one hand, trade digitization accelerates the innovation of business models and enhances the efficiency of product and service research and development by integrating advanced information technologies such as cloud computing and artificial intelligence (Stankovic et al., 2021), thus effectively improving the overall level of technological innovation. In terms of collaborative innovation, the digital sharing mechanism breaks industry boundaries, and the disruptive innovation it stimulates promotes the interaction of cross-field knowledge and the integration of technologies, thereby accelerating the transformation of innovation outcomes (Xiao et al., 2024). At the same time, enterprises have strengthened the interaction and cooperation between upstream and downstream innovation subjects in the industrial chain by building digital innovation platforms (Liu et al., 2024), driving collaborative innovation in emerging technology fields and thereby improving the level of technological innovation in enterprises (Huang & Gao, 2023). In terms of cost reduction, trade digitization reduces information asymmetry through the precise matching of big data, significantly lowering R&D costs and the threshold for trial and error. At the same time, digital infrastructure accelerates the diffusion and spillover of knowledge (Wen et al., 2023), forming a technical foundation for improving innovation efficiency.

On the other hand, technological innovation enhances regional economic resilience by breaking through path dependency and optimizing the allocation of factors. The recovery of the economy after a shock is often limited by the original development path, while technological innovation can improve the adaptability and adjustment ability of the region, breaking free from the "locked-in" state of the path, and drive the reconstruction of growth trajectories (Xu & Deng, 2020). The improvement of technological innovation capacity not only strengthens recovery and production transformation efficiency after a shock but also promotes industrial upgrading and transformation through optimized allocation of factors, thereby enhancing the sustainability of development (Luo et al., 2023; Deng et al., 2024). Meanwhile, digital applications driven by technological innovation reduce the cost of acquiring knowledge and improve the skill level of the workforce. This provides high-quality human capital for post-shock industrial reconstruction (Cheng & Jin, 2022), thus ensuring the stable operation of the economic system. Thus, the second hypothesis is proposed as follows:

Hypothesis 2: Trade digitization can promote regional economic resilience by stimulating technological innovation.

2.2.2 Industrial Structure Upgrading Effect

On the one hand, trade digitization drives industrial upgrading through dual pathways of industrial linkages and resource allocation. In terms of industrial linkages, trade digitization leveraging online transaction platforms and data-sharing mechanisms, not only catalyzes the emergence of innovative production paradigms and business models, but also accelerates industrial chain modernization through enhanced information transmission efficiency, thereby driving the transformation and upgrading of traditional industries and ultimately fortifying regional economic resilience. In terms of resource allocation, trade digitization breaks the dependence of factor mobility on physical space and effectively avoids resource misallocation caused by factors such as information asymmetry (Chen & Yang, 2021). Digital sectors can rapidly absorb new technologies and promote the spillover effects of knowledge factors within the regional economic system, driving the industrial structure to shift from labor-intensive to capital- or technology-intensive (Zhang et al., 2023). Furthermore, digital trade promotes industrial structure upgrading by enhancing labor remuneration rates, technological innovation, and R&D investment, thereby driving high-quality economic development (Liang, 2022).

On the other hand, industrial upgrading drives the enhancement of economic resilience. Industrial upgrading not only optimizes resource allocation across sectors but also strengthens inter-sectoral coordination, thereby enhancing the adaptability of regional economies in responding to external changes. Industrial digitalization not only promotes the integration of digital technology and traditional industries (Dai & Liu, 2022), but also drives product innovation (Wang & Yang, 2024) as well as industrial chain collaboration and the expansion of industrial scale (Han et al., 2023). Trade digitization promotes industrial upgrading, drives the agglomeration of production factors towards high value-added industries, and generates a "structural dividend" that not only breaks through the development barriers of high-end industries but also realizes the interconnection of the upstream and downstream of the industrial chain, providing industrial support for enhancing urban economic resilience (Gao, 2023). Moreover, technological progress is often accompanied by the advanced evolution of industrial structures (Liu & Gu, 2023). Digitalization accelerates the diffusion of technology and its penetration into industries, constructing a sustainable growth path through the transition of old and new growth drivers, thereby endowing the economic system with dynamic adaptability. Thus, the third hypothesis is proposed as follows:

Hypothesis 3: Trade digitization can promote regional economic resilience by promoting industrial structure upgrading.

2.2.3 Industrial Competitiveness Effect

First, trade digitization reconstructs the industrial competition landscape through "creative destruction." In the short term, digital transformation has a significant impact on traditional industries, especially those relying on traditional production models and sales channels. These industries face triple constraints of funding, technology, and talent during the technological upgrade process, hindering their ability to swiftly adapt to the digital market environment and leading to a gradual decline in their competitiveness (Petkovski et al., 2022). For example, some traditional manufacturing enterprises have gradually lost their market advantages and even face survival crises due to the failure to timely introduce intelligent manufacturing technologies. Although this transformational pain has a certain impact on economic stability in the short term, it lays an important foundation for the optimization and upgrading of the economic structure in the long run (Rajnoha & Lesnikova, 2022).

Secondly, digital platforms have reconstructed the traditional industrial landscape by dismantling information barriers, thereby promoting the formation of distributed competitive networks (Stallkamp & Schotter, 2021). In traditional industrial chains, large enterprises rely on their scale advantages to form information monopolies, which puts small and medium-sized enterprises (SMEs) at a long-term competitive disadvantage. However, the widespread application of digital technology has significantly enhanced information transparency, enabling SMEs to efficiently access global market resources (Pandey et al., 2024). This not only erodes the market monopoly advantages of traditional large enterprises but also drives the diversification of supply chains. As a result, a large number of SMEs have been integrated into the global value chain, forming a more resilient network structure (Añón Higón & Bonvin, 2024). Although the distributed competitive landscape has weakened the dominant position of some traditional enterprises, it has enhanced the adaptability and risk resistance of the economic system, thereby providing structural support for coping with market fluctuations.

Finally, the "skill polarization" in the labor market caused by trade digitization is deeply reconstructing the structure of human capital, forming a dual-driven momentum for transformation and upgrading. Under the dual effects of technological substitution and demand upgrading, traditional labor-intensive industries are facing the challenge of low-skill jobs being replaced, causing industries that rely on simple, repetitive labor to gradually lose their competitive edge. Meanwhile, technology-intensive fields are experiencing a surge in demand for digital talent, driving the employment structure towards a dumbbell-shaped shift characterized by "high-skill concentration and low-skill contraction." The high-quality human capital formed in this process not only constitutes the core element for enterprises to build competitive barriers but also injects continuous momentum into high-quality economic development (Simionescu et al., 2021). Thus, the fourth hypothesis is proposed as follows:

Hypothesis 4: Trade digitization can promote regional economic resilience by temporarily suppressing industrial competitiveness.

3 RESEARCH DESIGN

3.1 Variable Selection

3.1.1 Explained Variable

Economic resilience (*Res*). The essence of economic resilience is the adaptive ability of an economic system to make dynamic adjustments, that is, the ability of the economic system to avoid, resist, adapt, recover and find new growth pathways in a crisis when it encounters negative external shocks in the process of economic growth. There are two main methods for measuring economic resilience in the existing literature: the first is the multi-indicator system measurement method, which measures by selecting variables from various dimensions to construct a comprehensive indicator system. The second is the core variable method, which usually selects GDP data or employment data as economic indicators. For example, Cheng and Jin (2022) used the difference between the real GDP growth rate of different years and the overall base year in each region to measure economic resilience. Han et al. (2023) measured economic resilience based on regional GDP or employment sensitivity indicators. Given that the core variable method is mainly applicable to measuring the resilience level of an economy in the face of short-term shocks, it has a certain degree of one-sidedness. Therefore, according to the connotation of economic resilience, this paper constructs an economic resilience indicator system from the three dimensions of resistance recovery ability, regulating adaptive capacity, and innovative transformation capacity (Table 1). Based on the indicator system and referring to Lan and Chen (2013), this paper adopts the entropy value method to measure the level index of economic resilience and its three dimensions.

Tab. 1 – Economic Resilience Indicators System Source: own research

Dimension	**Indicator**	**Nature**	**Weight**
Resistance recovery ability (RR)	GDP per capita	+	0.049
	Per capita disposable income	+	0.053
	Urban registered unemployment rate	-	0.028
	External trade dependence	-	0.009
	Diversification of industrial structure	-	0.007
	Green coverage	+	0.011
Regulating adaptive capacity (RA)	Investment in fixed assets	+	0.068
	Total retail sales of consumer goods	+	0.081
	Level of financial self-sufficiency	+	0.036
	Level of financial development	+	0.046
	Local fiscal expenditures	+	0.048
	Social insurance coverage	+	0.045
	Level of human capital	+	0.129

Innovative transformation capacity (IT)	Level of expenditure on science and technology R&D	+	0.069
	Level of financial expenditure on education	+	0.053
	Patent grants	+	0.178
	Level of industrial sophistication	+	0.064
	Urbanization rate	+	0.026

Note: "+" means the nature of the indicator is positive, and "-" means negative.

Figure 1 illustrates the trend of China's economic resilience and its three dimensional levels from 2010 to 2023. Overall, the resilience level of the China's economy and its three dimensions have shown a stable upward trend, with a distribution pattern of "resistance recovery ability > regulating adaptive capacity > innovative transformation capacity." Among them, the resistance recovery ability is at a relatively high level, indicating that the outstanding ability of the Chinese economy to mitigate shocks, which is also the strength of the China's economic system. From a regional perspective, the economic resilience level of China's three major regions has shown a steady upward trend, with a distribution pattern of "Eastern > Western > Central." Specifically, the eastern region has made the greatest contribution to the national economic resilience level, mainly due to the developed economy, leading production technology, high innovation level, and developed high-tech industries in the eastern provinces, which make them more capable of mitigating shocks through factor restructuring. Although the central and western regions have relatively lagging economies, they have benefited from policy support and the implementation of regional development strategies, which have rapidly improved the resilience of the regional economy.

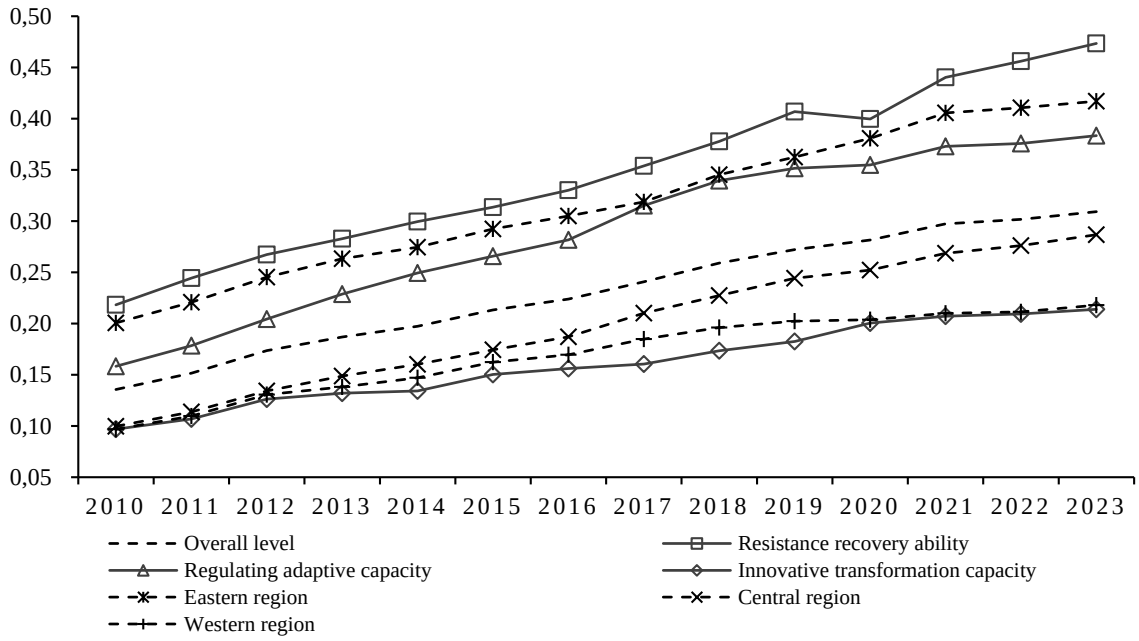

Fig. 1 – Trends in economic resilience and the levels of its three dimensions.

Source: own research

3.1.2 Explanatory Variable

Trade digitization (*Digit*). Based on the connotation of trade digitization, this paper comprehensively considers its basic conditions of trade digitization, market application, trade mode and other aspects, and constructs the trade digitization indicator system from the three dimensions of digital infrastructure, digital market structure, and digital trade structure (Table 2). Based on this indicator system, this paper adopts the entropy value method to measure trade digitization and the level index of its three dimensions.

Tab. 2 – Trade Digitization Indicator System Source: own research

Dimension	Indicator	Nature	Weight
Digital infrastructure (DI)	Network infrastructure	+	0.118
	Communications facility	+	0.032
	Logistics facility	+	0.162
Digital market structure (DM)	Digital on-demand market	+	0.265

	Digital supply market	+	0.178
Digital trade structure (DT)	Trade in digital Technologies	+	0.126
	Trade in digital products	+	0.051
	Digital informatization trade	+	0.070

Note: "+" means the nature of the indicator is positive, and "-" means negative.

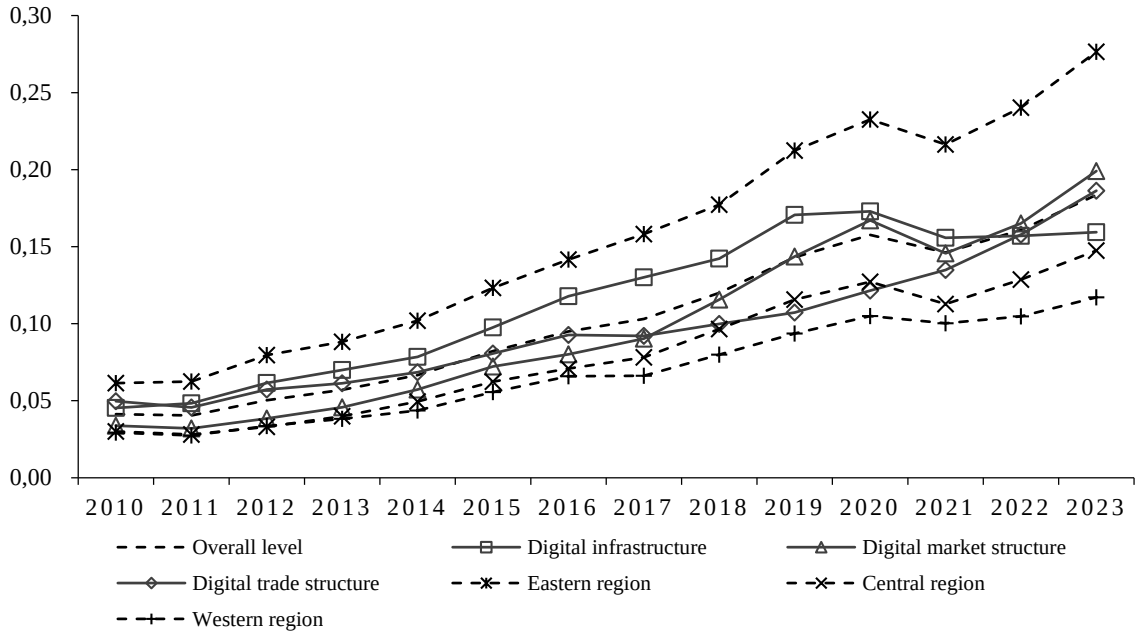

Fig. 2 – Trends in trade digitization and the levels of its three dimensions.

Source: own research

Figure 2 illustrates the trend of China's trade digitization and its three-dimensional levels from 2010 to 2023. Overall, the level of China's trade digitization and its three dimensions have shown a significant upward trend. Specifically, the growth trend of digital infrastructure is similar to the level of trade digitization, suggesting that the construction and improvement of infrastructure have played a significant supporting role in trade digitization. The development of digital market structure has grown in tandem with the level of trade digitization, indicating that e-commerce and online transactions have played an important role in prompting trade digitization. The trend of trade digitization level in the three major regions is basically consistent with the national level, and shows a distribution characteristic of "Eastern > Central > Western." As the most developed region of the Chinese economy, the eastern region has a relatively high starting point for digitization and a stable growth rate. Although the starting point of the central and western regions

is relatively low, their growth rate is relatively fast, especially in the western region, where a catching up effect has already been shown. Between 2020 and 2021, the level of trade digitization showed a downward trend. This was mainly due to the significant impact of the COVID-19 pandemic that erupted globally in 2020 on economic activities, which led to a sharp decline in trade activities and consequently constrained the process of trade digitization.

3.1.3 Mechanism Variables

Trade digitization may affect regional economic resilience through the mediating effects of technological innovation, industrial structure upgrading, and industrial competitiveness. Therefore, these three variables are selected as mechanism variables for transmission mechanism testing. Referring to Reznakova and Stefankova (2022), this paper uses the R&D expenditure intensity and the per capita number of authorized invention patent applications as indicators of innovation input and output, respectively. Factor analysis is used to calculate the comprehensive factor score of the two to measure the level of technological innovation.

Industrial structure upgrading is proxied by the advanced industrial structure. The advanced industrial structure indicates the process of development and transformation of the industrial structure from a lower to a higher stage. This paper measures the advanced industrial structure by the increase in the proportion of high-productivity industries.

Industrial competitiveness is measured by the international competitiveness coefficient (Icc). The international competitiveness coefficient is the ratio of net exports to total trade, with a value range between -1 and 1. When the Icc value is closer to -1, it indicates weaker international competitiveness of the industry; when the Icc value is closer to 1, it indicates stronger international competitiveness.

3.1.4 Control Variables

In order to avoid the issue of omitted variables as much as possible, this paper sets the following six representative control variables that may affect economic resilience. At the same time, all control variables were logarithmized in order to mitigate problems such as heteroskedasticity and multicollinearity. (1) Urban economic density (*Ecden*), expressed as the ratio of gross regional product to urban land area. Regions with higher economic density can promote effective resource

aggregation and interaction, which can enhance the city's resilience when facing external shocks. (2) Market size (*Mar*), expressed in terms of population density. The market size effect may lead to an over-concentration of resources and economic activities, which may increase systemic risk when facing external shocks. (3) Education level (*Edu)*, expressed as the number of full-time teachers in ordinary higher education institutions. A high level of education develops people's innovative capacities, adaptability, and problem-solving skills, thereby enhancing their flexibility and resilience in the face of economic challenges. (4) Infrastructure level (*Infra*), expressed in terms of per capita road area. While digital infrastructure can increase productivity and convenience of economic operations, over-reliance on digital infrastructure can also increase systemic risk. (5) Government policy support (*Poli*), expressed in terms of general public budget expenditures. Government policy support enhances its ability to cope with external shocks and internal challenges through measures such as investing in infrastructure, promoting innovative technologies, and providing fiscal and monetary support. (6) Social security intensity (*Soci*), represented by the number of health-care institutions. The regional imbalances in the development of social security may have exacerbated regional development disparities, affecting the resilience and coordinated development of the economy system.

3.2 Model Setup

3.2.1 Basic Regression Model

The two-way fixed effects model effectively controls for individual-specific and time-specific unobserved factors, allowing us to focus more on the impact of time-varying variables on outcomes and enhancing the accuracy of estimation results. Additionally, the two-way fixed effects model is particularly suitable for panel data analysis, as it better captures the dynamic changes of variables. Therefore, this paper employs the two-way fixed effects model to test the impact of trade digitization on economic resilience (Hypothesis 1). The benchmark regression model is constructed as follows:

$$Res_{it} = \alpha_0 + \alpha_1 Digit_{it} + \alpha_n Control_{it} + \delta_i + \varphi_t + \varepsilon_{it} \quad (1)$$

Where *i* denotes the province, *t* denotes the year, *Res* denotes economic resilience level, *Digit* denotes trade digitization level, *Control* denotes each control variable, $\delta_i$denotes provincial fixed effects, $\varphi_t$denotes time fixed effects, and ε_{it}denotes the random error term.

3.2.2 Mediation Effect Model

The mediation effect model allows for the decomposition of the total effect into direct and indirect effects, facilitating a detailed analysis of how the explanatory variable influences the dependent variable through mechanism variables. To clarify the specific transmission mechanisms through which trade digitization affects economic resilience, this paper employs the mediation effect model to test whether technological innovation, industrial structure upgrading, and industrial competitiveness exhibit mediating roles. Given that the positive effects of technological innovation, industrial structure upgrading, and industrial competitiveness on economic resilience have been extensively validated (Cainelli et al., 2019; Zhang & Yao, 2023; Mourão & Popescu, 2023; Liu et al., 2024), the causal relationships are well-established. Consequently, building upon model (1), this paper constructs the mediation effect model (2) to examine the transmission pathways:

$$M_{it} = \beta_0 + \beta_1 Digit_{it} + \beta_2 Control_{it} + \delta_i + \varphi_t + \varepsilon_{it} \quad (2)$$

Among them, M_{it} is the mechanism variable, including technological innovation (*Tech*), industrial structure upgrading (*Ind*) and industrial competitiveness (*Icc*). The meanings and measures of other variables are consistent with model (1).

3.3 Data

According to the principle of data availability and completeness, this paper selects the panel data of 30 provinces in China from 2010 to 2023 as the sample. Hong Kong, Macao, Taiwan and the Tibet Autonomous Region are excluded from the research due to the large amount of missing data. The sample data comes from the National Bureau of Statistics, the National Annual Report of Technology Market Statistics, the *China Statistical Yearbook*, the *China Labor Statistical Yearbook*, the *China Science and Technology Statistical Yearbook*, the *China Information Industry Yearbook*, the *China Tertiary Industry Statistical Yearbook*, and provincial statistical yearbooks. Minor missing data are imputed using interpolation and predictive modeling methods. Table 3 presents the descriptive statistics of the variables.

Tab. 3 – Descriptive Statistics Source: own research

Type	Symbol	Variable	Obs	Mean	SD	Min	Max
Explained variable	*Res*	Economic resilience	420	0.232	0.114	0.077	0.674
Explanatory variable	*Digit*	Trade digitization	420	0.103	0.092	0.008	0.558
Mechanism variables	*Tech*	Technology innovation	420	1.000	1.056	0.034	8.782
	Ind	Industrial structure upgrading	420	13.710	6.245	3.692	39.500
	Icc	Industrial competitiveness	420	0.101	0.342	-0.757	0.792
Control variables	*Ecden*	Urban economic density	420	4.674	2.402	0.767	12.560
	Mar	Market size	420	8.971	0.623	7.194	10.220
	Edu	Education level	420	1.738	0.552	0.315	2.790
	Infra	Infrastructure level	420	2.747	0.376	1.396	3.332
	Poli	Government policy support	420	5.982	0.676	3.947	7.544
	Soci	Social security intensity	420	10.120	0.833	8.326	11.440

4 RESULTS

4.1 Benchmark Regression Results

This paper uses model (1) to examine the impact of trade digitization on economic resilience, and the regression results are shown in table 4. Columns (1)-(4) present the results of trade digitization on economic resilience and its three dimensions – resistance recovery ability (RR), regulating adaptive capacity (RA), and innovative transformation capacity (IT)– without the inclusion of control variables. Columns (5)-(8) show the results after the inclusion of control variables. After the inclusion of control variables, R^2 continues to increase, indicating that the model fit is getting better and better, which verifies the rationality of the control variables selected in this paper. Columns (1) and (5) show that the regression coefficients of *Digit* are significantly positive regardless of whether control variables are included or not, indicating that trade digitization has a significant positive promoting effect on economic resilience, which confirms Hypothesis 1. This conclusion is consistent with the research findings of Kong et al. (2024), who found that digital trade can enhance economic resilience by leveraging diversified risk sharing effects, global resource misallocation effects, and trade cost savings effects. Columns (2)-(4) and columns (6)-(8) show that regardless of whether control variables are included or not, the regression coefficients of *Digit* are significantly positive, indicating that trade digitization can enhance economic

resilience from three dimensions of the economic system's resistance recovery ability, regulating adaptive capacity, and innovative transformation capacity. In addition, by comparing the regression coefficients, it can be seen that *Digit* has the greatest promoting effect on IT, followed by RA and RR.

In terms of realistic economic reasons, the differential impact of provincial trade digitization on the three dimensions of economic resilience in China during the sample period stems from the timeliness and structural differences in the economic transmission mechanism. This difference essentially reflects the gradient effect of digital technology from efficiency improvement to system restructuring. First, digital technology promotes trade ecological innovation by accelerating knowledge spillover, reducing information costs and strengthening industrial chain synergy, thus significantly enhancing innovative transformation capacity of the economic system. For example, e-commerce platforms promote technology supply and demand matching and cross-border digital trade forcing technology upgrading, which benefit the innovative transformation dimension most significantly. Second, the regulating adaptive capacity of the economic system involves deep-seated institutional reforms and factor reorganization. The catalytic effect of digital technology on such long-term structural adjustments is evident, but with a lag. Finally, the real-time monitoring and multiple substitutability of digital supply chains enhance the resilience of the economic system to external shocks, enabling resistance recovery ability to benefit from the resilience of such digital trade networks, albeit with a certain lag.

Tab. 4 – Benchmark Regression Results Source: own research

Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
	Res	**RR**	**RA**	**IT**	***Res***	**RR**	**RA**	**IT**
Digit	0.649*** (4.69)	0.330** (2.64)	0.577*** (3.20)	0.789*** (3.75)	0.512*** (5.13)	0.295** (2.39)	0.432*** (3.12)	0.626*** (3.81)
Ecden	/	/	/	/	0.012*** (2.94)	0.015*** (2.93)	0.022*** (3.97)	0.005 (0.93)
Mar	/	/	/	/	-0.017 (-1.00)	-0.018 (-0.95)	-0.065*** (-3.10)	0.013 (0.60)
Edu	/	/	/	/	0.173*** (3.49)	-0.177*** (-2.78)	0.277*** (4.18)	0.213*** (2.92)
Infra	/	/	/	/	-0.042* (-1.82)	0.004 (0.20)	-0.050* (-1.76)	-0.051* (-1.84)
Poli	/	/	/	/	0.033 (1.62)	0.041 (1.66)	0.012 (0.33)	0.045* (1.83)
Soci	/	/	/	/	0.019 (0.42)	0.091 (1.04)	-0.051 (-0.80)	0.042 (0.65)
Constant	0.109*** (11.44)	0.205*** (21.22)	0.134*** (10.69)	0.064*** (4.85)	-0.306 (-0.77)	-0.538 (-0.62)	0.805 (1.39)	-0.929 (-1.43)

Province FE	YES	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES	YES
R^2	0.87	0.89	0.84	0.73	0.92	0.92	0.91	0.79

Note: ***, **, and * indicate significant at the 1%, 5%, and 10% levels, respectively. The values in parentheses are t-statistics.

4.2 Robustness Test

4.2.1 Substitution of the Explained Variable

On the one hand, referring to Ding et al. (2020), this paper uses the absolute change in regional GDP growth rate and the product of GDP growth rates in consecutive years as a proxy for economic resilience to conduct the regression analysis. The results are shown in column (1) of table 5. The regression coefficient of *Digit* is 1.300, and it has passed the significance test at the 5% level, indicating that trade digitization can significantly improve economic resilience. Thus, this confirms the robustness of the benchmark regression results in table 4. On the other hand, following Zhao and Wang (2021), this paper uses the unemployment rate as a proxy for economic resilience to conduct the regression analysis. The results are shown in column (2) of table 5. The regression coefficient of *Digit* is 18.958, and it has passed the significance test at the 1% level, indicating that trade digitization can significantly enhance economic resilience This further validates the robustness of the benchmark regression results.

Tab. 5 – Robustness Test Regression Results Source: own research

Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6) Phase I**	**(7) Phase II**
Digit	1.300** (2.17)	18.958*** (5.49)	0.095** (2.08)	0.650*** (8.89)			1.100*** (9.27)
L.Digit					0.550*** (5.08)		
Post						0.143*** （6.35）	
Constant	-0.650 (-0.14)	-9.910 (-0.24)	-2.263 (-0.91)	-0.537 (-1.25)	-0.410 (-1.03)	-1.147*** （-3.46）	0.313 (1.07)
Control variable	YES	YES	YES	YES	YES	YES	YES
Province FE	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES
R^2	0.28	0.55	0.94	0.94	0.91	0.91	0.95
Weak instrumental variables test						40.5355	

Note: ***, **, and * indicate significant at the 1%, 5%, and 10% levels, respectively. The values in parentheses are t-statistics.

4.2.2 Substitution of Measurement Method

This paper uses the principal component analysis (PCA) method as a substitute for the entropy method to re-measure the level of trade digitization and economic resilience, and then the regression was conducted again. The results are presented in column (3) of table 5. The results show that the regression coefficient of *Digit* is 0.095 and passes the significance test at the 5% level. This indicates that after replacing the measurement method, trade digitization still exhibits a significant enhancement effect on economic resilience, which proves that the benchmark regression results in table 4 are robust.

4.2.3 Delete Municipalities

Given that Beijing, Tianjin, Shanghai, and Chongqing, as municipalities directly under the central government, have significant advantages in terms of economic strength, industrial structure, human capital, infrastructure, policy environment, and institutional guarantees, and considering the potential issue of selection bias for model cities, which could affect the empirical results, this paper excluded these four municipalities from the sample and conducted a re-regression. The results are shown in column (4) of table 5. The findings demonstrate that the regression coefficient of *Digit* is 0.650, and it has passed the significance test at the 1% level, proving the robustness of the benchmark regression results in table 4.

4.2.4 Endogeneity Test

In order to reduce endogeneity errors that may result from bidirectional causality and omitted variables, it is necessary to conduct endogeneity tests. The impact of trade digitization on economic resilience may have a time lag. Therefore, the explanatory variables are regressed with one period lag (*L.Digit*) to test the impact of trade digitization in the previous period on economic resilience in the current period. The results are shown in column (5) of table 5. The results show that the regression coefficient of *Digit* is 0.550, and it has passed the significance test at the 1% level, indicating that trade digitization has an enhancing effect on economic resilience. This further confirms the robustness of the benchmark regression results in table 4.

Meanwhile, this paper refers to Zhu and Sun (2021) and uses the total amount of China's provincial postal and telecommunications business (*Post*) in 1984 as an instrumental variable for trade digitization. Considering that the sample is panel data, this paper utilizes the interaction term

between total post and telecommunications business and the number of Internet users as an instrumental variable.[3] The reason for choosing this instrumental variable is that trade digitization improves information and communication technology, which is a continuation of traditional communication technology; in the era of digital economy, the frequency of the use of traditional postal and telecommunication tools gradually decreases with the advancement of technology, and the influence on economic development is constantly weakening. Therefore, this instrumental variable meets the requirements of "relevance" and "exclusivity." On this basis, this paper uses 2SLS for regression. Columns (6) and (7) of table 5 show the results of the first and second stages, respectively. The regression coefficients of *Digit* on the total volume of postal and telecommunications business are 0.143 and 0.100 respectively, and both have passed the significance test at the 1% level. The above results indicate that, after considering endogeneity issues, the empirical results of this paper are robust.

4.3 Transmission Mechanism Test

4.3.1 Technological Innovation Effect Test

Column (2) in table 6 shows the regression results of technological innovation (*Tech*) as a mechanism variable. The results show that the regression coefficient of *Digit* on *Tech* is 6.424, and has passed the significance test at the 5% level, indicating that trade digitization can enhance regional economic resilience by stimulating technological innovation effects, which verifies Hypothesis 2. This is primarily because trade digitization in China promotes technological innovation by restructuring the allocation mechanism of innovation factors, which in turn enhances regional economic resilience. Firstly, digital trade creates demand for new technologies, forcing firms to increase R&D investment to form technological barriers. Technological innovation enhances resilience to price fluctuations through high-value-added products, and the stock of digital-native technologies establishes a first-mover advantage. Secondly, intelligent algorithms optimize R&D processes, transforming trade-related data into precise innovation directions and thereby improving R&D efficiency. Lastly, digital platforms break geographical constraints, facilitating cross-regional technological cooperation and knowledge spillovers, which reduce the marginal costs of corporate innovation. This transmission mechanism of "digitization-induced

[3] Since the number of internet users before 2014 is not recorded in the Statistical Yearbook, data on the number of internet users before 2014 was calculated using the ratio of the number of internet users in each year to the number of internet users in 2014, multiplied by the number of internet users in 2014.

innovation—innovation-enhanced resilience" enables regional economies to maintain dynamic adjustment capabilities when facing external shocks.

4.3.2 Industrial Structure Upgrading Effect Test

Column (3) in table 6 shows the regression results of industrial structure upgrading (*Ind*) as a mechanism variable. The results show that the regression coefficient of *Digit* is 19.307 and passes the significance test at the 1% level, indicating that trade digitization has a significant promoting effect on industrial structure upgrading. In other words, the advancement of trade digitization process can contribute to the gradual seniorization of industrial structure, thereby enhancing regional economic resilience and thus confirming Hypothesis 3. This is mainly because trade digitization in China promotes industrial structure upgrading by restructuring the production-distribution-innovation chain, which in turn enhances regional economic resilience. Specifically, first, this is attributed to the data-driven innovation effect. Trade big data feedback accelerates product iteration and drives the value chain to climb to high-value-added segments such as R&D design. Second, there is the technology penetration effect. Digital platforms break geographical and temporal constraints, facilitating the cross-regional flow of factors and forcing traditional industries to transform toward smart manufacturing and service-oriented manufacturing. Third, there is the network synergy effect. Digital trade infrastructure can reduce transaction frictions, enabling regions to embed themselves in elastic supply chain networks and form multidimensional risk resistance capabilities. This structural upgrading shifts regional economies from reliance on low-cost expansion to innovation-driven growth. By increasing industrial complexity and substitutability, it enhances regional economic resilience.

Tab. 6 – Regression Results of the Mechanism Test Source: own research

Variable	***Res*** **(1)**	***Tech*** **(2)**	***Ind*** **(3)**	***Icc*** **(4)**
Digit	0.512*** (5.13)	6.424** (2.54)	19.307*** (8.00)	-0.077* (-1.98)
Constant	-0.306 (-0.77)	-5.730 (-1.44)	-20.327 (-1.09)	-0.876 (-0.33)
Control variable	YES	YES	YES	YES
Province FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
R^2	0.92	0.72	0.88	0.06

Note: ***, **, and * indicate significant at the 1%, 5%, and 10% levels, respectively. The values in parentheses are t-statistics.

4.3.3 Industrial Competitiveness Effect Test

Column (4) in table 6 presents the regression results with industrial competitiveness (*Icc*) as the mediating variable. The results show that the regression coefficient of *Digit* is -0.077 and passes the significance test at the 10% level. This indicates that trade digitization has a significant negative effect on industrial competitiveness in the short term, thereby confirming Hypothesis 4. The reason for this may be that the technological substitution effect triggered by trade digitization creates a "competitiveness valley" in the early stages of transformation. Traditional industries' existing technological pathways struggle to quickly align with the digital ecosystem, leading to the erosion of their original competitive advantages. However, this is merely a frictional loss during the transition between old and new drivers within the industrial system. As Schumpeter emphasized, "creative destruction" inevitably involves the pain of dismantling old structures, but it also provides the necessary metabolic space for higher-order competitiveness restructuring in subsequent phases. Overall, while trade digitization poses challenges to industrial competitiveness in the short term, it enables the economic system to better cope with various uncertainties and achieve sustainable development in the long run.

In summary, trade digitization can promote regional economic resilience through various transmission mechanisms, such as stimulating industrial structure upgrading, promoting technological innovation, and temporarily suppressing industrial competitiveness. The theoretical basis of the research results in this paper is that trade digitization enhances the efficiency of resource allocation and reduces transaction costs, thereby promoting the improvement of technological innovation levels and the gradual upgrading of industrial structures, which in turn has a positive impact on regional economic resilience. This is consistent with the research findings of Chang et al. (2023), Eapen (2012), and Thompson et al. (2013), who argue that digitization can solve the difficult problem of balancing technological upgrading and efficiency improvement within industries by accelerating information flow and resource allocation, promoting technological innovation, reducing innovation costs and risks.

4.4 Heterogeneity Analyses

4.4.1 Regional Heterogeneity: East-Central-West Perspective

Due to the differences in economic strength, innovation capability, industrial foundation, and digital infrastructure across regions, the impact of trade digitization on regional economic

resilience varies heterogeneously. Therefore, this paper divides the sample into three major regions, eastern, central and western,[4] and conducts regression analyses for each to assess the heterogeneous effects across these regions. The results are shown in columns (1)-(3) of table 7. The results indicate that the regression coefficients of *Digit* in all three regions are all significantly positive, suggesting that trade digitization enhances economic resilience in each region. Comparing the coefficients reveals a distribution pattern of "central > eastern > western." This may be because that the central region, benefiting from its proximity to the more developed eastern provinces and the implementation of the "rise of the Central Region" strategy, is in a catch-up phase of trade digitization. This enables it to continuously expand its market space by integrating resources from both the eastern and western regions, thereby enhancing the marginal impact of trade digitization on economic resilience. Although the eastern region leads in digital infrastructure, its outward-oriented economic model makes its resilience more susceptible to global market fluctuations. The western region is constrained by lagging digital infrastructure and talent shortage, coupled with a single industrial structure, relatively weaker in enhancing its risk resistance through trade digitization.

Tab. 7 – Regional Heterogeneity Test Regression Results Source: own research

Variable	**Eastern (1)**	**Central (2)**	**Western (3)**	**Southern (4)**	**Northern (5)**
Digit	0.467*** (3.65)	0.605*** (5.43)	0.432*** (3.47)	0.602*** (7.33)	0.297*** (4.28)
Constant	-0.034 (-0.03)	-0.524 (-0.72)	-0.043 (-0.14)	0.841 (1.78)	-0.619 (-1.41)
N	154	112	154	210	210
Control variable	YES	YES	YES	YES	YES
Province FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES
R^2	0.93	0.97	0.95	0.96	0.93

Note: ***, **, and * indicate significant at the 1%, 5%, and 10% levels, respectively. The values in parentheses are t-statistics.

4.4.2 **Regional Heterogeneity: Southern-Northern Perspective**

Further analysis reveals that Xi (2019) explicitly pointed out that new situations and problems have emerged in China's regional economic development. The differentiation trend in regional

[4] The eastern region includes 11 provinces (municipalities): Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan. The central region includes 8 provinces: Shanxi, Jilin, Heilongjiang, Henan, Hubei, Hunan, Anhui and Jiangxi; and the western region includes 11 provinces (municipalities): Inner Mongolia, Chongqing, Sichuan, Guangxi , Guizhou, Yunnan, Shanxi, Gansu, Qinghai, Ningxia and Xinjiang.

economic development has become more evident, with the national economic center shifting further south. The development gap between the southern and northern regions is increasingly prominent. Therefore, this paper divides the samples into southern and northern provinces,[5] based on the Qinling–Huaihe Line, to further assess the regional heterogeneity of the impact of trade digitization on economic resilience. The results are shown in columns (4) and (5) of table 7. The results indicate that the regression coefficient of *Digit* in the southern region is 0.602, which is significantly higher than that in the northern region. This suggests that the intensity of the positive effect of trade digitization on economic resilience follows a distribution pattern of "southern > northern," indicating a significant regional heterogeneity. This may be because southern coastal provinces, such as Guangdong and Zhejiang, have built efficient digital trade chains by relying on high-density 5G networks, data centers, and cross-border e-commerce ecosystems. In contrast, the northern region still has a high proportion of traditional industries, strong path dependency, and a weak foundation for digital transformation, resulting in a "strong south and weak north" pattern in the enhancement of economic resilience by trade digitization.

4.4.3 Dimensional Heterogeneity

In order to further explore the heterogeneous effects of the three dimensions of trade digitization—digital infrastructure, digital market structure, and digital trade structure—on economic resilience, this paper conducts separate regressions using each dimension as an explanatory variable. The results are shown in columns (1)-(3) of table 8. The results indicate that the regression coefficients of the three dimensions are significantly positive, suggesting that digital infrastructure, digital market structure and digital trade structure can significantly enhance regional economic resilience. The intensity of their effects follows a distribution pattern of "DM > DI > DT." This may be due to the fact that the digital market structure reflects the degree of application of information and communication technology in the economy, and the expansion of the digital market can bring more business opportunities and market participants, thereby promoting economic growth and diversification. Economies with greater market size and scope are more likely to diversify risks and seek new growth opportunities when facing shocks. As the cornerstone of digital transformation, digital infrastructure can achieve the networked integration of government

[5] The southern region includes 15 provinces (municipalities): Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Hubei, Hunan, Guangdong, Guangxi, Hainan, Chongqing, Sichuan, Guizhou, and Yunnan; the northern region includes 15 provinces (municipalities): Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia, Liaoning, Jilin, Heilongjiang, Shandong, Henan, Shanxi, Gansu, Qinghai, Ningxia, and Xinjiang.

governance and economic operations, and enhances an economy's resilience to shocks by narrowing the digital gap between different regions. In addition, digital infrastructure provides a robust network support for the digital and intelligent transformation of the economic system, enabling the economy to exhibit a higher level of resilience when facing risks.

4.4.4 Economic Development Heterogeneity

The urbanization rate can reflect the level of regional economic development to some extent and the urbanization rate of economically developed regions is usually higher. To clarify whether the impact of trade digitization on economic resilience is affected by differences in the level of economic development, this paper takes the mean urbanization rate (0.60) as the benchmark and divides the sample into high urbanization rate group and low urbanization rate group to carry out the regression respectively. The results are shown in columns (4) and (5) of table 8. The results show that the regression coefficients of *Digit* for both groups are significantly positive, but the coefficient for the low urbanization rate group is larger, indicating that trade digitization has a stronger effect on enhancing economic resilience in regions with a lower urbanization rate. This is mainly because that high urbanization rates may lead to the widening of the urban-rural digital divide. That is, the gap between urban and rural areas in terms of digital technology applications and Internet access increases (Lioutas et al., 2021), thereby limiting rural area's participation in digital trade and enjoyment of the benefits brought about by the development of the digital economy.

Tab. 8 – Dimensional and Economic Development Heterogeneity Test Results Source: own research

Variable	**Dimensional heterogeneity**			**Economic development heterogeneity**	
	Res (1)	*Res* (2)	*Res* (3)	higher (4)	lower (5)
Digit				0.420*** (3.62)	0.671*** (7.65)
DI	0.352*** (6.74)				
DM		0.387*** (3.81)			
DT			0.130* (1.80)		
Constant	-0.330 (-0.83)	-0.386 (-0.94)	-0.874 (-1.35)	0.589 (0.83)	-0.326 (-0.65)
N	420	420	420	154	266
Control variable	YES	YES	YES	YES	YES

Province FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES
R^2	0.90	0.92	0.86	0.92	0.94

Note: ***, **, and * indicate significant at the 1%, 5%, and 10% levels, respectively. The values in parentheses are t-statistics.

4.4.5 Technological Innovation Heterogeneity

Considering that there may be differences in technological innovation levels across regions and industries, which could potentially interfere with the impact of trade digitization on economic resilience, this paper uses the mean of technological innovation (1.00) as the benchmark and divides the sample into a high-tech innovation level group and a low-tech innovation level group for regression. The results are shown in columns (1) and (2) of table 9. The results show that the regression coefficients for both groups of *Digit* are significantly positive, but the coefficient for the low levels of technological innovation group is larger, indicating that trade digitization has a stronger effect on improving economic resilience in regions with lower levels of technological innovation. From the perspective of path dependence, regions with lower levels of technological innovation may be in a stage of positive path dependency lock-in. This implies that the regional economy relies on existing industrial structures and organizations, which promotes the gradual strengthening of inter-industry connections and the continuous emergence of technological innovations, thereby driving economic development. At this stage, due to the strengthening of inter industry connections and the acceleration of innovation spillovers, the adaptability of the regional economic system gradually improves, thereby strengthening the economic resilience of the region.

Tab. 9 – Mechanism Variable Heterogeneity Test Results Source: own research

Variable	**Technology innovation heterogeneity**		**Industrial structure upgrading heterogeneity**		**Industrial competitiveness heterogeneity**	
	higher (1)	lower (2)	higher (3)	lower (4)	higher (5)	lower (6)
Digit	0.263* (2.07)	0.376*** (3.60)	0.417** (3.18)	0.643*** (6.87)	-0.042 (-0.89)	-0.185** (-2.32)
Constant	-1.751 (-1.36)	0.410 (0.95)	-1.690 (-2.27)	-0.074 (-0.19)	3.617 (1.41)	-13.495** (-3.05)
N	154	266	140	280	266	154
Control variable	YES	YES	YES	YES	YES	YES
Province FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
R^2	0.94	0.94	0.92	0.94	0.10	0.20

Note: ***, **, and * indicate significant at the 1%, 5%, and 10% levels, respectively. The values in parentheses are t-statistics.

4.4.6 Industrial Structure Upgrading Heterogeneity

Industrial structure upgrading can significantly improve the resilience level of the local economy, but it may also negatively impact the economic resilience of neighboring areas through spillover effects (Yin et al., 2023). This suggests that industrial structure upgrading is a "double-edged sword" for regional economic resilience. Therefore, to clarify whether the impact of trade digitization on economic resilience is affected by differences in the level of industrial structure upgrading, this paper uses the mean level of industrial structure upgrade (13.71) as the benchmark and divides the sample into a high industrial structure upgrade level group and a low industrial structure upgrade level group. The results are shown in columns (3) and (4) of table 9. The results indicate that in regions with lower levels of industrial structure upgrading, trade digitization has a greater promoting effect on economic resilience. This may be because in regions with lower industrial structure upgrading, industries themselves may rely more on resources or labor, and technological innovation and digital transformation can bring new production methods and efficiency improvements to these industries, thereby significantly enhancing their economic resilience. Additionally, one of the main channels through which digital trade enhances economic resilience is the development effect of new economic sectors (Kong et al., 2024). In regions with lower industrial structure upgrading, digital trade may be more conducive to promoting the development of new economic sectors, providing new impetus for economic growth and enhancing the adaptability and resilience of the economic system.

4.4.7 Industrial Competitiveness Heterogeneity

In the context of a complex and volatile global trade environment, the heterogeneity of industrial competitiveness has become increasingly significant in its impact on economic resilience. In order to clarify the differential effects of trade digitization on economic resilience under different levels of industrial competitiveness, this paper divides the sample into high-level and low-level groups based on the average industrial competitiveness (0.10). The results are shown in columns (5) and (6) of table 9. The findings indicate that in regions with lower industrial competitiveness, trade digitization has a significant negative impact on economic resilience, while in regions with higher industrial competitiveness, the effect of trade digitization on economic resilience is not significant. This phenomenon stems from the digital capability gap between regions, which leads to

differentiated distribution of technological dividends, as well as differences in technological absorption capacity and transformation costs (Pang & Wang, 2023). In regions with lower industrial competitiveness, traditional industries dominate, and the technological foundation is weak. The digital transformation of trade may trigger a dual squeeze effect of excess low-end capacity and unsustainable investment in digital transformation. This misallocation of resources weakens the stability of local industrial chains and amplifies the impact of external shocks on the economic system. In contrast, in regions with higher industrial competitiveness, mature industrial support and innovation ecosystems form a buffer zone. As a result, trade digitization is more likely to manifest as efficiency improvements rather than structural disruptions, thus having limited marginal enhancement on economic resilience.

5 DISCUSSION

5.1 Research Contributions

Currently, theoretical research on trade digitization and economic resilience is rapidly developing, but direct studies on how trade digitization affects economic resilience remain scarce. Existing relevant research primarily focuses on four aspects. First, the impact of digital infrastructure on economic resilience. Most studies suggest that digital infrastructure enhances regional economic vitality and resilience by upgrading industrial structures and improving innovation efficiency (Yan & Guo, 2023), reducing communication costs, and simplifying redundant processes (Zhang et al., 2023). It also strengthens agricultural economic resilience by upgrading production equipment and promoting digital agriculture (Wang et al., 2023). Some research also indicates that new infrastructure construction provides a platform for knowledge spillover and the breakthrough of key core technologies (Chao & Xue, 2023), and promotes regional integration, industrial upgrading, and innovation vitality (Zhong et al., 2023), thereby enhancing economic resilience. Second is the impact of industrial digitization on economic resilience. Most studies suggest that industrial digitalization breaks spatial and geographical barriers (Fahmy, 2021), facilitates efficient resource allocation and market expansion (Chen, 2024), and enhances regional economic resilience through the integration of digital technologies with traditional industries (Dai & Liu, 2022). Some studies also find that industrial digitalization accelerates product innovation (Wang & Yang, 2024) and promotes industrial chain collaboration and the expansion of industrial scale (Han et al., 2023), thereby strengthening regional economic resilience. Third is the impact of digital technologies on economic resilience. Internet-based digital technologies strengthen

economic resilience by empowering government governance, improving economic efficiency, and enhancing information transparency (Hu & Mao, 2023). Research also finds that Internet technology reduces enterprise information costs, management costs, and transaction costs (Gu et al., 2023), and promotes technological innovation by alleviating information asymmetry, facilitating knowledge spillover, and accelerating information flow (Chen et al., 2024), thereby improving the adaptability and flexibility of industries and ultimately enhancing the ability of the economic system to cope with shocks. Fourth is the impact of digital trade on economic resilience. Studies have found that digital trade can enhance regional economic resilience by leveraging digital technology and digital platforms to diversify risks and optimize resource allocation (Kong et al., 2024). Additionally, digital trade reform enhances urban economic resilience by promoting the digital and intelligent transformation of traditional trade (Wang & Wang, 2024).

Thus, existing studies primarily explore the issue of economic resilience from four themes closely related to trade digitization: digital infrastructure, industrial digitalization, digital technology, and digital trade. And, it has propelled the development of theories related to trade digitization and economic resilience and broadened the research boundaries of the relationship between the two. The conclusions provide valuable references for the study of this paper. However, the mechanisms and effects through which trade digitization impacts economic resilience remain ambiguous. Compared with existing research, the contributions of this paper are mainly reflected in the following four aspects. First, considering the digital demand for economic resilience stimulated by the deep integration of digital trade into the economic system, this paper incorporates trade digitization into the scope of factors influencing economic resilience. It extends the research on the impact of trade digitization on economic resilience by analyzing the theoretical mechanisms. Second, based on the connotations of trade digitization and economic resilience, this paper constructs an indicator system to measure these concepts more scientifically. It builds a bridge from theoretical analysis to practical implementation. Third, by using technological innovation, industrial upgrading, and industrial competitiveness as mediating variables for empirical testing, this paper reveals the transmission mechanisms through which trade digitization enhances economic resilience, enriching the research on the mechanisms of this impact. Fourth, this paper also conducts heterogeneity analyses from six aspects: regional differences, dimensional differences, economic development differences, technological innovation differences, industrial upgrading differences, and industrial competitiveness differences. It uncovers the real-world reasons for the heterogeneous effects of trade digitization on regional economic resilience.

5.2 Practical Significance

Against the backdrop of global economic challenges such as trade protectionism, anti-globalization, and supply chain disruptions, as well as China's "triple pressures" of transitioning between old and new growth drivers, contracting demand, supply shocks, and weakening expectations, this paper investigates the relationship between trade digitization and regional economic resilience, as well as the mediating effects of technological innovation, industrial structure upgrading, and industrial competitiveness. The research findings provide a scientific measurement framework for trade digitization and economic resilience levels, along with valuable insights into how the digital transformation of trade significantly enhances regional economic resilience.

First, the study reveals that China's provincial trade digitization and economic resilience levels have demonstrated a steady upward trend, with trade digitization significantly enhancing regional economic resilience. This finding confirms a robust positive correlation between trade digitization and economic resilience. It provides the following key practical guidance for regional economic development, First, it offers a scientific basis and decision-making reference for continued investment in the construction of digital infrastructure, such as cross-border e-commerce platforms and intelligent logistics systems. Second, it emphasizes the need to implement differentiated policies. Developed regions should focus on original research and development of digital technologies, while areas with weaker industrial foundations need to prioritize the digital transformation of traditional industries and the cultivation of digital talent. Ultimately, economic resilience can be enhanced through phased development. Third, a transformation compensation mechanism should be established to alleviate the transition pains of vulnerable groups through digital skills training and tax incentives.

Second, the study finds that technological innovation and industrial structure upgrading play a positive mediating role in the impact of trade digitization on regional economic resilience, while industrial competitiveness exerts a negative mediating effect. These findings offer important practical guidance for policymakers. First, there should be a focus on strengthening the transmission effects of technological innovation and industrial upgrading, such as by establishing collaborative innovation centers for digital and industrial sectors to transform cross-border e-commerce data flows into production improvement measures. Second, the "digital enclave" model should be explored, supporting less developed regions in setting up joint innovation centers in

more developed areas to achieve synchronized progress in technology acquisition and industrial upgrading. Third, for regions with weak industrial competitiveness, measures such as cultivating local digital service providers should be implemented to strengthen the foundation and prevent blind access to global digital networks from exacerbating the risk of low-end lock-in.

Then, the study finds that the impact of trade digitization on economic resilience exhibits significant heterogeneity across the eastern, central, and western regions, as well as between the southern and northern areas, with the promoting effect of trade digitization following a distribution pattern of "central > eastern > western" and "southern > northern." These findings offer practical guidance for implementing a gradient-based trade digitization transformation strategy. First, the central region should leverage its manufacturing foundations to construct regional digital supply chain platforms and amplify agglomeration effects through digital collaboration along the industrial chain. Second, the eastern regions, such as the Yangtze River Delta and the Pearl River Delta, should establish special programs for digital technology breakthroughs and promote rule-oriented openness to avoid redundant low-end digital investments. Third, the western region needs to implement a "digital infrastructure plus" strategy in line with its resource endowments, strictly assess the compatibility of projects with local industries, and prevent idling and waste of data centers. Fourth, the southern region should expand digital empowerment of the private economy and pilot cross-border circulation rules for data elements to strengthen market-driven advantages. Fifth, the northern region needs to actively promote the digital and intelligent mixed-ownership reform of state-owned enterprises and establish digital compensation funds for resource-based cities to break free from institutional inertia.

Finally, the research results indicate that the positive impact of trade digitization on economic resilience is more pronounced in regions with lower levels of economic development, technological innovation, and industrial structure upgrading, while it turns into a negative effect in regions with weaker industrial competitiveness. These findings offer important practical guidance for addressing the "digital paradox." First, regions with relatively weaker economic development, technological innovation, and population density, such as the northwest, should implement a "digital infrastructure plus" strategy. This involves integrating the layout of digital infrastructure with characteristic industrial parks and enhancing technological absorption efficiency through scenario-based applications. Second, regions with weak industrial competitiveness should establish a digital access assessment mechanism. For example, before promoting digital projects such as cross-border e-commerce, priority should be given to cultivating

a digital service provider ecosystem rather than directly driving corporate transformation. Third, a regional digital resilience index should be developed to closely monitor key indicators such as the input-output ratio of data elements, changes in the profit margins of traditional industries, and deviations between the penetration rate of digital technologies and local employment structures. Immediate intervention measures should be initiated once any abnormal indicator is detected.

This paper elucidates the close relationship between trade digitization and regional economic resilience from a theoretical perspective, thereby enriching their theoretical knowledge system of both. The findings of this paper highlight the critical role of trade digitization transformation in enhancing regional economic resilience, demonstrating the regions or nations can strengthen their economic systems' capacity to withstand risks amid evolving trade environments, technological revolutions, and industrial transformations by leveraging the potential of trade digitization. Meanwhile, it deepens our understanding of how trade digitization affects regional economic resilience and provides empirical evidence for the role of trade digitization in enhancing regional economic resilience. Additionally, the conclusions offer valuable insights for trade practitioners, economic policymakers, and implementers in designing and executing digital trade strategies. In summary, the conclusions of this paper not only can provide ideas and references to promote digital transformation of trade and empower regional economic resilience, but also provide new empirical evidence and valuable references for countries around the world, especially developing countries, to promote trade liberalization and sustainable economic development.

5.3 Shortcomings and Research Prospects

This paper still has some limitations. First, due to limitations in data availability, we are unable to conduct research at the micro-level, such as counties and enterprises. Therefore, we cannot derive more micro-level results, nor can we conduct comparative studies between China and other countries simultaneously. Second, there may still be certain limitations in the time span and spatial scope of the data. When constructing the index system for trade digitization, limitations in data availability restricted the inclusion of more representative indicators, leaving room for improvement in this index system. Finally, in the context of the digital age, the relationship between trade digitization and regional economic resilience may also be influenced by many other factors, such as institutional environment, market efficiency, cultural differences, and variations in policy environment. Given the focus and scope of this paper, we have not included more variables in our analysis. In future research, we can explore the impact of trade digitization on

economic resilience from both the micro-levels such as counties and enterprises and the macro-levels such as major world economies. At the same time, we should try to expand the time span of the sample to observe the long-term changes in the relationship between trade digitization and economic resilience. Additionally, future research should include more valuable indicators and influencing factors in the analysis.

6 CONCLUSIONS

Faced with the complex and volatile global trade environment and numerous challenges, clarifying the impact of trade digitization on regional economic resilience in China can provide new empirical evidence and valuable references for countries around the world, especially developing ones, in promoting trade liberalization and economic sustainability. Based on a constructed indicator system, this paper employs the entropy method to measure and analyze the levels of trade digitization and economic resilience in 30 provincial regions of China using panel data from 2010 to 2023. Additionally, this paper explores the impact of trade digitization on regional economic resilience and its heterogeneous effects, as well as the mediating roles of technological innovation, industrial structure upgrading, and industrial competitiveness, from both theoretical and empirical perspectives. The findings are as follows. First, the levels of trade digitization and its three dimensions—digital infrastructure, digital market structure, and digital trade structure—in China's provincial regions all showed a steady upward trend from 2010 to 2023. Second, the levels of regional economic resilience and its three dimensions—resistance recovery ability, regulating adaptive capacity, and innovative transformation capacity—also exhibited a gradual upward trend. Third, trade digitization significantly enhanced regional economic resilience at both the 30 provincial regions level and across the eastern, central, and western regions, as well as the southern and northern areas. Fourth, technological innovation, industrial structure upgrading, and industrial competitiveness played mediating roles in the positive impact of trade digitization on economic resilience. Fifth, the positive impact of trade digitization on economic resilience is more pronounced in regions with lower levels of economic development, technological innovation, and industrial structure upgrading, while it turns into a negative effect in regions with weaker industrial competitiveness.

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