ISSN: 2688-9323

Digital Technology, Regional Economic Resilience and Income Disparities

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Abstract

Using panel data from China's first- and second-tier cities spanning from 2013 to 2021, this study empirically investigates the relationship between digital technology and income disparity through panel fixed-effects and mediation effects models. The findings reveal that the impact of digital technology on income disparity follows a U-shaped pattern, initially narrowing the income gap before subsequently widening it. Additionally, regional economic resilience is found to fully mediate the relationship between digital technology and income disparity. Geographic heterogeneity analysis shows that the effect of digital technology in narrowing the income gap is most pronounced in the western region, weaker in the central and eastern regions, and least significant in the northeastern region.

Keywords

Digital Technology; Regional Economic Resilience; Income Gap; Mediation Effect.

1. Introduction

Since the 18th National Congress of the Communist Party of China, the nation's economic strength has achieved a historic leap, leading to a comprehensive improvement in living standards and a gradual enhancement in income distribution among residents. Although disparities between the rich and poor persist, the income gaps between urban and rural areas, regions, and different demographic groups have generally narrowed. Statistics indicate that from 2013 to 2022, the average annual growth rate of per capita disposable income for rural residents was 8.8%, surpassing that of urban residents by 1.7 percentage points. Consequently, the urban-rural per capita disposable income ratio declined from 2.82 in 2013 to 2.45 in 2022. In his report to the 20th Party Congress, General Secretary Xi Jinping emphasized the need to "regulate the order of income distribution and the mechanism for accumulating wealth" and to "encourage hard work to become rich, and promote fairness of opportunity." Currently, optimizing income distribution under the goal of common prosperity has become a significant topic. Addressing issues of unbalanced and inadequate development, narrowing urban-rural development gaps, and achieving comprehensive human development and common prosperity for all remain long-term challenges.

According to the *Report on the Development of Digital Economy in China's Regions and Cities*, the world is undergoing a new wave of scientific and technological revolution alongside industrial transformation, marking the full advent of the digital economy era. In China, the rapid development of the digital economy not only fosters the deep integration of information technology with traditional industries but also significantly contributes to nationwide economic growth. Presiding over the 34th collective study session of the Political Bureau of the 19th Central Committee, General Secretary Xi Jinping emphasized that "In today's era, digital technology and the digital economy are at the forefront of the global scientific and technological revolution and industrial transformation, serving as key areas in the new round of international

ISSN: 2688-9323

competition. We must seize the first opportunity and the commanding heights of future development." Against this backdrop, investigating the impact of digital technology on income distribution has become particularly critical. Digital technology not only reshapes economic operations and enhances productivity but also profoundly influences labor markets and social structures. This is especially evident in China's first- and second-tier cities, where the digital economy has become a driving force for industrial upgrading and innovation[11]. However, digital technologies may also pose potential social challenges, particularly in income distribution, as the wealth-aggregation effect and the trend of automation could exacerbate income disparities[22].

"In recent years, regional economic resilience has emerged as a critical mechanism for addressing economic shocks and inequality, becoming a prominent research topic in academia. In 2015, proposed that regional economic resilience not only refers to an economy's ability to recover after external shocks but also encompasses its capacity to adapt and reallocate resources[2] [14]. Highly resilient regions can achieve structural optimization, transformation, and upgrading following economic crises through innovation and resource reallocation, thereby mitigating economic inequality[16]."

"Studying the relationship between digital technology, regional economic resilience, and income distribution is of significant importance in the current context. On one hand, digital technology has injected innovative momentum into traditional economic development, driving income growth for certain segments of the population[4] [5]. On the other hand, the uneven application of technology may pose a risk, as some workers may experience income reductions due to skill substitution. In this process, regional economic resilience plays a mediating role. More resilient regions can effectively mitigate the widening of income gaps by adapting more quickly to technological change and optimizing resource allocation. Conversely, less resilient regions may be more vulnerable to technology-induced income inequality. Therefore, a comprehensive analysis of the mechanisms through which digital technology influences income disparity, as well as the mediating effect of regional economic resilience, will not only enhance our understanding of the social stratification caused by technological progress but also provide a scientific foundation for policymaking aimed at promoting equitable income distribution while fostering the development of the digital economy. Thus, the core question of this study is: How does digital technology affect income disparity? Specifically, this paper will address the following questions: 1. Does digital technology have a non-linear impact on income disparity? 2. Does regional economic resilience play a moderating role in the mechanism through which digital technology affects income disparity?"

2. Literature Review

2.1. Studies on the Impact of Digital Technology on Income Disparity

The academic community has not reached a consensus on the definition of digital technology, and different studies offer varying perspectives based on their research objectives. Some define digital technology primarily as information and communication technology (ICT) [3], while others consider key components such as big data, blockchain, the Internet of Things (IoT), and cloud computing as essential elements of the digital technology framework [25]. According to the White Paper on the Development of China's Digital Economy(2020), digital technology includes the telecommunications industry, the electronic information manufacturing sector, the software and information technology services industry, the Internet, and related service sectors.

The impact of digital technologies on income disparities has been widely debated. While some scholars argue that digital technologies have helped reduce the income gap by facilitating access to education, healthcare, and financial services at lower costs, thereby increasing social

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mobility, others contend that these technologies may exacerbate social inequality. For instance, digital technology accelerates the sharing of resources, enabling low-income individuals to access essential services, thus narrowing the income gap between different groups [1]. However, introducing a non-linear perspective has revealed that the development of the digital economy exhibits a U-shaped relationship with the income gap between urban and rural populations [7][8][9]. On the other hand, some researchers argue that the spread of information technology may increase social inequality, particularly in terms of access to technology. The digital divide created by unequal access to information technology has hindered urban-rural integration and contributed to the widening income disparity between urban and rural residents [20].

2.2. Digital Technology, Regional Economic Resilience, and Income Disparity: Related Studies

Regional economic resilience refers to a region's ability not only to recover swiftly from economic shocks but also to enhance its long-term development capacity through adaptation, innovation, and the reconfiguration of resource allocation. Domestic theoretical research on regional economic resilience has become increasingly mature. However, the measurement of regional economic resilience within the academic community relies on different indicators and standards. In the Fifth Plenary Session of the 19th Central Committee of the Communist Party of China, the concept of resilient cities was introduced for the first time. The Resilient City Research Center of Zhejiang University proposed a theory of resilient cities, encompassing four dimensions: technology, organization, society, and economy. Supported by policy theories, several scholars have conducted research on the indicators of urban economic resilience[24].

The advancement of digital technology has significantly improved production efficiency and resource allocation, thereby enhancing the efficiency of production and service processes. Studies have shown that digital connections reduce geographical barriers, promote the efficient circulation of the inter-regional economy, and contribute to the balanced development of regional economies [19][18]. From a financial perspective, it has been found that the development of digital finance positively impacts the resilience of China’s regional economy [13]. Regarding technological innovation, digital technological innovation indirectly enhances urban economic resilience through improvements in urban industrial structure, total factor productivity, and urban innovation and entrepreneurship activities [15]. In conclusion, the development of digital technology plays a crucial role in enhancing regional economic resilience and achieving balanced development.

In summary, existing studies have provided initial insights into the mechanism by which digital technology impacts income disparity and the potential role of regional economic resilience in this process. The marginal contributions of this paper are as follows: (1) This paper integrates the mediating variable of regional economic resilience to examine in-depth how digital technology influences income distribution through regional economic resilience; (2) This study identifies a U-shaped non-linear relationship between digital technology and income disparity. Specifically, when the level of technology is low, technological progress helps narrow the income gap. However, once the technology level reaches a certain threshold, it may exacerbate income inequality. Notably, most of China's first- and second-tier cities are currently in the stage of narrowing the income gap; (3) While most existing studies focus on the provincial level, this paper organizes and empirically tests the relevant indicators at the prefecture and municipal levels; (4) Methodologically, this paper employs a city-level fixed-effects multiple regression model and instrumental variable approach, conducting robustness tests to ensure the reliability of the results and provide a more robust analytical framework.

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3. Mechanism by Which Digital Technology Affects the Income Gap of the Population

3.1. The Direct Impact of Digital Technology on Income Disparity

Digital technologies impact income disparity by increasing productivity, improving resource allocation, expanding employment opportunities, and promoting education and skills training, thereby providing more opportunities for low-income groups and directly affecting income distribution equity. First, the application of digital technology can significantly improve the productivity and resource allocation efficiency across various industries [19]. This creates more value for enterprises and offers higher value-added employment opportunities for workers. While productivity increases, some traditional industries may reduce low-skill jobs. However, the rise of high-tech industries and the digital economy, driven by digital technology, offers diversified employment options for workers at different skill levels, gradually narrowing the income gap between various income groups. A prime example is Alibaba's "Taobao Village" model, where residents in rural areas have seen a substantial increase in income by accessing global markets through e-commerce platforms [21].

Second, digital platforms-such as e-commerce, sharing economy, and online education platforms-offer low-income groups accessible employment and entrepreneurial opportunities. These platforms not only reduce the cost of starting a business but also provide diversified employment opportunities for individuals with different skill levels, allowing more people to generate income through online platforms [18]. Particularly in remote areas and among low-income groups, the platform economy can overcome geographical barriers and facilitate income growth, thus narrowing the income gap. Additionally, online education powered by digital technology provides high-quality educational resources to low-income groups, particularly those in rural areas [13]. Through online education platforms, low-income individuals, especially in rural and impoverished areas, can access quality educational resources, enhance their knowledge and vocational skills, and improve their chances of obtaining better employment opportunities. Furthermore, the application of digital technology in social security systems facilitates easier access to government assistance for the poor, improving their quality of life and further narrowing the income gap[10] [12]. To illustrate their interrelationship, a scatter plot is presented in Fig. 1, which shows a U-shaped curve. This indicates that the development of digital technology has a non-linear effect on income, characterized by a pattern of "initial decline followed by an increase."

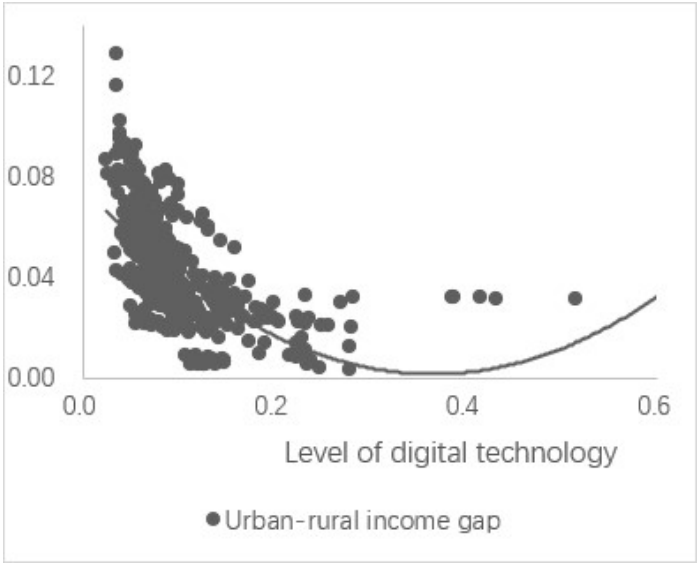

Fig. 1 Impact of Digital Technology on Income Disparity

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Hypothesis 1: Through its direct impact, the development of digital technology can reduce the income gap.

3.2. Indirect Effects of Digital Technology on Income Disparity

Regional economic development is often marked by volatility, particularly in response to external shocks and policy changes. The adoption of digital technologies has mitigated these challenges and enhanced regional economic resilience. First, digital technology lowers transaction costs by improving information transparency and resource allocation efficiency, thereby making inter-regional resource flows more efficient and strengthening the resilience of regional economies. Digital innovation not only fosters the upgrading of traditional industries but also spurs the development of new sectors. For instance, in Guangdong Province, digital transformation has enabled the traditional manufacturing industry to evolve into a high-value-added smart manufacturing sector, significantly improving its capacity to withstand external economic shocks. Second, digital platforms have enhanced the flexibility and adaptability of the labor market. A prime example of this is the "Taobao Village" in Yiwu, Zhejiang Province, where residents have successfully transitioned from traditional retail to Internet-based e-commerce through an e-commerce platform. This shift has not only increased their income levels but also bolstered the resilience of the local economy. The enhanced resilience of the regional economy has allowed low-income groups to restore their income sources more quickly, thereby narrowing the income gap between different groups. Finally, digital technology, through the use of big data and artificial intelligence, enables governments to more accurately identify poverty-stricken individuals and optimize resource allocation. This enhances the reach and effectiveness of social security and welfare programs. By implementing digitized, precision-targeted poverty alleviation measures, the government can effectively alleviate the living pressures on low-income groups and promote social equity. As regional economic resilience increases, the government can more efficiently deploy resources through digitization, promoting income redistribution, improving the economic conditions of low-income groups, and ultimately narrowing the income gap.

Hypothesis 2: The development of digital technology can enhance regional economic resilience, and through the mediating effect of regional economic resilience, digital technology can indirectly reduce income disparity.

3.3. Regional Economic Resilience and Income Disparities

The impact of regional economic resilience on income disparity is evident in several ways. A resilient economic system can help stabilize incomes for low-income groups and reduce income inequality by enhancing their ability to withstand risks, promoting coordinated regional economic development, facilitating industrial upgrading, increasing labor market flexibility, and providing targeted social protection. Regional economic resilience, driven by digital technology and innovation, can offer greater economic opportunities and social support for various groups, while fostering economic recovery. In doing so, it helps narrow income gaps and promotes more equitable and inclusive social development.

Hypothesis 3: Increased regional economic resilience can reduce income disparities.

4. Research Methodology

4.1. Sample and Data Sources

This study uses panel data from China's first- and second-tier cities for the period 2013-2021. The data sources include the cities' annual statistical yearbooks, the National Bureau of Statistics, and relevant databases. The selection of this time frame and city-level data allows for a more accurate analysis of the impact of digital technology on regional income distribution. During this period, the digital economy experienced rapid growth in Chinese cities, with first-

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and second-tier cities leading in the adoption of digital technologies. This provides a robust basis for in-depth causal analysis.

4.2. Variables and Modeling

The explanatory variable is the income gap, measured by the Theil index. This paper primarily examines the impact of digital technology on the income gap. Various indicators can measure income inequality, but given the data characteristics, the Theil index is selected to quantify income disparity within cities.

$$Theil_{it} = \sum_{j=1}^{2} \left(\frac{I_{it,j}}{I_{it}} \right) \times Ln \left[\left(\frac{I_{it,j}}{P_{it,j}} \right) \Big/ \left(\frac{I_{it}}{P_{it}} \right) \right] \quad (1)$$

Where t denotes the year, i represents different municipalities, I denotes income, P represents population size, j takes the values 1 (urban area) and 2 (rural area). $I_{it,1}$ represents the disposable income of urban residents in municipality iii in year t, and $I_{it,2}$ represents the disposable income of rural residents in the same municipality and year. I_{it} is the total disposable income of all residents in municipality iii in year t, and P_{it} denotes the total population of municipality iii in year t.

There are three primary methods for measuring the level of digital technology. The first method is based on the OECD input-output table. Many scholars have used the proportion of technological inputs and outputs from various industrial sectors to assess the level of digital technology application. For example, Fu Qingwei (2022) found through input-output analysis that digital technology inputs significantly contributed to the productivity improvement of the manufacturing industry [25]. Fan Shicheng and Niu Rui (2024) used a factor-level digital input measurement approach based on China's input-output table. By analyzing direct consumption and full consumption coefficients, they were able to assess the level of digital technology [7].

The second method involves constructing an indicator system, which is commonly used to capture the characteristics of different stages of technological innovation and diffusion. Zhao Tao et al. (2020) measured the level of digital technology development using four dimensions: digital technology innovation, digital technology scale, digital technology application, and digital technology users [23].

The third method utilizes Internet development indicators, where Internet sales in each region serve as a measure of the extent of digital technology usage. Additionally, Zhao Haiyi employed keyword searches related to digital technology and used the proportion of keyword frequency to total keyword frequency to gauge the level of digital technology in each province [17]. This approach led to the conclusion that digital technology can reduce the income gap between urban and rural residents.

To effectively measure the level of digital technology development at the city level, this study establishes an indicator system that considers three key aspects: digital infrastructure, digital technology transformation and upgrading, and digital technology innovation. The entropy weighting method is then employed to assess the level of digital technology development across 42 first- and second-tier cities, capturing the degree of penetration and application of digital technology in each city. The specific indicators used are presented in Table 1.

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Table 1. Three Scheme comparing

Level 1 indicators	Secondary indicators	causality
Digital technology innovation	Digital technology patents granted per 10,000 people R&D expenditure as a share of GPT	Forward Forward
Digital technology infrastructure	Internet users per 100 population Cell phone subscribers per 100 population Total telecommunication services per capita	Forward Forward Forward
Digital technology transformation and upgrading	China Digital Inclusive Finance Index Percentage of employees in computer services and software	Forward Forward

Table 2. Regional Economic Resilience Indicators

Level 1 indicators	Secondary indicators	Tertiary indicators	Indicator weights	Indicator properties
		Gross regional product per capita (yuan)	0.0467	forward
		Disposable income of urban residents (yuan)	0.0208	forward
	Resistance and Resilience	Savings balance of urban and rural residents (yuan)	0.001	forward
		Number of urban registered unemployed (persons)	0.1096	negative direction
		Total exports and imports as a share of GDP (%)	0.0022	negative direction
		Local fiscal balance ratio (%)	0.0237	forward
		Total retail sales of social consumption (million yuan)	0.0959	forward
Urban economic resilience	Adaptive and regulatory capacity	Share of tertiary sector in GDP (%)	0.0072	forward
		Deposit and loan ratio of financial institutions at the end of the year (%)		
			0.0232	forward
		Investment in fixed assets (million dollars)	0.0839	forward
		Number of patents granted (pieces)	0.1826	forward
	Transformation and development capacity	Number of students enrolled in general higher education institutions (persons)	0.0864	forward
		Expenditures on fiscal science (in millions of dollars)	0.0812	forward
		Financial education expenditure ($ million)	0.2357	forward

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Mediating Variable: Regional Economic ResilienceBuilding on the theory of regional economic resilience, several scholars have investigated urban economic resilience indicators. Xie Hongji (2022) examined the economic resilience of 30 provincial capitals (and municipalities directly under the central government) through four dimensions: economic development, economic diversity, economic innovation, and economic recovery. Huixian He (2024) assessed urban resilience based on four factors: economic resilience, ecological resilience, social resilience, and infrastructure resilience. Chen Jianfu and Deng Junjie (2024) developed indicators across three dimensions: economic resilience, economic regulation, and economic innovation.

In this paper, we construct a multidimensional index system for regional economic resilience, drawing on the theoretical framework and research of Zhang Liao and Yao Lei (2023). The system encompasses three key dimensions: resistance and resilience, adaptation and adjustment, and transformation and development (see Table 2). The entropy method is applied to calculate the comprehensive index of urban economic resilience.

To mitigate the influence of other factors, we include several control variables that may affect the income gap. These variables primarily include: the level of economic development (PGDP), the proportion of foreign direct investment (FDI), the proportion of local fiscal expenditure (LFE), the number of students enrolled in higher education per 10,000 people (ISE), and per capita land area (PLA).

Table 3. Regional Economic Resilience Indicators

Form	Variable Name	Variable Measurement	on average	(statistics) standard deviation	Number of observations
explanatory variable	digital technology	Level of digital technology	0.1038	0.0685	432
intermediary variable	digital technology	Level of digital technology	0.1038	0.0685	432
explanatory variable	Urban-rural income gap	Ratio of income between urban and rural areas	0.1760	0.1347	432
		Tyrell's index	0.0422	0.0211	432
control variable	China Digital Inclusive Finance Index	Forward			
	Percentage of employees in computer services and software	Forward			
	Level of economic development	GDP per capita (log)	11.4169	0.3784	432
	fixed-asset investment	Natural logarithm of investment in fixed assets	0.7431	0.3904	432
	Local fiscal expenditures as a percentage	Expenditures from the general budget of local finances/Gross Regional Product	0.1547	0.1296	432
	Students enrolled in higher education per 10,000 population (log)	3.2618	0.9690	432	Students enrolled in higher education per 10,000 population (log)

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This study employs the fixed-effects multiple regression method to examine the impact of digital technology on income disparity and the mediating effect of regional economic resilience. By fixing the city effect, we eliminate city-level bias that does not change over time. Based on this approach, we conduct endogeneity tests, robustness checks, and mechanism analysis using instrumental variable methods and indicator substitution. Specifically, when substituting the income gap indicator among the explanatory variables, we use the urban-rural income ratio to replace the Theil index.

4.3. Modeling the Impact of Regional Economic Resilience on Income Disparity

To test Hypothesis 2, this study constructs a panel multiple linear regression model:

$$Theil_{it} = \alpha + \beta_1 \times RER_{it} + Controls_{it} + \varepsilon_{it} \quad (2)$$

where α is the constant term, β_1 represents the effect of regional economic resilience (RER) on the income gap between urban and rural residents, $Controls$ represents the control variables, and ε_{it} it is the error term.

To examine the potential nonlinear effect of regional economic resilience on the income gap, the squared term of regional economic resilience is added. The modified model is as follows:

$$Theil_{it} = \alpha + \beta_1 \times RER_{it} + \beta_2 \times IF_{it}^{2} + Controls_{it} + \varepsilon_{it} \quad (3)$$

In this case, the coefficient β_1 and β_2 represent the combined effects of regional economic resilience development on the level of income disparity, while the other variables have the same meaning as in model (2).

4.4. Modeling the Urban-Rural Income Gap with Digital Technology

4.4.1. Modeling the Direct Impact Mechanism

To analyze the effect of digital technology on income distribution, a fixed-effects multiple regression model is employed, controlling for both city and year fixed effects. The model is specified as:

$$Theil_{it} = \alpha + \beta_1 \times DT_{it} + Controls_{it} + \varepsilon_{it} \quad (4)$$

where $Theil_{it}$ represents the income gap in city i during year i, DT_{it} denotes the level of digital technology, and ε_{it} is the random error term.

To explore the potential nonlinear effect of digital technology on income disparity, the squared term of digital technology is added. The modified model is:

$$Theil_{it} = \alpha + \beta_1 \times DT_{it} + \beta_2 \times DT_{it}^{2} + Controls_{it} + \varepsilon_{it} \quad (5)$$

In this model, the coefficients β_1 and β_2 capture the combined impact of digital technology on income disparity, while the other variables have the same interpretation as in model (4).

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4.4.2. Modeling Indirect Action Mechanisms

To explore the mediating role of regional economic resilience between digital technology and income distribution, this study utilizes a step-by-step analysis to examine the mediating effect. The analysis consists of three stages. In Step 1, the explanatory variable, digital technology (DT), is regressed to assess its impact on the income gap:

$$Theil_{it} = \alpha_1 + c \times DT_{it} + Controls_{it} + e_1 \tag{6}$$

In Step 2, the mediating variable, regional economic resilience (RER), is regressed to examine the impact of digital technology on it:

$$RER_{it} = \alpha_2 + a \times DT_{it} + Controls_{it} + e_2 \tag{7}$$

In Step 3, the indirect impact of digital technology on income distribution is analyzed by including the mediating variable, as follows:

$$Theil_{it} = \alpha_3 + c' \times DT_{it} + b \times RER_{it} + Controls_{it} + e_3 \tag{8}$$

In this analysis, c represents the total effect of digital technology (DT) on the urban-rural income gap (Theil), while α_2 in model (7) indicates the effect of digital technology on regional economic resilience (RER). The coefficient b in model (8) reflects the effect of regional economic resilience on the urban-rural income gap after controlling for digital technology, and c represents the direct effect of digital technology on the income gap when regional economic resilience is considered as a mediator.

Before proceeding with the analysis, it is essential to test for the presence of a mediating effect in the model. The academic community has proposed three primary methods for testing the mediating effect: the Sobel test, which uses statistical tests to determine whether the product of a and b (i.e., the indirect effect) is significantly different from zero when either a or b is not significant; the bootstrap method, which involves resampling the data with replacement to construct confidence intervals for the product ab, helping determine whether it is significantly different from zero. The bootstrap method assumes that the sample is representative of the population and is useful when either a or b not significant; and the stepwise test method, which involves stepwise regression of the model. The significance of the regression coefficients is tested to determine the existence of a mediating effect. The specific steps of this method are as follows: first, test whether the coefficient c in model (6) is significant. If it is, proceed to the second step; second, test whether the coefficient a, in model (7) is significant. If it is, proceed to the third step; third, test whether the coefficients *c* and b in model (8) are significant. If both coefficients are significant, it indicates a partial mediation effect. If only b is significant, it indicates full mediation. If all three coefficients a, b, and *c* are significant, the stepwise regression method is considered more robust than the other two methods.

5. Empirical Testing

5.1. Benchmark Regression of Economic Resilience on Income Disparity

As shown in Table 4, based on the panel data structure, the results in columns (1) and (2) are derived from fixed and random effects models for fixed cities, respectively. The findings

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indicate that regional economic resilience (RER) variables exhibit negative effects on income disparity. A Hausman test was conducted, revealing a P-value of zero, which leads to the rejection of the null hypothesis of the random effects model. Therefore, the conclusions drawn in this paper are based on the regression results from the fixed effects model, incorporating city-specific effects.

The results show that the coefficient of regional economic resilience on income disparity is significantly negative, suggesting that stronger regional economic resilience can reduce income disparity. This supports Hypothesis 3. Regions with greater economic resilience are not only more capable of recovering from economic shocks, but also better positioned to sustain long-term economic growth and stability.

Further analysis of the control variables reveals that an increase in economic development, expansion of fixed asset investment, and a higher proportion of local fiscal expenditure all contribute to a reduction in the income gap. However, the number of college students per 10,000 people and the per capita land area do not show a significant reduction in income disparity, nor do they exhibit a statistically significant relationship in the short term.

Considering potential non-linear effects, the results in columns (3) and (4) correspond to fixed and random effects models, respectively. These findings confirm that regional economic resilience variables have a negative impact on income disparity. The Hausman test again yielded a P-value of zero, rejecting the null hypothesis of random effects and reinforcing the use of the fixed effects model. Furthermore, the squared term of regional economic resilience has a significantly positive effect on income disparity, indicating the presence of a non-linear U-shaped relationship between regional economic resilience and income disparity.

It is further observed that regional economic resilience has been increasing steadily over the years, with the turning point of the U-curve occurring at x=0.6866, where the RER value falls within the range of [0.0796, 0.9021]. Analysis shows that only a small number of cities exceeded the turning point before 2020. Given that most regions in China remained on the left side of the U-curve from 2013 to 2022, it suggests that regional economic resilience generally contributes to a reduction in income disparity. This further supports Hypothesis 3.

Table 4. Empirical analysis of economic resilience on income disparity

Variant	(1) Fixed	(2) Random	(3) Fixed	(4) Random
RER	-0.0326*** (-3.7081)	-0.0316*** (-3.6351)	-0.1391*** (-6.2554)	-0.1424*** (-6.5309)
RER2			0.1445*** (5.1834)	0.1542*** (5.5041)
PGDP	-0.0134*** (-6.0195)	-0.0101*** (-6.1762)	-0.0102*** (-4.5337)	-0.0071*** (-4.2447)
IIB	-0.0785*** (-4.1705)	-0.0514*** (-3.9673)	-0.0522*** (-2.7633)	-0.0416*** (-3.2177)
IS	-0.0092*** (-3.8868)	0.0007 (0.3980)	-0.0071*** (-3.0490)	0.0017 (1.0102)
IIA	0.0021 (0.3426)	0.0238*** (9.5280)	-0.0034 (-0.5748)	0.0201*** (7.9537)
R	0.4183	0.5907	0.4570	0.6071
F-statistic	45.306	102.47	45.330	93.819

Note: ***,**,* denote significant at 1%, 5% and 10% respectively.

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5.2. Analysis of the Empirical Results of Digital Technology on Income Disparity

5.2.1. Benchmark Regression

The results examining the direct effect of digital technology on income disparity are presented in Table 5. Based on the panel data structure, the results in columns (2) and (4) correspond to fixed effects, while columns (1) and (3) reflect random effects models. The findings indicate that digital technology (DT) variables exhibit a negative effect on income disparity. A Hausman test yielded a P-value of 0.000, leading to the rejection of the null hypothesis for the random effects model. Thus, the conclusions of this paper are based on the regression results from the fixed effects model, as shown in columns (2) and (4).

The results reveal that the coefficient for digital technology is significantly negative at the 5% significance level, indicating that the development of digital technology can significantly reduce income disparity within the context of each city. This supports Hypothesis 2, which posits that digital technology directly influences the income gap.

Further analysis, which introduces the squared term of digital technology, shows a significantly positive coefficient for the squared term, while the coefficient for digital technology remains significantly negative. This suggests a non-linear U-shaped relationship between digital technology and regional economic resilience. The turning point of the U-curve occurs at x=0.4206x = 0.4206x=0.4206, with the DT value ranging from [0.0247, 0.7374]. After analyzing the data, it is found that only a small number of cities are in the right half of the U-curve after 2019. Given that most regions in China remained in the left half of the U-curve from 2013 to 2022, it indicates that digital technology can indeed reduce the income gap. This further verifies Hypothesis 1.

Table 5. Benchmark regression results for the direct impact of digital technology on income disparity

Variant	(1) Fixed	(2) Random	(3) Fixed	(4) Random
DT	-0.0376*** (-3.3870)	-0.0224** (-1.9977)	-0.1636*** (-7.6775)	-0.1261*** (-5.6048)
DT^2			0.1908*** (6.7678)	0.1499*** (5.2604)
PGDP	-0.0109*** (-7.0572)	-0.0158*** (-7.3287)	-0.0069*** (-4.4375)	-0.0119*** (-5.4289)
IIF	-0.0074 (-5.2068)	-0.0069*** (-4.7652)	-0.0061*** (-4.4432)	-0.0063*** (-4.4718)
IIB	-0.0508*** (-4.0023)	-0.0811*** (-4.2571)	-0.0389*** (-3.2633)	-0.0593*** (-3.1431)
IS	0.0008 (0.4614)	(-3.9087) 0.0062	(1.5100) 0.0188***	(-2.7615) -0.0006
IIA	0.0247*** (10.4707)	0.0062 (1.0365)	0.0188*** (7.9515)	-0.0006 (-2.7615)
R	0.602	0.404	0.652	0.444
F-statistics	107.40	42.608	100.04	43.051

Note: ***,**,* denote significant at 1%, 5% and 10% respectively.

5.3. Endogeneity Test

This study acknowledges the potential endogeneity issues in examining the impact of digital technology on income disparity. To address this concern, the instrumental variable (IV) method

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is employed, with the lag of digital technology selected as the instrumental variable. To test for endogeneity, a Hausman test is conducted, and the results suggest the presence of endogeneity in the model.

Next, to validate the instrumental variable, a weak instrument test is performed. The result shows an F-statistic of 917.8, significantly greater than the threshold of 10, with a P-value of 0.000. This indicates that the model does not suffer from weak instrument problems.

Table 6 presents the results of the first and second stages of the Two-Stage Least Squares (2SLS) regression, using the lag of digital technology as the instrumental variable. In the first stage, the coefficient of the lagged digital technology variable (DTS) is significantly positive at the 1% significance level, indicating that the lagged term is strongly correlated with digital technology. This further confirms the validity of the instrumental variable, as indicated by the weak instrument test.

In the second-stage regression, the coefficient of the lagged digital technology (DTS) on the urban-rural income gap is significantly negative at the 1% significance level. This suggests that, even after addressing endogeneity, DTS still has a significant negative effect on the urban-rural income gap. These findings align with the conclusions from the benchmark regression, providing further evidence of the robustness and reliability of the results.

Table 6. 2SLS regression results of digital technology on income disparity

Variables	2SLSPhase I	$2SLS_{Phase\ II}$
	DT	Theil
DT		-0.0239*** (-2.5827)
DTS	1.0290*** (19.417)	
PGDP	0.0128 (1.4368)	-0.0144*** (-6.9407)
IFI	0.0031 (0.6929)	-0.0056*** (-5.0866)
IIB	-0.1185* (-1.9540)	-0.0741*** (-4.9613)
IS	0.0098 (-1.9540)	-0.0060*** (-2.8544)
IIA	0.0384* (1.8777)	-0.0026 (-0.5396)
fixed effect	containment	containment
R	0.7166	0.4471
F-statistic	139.10	44.475

Note: ***,**,* denote significant at 1%, 5% and 10% respectively.

5.4. Robustness Tes

To verify the reliability of the model results, additional robustness tests were conducted using alternative explanatory variables and the instrumental variable method. Table 7 presents the regression results with the replacement of digital technology-related explanatory variables, while Table 8 shows the regression results with the replacement of explanatory variables for the Theil index.

For the robustness test, we replaced the digital technology variables with internet development indicators from 2013 to 2021, including the number of internet broadband users per 100 people, the ratio of employees in the computer software and software industry, total

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telecommunication services per capita, and the number of mobile phone subscribers per 100 people. These indicators were combined using the entropy weighting method to create a synthetic digital technology variable (DT') for testing.

The regression results in Table 7, specifically columns (1) and (3), indicate that the effect of digital technology on regional economic resilience first narrows and then expands. This pattern supports the reliability of the model results.

Table 7. Replacement of explanatory variables

Variables	(1)	(2)	(3)	(4)
DT'	-0.0095 (-0.9655)	-0.0235** (-2.3384)	-0.0901*** (-3.4268)	-0.1521*** (-5.9669)
DT's			0.1482*** (3.2995)	0.2425*** (5.4381)
PGDP	-0.0172*** (-8.5733)	-0.0123*** (-8.6904)	-0.0158*** (-7.8581)	-0.0104*** (-7.3565)
IIF	-0.0069 (-4.7587)	-0.0076*** (-5.3200)	-0.0069*** (-4.8110)	-0.0078*** (-5.6005)
IIB	-0.0828*** (-7.3578)	-0.0512*** (-4.1381)	-0.0746*** (-3.8989)	-0.0444*** (-3.7309)
IS	-0.0101 -9.4553	0.0009 -0.574	-0.0086*** (-3.5404)	0.0021 (1.335)
IIA	0.0083 (-6.8697)	0.0267*** (-12.391)	0.0092 (1.5781)	0.0243*** (11.493)
R	0.3986	0.6159	0.4155	0.6470
F-statistics	41.763	113.85	38.288	111.30

Note: ***,**,* denote significant at 1%, 5% and 10% respectively.

Table 8. Replacement of explanatory variables

Variant	(1) Fixed	(2) Random	(3) Fixed	(4) Random
DT	-0.3840*** (-1.8023)	-0.5012** (-2.4404)	-1.7935*** (-4.1302)	-2.1031*** (-5.1922)
DT^2			2.0384*** (3.7060)	2.4270*** (4.5529)
PGDP	-0.0824*** (-2.0206)	-0.0173*** (-0.5998)	-0.0306 (-0.7201)	0.0341 (1.1218)
IIF	-0.1064 (-3.8703)	-0.1247*** (-4.7510)	-0.0980*** (-3.6102)	-0.1083*** (-4.1809)
IIB	-0.7794*** (-2.1566)	-0.4074*** (-1.6922)	-0.4831 (-1.3259)	-0.2505 (-1.0564)
IS	-0.0753 (-1.6313)	0.0760*** (2.4000)	-0.0366 (-0.7852)	0.0946*** (3.0372)
IIA	0.0834*** (0.7356)	0.3149 (7.1131)	-0.7852 (-0.0792)	0.2392*** (5.1696)
R	0.1561	0.8740	0.1858	0.8810
F-statistics	11.653	492.52	12.287	449.59

Note: ***,**,* denote significant at 1%, 5% and 10% respectively.

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Table 8 presents the regression results using the urban-rural income ratio as a replacement for regional economic resilience to measure the income gap. The regression results for the relationship between digital technology and regional economic resilience in columns (1) and (3) of Table 8 are consistent with the benchmark regression results. This further confirms the robustness of the benchmark model.

5.5. Heterogeneity Analysis

To explore the impact of digital technology on income disparity, this paper divides cities into four regions based on geographic location: East, Central, West, and Northeast. The fixed-effect model, controlling for city-specific effects, is applied to regress each region's sub-samples. The regression results for the four regions-East, Central, West, and Northeast-are presented in the table. In the table, (1) represents the fixed-effect model controlling for city effects, (2) represents the fixed-effect model without control variables but including the non-linear term, and (3) shows the fixed-effect model with both control variables and the non-linear term.

The results indicate that in model (1), the coefficient for the digital technology development level in the East is negative but not statistically significant, suggesting that digital technology has no significant effect on income disparity in this region. However, the results from models (2) and (3) demonstrate a dual effect of digital technology on the income gap. Initially, digital technology helps narrow the gap, but as its use becomes more widespread, its effect shifts toward widening the income gap. This non-linear effect reflects the uneven impact of technological progress on income distribution.

The results for the Central and East regions show similar patterns. In the West, the impact of digital technology on the income gap also reflects this non-linear characteristic: it initially narrows the gap but may eventually widen it as technology spreads. At the early stages, lower-income groups benefit more, but as technology advances, high-income groups gain higher returns, leading to a widening of the income gap. In contrast, digital technology significantly reduces the income gap in the Northeast.

In summary, the impact of digital technology is more pronounced in the Central and West regions, somewhat lacking in the East, and less noticeable in the Northeast. The need for digital transformation is greater in the Central and West regions. The introduction of digital technology can significantly enhance regional economic resilience and reduce income disparities by boosting productivity, promoting industrial upgrading, and creating job opportunities. However, in the Northeast, the impact of digital technology has been slower and less effective due to factors such as lower technology penetration and weaker population mobility.

The level of the digital economy in the Eastern region is significantly higher than in the Central and Western regions[6]. Additionally, the economic and technological foundations in the Eastern region are more developed, leading to a relatively weaker effect of digital technology on further reducing the income gap, particularly when high-income groups are already at the forefront of technological development. In contrast, the Western region, which is economically less developed, may initially experience an exacerbation of the income gap due to the introduction of digital technology. However, as technology becomes more widespread, the gap gradually narrows, exhibiting a significant U-shaped relationship. The impact in the Central region is more complex, as digital technology drives industrial upgrading, and the income gap narrows over time in a non-linear manner. In the Northeastern region, due to an aging industrial structure and difficulties in economic transformation, the impact of digital technology is more limited and does not significantly alter the income gap.

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Table 9. Regression results on the impact of digital technology level on income disparity in East, Central, West and Northeast cities

Variable	the east			central section		
	(1)	(2)	(3)	(1)	(2)	(3)
DT	-0.0123	-0.1916***	-0.0837***	-0.0539	-0.7003***	-0.7607***
	(-1.6444)	(-11.559)	(-4.7438)	(-1.0721)	(-6.5851)	(-3.6077)
DT^2		0.2058***	0.0917***		2.5158***	2.6617***
		(9.433)	(4.4335)		(5.1828)	(0.0014)
Control Variable	Yes	No	Yes	Yes	No	Yes
R	0.58	0.36	0.61	0.53	0.62	0.64

Note: ***,**,* denote significant at 1%, 5% and 10% respectively.

Table 10. Regression results on the impact of digital technology level on income disparity in West and Northeast cities

variable	western part			north-eastern		
	(1)	(2)	(3)	(1)	(2)	(3)
DT	-0.1332*	-0.8229***	-0.7409***	-0.3889***	-1.2172*	0.3985
	(-2.0059)	(-7.4)	(-3.4824)	(-3.4679)	(-1.8764)	(0.624)
DT^2		2.2142***	1.7979***		5.2773	-5.1021
		(5.8049)	(2.9846)		(1.2204)	(-1.2521)
control variable	Yes	No	Yes	Yes	No	Yes
R	0.58	0.57	0.64	0.75	0.32	0.76

Note: ***,**,* denote significant at 1%, 5% and 10% respectively.

5.6. Analysis of the Mediating Effect of Digital Technology on the Urban-Rural Income Gap

The empirical results presented above show that both digital technology and regional economic resilience influence income disparity. Based on the theoretical framework proposed in this paper, digital technology indirectly affects income disparity through regional economic resilience. Table 11 displays the empirical results of the mediation effect using the stepwise regression model. The coefficients a, b, and c are all significant at the 1% level. As described previously, the mediation effect is tested through the steps of the stepwise regression. For comparison, the impact of digital technology on income disparity, as shown in Table 5, is included in the results of Table 10 (1). From the results in (2), it is evident that digital technology has a significant positive impact on regional economic resilience at the 1% significance level. This supports the theoretical analysis, concluding that the development of digital technology enhances regional economic resilience, which validates the hypothesis proposed in this paper. Furthermore, the results in (3) reveal that the coefficient c of digital technology remains significant after adding regional economic resilience (IF). This indicates a full mediation effect in the model, confirming that regional economic resilience fully mediates the relationship between digital technology and income disparity, as established by the above test steps.

The full mediation effect indicates that digital technology positively impacts the urban-rural income gap through the fully mediated path of regional economic resilience. This also supports the existence of the mediation effect and justifies the inclusion of regional economic resilience as a mediating variable. From the perspective of the stepwise regression model, the full mediation effect suggests that the influence of digital technology on the urban-rural income gap

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occurs solely through regional economic resilience. However, the academic community has not reached a consensus on the interpretation of a fully mediated effect, with the primary points of contention focusing on the following: (1) The distinction between full and partial mediation lies in the significance of the direct effect (c'). A sufficiently large sample size may cause a fully mediated effect to become a partially mediated effect; (2) The full mediation effect assumes that other mediating variables are completely isolated, but in reality, multiple mediating variables may be at play. Consequently, Preacher and Hayes (2008) argue that the full mediation effect should not be the primary conclusion of a study. For these reasons, and based on the relevant theoretical analysis in Chapter 3, this paper revises its conclusion regarding the fully mediated effect. Specifically, digital technology reduces the urban-rural income gap primarily through regional economic resilience, thereby verifying Hypothesis 3. This conclusion suggests that, in addition to regional economic resilience, other mediating variables may play a role in the mechanism through which digital technology impacts the urban-rural income gap. Therefore, the mediating role of regional economic resilience should be emphasized when analyzing the indirect impact of digital technology on the urban-rural income gap. Additionally, the coefficient of regional economic resilience in result (3) is significantly negative at the 1% level, further reinforcing the idea that regional economic resilience plays a critical role in narrowing the income gap in the mechanism of the indirect effect of digital technology on the urban-rural income gap.

Table 11. Regression Impact of mediated effects digital technology on income disparity

Variables	(1)	(2)	(3)
DT	-0.0224**	0.7468***	-0.0029
	(-1.9977)	(14.277)	(0.1636)
RER			-0.0340**
			(-2.4559)
PGDP	-0.0158***	0.0676***	-0.0135***
	(-7.3287)	(6.7557)	(-4.2502)
IFI	-0.0069***	0.0138*	-0.0064***
	(-4.7652)	(2.0460)	(-3.8189)
IIB	-0.0811***	0.0798**	-0.0784***
	(-8.627)	(0.8997)	(-3.7299)
IS	-0.0095***	0.0056**	-0.0093***
	(-3.9087)	(0.4922)	(-2.9497)
IIA	0.0062	-0.1192**	0.0021
	(1.0365)	(-4.2812)	(0.3524)
Fixed Effect	containment	containment	containment
R	0.4035	0.6356	0.4184
F-statistic	42.608	109.87	38.742

Note: ***,**,* denote significant at 1%, 5% and 10% respectively.

6. Research Findings and Policy Recommendations

6.1. Conclusion of the Study

The impact of digital technology on the income gap presents a U-shaped non-linear relationship. From 2013 to 2021, China's first- and second-tier cities were positioned on the left side of the curve, indicating that they are in the phase of narrowing the income gap. During this phase,

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regional economic resilience plays a significant role in reducing the income gap. Furthermore, the enhancement of digital technology levels significantly contributes to narrowing the income gap by promoting the strengthening of regional economic resilience. The impact of digital technology is heterogeneous, with a more substantial effect on reducing the income gap in the western region, a weaker impact in the central and eastern regions, and a less pronounced effect in the northeastern region.

Regional economic resilience plays a critical mediating role in the relationship between digital technology and income disparity. Increased levels of digital technology have significantly reduced the urban-rural income gap by improving regional economic resilience.

6.2. Policy Recommendations

Based on the findings of this paper, four substantive policy recommendations are proposed:

Promote the Balanced Development of Digital Technology. This study shows that there is a U-shaped non-linear relationship between the impact of digital technology and income disparity at different stages of development. Therefore, while promoting the development of digital technology, the government should also address the uneven impact of technology on income inequality. At the early stage, policies should focus on the popularization of technology, especially in the central and western regions, to bridge the technological gap between regions. As technology advances to higher levels, policies should target the income inequality exacerbated by technology by implementing moderating measures, such as increasing investment in technical education and training. This will enhance the technological adaptability of the workforce and reduce the negative impact of technological progress on low-skilled workers.

Strengthen Regional Economic Resilience. Research has shown that regional economic resilience is a key mediating variable in the impact of digital technology on income distribution. The government should focus on strengthening the economic resilience of the central and western regions to enhance their adaptability. This would promote balanced regional development and help narrow the income gap. For example, fostering complementary development between the eastern, central, and western regions through regional technological innovation cooperation and industrial chain integration can facilitate resource sharing and technology transfer. Policies should aim to reduce the technological gap and income disparity to ensure that the benefits of technological development are distributed equitably across all regions and social groups.

Strengthen Social Security and Skills Training. With the advancement of digital technology, the structure of the labor market is undergoing significant changes. The government should introduce differentiated income distribution policies, particularly between the eastern and western regions. Social security measures for low-income groups should be enhanced, and the coverage of unemployment insurance and re-employment training should be expanded. Efforts should be made to support the career transitions of low-skilled workers. Additionally, more employment opportunities should be created, particularly in industries with rapid technological development, to ensure that affected groups can smoothly transition into new industries.

Promote Education Reform and Talent Cultivation. The development of digital technology requires a highly skilled workforce. The government should prioritize education reform and ensure that higher education and vocational training are aligned with market demands, especially in technology-intensive industries. Simultaneously, more skills training opportunities should be provided to low-skilled workers to help them adapt to technological changes, improve their employment competitiveness, and prevent employment inequality arising from technological advancements.

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