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Original Research Articles

How the digital economy significantly enhances the resilience of fishery economy:An empirical evidence from China

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Against the backdrop of global geopolitical instability and domestic economic challenges, the development of the digital economy plays a crucial role in industrial upgrading and has significantly influenced the resilience of the fishery economy. Under the combined influence of internal and external factors, the development of the fisheries economy faces severe challenges. In order to adjust the industrial structure as quickly as possible and maintain stable economic output in the face of environmental shocks, exploring ways to enhance the resilience of the fisheries economy is a topic of practical significance. This study uses panel data from 2013 to 2022 covering ten coastal provinces in China to investigate the impact of digital economy development on fishery economic resilience. The empirical analysis yields the following key findings: First, the development level of the digital economy has a significant positive effect on enhancing fishery economic resilience. Second, the digital economy improves resilience by facilitating industrial structure upgrading. These conclusions remain robust after replacing the core explanatory variables, excluding abnormal years, applying winsorization, and using instrumental variable methods. Third, the positive impact of digital economy development on fishery economic resilience is more pronounced in economically underdeveloped regions and provinces with limited freshwater resources. This study systematically validates for the first time the significant promoting effect of digital economic development on the resilience of the fisheries economy and the mediating role of industrial structure upgrading in this process, expanding the application boundaries of digital economy research in the resilience of specific industries. In addition, through heterogeneity analysis based on regional development levels and resource abundance, this paper provides empirical evidence for formulating differentiated policies tailored to local conditions.

INTRODUCTION

The concept of resilience originally comes from engineering as a physical term. Reggiani and De Graaff first introduced it into the field of economics, exploring its relevance within socioeconomic systems.[1] Existing literature, both domestic and international, mainly focuses on regional and industrial economic resilience.[2] For instance, used the Entropy method to analyze 25 core cities in China and found a relatively stable spatial heterogeneity in urban resilience, with the general pattern of East > Central > West > Northeast. Wang and Yu applied social network analysis to investigate the structural characteristics and evolution of spatial networks of agricultural resilience and used the Spatial Dubin model to identify its driving factors.[3] Economic resilience refers to a system's ability to maintain stability or quickly adapt to environmental changes in the face of uncertain shocks. Fisheries economic resilience refers to the ability of the fisheries to quickly adjust and respond to risks, and to restore the stability of economic output when facing external environmental changes that cause certain shocks and fluctuations to their economic production. In recent years, China's fishery economic system has faced external challenges such as geopolitical instability, international trade disputes, and macroeconomic downturns. Notably, environmental incidents like Japan's discharge of

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nuclear wastewater and South Korea's nuclear waste leaks have further deteriorated the marine environment, posing significant threats to the habitats and output of fishery products. Internally, it faces issues such as marine environmental pollution and threats from extreme weather, overfishing, the decline of fishery resources, and impeded economic development—factors that collectively challenge the resilience of the fishery economy.[4] Under the combined influence of internal and external factors, the development of the fisheries economy faces severe challenges. In order to adjust the industrial structure as quickly as possible and maintain stable economic output in the face of environmental shocks, exploring ways to enhance the resilience of the fisheries economy is a topic of practical significance. Moreover, as the world's largest fisheries producer, China contributes about one-third of the global total fishery output, with its aquaculture production accounting for more than 60% of the world's total. Therefore, understanding the dynamics of China's fisheries is crucial for the sustainable development of global fisheries.

Currently, the fisheries economy still exhibits certain vulnerabilities when facing both internal and external comprehensive challenges, mainly reflected in three aspects. First, there is insufficient risk resistance. Traditional fisheries rely heavily on natural endowments and the experience of practitioners, and they lack proactive monitoring, early warning systems, and effective buffer mechanisms to cope with external shocks such as ocean acidification caused by climate change, shifts in fishing grounds, and sudden environmental pollution events like red tides and the discharge of nuclear-contaminated water. Second, the capacity for recovery and adjustment is limited. There are significant information barriers within the current fisheries industry chain, leading to a disconnect between production and consumer markets, which can easily trigger supply-demand imbalances and price volatility. At the same time, the post-disaster recovery of fisheries production generally faces financial constraints, such as limited financing channels and delayed credit support, which slows down the recovery of the fisheries economic system. Third, the current fisheries economy has relatively weak innovation and transformation capabilities. The industrial structure has long been biased toward primary resource-dependent production segments, facing the dual pressures of declining fishery resources and rising production factor costs. The transformation and upgrading toward high value-added formats, such as recreational fisheries and deep processing, is arduous, and the system's adaptability urgently needs improvement. The digital economy can be applied in fisheries for generating and processing basic information, fishery production, processing, circulation, and service management, throughout the entire fisheries process,[3] effectively addressing these inherent weaknesses. On one hand, the digital economy enables smart aquaculture production to conduct disease detection, real-time monitoring of water environments, and timely response to changes in external conditions, thus enhancing the system's resistance, resilience, adaptability, and capacity to adjust. On the other hand, using data as a carrier, the digital economy, through industrial digitalization and digital industrialization, affects structural transformation among industries, improves labor productivity within industries, and enhances the efficiency of industrial resource allocation, thereby boosting the innovation and transformation capacity of the fisheries system.[5]

The digital economy, first conceptualized in the United States, is characterized as a new form of economy in which data is a key production factor, and integration of communication technologies with industries promotes digital transformation across all sectors. Scholars such as Gong have extensively explored its connotation, core features, economic impacts, and mechanisms of influence.[6] Research perspectives have expanded from technical viewpoints to include social and managerial dimensions. As studies deepen, both macro- and micro-level measurement systems for the digital economy have become increasingly comprehensive and diversified. For example, constructed a composite evaluation index system based on four dimensions: digitalization, networking, platformization, and intelligence applied principal component analysis to develop a digital economy index system from the dual perspectives of digital industrialization and industrial digitalization.[7]

Current empirical research on the impact of the digital economy on economic resilience mostly focuses on the effects of the digital economy on agricultural economic resilience and urban economic resilience development. For example, Song and Liu studied panel data from 30 provinces, autonomous regions, and municipalities in China and used a two-way fixed effects model and system GMM model to empirically analyze the impact of the digital economy on agricultural resilience.[8] Cui and Feng, based on panel data from 285 Chinese cities, measured the degree of integration between the digital and real economy and economic resilience using coupling models and sensitivity analysis, and further explored the impact of digital-real integration on the enhancement of urban economic resilience and its mechanisms.[9] Although the concepts of the digital economy and economic resilience were proposed as early as the 20th century, and there is a wealth of literature on their connotations, measurement methods, and spatial heterogeneity analysis, there is relatively little research on the relationship and mechanisms of influence between the two.

In response, this study utilizes panel data from ten coastal provinces and municipalities in China (Liaoning, Hebei, Shandong, Jiangsu, Zhejiang, Shanghai, Fujian, Guangdong, Guangxi, and Hainan) to empirically investigate the direct and mediating effects of digital economy development on fishery economic resilience. By constructing a panel data model, the study aims to provide a theoretical basis for enhancing the resilience of China's fishery industry through the development of the digital economy. The study not only verifies the important role of the digital economy in enhancing the resilience of the fisheries economy through linear regression, enriching the literature in the fields of digital economy development and fisheries economic resilience, but also provides a reference for policymakers.

THE DIRECT EFFECT OF THE DIGITAL ECONOMY ON FISHERY ECONOMIC RESILIENCE

The digital economy integrates data throughout the entire process of fishery production and circulation. It draws extensively from data resources generated within the real fishery economy and, through its strong penetrative capacity, facilitates industrial integration, thereby promoting the digital transformation of traditional fisheries and enhancing economic resilience in the sector.[10]

On one hand, data is characterized by zero marginal cost and indistinguishable replication . In fishery production activities, this enables firms to obtain rich data resources at relatively low cost, improving the efficiency of resource allocation. While ensuring the production and distribution of fishery products, it also provides favorable economic conditions for enterprises to expand production scale and diversify their product offerings—thus strengthening their capacity to withstand external risks and respond to environmental changes in a timely manner. On the other hand, the total value of a network exhibits increasing marginal returns. The rapid development of the digital economy can effectively reduce firms' long-run average production costs, which enhances their willingness to innovate and provides financial support for research and development activities, thereby improving their capacity for innovation and transformation.[11] Additionally, the digital economy breaks down barriers between enterprises and removes spatial limitations, facilitating cross-regional collaboration and enabling spatial synergy in enterprise value creation, which in turn benefits technological innovation within the industry.

Accordingly, we propose the following hypothesis:

> Hypothesis 1: The digital economy has a positive impact on enhancing the resilience of China's fishery economy.

THE MEDIATING MECHANISM: INDUSTRIAL STRUCTURE UPGRADING

Industrial structure upgrading refers to the process or trend of transitioning from a lower-level to a higher-level industrial configuration.[12] The digital economy promotes the upgrading of the fishery industrial structure at both micro and medium levels. At the micro level, it supports structural upgrades within enterprises through multiple pathways, such as the establishment of intelligent communication platforms to improve management models, real-time environmental monitoring for healthier aquaculture systems, and the use of data inputs to enhance intra-firm resource allocation efficiency. At the medium level, the digital economy increases market transparency and gives rise to new business formats such as livestream e-commerce. These developments not only broaden the downstream sales channels and methods within the fishery value chain but also stimulate the growth of the tertiary sector. Furthermore, with the help of information technology such as cloud computing and blockchain, the development of recreational fisheries can be further promoted. By integrating ecological operations, food services, sightseeing, and science education based on fisheries, the digital economy enhances the added value of fishery products.

Accordingly, we propose the following hypothesis:

> Hypothesis 2: The digital economy enhances fishery economic resilience by facilitating industrial structure upgrading.

MATERIALS AND METHODS

2.1. ANALYTICAL METHODS

2.1.1. THE ENTROPY-WEIGHT METHOD

Since the resilience of the fisheries economy and the level of digital economy development are abstract concepts that cannot be directly measured, it is necessary to construct a system containing multiple specific indicators when measuring them. Therefore, this study uses the entropy weighting method to measure the two core variables. Compared with subjective weighting methods such as the Analytic Hierarchy Process (AHP), the weights in the entropy weighting method are entirely derived from the data itself, allowing for an objective and effective handling of comprehensive evaluation issues involving multiple indicators and large samples, such as the resilience of the fisheries economy and the level of digital economy development, thereby providing a more rigorous measurement of the core variables in this study. The steps are as follows:

Step one, standardize the data. The handling of positive and negative indicators is shown in equations (1) and (2), respectively.

$$\text{Positive indicators: } X_{ij} = \frac{x_{ij} - \min(x_{ij})}{\max(x_{ij}) - \min(x_{ij})} \quad (1)$$

$$\text{Negative indicator: } X_{ij} = \frac{\max(x_{ij}) - x_{ij}}{\max(x_{ij}) - \min(x_{ij})} \quad (2)$$

In the formula, i = 1, 2, ..., m represents the sequence of years, j = 1, 2, ..., n represents the sequence of indicators,x_{ij} is the original data, and X_{ij} is the standardized data.

Step two, calculate the indicator weights using the following formula:

$$\text{Coefficient of Variation: } p_{ij} = \frac{X_{ij}}{\sum_{i=1}^{m} X_{ij}} \quad (3)$$

$$\text{Information Entropy: } E_j = -\ln(n)^{-1} \sum_{i=1}^{m} p_{ij} \ln(p_{ij}) \quad (4)$$

$$\text{Weight: } w_j = \frac{1 - E_j}{k - \sum E_j} \quad (5)$$

Step 3, calculate the overall score:

$$s_i = \sum_{j=1}^{n} w_j \cdot X_{ij} \quad (6)$$

2.1.2. BASELINE REGRESSION MODEL

To investigate the impact and mechanisms of the digital economy on the resilience of the fishery economy, we first construct the following baseline regression model:

$$FEI_{i,t} = \alpha_0 + \alpha_1 \text{ DIT }_{i,t} + \alpha_2 \text{ Control }_{i,t} + \delta_{i,t} + \varepsilon_{i,t} \quad (7)$$

Where:

Table 1. Variable definition

Type	Variable Name	Symbol	Description
Dependent	Fishery Economic Resilience	FEI	Constructed based on the entropy method
Independent	Digital Economy Development	DIT	Constructed based on the entropy method
Mediator	Industrial Structure Upgrading	ISA	Tertiary Industry Output / Secondary Industry Output
Control	Fiscal Support	FS	General Budget Expenditure / Regional GDP
	Urbanization Level	UR	Urban Population / Total Population
	Economic Development Level	EDL	GDP per capital(RMB/person)
	Urban-Rural Income Gap	URI	Urban per capital disposable income / Rural per capital disposable income
	Fixed Asset Investment	FI	Investment in fixed assets for agriculture, forestry, animal husbandry, and fisheries
	Research Funding	RPF	Logarithm of research funding for fishery-related topics

Table 2. Fishery Economic Resilience Indicator System

Primary Dimension	Secondary Indicator	Attribute
Resistance & Recovery	Total Fishery Output Value	+
	Per Capital Net Income of Fishers	+
	Aquaculture Area	+
	Entropy of Fishery Industrial Structure	+
	Composite Index of Fishery Disasters	–
	Industrial Wastewater Discharge	–
Adjustment & Adaptability	Number of Fishery Workers	+
	Total Aquatic Product Output	+
	Number of Powered Fishing Vessels	+
Innovation & Transformation	Comprehensive Index of Fishery Extension	+
	Fishery Trade Openness	+

$FEI_{i,t}$ denotes the fishery economic resilience of coastal province/city i in year t; $DIT_{i,t}$ represents the level of digital economy development in the same region and time; $Control$ includes control variables; δ_i denotes province fixed effects; $\varepsilon_{i,t}$ is the error term (see **Table 1**).

2.2. VARIABLE DEFINITIONS

2.2.1. *DEPENDENT VARIABLE*

The dependent variable in this study is fishery economic resilience (FEI). Due to limited literature and a lack of standardized measures for fishery economic resilience, this study draws upon the comprehensive index systems developed by scholars such as Beibei Liang and Wei Mao, with adjustments to certain indicators. Based on the entropy method, fishery economic resilience is measured across three dimensions: resistance and recovery capacity, adjustment and adaptability, and innovation and transformation capability. See **Table 2** for the detailed indicator system.

Among them, the entropy of fishery industry structure $= \sum_{i=1}^{n} W_{i,t}^{n} \ln \frac{1}{W_{i,t}^{n}}$, where $W_{i,t}^{n}$ is the proportion of the output value of the fishery industry in the area i in the t period to the total output value of the fishery economy. n=1, 2, 3, representing the three major fishery economic industries of fishery, fishery industry and construction, fishery circulation and service industry, respectively.

Composite Index of Fishery Disasters=$\sum W_i X_i$, where i represents the economic loss and affected aquaculture area caused by fishery disasters, W_i represents the weight of the index, and X_i is the corresponding index.

The Comprehensive Index of Fishery Extension is the same as the Composite Index of Fishery Disasters, in which i represents the number of aquatic extension institutions, aquatic technology promotion funds, and actual personnel of aquatic technology promotion respectively.

Fishery Trade Openness = amount of import and export trade of aquatic products / total output value of fishery economy.

Table 3. Digital Economy Development Indicator System

Indicator Category	Description	Attribute
Internet Penetration	Internet users per 100 people	+
Internet Workforce	Share of computer and software service personnel	+
Internet Output	Telecom service volume per capital	+
Mobile Internet Users	Mobile phone users per 100 people	+
Inclusive Digital Finance	China Digital Inclusive Finance Index	+

2.2.2. *EXPLANATORY VARIABLE*

The core independent variable is the digital economy (DIT). At present, there is no unified standard for measuring the development of the digital economy. International institutions such as Eurostat, OECD, WEF, ITU, as well as domestic institutes like the Shanghai Academy of Social Sciences and CAICT, have proposed various macro-level indicator systems.[13] Chinese scholars have also developed different micro-level evaluation frameworks. Based on data availability and scientific rigor, this study adopts the methodology from,[14] which measures the digital economy from two dimensions: Internet development and inclusive digital finance. See **Table 3** for the indicator system.

2.2.3. *CONTROL VARIABLES*

Fishery economic resilience is also influenced by regional economic conditions, fiscal policies, and social factors. Drawing from relevant literature, this study includes the following control variables:

Fiscal Support (FS): Measured by general budget expenditure relative to GDP. Higher fiscal support reflects stronger government capacity to support urban fishery development.

Urbanization Level (UR): The urbanization process may promote industrial upgrading but could negatively affect traditional agriculture and fisheries.

Economic Development Level (EDL): More economically developed regions typically have better infrastructure and disaster response capacity, enhancing fishery resilience.

Urban-Rural Income Gap (URI): Reflects inequality; greater gaps may reduce resilience.

Fixed Asset Investment (FI): Captures the scale, structure, and efficiency of investment in agricultural and fishery fixed assets, which can improve resilience.

Research Funding (RPF): Measured as the natural logarithm of fishery-related research project funding.

2.2.4. *MEDIATING VARIABLE*

Previous research has shown that digital transformation positively impacts industrial structure upgrading.[5] Similarly, finds that upgrading the industrial structure improves urban economic resilience.[12] Based on these findings, this study adopts the industrial structure upgrading indicator (ISA)—measured as the ratio of tertiary to secondary industry output—following the approach of Liao et.al., as the mediating variable.[15]

2.3. DATA AND SAMPLE

Although inland provinces in China also have freshwater fisheries, because the scale of the industry, economic significance, and types of risks they face differ significantly from those of marine fisheries, combining the two in research would introduce too much noise and bias, therefore this study selects 10 coastal provinces and municipalities in China—Liaoning, Hebei, Shandong, Jiangsu, Zhejiang, Shanghai, Fujian, Guangdong, Guangxi, and Hainan—as the research sample, covering the period from 2013 to 2022. The primary data sources include the China Fishery Statistical Yearbook, China Environmental Statistical Yearbook, CSMAR database, and provincial statistical yearbooks.

RESULTS

3.1. DESCRIPTIVE STATISTICS

Table 4 presents the descriptive statistics of the variables. Among the 100 observations, the standard deviations of the dependent variable—Fisheries Economic Resilience (FEI)—and the core explanatory variable—Digital Economy Development Level (DIT)—are relatively close, suggesting similar degrees of variability and a potential correlation between the two.

The mean and maximum values of Fiscal Support (FS) differ considerably, indicating that during the study period, certain cities received significantly higher fiscal support in specific years. The mean Urbanization Rate (UR) is 0.660, with a minimum of 0.451, reflecting substantial regional variation in the pace of urbanization across China during the study period.

The median of the Urban-Rural Income Gap (URI) is 2.359, while the mean is 2.356—almost identical—indicating that the disparity in income between urban and rural residents across provinces remained relatively stable and evenly distributed. The minimum and maximum values of Economic Development Level (EDL) are 26,416 and 180,536 respectively, highlighting substantial progress in China's economic development over the past decade.

The value of Fixed Asset Investment (FI) shows wide variation across provinces, with a maximum of 2,231 and a minimum of 1.605; the median is 534.46. This suggests that some provinces had extremely high or low levels of investment. Research Project Funding (RPF), expressed in logarithmic form, has a mean of 7.49 and a standard deviation

Table 4. Descriptive Statistics

Variable Name	Symbol	Obs.	Mean	Std. Dev.	Min	Max	Median
Fisheries Economic Resilience	FEI	100	0.337	0.140	0.110	0.590	0.333
Digital Economy Development	DIT	100	0.401	0.139	0.133	0.755	0.403
Fiscal Support	FS	100	0.196	0.0652	0.105	0.354	0.177
Urbanization Rate	UR	100	0.660	0.108	0.451	0.896	0.664
Urban-Rural Income Gap	URI	100	2.356	0.197	1.897	2.911	2.359
Economic Development Level	EDL	100	75,129	34,286	26,416	180,536	66,799
Fixed Asset Investment	FI	100	743.4	643.8	1.605	2,231	534.56
Research Project Funding	RPF	100	7.4899	1.6494	4.4176	9.4773	8.0741

Table 5. Correlation Matrix

	FEI	DIT	FS	UR	EDL	URI	FI	RPF
FEI	1							
DIT	0.114	1						
FS	-0.723***	-0.181*	1					
UR	0.150	0.659***	-0.307***	1				
EDL	0.290***	0.771***	-0.451***	0.847***	1			
URI	0.0800	-0.636***	0.295***	-0.445***	-0.595***	1		
FI	0.236**	-0.124	-0.222**	-0.466***	-0.274***	0.0960	1	
RPF	0.595***	0.285***	-0.498***	0.607***	0.556***	-0.313***	-0.391***	1

Note: *, **, and *** denote significance levels at the 10%, 5%, and 1% levels, respectively.

of 1.65, indicating relatively moderate variation across the sample.

3.2. CORRELATION ANALYSIS

Before conducting the regression analysis, we examine the pairwise correlations among the variables. Table 5 presents the correlation test results. It is observed that the explanatory variable (DIT) is positively correlated with the dependent variable (FEI); however, this correlation is not statistically significant at the 10% significance level. This may be due to the presence of confounding variables that obscure the true relationship between the two.

While correlation analysis provides preliminary insights into the linear relationships among variables, it does not control for other influencing factors. Therefore, to gain a more accurate understanding of the relationships, we proceed with regression analysis in the next section.

The correlation analysis reveals that some variables have correlation coefficients greater than 0.8, indicating a potential risk of multicollinearity. Therefore, we further conducted a Variance Inflation Factor (VIF) test. The results are presented in Table 6. As all VIF values are less than 10, it indicates that there is no severe multicollinearity among the variables in the hypothesized model.

3.3. REGRESSION ANALYSIS

This study employs a multiple regression method. After conducting the Hausman test, a fixed effects model was selected to examine the relationship between the level of fishery economic resilience and the level of digital economy development. The regression results are shown in Table 7. Column (1) presents the results without controlling for province and time fixed effects. In this case, the coefficient of digital economy development (DIT) on fishery economic resilience (FEI) is 0.198 and is statistically significant at the 1% level. Column (2) includes province and time fixed effects. The coefficient of DIT increases to 0.479 and remains statistically significant at the 5% level.

These results suggest that higher levels of digital economic development in a region are associated with a higher degree of digitalization in the fishery industry. This, in turn, enhances the fishery sector's capabilities in resistance and recovery, adjustment and adaptation, as well as innovation and transformation, thereby improving fishery economic resilience. Thus, Hypothesis H1 is supported.

3.4. ROBUSTNESS TEST AND ENDOGENEITY TEST

To verify the reliability of the estimated results of the analysis model, this study draws on existing literature and adopts several methods to conduct robustness and endogeneity tests on the baseline regression results.

3.4.1. ROBUSTNESS TEST

This study employs three methods to test the robustness of the baseline regression. First, the study reconstructs the measurement of the digital economy using principal com-

Table 6. Multicollinearity Test

Variable	VIF	1/VIF
EDL	6.52	0.153
UR	4.92	0.203
DIT	3.56	0.281
URI	2.32	0.431
FS	2.31	0.434
FI	2.05	0.489
RPF	1.86	0.537
Mean VIF	3.36	

Table 7. Multiple regression empirical results

	(1)	(2)
Variable	FEI	FEI
DIT	0.198***	0.479**
	(3.60)	(2.125)
_cons	0.323	1.289***
	(3.60)	(2.71)
Control	Yes	Yes
Year	No	Yes
Province	No	Yes
Within r2_a	0.3947	0.6215
N	100	100

Note: *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Table 8. Robustness Test

	(1)	(2)	(3)
Variable	FEI	FEI	FEI
DIT	1.120**	0.565**	0.515**
	(2.440)	(2.441)	(2.135)
_cons	0.587	1.176***	1.289***
	(0.97)	(2.60)	(2.82)
Control	Yes	Yes	Yes
Year	Yes	Yes	Yes
Province	Yes	Yes	Yes
Within r2_a	0.6361	0.6670	0.6226
N	100	90	100

ponent analysis and then re-conducts the baseline regression analysis accordingly. The results, shown in Column (1) of **Table 8**, indicate that the digitally measured variable still exhibits a significant positive effect on the resilience of the fisheries economy.

Second, since 2020 marked the initial outbreak of the COVID-19 pandemic, which had a considerable impact on various industries and regional economic development across China, to reduce the uncertainty caused by this year on the research results, the data for 2020 was excluded and the regression was rerun. The results, shown in Column (2) of Table 8, demonstrate that the sign, significance level, and economic meaning of the core explanatory variable's coefficient did not change substantially. This indicates that the impact of digital economic development on China's fisheries economic resilience remains significant and that the baseline regression results are robust and reliable.

Third, since some extreme values might interfere with the regression results of the digital economy on fisheries industry resilience, this study performs winsorization by trimming the top and bottom 1% of both the explanatory and dependent variables and reruns the regression. The re-

Table 9. Instrumental Variable Method

Variable	(1) DIT	(2) FEI	(3) DIT	(4) FEI
LDIT	0.755***			
	(8.67)			
IV			0.0019***	
			(10.67)	
DIT		0.556**		0.369**
		(2.519)		(2.03)
Kleibergen-Paap rk LM statistic	25.601***		23.416***	
Kleibergen-Paap rk Wald F	75.205		113.827	
Control	YES	YES	YES	YES
Year	YES	YES	YES	YES
Province	YES	YES	YES	YES
N	100	100	100	100

sults in Column (3) of **Table 8** show that the coefficient for the digital economy is 0.515 and significant at the 5% level, further confirming the reliability of the previous results.

3.4.2. ENDOGENEITY TEST

Considering the possible bidirectional causal relationship between the digital economy and fisheries economic resilience, to mitigate the endogeneity problem caused by this phenomenon, this study refers to the related research of and selects the one-period lagged digital economy variable (LDIT) as an instrumental variable for robustness analysis. The results are shown in Columns (1) and (2) of **Table 9**. Additionally, this study introduces mobile phone penetration rate (IV) as another instrumental variable, which is closely related to the digital economy development level but has no direct causal relationship with fisheries economic resilience, thus satisfying the exogeneity requirement. The results are presented in Columns (3) and (4) of **Table 9**. The findings indicate that the instrumental variables are significantly correlated with the digital economy development level, and the coefficient of the digital economy development level on fisheries economic resilience in the second-stage regression is significantly positive, consistent with the baseline regression results.

3.5. MEDIATION ANALYSIS

According to the theoretical hypothesis of this study, the level of digital economy can enhance the economic resilience of the fisheries industry by promoting industrial structure upgrading. Considering that the traditional three-step mediation effect test may produce biased results due to endogeneity issues and its effectiveness is somewhat controversial, this paper draws on the findings of Reggiani, A et.al. and further constructs the following mechanism test model.[16]

$$STR_{it} = \beta_0 + \beta_1 \text{ DIT }_{it} + \beta_2 \text{ Control }_{it} + \delta_{it} + \varepsilon_{it} \quad (8)$$

In the equation, STR represents the mediating variable, and the meanings of the other variables are consistent with those in equation (8). The results of the mediation effect test are shown in **Table 10**. In column (2), the regression coefficient of digital economy development level on industrial structure upgrading is significantly positive, indicating that digital economy development can enhance the resistance and recovery capacity of the fisheries industry by promoting industrial structure upgrading, thereby improving the economic resilience of the fisheries industry. Thus, hypothesis H2 is supported.

3.6. HETEROGENEITY ANALYSIS

Considering that economic level and ecological resources have certain impacts on fisheries development, this study divides the provinces into economically developed and less developed regions based on the median of per capital GDP, as well as into resource-rich and resource-poor regions based on the abundance of freshwater resources, and further conducts heterogeneity analysis.[17]

As shown in columns (1) and (3) of Table 11, the coefficient of digital economy development level on fisheries economic resilience is positive but relatively small and not significant, indicating that in economically developed provinces and provinces rich in freshwater resources, the digital economy has not played an effective role in improving fisheries economic resilience.

In columns (2) and (4), the coefficient is positive and significant at the 1% and 5% levels, respectively, suggesting that in economically less developed regions and provinces with scarce freshwater resources, digital economy development has a more pronounced positive effect on enhancing fisheries economic resilience.

DISCUSSION

This study, based on panel data from 10 coastal provinces and cities in China from 2013 to 2022, constructs indicator

Table 10. Mediation Effect Test

Variable	(1) FEI	(2) STR
DIT	0.479**	3.818***
	(2.125)	(3.31)
_cons	1.289***	5.292***
	(2.72)	(2.72)
Control	Yes	Yes
Year	Yes	Yes
Province	Yes	Yes
Within r2_a	0.6361	0.8619
N	100	100

Table 11. Heterogeneity Test

Variable	(1) Economically Developed Provinces	(2) Economically Less Developed Provinces	(3) Resource-Rich Provinces	(4) Resource-Scarce Provinces
DIT	0.189	0.574***	0.016	0.388**
	(0.51)	(3.65)	(0.08)	(2.02)
_cons	3.014**	0.129	1.865***	0.004
	(2.24)	(0.02)	(5.13)	(0.01)
Control	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
Province	Yes	Yes	Yes	Yes
Within r2_a	0.8188	0.7774	0.8595	0.7663
N	50	50	50	50

systems for fishery economic resilience and digital economy development levels. Through benchmark regression, robustness tests, and endogeneity tests, the study comprehensively verifies the mechanisms and pathways through which digital economy development empowers the improvement of fishery economic resilience. The results show that digital economy development significantly promotes the resilience of China's fishery economy. Furthermore, mechanism testing reveals that digital economy development mainly enhances fishery economic resilience by promoting industrial structure upgrading. In different regions, the promotion effect of digital economy development on fishery economic resilience is more pronounced in economically less developed provinces and provinces with relatively scarce freshwater resources. Existing literature mostly focuses on the relationship between the digital economy and urban economic resilience, agricultural economic resilience, and other areas, lacking more micro-level and specific research. Compared with previous studies, this research establishes the relationship between the digital economy and the resilience of the fisheries economy, and empirically verifies through linear regression the significant positive effect of the digital economy on the resilience of the fisheries economy , expands both the scope and depth of exploration, and holds important theoretical significance.

Based on these findings, to fully leverage the significant positive impact of the digital economy on fishery economic resilience—especially through its key path of promoting industrial upgrading—this study proposes the following policy recommendations:

On the one hand, since the digital economy enhances fishery resilience through industrial structure upgrading, other countries can learn from China's successful experience in this field. It is recommended that countries strengthen digital infrastructure construction, especially investments in data collection, storage, and analysis technologies. This will help improve fisheries' ability to adapt to external factors such as climate change and market fluctuations. On the other hand, to fundamentally enhance the resilience of the fishery economy, policymakers need to move beyond the general promotion of digital technologies and implement targeted industrial policies, focusing on guiding and funding the transformation of fisheries from traditional fishing activities to high value-added operations, and steering and supporting the industry's strategic shift from resource-dependent traditional fishing to knowledge-intensive and value-driven high value-added activities.

This study also has certain limitations. First, due to data availability, this study used 100 data samples from coastal cities in China from 2013 to 2022. The relatively small sample size may reduce the statistical power of the regression analysis. Second, the study is limited to reflecting the characteristics of provincial areas and does not break down the indicators to the level of individual cities or districts. Future research could expand the study period and the scope of provinces within this framework, providing more convincing empirical evidence to verify the relationship between the digital economy and the resilience of the fisheries economy.

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Conceptualization: Junhui Wang (Equal), Qiaoya Wang (Equal), Qingqing Jiang (Equal), Zhuming Zhao (Equal). Funding acquisition: Junhui Wang (Equal), Zhuming Zhao (Equal). Supervision: Junhui Wang (Lead). Formal Analysis: Qiaoya Wang (Equal), Qingqing Jiang (Equal). Validation: Qiaoya Wang (Equal), Zhuming Zhao (Equal). Writing – original draft: Qiaoya Wang (Equal), Qingqing Jiang (Equal). Software: Qiaoya Wang (Lead). Project administration: Qiaoya Wang (Lead). Visualization: Qiaoya Wang (Lead). Writing – review & editing: Qiaoya Wang (Equal), Qingqing Jiang (Equal). Data curation: Qingqing Jiang (Equal). Investigation: Qingqing Jiang (Equal), Zhuming Zhao (Equal). Resources: Zhuming Zhao (Equal).

ETHICAL CONDUCT APPROVAL – IACUC

No animal was involved in this work.

INFORMED CONSENT STATEMENT

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

DATA AVAILABILITY STATEMENT

The datasets generated and/or analyzed during the current study are available from the corresponding authors upon reasonable request.

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