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Analysis of the Impact of the Digital Economy on High-Quality Regional Economic Development

Feixiang Wang[1,*] and Lihao Wu[2]

[1] School of Economics and Management, Xinjiang Institute of Technology, Aksu, Xinjiang, 843100, China
[2] School of Economics, Guizhou University of Finance and Economics, Guiyang, Guizhou, 550025, China

Corresponding authors: (e-mail: WangFeix0@163.com).

Abstract The digital economy not only injects new momentum into regional economic growth but also serves as a crucial catalyst for advancing high-quality regional economic development. This paper identifies the direct effects of the digital economy on regional economic coordination and its indirect effects in promoting technological innovation to support high-quality regional economic development. Based on this framework, data from multiple provinces in China spanning 2015–2023 were selected. Comprehensive empirical tests were conducted using bidirectional fixed effects models, mediation effect models, and geographic detector models. The results indicate that the digital economy significantly promotes high-quality regional economic development, with pronounced regional heterogeneity—particularly benefiting central, western, and southern regions. Technological innovation serves as a key mediating pathway for digital economy-driven development, and fostering interregional innovation cooperation further advances coordinated high-quality regional economic development. This study provides an innovative theoretical foundation for cross-regional digital economy collaboration.

Index Terms Two-way fixed effects model, Mediating effects model, Geodetector, Digital economy, Regional economy

I. Introduction

The G20 Digital Economy Development and Cooperation Initiative adopted at the 2016 G20 Hangzhou Summit defines the digital economy as a series of economic activities that utilize digital knowledge and information as core production factors, rely on modern information networks as key carriers, and leverage information and communication technologies to optimize economic structures and enhance efficiency [1]. With the accelerated large-scale commercial application of next-generation information technologies such as mobile internet, 5G technology, big data analytics, and artificial intelligence, capabilities in data collection, storage, and analysis have significantly improved. This is propelling a new round of technological revolution and industrial transformation toward higher levels of evolution. Countries worldwide are continuously enhancing their digitalization levels, and the digital economy is increasingly elevating its status within national economic development, emerging as a vital engine driving global economic growth [2]-[4]. Research by Mao, Y et al. indicates that between 2008 and 2022, China's digital economy achieved an average annual growth rate of approximately 15% in value-added output, significantly outpacing the concurrent growth rate of its gross domestic product (GDP) [5]. The rapid development of the digital economy and its immense driving force have prompted governments worldwide to recognize its crucial role in promoting regional economic growth. Nations are striving to leverage the digital economy to propel their own economic development, further seize the initiative in the global economic competition, and gain a head start and competitive edge for future growth.

In recent years, as the digital economy has surged, its reshaping influence on the global economic system has become increasingly evident. As Knickrehm, M. et al. noted, the digital economy is propelling the global technological revolution and industrial transformation into deeper waters, emerging as the core driver of global technological innovation and economic system modernization [6]. Research on the digital economy's impact on economic growth originated from studies examining the contribution of digital technologies or services to economic expansion. Mgadmi, N. et al. investigated the digital economy's contribution to economic growth in developed and developing countries from 1990 to 2020, finding a significant positive effect and elucidating the relationship between information and communication technologies (ICT) and economic growth [7]. Jiao, S and Sun, Q examined the impact of digital economic development on urban economic growth in China, finding positive effects that varied across regions. These effects were mediated by urban entrepreneurial activities and exhibited spatial spillover effects [8]. Ding, C et al. employed mediation models and spatial Durbin models to analyze the impact mechanism of China's digital economy on high-quality economic development across 30 provinces from 2011 to 2019. They found that the digital economy enhances high-quality economic development, with highly significant spatial spillover effects [9]. Murthy, K et al. observed that developed economies exhibit robust network economies, with strong links between economic growth and mobile digital services. They identified bidirectional causality between growth and digital variables, noting that the digital divide benefits developed economies—particularly in e-commerce [10]. Chen, W et al. empirically examined the impact of the digital economy on regional total factor productivity (TFP), revealing a U-shaped relationship and highlighting innovation and entrepreneurship as key pathways to enhancing TFP [11].

As the new economic paradigm following agricultural and industrial economies, the digital economy has become a pivotal driver of profound socioeconomic transformation. Its core lies in digital technologies and the novel business models derived from them [12], [13]. Currently, scholars have extensively researched the impact of the digital economy on economic growth. From a macro perspective, Sawng, Y. et al. further discovered that the promotional effect of information and communication technology (ICT) on economic growth primarily manifests in the short term, a conclusion validated by subsequent scholars [14]. Additionally, Ward, M and Zheng, S observed that the impact of the digital economy on economic growth may also be influenced by regional development levels [15]. Thompson Jr, H and Garbacz, C argue that the growth-promoting effect of informatization is significantly greater in low-income regions than in high-income regions. Consequently, benefiting from ICT development, low-income regions can rapidly narrow the economic development gap with high-income regions [16]. With the widespread adoption of ICT, Niebel, T. observed that the relative price decline of ICT equipment in developed countries may outpace that in developing countries. This trend attracts greater ICT investment, and the resulting learning-by-doing effects further stimulate regional economic growth [17].

From a microeconomic perspective, existing research primarily explores how the digital economy facilitates industrial restructuring and optimization while enhancing corporate innovation and entrepreneurship capabilities. Li, M and Du, W's research indicates that digital technology applications boost corporate scientific and technological innovation outputs by reducing inefficient misallocation of innovation resources [18]. Chang, X et al. examined the digital economy's impact on industrial restructuring through the lens of innovation factor allocation, finding that by optimizing innovation resource allocation, the digital economy significantly accelerates transformation and offers policy recommendations for sustainable economic development [19]. Song, Y and Jiang, Y found that the digital economy positively drives the optimization and rationalization of China's industrial structure, with regional variations. This effect is realized through innovation, moderated by economic resilience, and exhibits a threshold effect in promoting optimization and upgrading [20]. Pang, J et al. found that the digital economy significantly drives industrial upgrading by optimizing capital and labor allocation, particularly in relatively underdeveloped regions. It offers guidance for sustainable economic growth and escaping the "poverty trap" [21]. Li, R et al. examined the impact of regional digital economies on corporate innovation, identifying a positive correlation between the two. They noted that corporate digital transformation serves as a secondary influencing factor in this relationship, while corporate efficiency acts as a positive moderating factor [22]. Zhao, S. et al. conducted an empirical analysis exploring the role of the digital economy in enhancing China's urban industrial structure. They found that through the mediating effects of technological progress and human capital, the digital economy exerts a significant positive influence on industrial upgrading and service-sector expansion, while also generating spatial spillover effects on surrounding regions [23].

To thoroughly examine the mechanism and practical impact of the digital economy on high-quality regional economic development, this paper proposes a theoretical framework encompassing both direct and indirect effects. It examines the direct effects of the digital economy on regional development disparities through its driving role, then explores its indirect effects on regional economic development using technological innovation as a mediating factor. Employing fixed-effects models, mediation models, and geographic probes, the study investigates the influence mechanisms of the digital economy on regional high-quality development, regional disparities, and specific driving factors. Taking China as the research subject, empirical analysis is used to explore the reliability of the constructed model.

II. Theoretical Research and Research Hypotheses

II. A. Direct Effects of the Digital Economy on Regional Economic Development

Compared to traditional agricultural and industrial economic development models, the digital economy exhibits numerous novel characteristics, such as economies of scale, economies of scope, and the long-tail effect. These features endow the digital economy with distinctive new advantages, exerting comprehensive and profound impacts on economic growth and development through reducing transaction costs, boosting overall societal productivity, and catalyzing disruptive technological transformations. Due to these novel characteristics, the digital economy significantly influences interregional economic growth linkages.

First, the digital economy inherently possesses spatial spillover properties. This spatial spillover effect stems primarily from the virtual nature of the digital economy. As the core drivers of the digital economy, data production factors and digital technologies are incorporated into production in non-physical forms, thereby boosting economic growth. Most crucially, this virtual characteristic exhibits non-exclusivity and spatial openness, reducing barriers to interregional economic connections. New economic forms emerging from the internet, such as platform economies and virtual electronic products, exemplify the internet-driven information resource integration and sharing fostered by the digital economy.

The technological foundations of the digital economy—including blockchain, cloud computing, big data, and 5G—possess broad applicability. They enable deep integration with primary, secondary, and tertiary industries, driving innovative consolidation across industrial chains through the interaction of digital technologies and data. This process gives rise to new "Internet Plus" industry models. The co-construction and sharing mechanisms across industries not only reshape industrial organizational structures and alter industrial layouts but also transform regional industrial spatial arrangements through the widespread dissemination and application of digital technologies. The generalized effects of digital technologies foster mutual support and penetration between new and existing technologies. The expansion of this technological ecosystem further blurs temporal and spatial boundaries, enabling new applications and scenarios to connect diverse industries across regions via digital pathways. Neo-classical growth theory posits that economic growth without technological progress will ultimately stagnate. The digital economy not only drives synchronized technological innovation across industries but also significantly reduces the lag in technology diffusion and adoption across regions, fostering coordinated regional economic growth.

Finally, the driving transmission effect of the digital economy will propagate the digital revolution from one production sector to another, even sparking digital transformations in non-production sectors. The digital economy's transformation begins internally within a production sector. Initially, it drives change in computing and information communication, connecting more cities and regions to form the technological foundation of the digital economy. Subsequently, computing begins altering material production methods, triggering digital transformation in manufacturing and machine production sectors. The enhanced productivity in material production sectors then compels digital transformation in non-production sectors. For instance, front-end development and terminal services digitize the entire chain from R&D to production and sales. This digital transformation in production simultaneously drives digital governance reforms, encompassing digital enterprise management and digital government operations. The horizontal effects of the digital economy's driving transmission will elevate overall social productivity across different regions.

Hypothesis 1: The digital economy directly promotes high-quality regional economic development.

II. B. Indirect Effects of the Digital Economy on Regional Economic Development

The development of the digital economy undoubtedly represents a tremendous boon for small and medium-sized enterprises (SMEs). It not only enhances capital allocation efficiency but also provides SMEs with more abundant human resource support. Moreover, it has significantly stimulated the innovative vitality of SMEs, enabling them to venture into emerging industries, generate substantial benefits for the public, and accelerate the optimization and upgrading of regional economic structures. By elevating scientific and technological innovation capabilities, strengthening the public's information application skills, and exploring and developing various local resources, it forms a new resource integration platform that provides powerful momentum for high-quality economic development. The application of information technology has markedly enhanced poverty alleviation outcomes, indirectly propelling high-quality regional economic development and improving the precision of poverty reduction measures. The digital economy reduces the probability of traditional financial risks, promotes efficient resource circulation and sharing, stimulates corporate innovation potential, expands employment markets, and injects robust momentum into high-quality economic development. In summary, the digital economy drives high-quality economic development by advancing technological innovation.

Hypothesis 2: The digital economy promotes high-quality regional economic development by elevating technological innovation levels.

III. Research Design on the Digital Economy for High-Quality Regional Economic Development

III. A. Variable Selection and Definition

Explanatory variables and dependent variables: Comprehensive score for high-quality economic development. Scholars have yet to establish a clear definition for measuring indicators of high-quality economic development. In earlier stages, researchers defined indicators as sustainable development and social welfare. Subsequently, increasingly diverse academic achievements emerged, leading to more varied approaches in constructing indicators for high-quality economic development. Most scholars develop these indicators from two perspectives: First, treating total factor productivity as a proxy variable for economic growth quality. Second, following the introduction of the "New Development Philosophy," many scholars have established five core concepts for high-quality economic development based on this framework. While TFP can describe economic development from environmental and social welfare perspectives, it remains relatively limited and cannot fully reflect high-quality economic development. The New Development Philosophy was proposed during a critical period when China's economy entered a new normal and faced structural transformation, making it an indicator aligned with China's current economic context for high-quality development. Therefore, this paper constructs indicators suitable for economic development based on these five new development concepts.

Level of Digital Economic Development. In existing research, most scholars measure the level of digital economic development using two main approaches: first, constructing an index based on online search popularity as a variable to explain digital economic development; second, using digital inclusive finance index data as an index to measure the level of digital economic development. Digital inclusive finance data forms a digital economy indicator system developed by integrating microdata provided by Ant Group with research from Peking University's Digital Economy Research Center. This system comprehensively analyzes digital economy development across three dimensions: coverage breadth, usage depth, and digitalization level. As a leading Chinese fintech enterprise, Ant Group possesses substantial market share and the most comprehensive data coverage. Indices constructed based on online popularity suffer from issues such as poor accuracy and coverage due to their time-sensitivity. Therefore, this paper adopts the Digital Inclusive Finance Index data as a proxy variable for measuring the level of digital economic development.

The level of digital economic development is measured by taking its logarithm and serves as the explanatory variable ($lnDIG$) in this study. The level of high-quality regional economic development is also measured by taking its logarithm and serves as the dependent variable ($lnRECD$).

Control variables: Government intervention level (GOV), financial development level (FIN), transportation infrastructure development level ($lnTRA$), industrial structure upgrading (STR), urbanization level (UL).

Mediating variable: Technological innovation is set as the mediating variable. Technology market transaction volume reflects market activity and the overall scale of scientific and technological achievement transformation, representing technological innovation dynamics. The ratio of technology market transaction volume to GDP is used to represent provincial technological innovation levels ($TECH$).

Influencing factors for regional economic high-quality development divergence patterns: Five variables—digital economy, government intervention level, financial development level, transportation infrastructure development level, industrial structure upgrading, and urbanization level—are examined as factors influencing regional economic high-quality development divergence. The natural breakpoint method is employed to categorize each annual influencing factor into four distinct groups and assign corresponding values.

III. B. Data Sources

This study utilizes panel data from selected Chinese provinces covering the period 2015–2023, sourced from the China Statistical Yearbook, the China Digital Economy White Paper, and provincial statistical yearbooks. Due to data unavailability and other constraints, missing values were imputed using the average incremental method.

III. C. Descriptive Statistical Analysis

Table 1 presents the descriptive statistics for the variables. As shown in Table 1, the level of high-quality economic development is moderate, with a mean value of 0.686. Significant disparities exist in the coordinated economic development across different regions. The control variables indicate that the government exerts a certain degree of intervention in economic development. Regional variations in industrial structure upgrading are substantial, while the development levels of transportation infrastructure, financial systems, and urbanization remain uneven. Differences in technological innovation capabilities are also evident across regions.

Table 1: Descriptive statistics

Variable	Variable meaning	Variable meaning	Minimum value	Maximum value	Mean	Standard deviation
$RECD$	Regional economic high quality development	300	0.421	0.791	0.686	0.098
DIG	Digital economic development	300	0.102	0.630	0.268	0.112
GOV	Government intervention	300	0.109	0.758	0.255	0.108
STR	Industrial upgrading	300	2.196	2.836	2.400	0.119
TRA	Advanced traffic infrastructure	300	0.045	1.422	0.429	0.247
FIN	Financial development level	300	1.904	7.575	3.501	1.080
UL	Level of urbanization	300	0.375	0.897	0.608	0.110
$TECH$	Technical innovation level	300	0.004	0.173	0.020	0.029

III. D. Model Construction

III. D. 1) Fixed Effects Model

The fixed effects model [24] is a panel data model used to analyze differences among individuals within panel data. In this model, the fixed effects of individuals are treated as constants that do not change over time. By subtracting these fixed effects, the model eliminates the impact of individual heterogeneity, thereby enabling a more accurate analysis of the factors influencing time series data. The advantage of the fixed effects model lies in its ability to control for individual differences, eliminating some influences and thereby enabling more precise estimation of factors affecting time series data. Additionally, the fixed effects model can control for the effects of unobserved individual characteristics, reducing estimation errors.

Based on the aforementioned assumptions, this paper posits that the digital economy can drive high-quality regional economic development and can promote such development through mediating variables. Furthermore, drawing upon the theoretical analysis and indicator variable construction outlined above, we can first demonstrate the relationship between the digital economy and high-quality economic development, then employ empirical methods to verify their specific impact dynamics. Accordingly, the bidirectional fixed effects model constructed in this paper is as follows:

$$\begin{aligned}\ln RECD_{it} &= \beta_0 + \beta_1 \ln DIG_{it} + \beta_2 X_{it} \\ &+\alpha_i + \theta_t + \varepsilon_{it}\left(i = 1,\cdots,n; t = 1,\cdots,T\right)\end{aligned} \tag{1}$$

Here, i denotes province, t denotes year, $\ln RECD$ represents the level of high-quality regional economic development, $\ln DIG$ is the explanatory variable for the level of digital economic development, X denotes a series of control variables, α_i is the regional fixed effect, θ_t is the time fixed effect, and ε_{it} represents the random error term.

III. D. 2) Mediated Effect Model

Mediation effect models [25] are used to analyze whether the influence of independent variables on dependent variables is mediated by intermediate variables. These models posit that independent variables affect dependent variables through intermediate variables, which serve as conduits and explanatory agents between the former and the latter. This paper employs stepwise regression to test for the presence of mediation effects, following these steps:

Step one involves regressing the independent variable and the mediating variable separately against the dependent variable to test whether the effects of the independent variable and the mediating variable on the dependent variable are significant.

Step two regresses the dependent variable using both the independent variable and the mediating variable as independent variables simultaneously. This tests whether the effect of the independent variable on the dependent variable diminishes, determined by comparing the magnitudes of the regression coefficients.

Step three involves testing the mediation hypothesis: examining whether the mediating variable significantly influences both the independent variable and the dependent variable, and whether the relationship between the independent variable and the dependent variable is mediated by the mediating variable.

Following the steps for testing mediation effects, Models (2), (3), and (4) were constructed based on Model (1), where Med represents the indicator for technological innovation.

$$\ln RECD_{it} = \beta_0 + \beta_1 \ln DIG_{it} + \beta_2 X_{it} + \alpha_i + \theta_t + \varepsilon 1_{it} \tag{2}$$

$$Med_{it} = \gamma_0 + \gamma_1 \ln DIG_{it} + \gamma_2 X_{it} + \alpha_i + \theta_t + \varepsilon 2_{it} \tag{3}$$

$$\ln RECD_{it} = \mu_0 + \mu_1 \ln DIG_{it} + \mu_2 Med_{it} + \mu_3 X_{it} + \alpha_i + \theta_t + \varepsilon 3_{it} \tag{4}$$

III. D. 3) Geodetector Model

Geodetector [26] is a statistical method used to detect spatial heterogeneity in target attributes and analyze the driving factors behind such spatial variation. Its core concept is based on the following assumption: if a factor significantly influences a target variable, then this factor and the target variable should exhibit similar spatial distribution characteristics. A key advantage of this method is that it detects relationships between drivers and spatial patterns without requiring any linear assumptions. Its computational process and results remain unaffected by multivariate multicollinearity.

The primary tools of the Geodetector include: Factor Detection, Interaction Detection, Ecological Detection, and Risk Detection. This paper utilizes indicators from the digital economy development index system as factors, focusing on the Factor Detection tool. It conducts detection and analysis of the driving factors and their respective magnitudes for regional high-quality development, examining the eastern, central, western regions of China, and the national level as distinct research scopes.

The fundamental principle of factor detection is as follows: First, the study area is spatially stratified based on specific characteristics. Then, the within-subregion variance of the influencing factor is compared with its total variance across the entire region. This comparison enables the calculation of the factor's influence on the level of high-quality regional development. Factor detection employs the q value as a metric, calculated using the following formula:

$$q = 1 - \frac{\sum_{h=1}^{L} N_h \sigma_h^2}{N\sigma^2} = 1 - \frac{SSW}{SST} \tag{5}$$

Here, q represents the driving force of each digital economy indicator on regional high-quality development levels, h denotes the stratification of digital economy indicators X_i, N is the sample size, σ^2 is the variance of X_i, SST is the total variance of X_i across all regions, and SSW is the sum of within-stratum variances of X_i. The value range of q is

$[0,1]$. A higher value indicates a stronger influence of X_i on regional high-quality development. The significance of q can be assessed through the P value.

IV. Empirical Findings and Analysis

IV. A. Analysis of Benchmark Regression Results

Table 2 presents the benchmark regression analysis results on the impact of digital economic development levels on regional high-quality economic development. Column (1) shows the benchmark regression results without including other variables. An increase in digital economic development levels can raise regional high-quality economic development levels by 0.209%, which is statistically significant at the 1% level. Column (2) incorporates fixed effects, showing that an increase in the level of digital economic development can raise regional high-quality development by 0.306%, which is statistically significant at the 1% level. Column (3) includes both fixed effects and control variables, indicating that an increase in the level of digital economic development can raise regional high-quality economic development by 0.141%. The results demonstrate that, after controlling for other unknown influencing factors, the level of digital economic development still exerts a positive promotional effect on regional high-quality economic development, validating Hypothesis 1.

Table 2: Benchmark regression

	(1)	(2)	(3)
	$\ln RECD$	$\ln RECD$	$\ln RECD$
$\ln DIG$	0.209***	0.306***	0.141***
	(0.072)	(0.058)	(0.043)
Control variable	NO	NO	Yes
Individual fixation effect	NO	Yes	Yes
Time fixed effect	NO	Yes	Yes
N	300	300	300
R^2	0.054	0.534	0.709

IV. B. Parallel Trend Test

An important prerequisite for the double difference model is satisfying the parallel trend assumption, meaning that prior to the implementation of digital economy policies, the regional high-quality economic development of the treatment group and control group exhibits identical temporal trends. After the implementation of digital economy policies, significant differences exist in the outcome variables between the treatment group and control group. Using the event study method, the following model is constructed:

$$\begin{aligned}\ln RECD_{it} &= \alpha_0 + \sum_{T=-m}^{n} \alpha_k \ln DIG_{i,t-T} \\ &+\alpha_2 control_{it} + v_i + \mu_t + \varepsilon_{it}\end{aligned} \tag{6}$$

Among these, $\ln DIG_{i,t-T}$ is a dummy variable that takes the value 1 if region i implemented a digital economy policy in period $t-T$, and 0 otherwise, where m and n denote the number of periods before and after the policy implementation, respectively. When $T=2$, the dummy variable $\ln DIG_{i,t-T}$ indicates whether region i implemented a digital economy policy in period $t-2$, measuring the effect in the second year following implementation. Thus, α_1 measures the effect in the policy implementation period, α_{-m} to α_{-1} measure the policy effect in the $1-m$ periods prior to implementation, and α_1 to α_n measure the policy effect in the $1-n$ periods after implementation. If α_{-m} to α_{-1} are significantly equal to 0, this indicates no significant difference between the treatment and control groups during the $1-m$ periods preceding the policy implementation, thus confirming the parallel trends assumption.

Figure 1 presents a parallel trend test graph. The horizontal axis represents the time series before and after the implementation of digital economy policies, with 0 denoting the period when the policies were implemented. The vertical axis indicates the regional high-quality economic development coefficient, which measures the specific impact of big data and digital economy levels on regional high-quality economic development. The figure reveals that prior to the implementation of digital economy policies, the estimated value of parameter α fails to reject the null hypothesis of a coefficient equal to zero. This indicates that before policy implementation, the level of the digital economy had no significant impact on regional high-quality economic development, satisfying the parallel trend assumption. However, after the implementation of digital economy policies, the estimated coefficient deviates from zero, and this deviation gradually increases over time. This indicates that digital economy policies not only significantly promote regional high-quality economic development but also exhibit an effect that intensifies annually. This result demonstrates that the implementation of digital economy policies has generated a positive and sustained driving force for regional high-quality economic development.

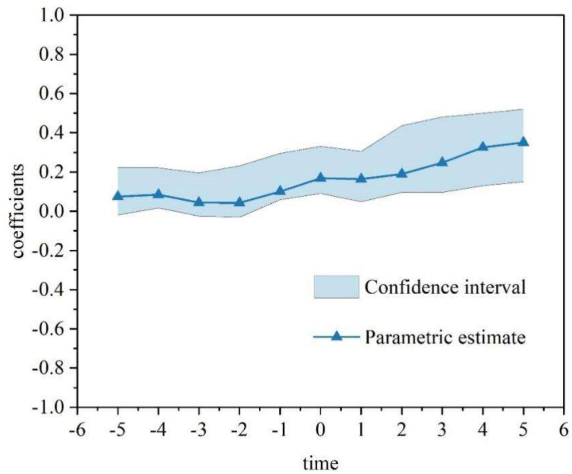

Figure 1: Parallel trend survey

IV. C. Testing for Multicollinearity

Multicollinearity affects the stability and accuracy of regression coefficient estimates, making it difficult to accurately distinguish the independent effects of each explanatory variable on the dependent variable. It also fails to accurately reflect causal relationships between variables, leading to unstable model prediction and explanatory power. Therefore, this study conducted multicollinearity tests on the explanatory variables and control variables. As shown in Table 3, the variance inflation factors for all variables are below 10, indicating no multicollinearity among the variables. Consequently, all variables can be included in the baseline regression model.

Table 3: VIF test

Variable	*VIF*	1/*VIF*
ln *RECD*	1.45	0.690
FIN	1.41	0.709
GOV	1.25	0.800
ln *TRA*	1.23	0.813
STR	1.16	0.862
UL	1.11	0.901

IV. D. Robustness Tests

Placebo tests typically employ two approaches: one involves simulating policy implementation periods, while the other simulates treatment groups. This study employs a combined approach of fictitious treatment groups and fictitious policy periods for the placebo test. The specific methodology is as follows: Twelve provinces were randomly selected from multiple Chinese provinces to form the treatment group, where digital economy policies were implemented, while the remaining provinces served as the control group. A fictitious time period was randomly assigned to the treatment group to generate a "fictitious policy dummy variable" for regression analysis. This regression process was repeated 1,500 times to obtain the regression results. The placebo test results are shown in Figure 2. The horizontal axis represents regression coefficients, which are concentrated around zero. The vertical axis displays p-values, with the vast majority exceeding 0.1. This indicates that the implementation of digital economy policies holds no significant meaning for the randomly selected treatment group, passing the test.

When examining the impact of digital economy policy implementation on regional high-quality economic development, potential interference from the "Broadband China" pilot city policy and smart city pilot policy must be considered. To ensure robustness, these two policy variables were incorporated as controls in the regression model to eliminate their influence on the results. As shown in Table 4, digital economy policies still significantly and positively promote regional high-level economic development.

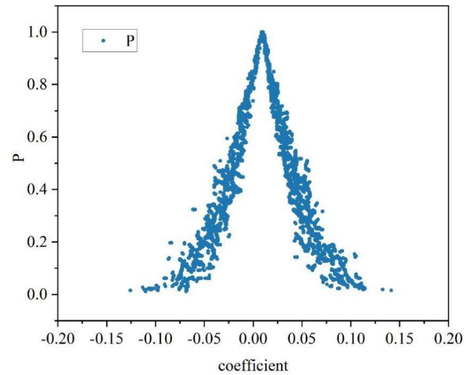

Figure 2: Placebo test results

Table 4: Exclude other policy interference tests

	(1)	(2)	(3)
	ln *RECD*	ln *RECD*	ln *RECD*
ln *DIG*	0.145***	0.148***	0.140***
	(0.048)	(0.048)	(0.048)
Control variable	Yes	Yes	Yes
Individual fixation effect	Yes	Yes	Yes
Time fixed effect	Yes	Yes	Yes
N	300	300	300
R^2	0.705	0.705	0.705

IV. E. Regional Heterogeneity Analysis

The selected Chinese provinces are categorized into eastern, central, and western regions based on policy divisions. Table 5 presents the results of the regional heterogeneity test. Models (1) to (3) in the table respectively demonstrate the effects of digital economic development levels in the eastern, central, and western regions on regional high-quality economic development. The regression coefficients for the digital economy are significantly positive in the central and western regions. Comparing the magnitude of these coefficients reveals that the digital economy exerts a more pronounced promotional effect on high-quality regional economic development in central provinces, with a regression coefficient of 0.093. In contrast, the regression coefficient for eastern provinces is not significant, indicating that the digital economy primarily promotes coordinated economic development in central and western provinces. Regarding control variables, urbanization levels inhibit coordinated economic development in eastern provinces, while other control variables show no significant impact. Industrial structure upgrading and urbanization levels negatively affect coordinated economic development in central regions. Conversely, advanced transportation infrastructure and urbanization levels promote coordinated economic development in western regions. As resources and factors become saturated and production costs rise in eastern regions, key elements like capital and labor naturally diffuse toward central and western areas. Driven by the digital economy, China stands to establish a sound mechanism for regional economic complementarity and coordinated development.

Additionally, regional economic imbalances are exhibiting a new "north-south disparity" characteristic. We again divided the national sample into northern and southern regions for regression analysis. Models (4) and (5) respectively illustrate the effects of digital economic development levels in southern and northern regions on high-quality regional economic development. The regression coefficient for the digital economy is significantly positive in the southern region, while it is positive but not significant in the northern region. Overall, the impact of the digital economy on high-quality regional economic development exhibits distinct regional heterogeneity, whether analyzed by eastern, central, and western divisions or by southern and northern divisions.

IV. F. Analysis of the Mediating Effect Based on Technological Innovation

Using technological innovation level as the mediating variable, we examined the mediating effect of the digital economy on regional high-quality economic development, with results shown in Table 6. Model (2) demonstrates that the digital economy exerts a significant positive effect on technological innovation, while in Model (3), the regression coefficient for the digital economy remains positively significant but is smaller than the benchmark regression coefficient. Furthermore, the mediation model passed the Sobel test at the 10% significance level, indicating that the digital economy promotes high-quality regional economic development by enhancing technological innovation levels. Hypothesis 2 is thus validated.

Table 5: Regional heterogeneity test results

	ln *RECD*				
	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
ln *DIG*	0.045	0.093**	0.048**	0.056***	0.012
	(1.310)	(2.570)	(2.160)	(2.640)	(0.810)
GOV	−0.044	−0.101	−0.084	−0.231*	−0.102**
	(−0.520)	(−1.220)	(−0.880)	(−1.830)	(−2.550)
FIN	0.005	0.004	0.003	−0.005	0.012***
	(0.560)	(0.670)	(0.150)	(−0.810)	(2.840)
ln *TRA*	0.021	0.015	0.073***	0.062**	0.004
	(0.970)	(0.940)	(2.810)	(2.610)	(0.400)
STR	0.082	−0.101***	−0.124	−0.215***	−0.052*
	(0.930)	(−3.310)	(−1.440)	(−3.340)	(−1.810)
UL	−0.381***	−0.424**	0.862**	−0.096	−0.333***
	(−2.850)	(−2.110)	(2.620)	(−0.610)	(−4.950)
Cons	−0.342	0.373*	−0.260	0.405**	−0.032
	(−1.610)	(1.830)	(−0.840)	(2.230)	(−0.330)
Time fixed effect	control	control	control	control	control
Regional fixation effect	control	control	control	control	control
N	0.465	0.503	0.566	0.485	0.582
R^2	56	46	54	72	72

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

Table 6: Technical innovation intermediary effect test results

	ln *RECD*	*TECH*	ln *RECD*
	Model (1)	Model (2)	Model (3)
ln *DIG*	0.048***	0.015**	0.042***
	(3.362)	(2.072)	(2.953)
TECH			0.453***
			(3.272)
GOV	−0.145***	−0.015	−0.135***
	(−3.075)	(−0.720)	(−2.980)
FIN	0.012**	0.012***	0.004
	(2.032)	(4.720)	(1.000)
ln *TRA*	0.045***	−0.008	0.044***
	(3.210)	(−1.060)	(3.540)
STR	−0.135***	0.032**	−0.148***
	(−4.220)	(2.020)	(−4.720)
UL	−0.203**	0.193***	−0.116
	(−2.560)	(−5.320)	(−1.430)
Cons	0.179*	0.041	0.165
	(1.620)	(0.780)	(1.620)
Time fixed effect	control	control	control
Regional fixation effect	control	control	control
R^2	0.400	0.609	0.423
N	300	300	300
Goodman test 2	0.005*(z=1.745)		
Mediation effect coefficient	0.005*(z=1.745)		
Direct effect coefficient	0.042(z=2.952)		
Coefficient of total effect	0.048(z=3.359)		
Ratio of intermediary effect	0.133		

IV. G. Analysis of Factors Influencing Spatial Differentiation

At the level of spatial differentiation analysis for high-quality regional economic development, the years 2015, 2018, 2021, and 2023 were selected as cross-sectional studies. Both the digital economy and the five control variables mentioned above were treated as influencing factors. A geographic detector was employed to interpret the strength of each factor's impact and analyze the interactions among factors, thereby further examining the changing role of the digital economy in regional high-quality economic development during the sample period. Through factor detection, we can obtain the degree of influence each factor exerts on the spatial differentiation of economic coordination, measured by the q-value. A larger q-value indicates a greater influence of that factor on regional high-quality economic development. The results are shown in Table 7.

It can be seen that the q-values of most influencing factors passed the significance test. Industrial structure upgrading emerges as the dominant factor in spatial differentiation of regional economic high-quality development. Urbanization levels, digital economy development levels, transportation infrastructure development levels, and financial development levels also play crucial roles, while government intervention exerts the least influence on the spatial pattern of regional economic high-quality development. Trend analysis indicates that the explanatory power of financial development levels and industrial structure upgrading for coordinated spatial differentiation has strengthened, whereas that of transportation infrastructure development levels and urbanization levels has weakened. Additionally, during the sample period, the explanatory power of the digital economy for spatial differentiation in regional high-quality economic development has steadily declined, falling from 0.605 in 2015 to 0.333 in 2023. However, numerically speaking, it continues to play a relatively critical role in regional high-quality economic development.

Table 7: Spatial diversity detection results

Factor	$\ln DIG$	GOV	FIN	$\ln TRA$	STR	UL
2015	0.605***	0.155	0.422*	0.495**	0.705***	0.695***
2018	0.473**	0.026	0.400	0.455*	0.726***	0.708***
2021	0.372**	0.036	0.635**	0.458*	0.599**	0.686***
2023	0.333*	0.044	0.632**	0.377	0.960***	0.671***

Furthermore, after pairwise spatial interactions between factors were superimposed, interaction factors were formed. The computational results indicate that interactions exist between any two factors, with no completely independent factors present. The q-values for the top six most influential interaction factors are listed in Table 8.

The table reveals that the q-value for each pair of interacting factors is generally greater than the q-value of either individual factor within that pair. Moreover, interaction factors with stronger influence exhibit either a dual-factor enhancement or a nonlinear enhancement effect on the spatial differentiation of high-quality regional economic development. No cases of nonlinear weakening, single-factor nonlinear weakening, or mutually independent effects were observed.

Comprehensively, the spatial differentiation of high-quality regional economic development results from the combined effects of various socioeconomic factors. Tracking the explanatory power of the digital economy over the study period reveals that while its direct influence on the spatial distribution of high-quality regional economic development has gradually weakened annually, the interaction factors it forms with elements such as industrial structure upgrading and urbanization levels continue to profoundly shape the spatial patterns of high-quality regional economic development. This indicates that the digital economy does not exert a singular influence on high-quality regional economic development but rather plays a pivotal role by affecting multiple factor inputs throughout the economic development process.

Table 8: Spatial differentiation

Sort	(1)	(2)	(3)	(4)	(5)	(6)
2015	$\ln DIG \cap \ln TRA$	$\ln DIG \cap UL$	$GOV \cap UL$	$UL \cap STR$	$\ln DIG \cap FIN$	$\ln DIG \cap STR$
q	0.926	0.902	0.894	0.888	0.885	0.873
2018	$\ln DIG \cap \ln TRA$	$GOV \cap UL$	$\ln DIG \cap UL$	$GOV \cap \ln TRA$	$\ln DIG \cap STR$	$\ln DIG \cap GOV$
q	0.928	0.903	0.894	0.885	0.882	0.851
2021	$\ln DIG \cap CZ$	$\ln DIG \cap \ln TRA$	$UL \cap FIN$	$GOV \cap UL$	$\ln DIG \cap STR$	$UL \cap \ln TRA$
q	0.902	0.893	0.835	0.811	0.802	0.801
2023	$\ln DIG \cap STR$	$GOV \cap STR$	$UL \cap STR$	$\ln TRA \cap STR$	$FIN \cap STR$	$\ln DIG \cap UL$
q	0.976	0.971	0.971	0.971	0.965	0.886

V. Conclusion

This study utilizes panel data from selected provinces in China covering the period from 2015 to 2023. By constructing fixed-effects models, mediation models, and geographic detector models, it investigates the mechanism through which the digital economy influences regional high-quality development.

After incorporating fixed effects and control variables, the digital economy boosted regional high-quality economic development by 0.141%, indicating a significant positive effect. Even when including the "Broadband China" pilot city policy and smart city pilot policy as control variables, regression results still show the digital economy significantly and positively promotes regional high-level economic development.

The impact of the digital economy on regional high-quality economic development exhibits pronounced regional heterogeneity. Central and western regions benefit more significantly from digital economy policies than eastern regions, with the digital economy driving regional high-quality economic development. Meanwhile, digital economy policies in northern and southern regions primarily promote high-quality regional economic development in southern areas.

The digital economy exerts an indirect driving effect on regional high-quality economic development through the mediating variable of technological innovation. By enhancing corporate technological innovation capabilities, the digital economy stimulates regional innovation capacity, confirming innovation as a crucial mechanism for digitally driven development.

Although the impact of the digital economy on spatial differentiation in regional high-quality economic development gradually weakened between 2015 and 2023, its effect strength factor reached 0.333, remaining relatively significant. Interaction detection analysis revealed that the dual-factor enhancement and nonlinear enhancement effects among various influencing factors exerted a more pronounced impact on regional high-quality economic development than single-factor effects. This suggests that relevant departments should accelerate the construction of an interactive network compatible with digital economic development to further open up the digital economy market.

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