



Research on the mechanism of digital economy's impact on high-quality development based on panel regression modeling

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SUMMARY: *With its ability to increase total factor productivity through innovations, reallocation of resources, and structural transformation, the digital economy has become one of the essential driving forces behind regional cooperation and ecological sustainability. With this theoretical background in mind, this paper constructs indices for the advancement of digital economies and high-quality development based on the entropy weight method using panel data from 30 provinces between 2014 and 2023. A series of regressions, mediations, thresholds, and heterogeneous tests subsequently explore the promotion process. The main conclusions can be summarized into four points: scientific and technological innovation is the primary pathway of how the digital economy influences high-quality development; the stimulating influence is most pronounced on innovative development and common development, a conclusion that stands up to various robustness tests; the connection is non-linear and threshold-dependent; and geographic locations play an important role, as western provinces benefit more from the development of digital economies compared to their eastern and central counterparts.*

KEYWORDS: *digital economy; high-quality development; panel regression; mediation effect; threshold effect; technological innovation; regional heterogeneity; entropy weight method*

1 Introduction

It would be hard to find other forces that had a greater effect on the global economic map in recent years than digitalization. Based on IT solutions and accelerated by the development of technologies for making payments with smartphones, big data analysis, and cloud computing facilities, the digital economy has changed not only the nature of industries but also the way of production and source of competitive advantages. The effects of digitalization now affect the very process and orientation of growth of the global economy [1-4]. According to the reports made by the China Academy of Information and Communications Technology, the share of the contribution of digitalization to GDP is estimated to reach 41.5%. This does not mean just quantitative growth. The figures also show the dynamics of qualitative change of the sector itself due to the transformations that it undergoes [5]. In spite of seeming like a technological process, digitalization has started to play a much more significant role for the future development of economies around the globe. In addition to being an innovation-driven approach towards industrial development, it has created its own niche in the system of factors determining international competitiveness of national economies [6, 7]. Digital economy becomes an indispensable instrument for achieving growth and prosperity. However, along with the mentioned processes, there persists great inequality: disparity between the level of economic development and digitalization of various regions is very high which implies that digital

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economy will hardly evolve uniformly in all the regions of the country. Spatial disparities across regions therefore shape both the trajectory of digital economy growth and its capacity to translate into meaningful high-quality development outcomes [8-12].

The digital economy advances high-quality development through a set of mutually reinforcing channels. This includes the fusion of IT with traditional industries, the enhancement of regional innovation capabilities, greater economic linkages, and improved allocation of educational and medical resources across different regions. With the help of entropy weight methods and TOPSIS, one article [13] uses Feder's dual sector model and proves that economic efficiency and structure transition act as intermediary means through which the digital economy functions. In another study [14], based on the panel dataset for the provinces in China, empirical analysis shows that entrepreneurship, industrial upgrading, and the reduction of regional differences form an entire chain of full mediation to link the digital economy and low-carbon inclusive development. Apart from these insights, a study in [15] demonstrates a delayed promotion effect that lasts up to five periods. The results from the threshold panel models show that this effect exhibits an inverse relation and gradually intensifies until a certain threshold point is reached, followed by a gradual decline. From the city-level perspective, [16] measures a positive stimulating impact with a regression coefficient of 0.575, exhibits substantial spatial heterogeneity between the eastern and western parts, and uncovers three major intermediaries such as technological innovation, industrial adjustment, and resource reallocation.

The increase in development of the digital economy leads to the creation of innovations and entrepreneurial activities resulting in the formation of the U-shaped curve in high-quality economic development [17]. In an application of the spatial Durbin model along with mediation effects on panel data, there is evidence to show that digital economy not only stimulates high-quality economic development but also serves as a significant mediator between science, technology, and innovation [18]. Literature [19] reveals that large-scale green innovation that uses innovative technologies for environmental benefits has a larger mediating effect in comparison with strategic innovation in contributing to the DE towards high-quality economic development, and different mediating effects have significant regional disparities and rural-urban gaps. The digital economy is known for restructuring China's industrial structure due to increasing labor productivity and technological spillovers [20]. The restructuring effect diminishes as one moves geographically from the east to the center and then westward. The examination of the existing literature [21] revealed that the digital economy restructures China's industry by facilitating technological innovations and financial development, and its effect increases in more developed areas. There are two transmission mechanisms through which the digital economy influences agricultural and rural high-quality development: a consolidation effect based on restructuring industrial structure and operating positively, and an upgrading effect through which the digital economy impacts agricultural and rural development indirectly and negatively in the short run [22]. Export-oriented firms see their profitability and resource allocation efficiency rise as the digital economy expands, and this improvement in turn creates space for further digital growth while advancing the overall quality of international trade, as panel regression evidence confirms [23]. From a resource allocation perspective, the development of the digital economy brings about tangible enhancements in the allocation of resources to manufacturing companies in the central and western parts of the country, as well as companies facing competition and private companies. The decline in the monopolistic control of industries appears to be the key factor behind these benefits [24]. The role of government policy adds an element to the process whose analysis is complicated. While its impact on resource allocation efficiency can be either direct or indirect, the paths taken appear similar to those used by the digital economy.

By integrating panel econometric models with threshold effect studies, we can understand

the nonlinear process generated by the interaction between producer services and digital economy, especially during industrial serviceization. This helps us better understand how manufacturing quality development operates in these conditions [25]. In the case of tourism, the presence of effective government performance and market expansion plays a positive mediating role between the digital economy and development quality, leading to a desirable result in terms of central cities and neighboring areas. But the peripheral and distant areas present a distinct picture, where negative influences arise as a real threat [26]. A typical panel regression study on China's forestry industry indicates three major pathways through which the digital economy achieves its influence, including tighter environmental regulation, increased ecological consciousness, and technological innovation capabilities. These effects have different strengths depending on the geographical locations, with stronger impacts being observed in northern provinces, richer regions, and areas with sound financial backgrounds [27]. The dynamic panel approach to estimation of the relationship between the digital economy and high-quality energy development reveals that there are four mediators that link them; innovation, application, economic growth, and employment, together contributing to 0.191 [28]. The review of the existing studies on the subject matter shows that there is a distinct structural bias in design with the digital economy viewed as an independent factor while industrial structure serves as a mediator.

The study begins by defining the relationship between the digital economy and high-quality development theoretically before stating its hypotheses. The methodology employed in the study is based on ten-year provincial panel data spanning 2014 to 2023 involving 30 units. The two variables are operationalized using index systems designed specifically for the purpose, and prior to their use in regressions, indicator weights were derived through the objective application of entropy weights. Subsequently, the impact of progress made in the digital economy on high-quality development as measured along each of its five dimensions is estimated using regression analysis. The robustness of these findings is tested through robustness checks, and indirect channels are evaluated using mediation effects models.

2 Theoretical Background and Hypotheses

2.1 The Digital Economy and Development Quality

1. How the Digital Economy Promotes High-Quality Development

Three principal channels connect the digital economy to the high-quality development framework. The first runs through urban-rural balance, a dimension of enduring structural importance. Rural entrepreneurs have historically been shut out of formal financing channels, making business formation an uphill struggle, per capita incomes remained relatively low. Thanks to an expanded availability of online funding services and a wider distribution of financial products within the country's territory, this problem has largely been solved. As a result, village-based business creation becomes feasible while increasing the income of local households. The second route involves productive capital usage. Functioning as a new financial structure, the digital economy optimizes the process of performing basic monetary functions like raising money and calculating prices or settlements and payments. In other words, a greater share of available financial resources tends to flow towards the areas of actual demand instead of institutional inertia. Misallocation of resources becomes inevitable, thus leading to efficient capital allocation. Another aspect in which growth in the digital economy affects quality development is through risk management. Traditional interbank transfers have always been constrained by the inability to track where the money eventually ended up going, thus creating room for unexpected losses. With the introduction of the digital economy, transactions become

fully transparent since all funds move in an understandable way.

H1: The digital economy can promote high-quality development.

2. The Intermediary Role of Science and Technology Innovation

Large-scale investment of both human capital and finances is required as a prerequisite for scientific and technological innovation. In case when it starts bearing its fruits, the effects that are generated as a consequence of such innovative processes start spreading across society, reaching the productive potential of the economy as a whole, thus increasing the overall quality of social development, which cannot be achieved by any separate entity alone. Due to this feature, scientific and technological innovation possesses traits similar to those of quasi-public goods, which in turn, means that relying only on the market mechanism would be inefficient and therefore, public authorities have to get involved into the process. Through various measures, such as allocating funds for research institutions, governments promote innovation-friendly environments within their jurisdictions. However, in this situation, another aspect comes into play – the digital economy complements public intervention by reducing the costs associated with funding for research and innovation, thereby allowing companies to engage into these activities without having much trouble with finances while at the same time utilizing the support provided by the government.

H2: The digital economy's influence on high-quality development does not conform to a simple linear pattern. Instead, the relationship is threshold-contingent, changing in strength and nature once key critical values are crossed.

2.2 Pathways Linking the Digital Economy to Quality Development

As the digital economy reshapes market scale and factor combinations, regional innovation capacity grows in tandem, along with accelerating information flow and broader idea dissemination that constantly replenishes innovation's basic materials, the economic rationality of production moves beyond the standard output structure recognized by conventional economics. Instead of producing in response to existing demands, the digital economy predicts consumers' hidden demands and develops innovative consumption structures with information technology. This personalized production based on consumers' demands, meanwhile, drives non-platform production towards specialization, thereby intensifying the natural division of labor stimulated by expanded market size. Scientific and technological innovation occupies a pivotal position within this broader sequence, strengthening resource allocation and lifting total factor productivity in ways that actively support the pursuit of quality development.

Three mechanisms should be highlighted here. The first is the impact of innovation-led specialization in boosting the exit of inefficient zombie firms, thereby releasing resources that can go to technology-oriented industries in which productivity is relatively high. Secondly, through skills upgrading among employees due to evolving technology, the skill structure within the labor market becomes more efficient, which contributes to productivity in businesses and the economy as a whole. Lastly, through science and technology innovation that is integrated with the larger economic strategy, the growth strategy is progressively oriented towards environmental sustainability.

H3: Scientific and technological innovation functions as the conduit through which the digital economy produces concrete improvements in high-quality development.

3 Research design

3.1 Variable selection and data sources

In this paper, the impact of digitalization on the economic growth and high-quality development of China is analyzed. This study covers the period between 2014 and 2023 in order to achieve the highest levels of reliability and sufficiency of the results obtained. As there were no available data for the Tibet Province, only 30 Chinese provincial-level units were selected, including provinces, autonomous regions, and centrally administered municipalities.

Four categories of variables will be analyzed in this research. The first one includes a dependent variable named HQD that is based on the statistics provided by the National Bureau of Statistics. The second group comprises an independent variable that is digital economy advancement, represented by DIGE and relying on data collected by the Ministry of Industry and Information Technology and the National Engineering Laboratory of E-commerce. Control variables comprise FDI, HUM, GOV, and FIN. Initially, URBAN was taken into account; however, the variable was excluded due to its multicollinearity with the other variables. All control variables were collected from the National Statistical Yearbook.

3.2 Definition of variables

3.2.1 Explained variables

Capturing high-quality development (HQD) demands a structured measurement architecture. Building on prior empirical work, the framework organizes around five secondary dimensions: innovation, coordination, green development, openness, and sharing. Beneath these sit 19 tertiary indicators, of which authorized patents serve as one illustrative example. The complete HQD indicator system is presented in Table 1.

Table 1: Indicator System for the Level of High-Quality Development

Primary indicator	Secondary indicator	Third-level index
High-quality development	Innovative development	Number of invention patents granted per 10,000 people
		The intensity of funding for research
		The technology trading is active.
		The proportion of new product sales revenue to the total industrial output value
	Harmonious development	Urbanization rate of the permanent resident population
		The proportion of the added value of the tertiary industry in GDP
		Per capita disposable income of urban and rural residents
	Green development	Urban and rural per capita consumption expenditure ratio
		Comprehensive utilization of industrial solid waste
		Energy consumption per unit of GDP
		Proportion of surface water reaching or exceeding Class III water quality standards
	Open development	per capita gross import and export value
		ratio of dependence on foreign trade
		foreign capital openness
	Shared development	per capita GDP
		per capita general public budget expenditure
		Number of full-time teachers per 100 junior high school students
		Health workers per 10000 population

3.2.2 Core explanatory variables

The DIGE index comprises five secondary indicators according to industry standards: Internet Penetration Rate, Internet Users, Internet Value Added, Internet Population Size, and Digital Financial Inclusion. Digital Financial Inclusion is based on the Digital Financial Inclusion Index of China released by the Digital Finance Research Center at Peking University. Please refer to Table 2 for the complete list of indicators.

Table 2: Indicator Framework for Assessing Digital Economy Development

Primary indicator	Secondary indicator	Third-level index
Comprehensive Development Index of the Digital Economy	Internet penetration rate	Internet users per 100 people
	Number of people employed in the internet-related industry	Percentage of employees in computer services and software
	Internet-related output	Total telecommunications service volume per capita
	Number of mobile internet users	number of mobile phone users per 100 population
	The inclusive development of digital finance	China Digital Inclusive Finance Index

Both composite indices constructed in this study, covering digital economy development and high-quality development, are built using the entropy weight method. Before weights can be assigned, two preliminary procedures must be performed: scaling the data of raw indicators into a consistent scale using normalization and determining if each indicator is positively or negatively oriented in the framework of evaluation.

Entropy weight method functions on the principle that each indicator's weight depends solely on the information it contains, not on any other factors, such as subjective assessment, meaning that high-weighted indicators contain substantial information, whereas low-weighted indicators have less variability. The calculation process consists of the following stages:

Normalization is the first stage where, in addition, each indicator is marked as benefit-type or cost-type, depending on its purpose within the indicator layer. The appropriate formula varies according to this classification. Throughout the procedure, X_{ij} refers to the original recorded value of a given indicator, with $\max(X_{ij})$ and $\min(X_{ij})$ representing the upper and lower bounds of X_{ij} observed within each respective year. The standardization formulas are constructed as follows.

Where an indicator contributes positively to the evaluation objective, the following transformation is applied:

$$X_{ij} = \frac{X_{ij} - \min(X_{ij})}{\max(X_{ij}) - \min(X_{ij})} \quad (i = 1, 2, \dots; j = 1, 2, \dots, m) \quad (1)$$

For cost indicators, the corresponding normalization equation is:

$$X_{ij} = \frac{\max(X_{ij}) - X_{ij}}{\max(X_{ij}) - \min(X_{ij})} \quad (i = 1, 2, \dots; j = 1, 2, \dots, m) \quad (2)$$

All normalized values are uniformly expressed as a_{ij} , and the weight assigned to each indicator is subsequently derived on this basis.

In the second step, the proportion that the i th year contributes under the j th indicator is computed as follows:

$$\eta_{ij} = \frac{a_{ij}}{\sum_{i=1}^n a_{ij}} \quad (3)$$

In the third step, the information entropy e_j and the corresponding weight W_j for the j th indicator are determined through the following expressions:

$$e_j = -1/\ln(n) * \sum_{i=1}^n \eta_{ij} \ln \eta_{ij} \quad (4)$$

$$W_j = (1 - e_j) / \sum_{j=1}^m (1 - e_j) \quad (5)$$

A weighted summation closes the index construction process in step four. The value of each index is multiplied by its weight, and then the weighted values are added up to obtain a composite score that shows the extent of development of the digital economy.

3.2.3 Intermediate variables

Innovation and scientific and technological innovation (TI) function as intermediate variables. There are five proxies of TI based on earlier studies, which are internal R&D expenses, full time equivalent researchers head count, number of students studying at regular higher education establishments, combination of number of patent inventions and grants, and number of transactions on the technology market. Instead of relying on these five indexes separately, a factor analysis would be conducted to generate a composite TI index.

3.2.4 Control Variables

FDI refers to the proportion of foreign investments in relation to the GDP of the region, showing the extent of contribution made through foreign investments to economic activities in the region. The indicator HUM is the proportion of the total workforce engaged in scientific and technological research. The indicator GOV is represented by government expenditure as a percentage of the GDP of the region.

3.3 Model construction

To empirically examine the research hypotheses put forward above, the following baseline regression specification is constructed:

$$HQD_{i,t} = \alpha_0 + \alpha_1 DIGE_{i,t} + \alpha_3 X_{i,t} + \varepsilon_{i,t} \quad (6)$$

In this specification, $HQD_{i,t}$ denotes the level of high-quality development attained by a

given regional economy, $DIGE_{i,t}$ reflects the extent of digital economy progress, $X_{i,t}$ stands for the vector of control variables included in the model, and $\varepsilon_{i,t}$ captures the stochastic error term.

To determine if innovation in science and technology mediates the relationship between the digital economy and high-quality development, there needs to be an analysis that goes beyond Equation (6). The process takes two stages. First, it is important to establish statistical significance for the coefficients in Equation (6). Once this is achieved, two additional equations are developed, with the innovation in science and technology being the dependent variable regressed against the digital economy on the one hand and both variables regressed against high-quality development on the other. They take the following forms:

$$\pi_{i,t} = \beta_0 + \beta_1 DIGE_{i,t} + \beta_3 X_{i,t} + \varepsilon_{i,t} \quad (7)$$

$$HQD_{i,t} = \gamma_0 + \gamma_1 DIGE_{i,t} + \gamma_2 \pi_{i,t} + \gamma_3 X_{i,t} + \varepsilon_{i,t} \quad (8)$$

Testing Hypothesis 2 calls for an analytical tool that goes beyond what the mediation framework can offer, and the threshold effect model fills this role. The specification adopted in this paper takes the following form:

$$\begin{aligned} HQD_{i,t} = & \varphi_0 + \varphi_1 DIGE_{i,t} \times I(\delta_{i,t} \leq \theta_1) + \varphi_2 DIGE_{i,t} \times I(\theta_1 < \delta_{i,t} \leq \theta_2) \\ & + \varphi_3 DIGE_{i,t} \times I(\delta_{i,t} > \theta_2) + \varphi_4 X_{i,t} + \varepsilon_{i,t} \end{aligned} \quad (9)$$

In this specification, $\delta_{i,t}$ denotes the threshold variable, which encompasses both the digital economy and the level of scientific and technological innovation, while θ represents the threshold value to be estimated from the data.

4 Findings and Discussion

4.1 Statistical Overview of Study Variables

Table 3 summarizes descriptive statistics for all variables in the model: HQD as the outcome variable, DIGE as the primary explanatory variable, TI as the moderating variable, and FDI, HUM, GOV, and FIN as controls. The HQD index records a mean of 0.258, a maximum of 0.561, a minimum of 0.022, and a standard deviation of 0.093. This indicates that although there have been many high-quality developments, there are significant differences between different regions. It should be noted that the maximum and minimum values and the large standard deviation of variables like the DIGE index and the TI index demonstrate large variations in economic performance among the provinces/cities in the sample population.

Table 3: Descriptive statistics

Code	Observed number	Average value	Median	Standard error	Least value	Crest value
HQD	1869	0.258	0.247	0.093	0.022	0.561
DIGE	1869	0.133	0.116	0.089	0.014	0.711
FDI	1869	0.817	0.718	0.551	0.003	3.816
HUM	1869	0.888	0.755	0.516	0.189	4.512
GOV	1869	0.889	0.897	0.078	0.573	0.992
FIN	1869	0.024	0.019	0.025	0.002	0.214

4.2 Regression Estimation and Interpretation

4.2.1 Baseline Estimation Results

Stability analysis of models and cross-model comparison were carried out via both OLS and fixed effects regression analysis, whose outputs are provided in table 4. A significant and positive correlation between development in digital economy and development in high-quality exists in all model formulations, thereby providing proof of robustness and supporting H1 regardless of the analytical framework used. Model (5) is selected as the best through the Hausman test procedure. In this model, a one-unit improvement in development in digital economy causes a corresponding 10.9% increase in high-quality development, and the 0.109 coefficient value proves H1 since it is statistically significant at 1%. Compared to Model (3) and Model (5), there is an apparent reduction in the coefficient value from 0.111 to 0.109 owing to the control variables. Of the control variables considered, FDI has the most influence on high-quality development, and the effect is statistically significant at 5%.

Table 4: Regression result of base line

Variable name	OLS		FE		
	(1)	(2)	(3)	(4)	(5)
DIGE	0.171*** (28.09)	0.177*** (19.27)	0.111*** (3.02)	0.203*** (21.17)	0.109*** (3.54)
FDI		-0.024*** (-3.82)		0.001 (0.09)	-0.009** (-2.49)
HUM		0.013 (1.67)		0.033*** (3.49)	0.015 (1.12)
GOV		-0.14*** (-2.71)		0.007 (1.05)	0.009 (1.14)
FIN		-0.322*** (-3.31)		-0.309** (-2.37)	-0.142 (0.87)
Constant term	1.149*** (75.09)	1.894*** (9.01)	1.276*** (18.74)	1.607*** (6.17)	1.496*** (4.12)
Individual effect			√	√	√
Time effect			√	×	√
Observed value	315	315	315	315	315
R ²	0.721	0.754	0.737	0.729	0.748

Note: *, **, *** represent significant at the 10%, 5%/1% statistical level, respectively, as below.

This is illustrated in Figure 1 below. What Figure 1 clearly indicates is that areas or time frames with a higher level of digital economy development generally correlate with improved

high-quality development outcomes, and vice versa, and such a relationship is anything but trivial or equivocal. There is a clear positive correlation between the two factors, visually validating the statistical results presented previously.

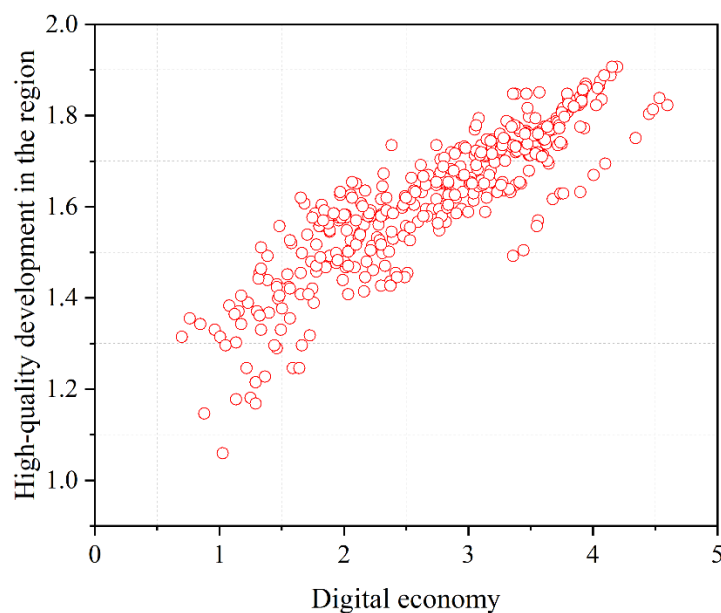


Figure 1: Scatterplot Illustrating the Relationship Between the Digital Economy and High-Quality Agricultural Development

4.2.2 High-Quality Development Disaggregated by Dimension: Estimation Outcomes

The entropy weight method, implemented in IBM SPSS Statistics 25, is used to derive weights for each of the five dimensions composing the high-quality development index. The resulting weights are distributed as follows: innovative development accounts for 0.2233, coordinated development for 0.1807, green development for 0.1385, open development for 0.1795, and shared development for 0.2780. These dimensional weights are subsequently applied to derive the weight of each constituent component, from which the high-quality development index Hqed is constructed. The Hqed scores are then introduced into the regression equation, and the corresponding estimation output is reported in Table 5.

From models 4 to 8, the net coefficient connected with the development level of the digital economy, being the main independent variable, significantly passes the 1% test threshold and stays significantly higher than zero all along. The results always tend to show the digital economy as a contributing factor to improvements in all aspects of quality development. Such aspects include innovative development, regional cooperation, green ecological development, and shared development. The two dimensions with the highest responsiveness are Innovative Development and Shared Development. The coefficient for each dimension of 0.109 and 0.108 is greater than the coefficients of the other three dimensions, indicating that there is a heavy focus of the promotion power of the digital economy on the two dimensions mentioned. The trend supports the theory that Hypothesis 2 put forward.

Table 5: Regression Estimates for the Impact of the Digital Economy on Five Dimensions of High-Quality Development

Explanatory variable	1	2	3	4	5
	Innovation	Coordinate	Green	Open	Share
DIGE	0.109*** (0.033)	0.087*** (0.027)	0.088*** (0.027)	0.088*** (0.027)	0.108*** (0.033)
FDI	0.005 (0.009)	0.003 (0.006)	0.003 (0.006)	0.003 (0.006)	0.005 (0.009)
HUM	-0.004 (0.003)	-0.003 (0.002)	-0.003 (0.003)	-0.003 (0.003)	-0.004(0.003)
GOV	-0.207** (0.093)	-0.162** (0.072)	-0.165** (0.073)	-0.165** (0.073)	-0.209** (0.085)
FIN	0.008*** (0.001)	0.007*** (0.001)	0.007*** (0.001)	0.007*** (0.001)	0.008*** (0.001)
_cons	0.107* (0.061)	0.085* (0.046)	0.086* (0.047)	0.086* (0.047)	0.105* (0.058)
R ²	0.939	0.939	0.939	0.939	0.939
Individual effect	√	√	√	√	√
Time effect	√	√	√	√	√

4.3 Robustness Tests

Another issue that should be considered here is reverse causality, when improvements in quality of development can have a feedback effect and impact the growth of digital economy. Failing to take into account such interaction results in the emergence of endogeneity in addition to inconsistency of estimated coefficients. However, there is always the danger of omitted variable bias in any regression model since not all the factors affecting economic development are captured in such models. This problem is directly addressed by the instrumental variables approach, which deals with the problem of endogeneity caused by reverse causality and omitting of variables. Table 6 brings together the estimation outcomes based on instrumental variables and other robustness checks.

The first column provides results of the instrumental variables regression. When endogeneity issues are resolved, the digital economy continues to play an important role in high-quality economic development. The validity of instruments used here is checked with the help of two diagnostic statistics, namely the KP rk LM statistic yields a probability of 0.000, thus rejecting the hypothesis of under-identification, while the KP rk Wald F statistic equals 36.873 and is much higher than the Stock-Yogo weak identification critical value of 21.03. The second column presents a positive digital economy estimate significant at 1%.

Table 6: Instrumental variables and change measures Robust results

Variable	2SLS	Fixed effect
	(1)	(2)
DIGE	0.3521*** (0.0293)	0.3655*** (0.0241)
FDI	0.0851*** (0.0261)	0.1309*** (0.0427)
HUM	2.0718** (0.89378)	0.1642 (0.7628)
GOV	0.1907* (0.1109)	0.0735 (0.0459)
FIN	0.1335*** (0.0305)	0.0815*** (0.0157)
Constant term	-0.0721** (0.0309)	0.0418** (0.0193)
R ²	0.9107	0.7643
KP rk LM	58.573***	
KP rk Wald F	36.873	

In order to eliminate any potential biases introduced by outliers, two-sided winsorization at the 1% level is adopted across all continuous variables. The coefficients after winsorization are given in Table 7. Specifically, the coefficients from the winsorized full sample regression are provided in column (1), whereas the mediation test statistics with scientific and technological innovation being the mediator variable can be found in columns (2) and (3).

It should be noted that the statistical significance of coefficients from all independent variables remains unaffected by winsorization, thereby indicating that the positive role played by the digital economy in facilitating high-quality development is not caused by any form of bias. Partial mediation through both channels is observed, further supporting the claim that scientific and technological innovation acts as a mediator for the developmental impacts of the digital economy.

Table 7: Bilateral tail-shrinking robustness result

Variable	High-quality development	Technological innovation	High-quality development
	(1)	(2)	(3)
Lagging indicators in high-quality development	0.5972*** (0.1241)		0.6519*** (0.1126)
Digital economy	0.2752*** (0.0643)	0.9852*** (0.3426)	0.2237*** (0.0618)
Lag in technological innovation		0.8032*** (0.0718)	
Technological innovation			0.0218* (0.0073)
Constant term	0.0318 (0.0217)	2.6541*** (0.6218)	-0.1123* (0.0571)
Controlled variable	YES	YES	YES
AR(1)	0.037	0.004	0.019
AR(2)	0.922	0.674	0.791
Hansen	0.819	0.483	0.872

4.4 Further analysis

4.4.1 Examination of Transmission Mechanisms

As illustrated in the table below, the findings follow the chain through which the digital economy impacts high-quality development through scientific and technological innovation. In model (1), there is confirmation of the direct impact of the digital economy on high-quality development where the value of the independent variable is found to have a positive and statistically significant coefficient. In model (2), there is an investigation into the connection between the digital economy and innovation, resulting in the coefficient of 4.078, which is also statistically significant. One-unit change in the digital economy is equivalent to a 4.078 change in the variable representing scientific and technological innovation. Finally, in model (3), both variables are included in order to examine the mediating effect of innovation. Innovation is found to be significant and act as the mediator.

Table 8: Results of the mediation effect test

Variable	Model(1)	Model(2)	Model(3)
	HQD	TI	HQD
DIGE	4.879** (2.581)	4.078*** (0.738)	0.174 (0.2590)
TI			1.097*** (0.307)
Controlled variable	YES	YES	YES
Constant term	8.019 (6.917)	-1.879 (1.891)	9.419 (6.872)
Provincial fixed effects	YES	YES	YES
Year fixed effect	YES	YES	YES
R-squared	0.773	0.981	0.824

4.4.2 Analysis of threshold effects

Digital economy and innovation of science and technology are considered threshold variables during this phase of analysis. Bootstrap testing is conducted at 300 replications using Stata 16 software in order to examine for one, two, and three threshold effects. Digital economy and innovations of science and technology meet the criteria for single threshold and reject two and three threshold hypotheses, which indicate that a single threshold should be considered. Results are presented in Table 9. The estimated values of the threshold variable are 0.672 for the digital economy and 0.943 for innovations of science and technology. In all regimes specified by these thresholds, the impact of the digital economy on high-quality development is statistically significant.

Table 9: Threshold test results

Threshold variable	Threshold	F	P	Critical value			Threshold value	95% confidence interval
				1%	5%	10%		
DIGE	Single threshold	40.073**	0.051	62.275	36.038	31.284	0.672	(0.668,0.705)
	Duble threshold	-21.128	1.000	56.115	27.642	19.151	0.701	(0.661,0.759)
TI	Single threshold	94.273***	0.000	58.374	46.585	34.793	0.943	(0.918,0.983)
	Duble threshold	16.073	0.419	72.184	40.275	31.374	2.583	(2.475,4.629)

The threshold point is determined by the γ point at which the likelihood ratio test statistic (LR) tends towards zero. Thus, the graph of the LR statistic against the set of threshold candidates within the 95% confidence interval is produced. Figure 2 shows the graph of the LR statistic against the range of thresholds with digital economy acting as the threshold variable, while Figure 3 shows the graph of the LR statistic with the same range of thresholds but now using scientific and technological innovation as the threshold variable. The lowest point in the LR statistic graph indicates the threshold point. The dashed lines below the LR statistic graphs indicate the threshold interval using the critical value of 7.17 at the 5% significance level.

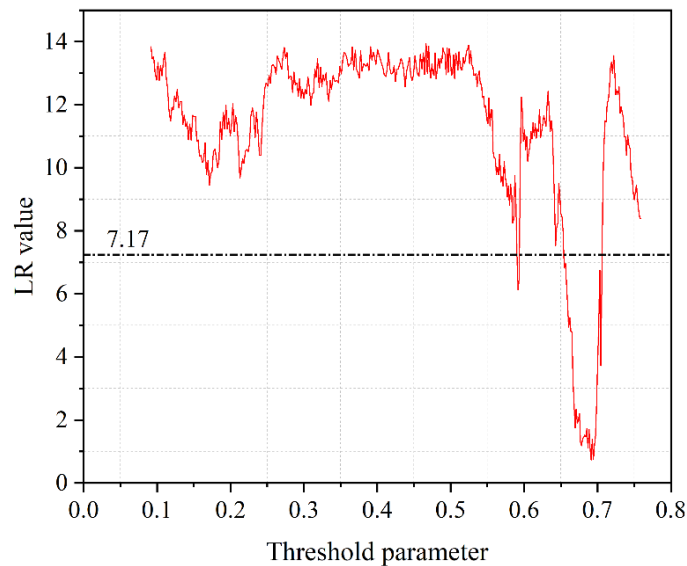


Figure 2: logistic regression plot with DIGE as the threshold variable

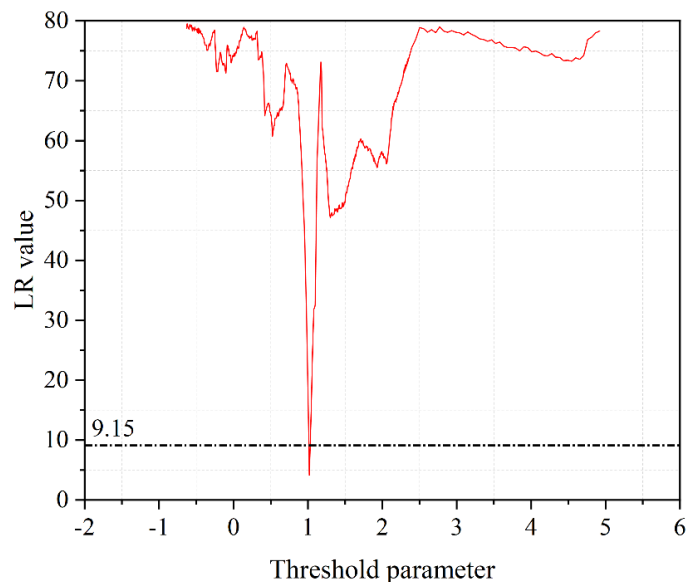


Figure 3: logistic regression plot with TI as the threshold variable

Table 10 shows the results for the single threshold regression estimates under both threshold variable cases; digital economy and scientific and technological innovation. These threshold regressions are estimated based on all control variables including foreign direct investments, human capital, government intervention, and financial development in the economy.

On the other hand, the coefficient for the relationship between the threshold DIGE and Y

when $DIGE \leq 0.709$ is equal to 4.753, and it passes the test of statistical significance at the 1% confidence level. When this threshold is exceeded, the estimate increases significantly up to 9.098, while still being significant at the 1% confidence level. This analysis allows two conclusions. First, the sign of the influence on Y does not change regardless of whether DIGE exceeds the critical value or not, implying that the promotion of the digital economy is unconditional in terms of reaching certain digitalization thresholds. Second, there is a clear escalation of its impact once the critical value is crossed. This change in coefficients points towards nonlinearity in the relationship. The reason behind such behavior is the increasing scale of industries due to economic growth in the digital economy.

When scientific and technological innovation serves as the threshold variable, the coefficient relating the key independent variable DIGE to high-quality development Y equals 2.574 in the regime where $0 < TI \leq 0.947$, a value that is statistically significant at the 1% level. Once TI surpasses the 0.947 threshold, this coefficient rises to 5.792, again clearing the 1% significance bar. Several interpretations follow from these figures. Scientific and technological innovation does not advance in isolation from digital economy growth. The two are bound together in a process of mutual evolution, each reinforcing the trajectory of the other. Furthermore, the realization of scientific and technological innovation is contingent on the presence of capable and efficient infrastructure, and it is precisely through digitalization that such infrastructure becomes attainable. As the spread of digital technology raises the quality and effectiveness of infrastructural conditions, the environment becomes progressively more fertile for generating returns. It is at the point where this improved foundation matures sufficiently that the digital economy's capacity to propel high-quality development enters a markedly stronger phase.

Table 10: Threshold regression results

Model(1)		Model(2)	
Explanatory variable	Estimation coefficient	Explanatory variable	Estimation coefficient
DIGE-I($DIGE \leq 0.709$)	4.753***	TI-I($TI \leq 0.947$)	2.574***
DIGE-I($DIGE > 0.709$)	9.098***	TI-I($TI > 0.947$)	5.792***
Controlled variable	YES	Controlled variable	YES
Provincial fixed effects	YES	Provincial fixed effects	YES
Year fixed effect	YES	Year fixed effect	YES

Note: *** denotes 1% significance level.

4.4.3 Analysis of locational heterogeneity

Different provinces or cities in China may show distinct differences in terms of natural resource endowment and policy settings, thus affecting their performance with regards to digital economy development. In light of that, the geographical disparity is incorporated into the research by classifying different provinces or cities based on the regional classification provided by the National Bureau of Statistics, whereby the northeastern region is included in the central one, and then analyzing in three groups: eastern, central, and western. The regression result grouped by the regional classification is shown in Table 11.

The western region stands out in that it is the only one among all the groups that displays a statistically significant relationship between the digital economy and high-quality development. Specifically, the net coefficient of Model 23 for the western region is 0.397, which has passed

the test at 1% level. Both eastern and central regions display positive coefficients, although neither is statistically significant.

Table 11: Regional Heterogeneity in the Effect of the Digital Economy on High-Quality Development

Variable	Model 21	Model 22	Model 23
	Eastern Region	Central region	Western region
DIGE	0.597 (0.373)	0.119 (0.342)	0.397*** (0.129)
Controlled variable	YES	YES	YES
_cons	1.982** (0.831)	1.625* (0.874)	-0.231 (1.264)
R ²	0.9512	0.9425	0.9617
Individual effect	YES	YES	YES
Time effect	YES	YES	YES

5 Conclusion

Based on the methods of fixed effects modeling, entropy weighting, mediation effects, and threshold regression, this paper analyzes the promoting effect of the digital economy on high-quality development. There are some important findings. With the coefficient of 0.109 and the significance of 1%, it is proven that there exists a positive promoting effect of the digital economy on the achievement of high-quality development. This effect is universal and not just restricted to one aspect, covering the five elements including innovation, coordination, ecological civilization, openness, and inclusiveness. The mechanism behind is achieved via two intermediaries, which are the improvement of scientific and technological innovation capacity and the industrial structure adjustment. Moreover, by using the digital economy and scientific and technological innovation as the threshold variable, the non-linear relationship is revealed.

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