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Research on the mechanism and path of influence of digital economy on the high-quality development of regional economy

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

[1] School of Economics and Management, Xinjiang Institute of Technology, Aksu, 843100, China

[2] School of Economics, Guizhou University of Finance and Economics, Guiyang, Guizhou, 550025, China

SUMMARY: *The presented research paper addresses the role of the stimulative effect of the digital economy in the high-quality development of the regional economy.Initially, we have developed individual assessment systems based on the level of development of the digital economy and the level of high-quality development in the regional economy. Using the panel data of 30 Chinese provincial regions (2014-2023) and combining the methodology of entropy weighting with TOPSIS (Technique of Order Preference by Similarity to Ideal Solution) method,the measurement of both aspects are obtained.Next, a benchmark panel regression model is constructed based on the multiple regression approach in order to study the relationship The correlation between the development of the digital economy and the rapid development of the regional economy with high standards.The results show that since 2014, there has been an exceptional growth in both the level of digitalization of China economy and the high-quality development of regional economies at overall growth rates of 447 percent and 87.60 percent respectively.The digital economy can be effectively used to support the high-quality development of the regional economy.Technological innovation can drive the high - quality development of the local economy. The computed metric for the extent of digital economy implementation stands at 0.318, and it has the most substantial promotional effect. When it comes to the impact on the high - quality development of the regional economy, the estimated coefficient of the digital economy in the eastern region is 0.175, which exerts the most notable influence. Subsequently, when considering the impact of the digital economy on local economic output, the central and western regions follow in sequence. In summary, fostering the growth of the digital economy, reducing the regional disparities, and advancing technological innovations are all crucial for enhancing the level of regional economic development.*

KEYWORDS: *entropy weight method; TOPSIS method; multiple regression analysis; digital economy; regional economic high-quality development*

1 Introduction

Following the agricultural and industrial economic epochs, the digital economy has emerged as a transformative economic model and a core engine powering global economic expansion [1]. In recent years, major economies worldwide have incorporated digital economy strategies into their national long-term development plans. The G20 Digital Economy Development and

*WangFeix0@163.com
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Cooperation Initiative, adopted at the G20 Hangzhou Summit, defines the digital economy as a knowledge-centered economic pattern built on digital resources. High-quality economic development constitutes a core pillar of national modernization, signifying a strategic shift from a pure growth-oriented model to one that prioritizes efficiency, sustainability, and structural optimization. Rooted in the information technology revolution, the digital economy acts as a vital catalyst for high-quality development by deepening the integration of digital technologies with the real economy.The theoretical framework underlying the way the digital economy stimulates high-quality economic growth was explored by heping and co-workers [11] constructed a theoretical framework to explain how the digital economy boosts high-quality growth. They concluded that digital transformation accelerates industrial upgrading and resolves structural inefficiencies that constrain economic performance. Yang et al. [12] conducted empirical tests and confirmed that the digital economy supports coordinated regional and urban-rural development, enhances innovation efficiency, and advances the digitalization of the real economy alongside ecological sustainability.From a supply-demand perspective, Pang and his team [13] drew upon Nax's poverty cycle theory and revealed that the digital economy drives China's high-quality growth by balancing supply and demand dynamics, requiring a continuously adaptive equilibrium mechanism. Ren and Zhang [14] explored the interactive links among the digital economy, clean energy consumption, and high-quality development, arguing that digital advancement stimulates wider adoption of clean energy and thereby fosters greener growth. They put forward the view that the digital economy promotes high-level economic growth through stimulating the use of clean energy.The digital economy, which takes information as its core production element, relies on modern information networks and uses information communication technologies to promote the promotion of economic structure and the growth of efficiency. High-quality development emphasizes innovation-driven, green, coordinated, inclusive, and open growth patterns [2]. Unlike the conventional factor-driven model, it attaches greater importance to industrial optimization, technological progress, resource utilization, and social equity [3, 4]. In this context, The digital economy serves as a fresh driving force for high - quality economic advancement. To begin with, digital technologies have been extensively utilized in traditional sectors, leading to enhancements in production efficiency and the efficacy of resource allocation. In this context, the digital economy provides new momentum for high-quality economic progress. Digital technologies are widely applied in traditional sectors, lifting production efficiency and resource allocation quality. Meanwhile, the digital economy nurtures emerging industries, business formats, and organizational models, creating new growth pathways for the economy [5–7]. Nevertheless, the digital economy still faces multiple constraints, including uneven regional development, inadequate regulatory systems, and data security and privacy risks, all of which hinder high-quality progress [8–10]. Regional economic disparities have also widened noticeably. Against this backdrop, exploring the mechanisms and pathways through which the digital economy affects regional high-quality development is highly meaningful. It is also critical to recognize spatial heterogeneity in these effects. Such investigations can lay a foundation for advancing the digital economy and promoting coordinated regional development. Luo et al. [15] found that regional digitalization improves quality, efficiency, and dynamic drivers of the economy, supporting high-quality development—especially in regions with higher marketization and stronger governance capacity. Song and colleagues [16] used static and dynamic panel models to analyze data from 2013 to 2021 and found that the digital economy exerts stronger effects in eastern China due to superior innovation capacity and lower carbon emissions. Gao et al. [17] applied fixed-effects and threshold models and verified that digital technologies drive green innovation, optimize factor allocation, and boost entrepreneurial vitality, thereby lifting high-quality development. Zhao and Xia [18] noted that deep integration between the digital and real economies raises regional high-quality development at a ratio of 1:4.81, with regional disparities; industrial upgrading and technological innovation act as mediators, with innovation playing a dominant role.

Qixiang and Xinfa [19] proposed a technological innovation paradigm for high-quality development, with enterprises, research institutes, and universities as core innovators. Innovation enhances factor quality, delivers high-end products and services, upgrades industrial and consumption structures, balances resource use and environmental protection, and advances social equity. This study uses panel data from 30 Chinese provincial regions covering 2014–2023. We first build separate evaluation systems for the digital economy and regional high-quality development, and measure their levels using the entropy weight-TOPSIS method, then analyze overall and regional disparities. We establish a research framework and propose hypotheses, construct a benchmark panel regression model, and use stepwise regression to examine how the digital economy influences high-quality development. We also test dimensional effects and regional heterogeneity to validate our hypotheses.

2 Measuring levels of development

2.1 System of evaluation indicators

2.1.1 Indicators for Assessing the Digital Economy

As shown in Table 1, the assessment framework for the digital economy measures the development achievements through three main aspects: infrastructure, development situation, and application intensity. This framework encompasses 14 particular indicators to comprehensively assess the state of the digital economy.

Table 1: Assessment Index Framework for the Digital Economy

Primary metricSignificant:	Secondary metricCrucial:	Index metricCrucial: This text should be replaced to meet the requirements as it is too short to have 70% of its vocabulary replaced and undergo significant restructuring. Please provide a longer text for proper revision.
Infrastructure	Average individual access to Internet broadband ports	The proportion of internet broadband access ports in relation to the year - end resident population
	Cable density	Cable length/area
	Per capita domain number	Domain number/year-end permanent population
	The quantity of sites that the business possesses	The quantity of sites that the enterprise possesses
Development level	The percentage of individuals participating in the Internet	Staff members in city work units who take part in information spreading, software making, and information technology services inside city regions / Staff members in city work units
	Information technology service income	Information technology service income
	Software revenue	Software revenue
	E-commerce sales	E-commerce sales
	The total volume of telecommunications services on a per - person basis	The aggregate count of the telecommunications sectors divided by the year - end permanent population
Application level	Internet penetration	The quantity of Internet users per every 100 individuals
	Penetration of mobile phones	The number of mobile equipment in each one hundred people
	Digital universal financial index	Chinese digital universal financial index
	Mobile payment level online	Mobile payment level online

2.1.2 Approaches for Assessing the High - Quality Condition of Regional Economies

This research assesses the high - quality economic development at the regional level from four interrelated aspects: growth driven by innovation, ecological viability, the well - being of the populace, and stable and effective economic growth. As presented in Table 2, the assessment framework is composed of four main indicators and 12 secondary indicators.

Table 2: Evaluation Index System for the Degree of High - quality Development of Regional Economy

Main Indicator Crucial:	Secondary Indicator Crucial	Indicator metric IMPORTANT
Innovative high quality development	R&D intensity	R&D test funds internal expenditure/regional GDP
	Innovative output level	Three patents authorized quantity/ total population
	Technical trading activity	Technical transaction volume/regional GDP
Ecological high quality	The energy consumption amount for each single unit of the Gross Domestic Product	Standard coal/region GDP
	Unit GDP pollution discharge	The ratio of emissions of sewage, exhaust gases, and solid waste to the regional gross domestic product
	Elasticity of energy consumption	The proportion between the rate of increase in energy consumption and the rate of growth of the regional gross domestic product
	The green coverage of the construction zone	The green coverage of the construction zone
People's high quality of life	Discrepancy between City and Countryside Areas	The ratio of the per - capita income of urban inhabitants to that of rural inhabitants
	Expense for education per individual	Funding for education divided by the entire population
	Medical services on a per - person basis	Health institutions bed number/total population
	The cost of cultural undertakings per capita	Cultural expenses/total population
High quality economic growth	Openness to foreign trade	Import and export amount /regional GDP
	Regional GDP	Regional GDP
	Overseas direct investment	The proportion of the overall investment made by foreign - invested enterprises in relation to the regional gross domestic product
	Overseas direct investment	Ratio of non - monetary foreign direct investment in relation to the regional total domestic output value
	The ratio of the service domain	The investment in the tertiary sector relative to the regional gross domestic product
Main Indicator Crucial	Secondary indicator	Index measure
Innovative high quality development	R&D intensity	R&D test funds internal expenditure/regional GDP
	Innovative output level	Three patents authorized quantity/ total population
	Technical trading activity	Technical transaction volume/regional GDP
Ecological high quality	The energy consumption for each unit of gross domestic product	Standard coal/region GDP
	Unit GDP pollution discharge	Discharge volumes of waste water, waste gas and solid wastes in relation to the region's gross domestic product
	Elasticity of energy consumption	The ratio that compares the growth speed of energy consumption to the growth speed of regional gross domestic product
	The green coverage of the construction zone	The green coverage of the construction zone
People's high quality of life	Urban and rural gap	Per - capita income of urban residents divided by per - capita income of rural residents
	Per capita education expense	Education funding/total population
	Per capita medical service	Health institutions bed number/total population
	The cost of cultural undertakings per capita	Cultural expenses/total population
High quality economic growth	Openness to foreign trade	Import and export amount /regional GDP
	Regional GDP	Regional GDP
	Overseas direct investment	The proportion of the overall investment made by foreign - invested enterprises in relation to the regional gross domestic product
	Foreign direct investment	Ratio of non - monetary foreign direct investment to regional gross domestic product
	The ratio of the tertiary sector	The investment of the third industry/regional GDP

2.2 Determination of evaluation methodology

Drawing on a multi - indicator assessment framework, this research integrates the entropy weight approach and the TOPSIS technique. Subsequently, One assessment frame for measuring the digital economy and the high-quality development condition of the regional economy is built through the entropy weight-TOPSIS method.

2.2.1 Method of Entropy Weights

The entropy weight approach has its roots in information theory and is designed to assess the weights of the indicators within the information,the basic rule is that the weight numbers given to the indexes are set up according to the degree of the indexes' change range. When the entropy value of a particular variable is lower, it implies that the degree of variability of this indicator is higher, and its significance in the evaluation process is more prominent. As a result, the proportion of its weight is greater. The subsequent content outlines the comprehensive procedures of the entropy weight approach:

(1) Create the initial assessment matrix

Let's assume that there are m exist assessment entities, each of which has n evaluation indicators, $X_{ij}\left(i=1,2,3,\dots,m;\ j=1,2,3,\dots,n\right)$ is the data corresponding to the i th evaluation indicator of the j th evaluated object:

$$X_{ij}=\begin{Bmatrix} X11 & X12 & X13 & \cdots\cdots & X1n \\ X21 & X22 & X23 & \cdots\cdots & X2n \\ . & . & . & & . \\ Xm1 & Xm2 & Xm3 & \cdots\cdots & Xmn \end{Bmatrix} \tag{1}$$

(2) Standardize the data in the evaluation matrix

In the evaluation system constructed by multiple indicators, the unit and order of magnitude of each indicator are not the same, and cannot be directly compared, so the standardization of the raw data of each indicator is the first step in the subsequent financial risk evaluation. Its purpose is mainly to eliminate the problem of inconsistency in the outline of the evaluation indicators and the adverse effects caused by differential factors. Among other things, the processing methods are different for indicators of different natures.

For positive indicators:

$$X'_{ij}=\frac{X_{ij}-\min X_{ij}}{\max X_{ij}-\min X_{ij}} \tag{2}$$

For negative indicators:

$$X'_{ij}=\frac{\max X_{ij}-X_{ij}}{\max X_{ij}-\min X_{ij}} \tag{3}$$

(3) Normalization of standardized data

Calculate the proportion of the standardized index value i to the evaluation object j, mainly to lay the foundation for the calculation of entropy value:

$$X_{ij} = \frac{X'_{ij}}{\sum_{i=1}^{m} X'_{ij}} \tag{4}$$

(4) Compute the entropy value of every indicator

Indicator weights serve to mirror the relative significance of each attribute. When an attribute is more significant, a larger weight is assigned; conversely, when it is less significant, a smaller weight is given. Then:

$$E_j = -\frac{1}{\ln m} \sum_{i=1}^{m} \left(X_{ij} * \ln X_{ij} \right) \tag{5}$$

(5) Determine the coefficient of variation for each metric G_j and the significance of the metric W_j:

$$G_j = 1 - E_j \tag{6}$$

$$W_j = \frac{G_j}{\sum_{j=1}^{n} G_j} \tag{7}$$

2.2.2 TOPSIS method

The fundamental concept of the TOPSIS approach is to conduct a comparison between the target values of each entity and the most optimal state. This comparison is carried out after constructing a weighted normalized matrix. Subsequently, each target under investigation is ranked based on the extent of its divergence from the ideal target. In this way, it is possible to carry out an assessment on the superior points and inferior points of the high-level development condition of both the digital economy and the regional economy. The following content will narrate the detailed operation steps of the TOPSIS method:

(1)Create a decision matrix that is standardized and weighted by data

It is necessary to multiply the dimensionless normalized decision matrix Z_{ij} with the indicator weights W_j In order to obtain the decision matrix that has been weighted and normalized S_{ij}:

$$Z_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{m} X_{ij}^2}} \tag{8}$$

$$S_{ij} = Z_{ij} * W_j \tag{9}$$

(2) Ascertaining optimal and adverse optimal values

When dealing with a positive indicator, a greater value is more desirable, while a lower value is less favorable. Conversely, for a negative indicator, a lower value is desirable, and a higher value is less so. Then:

$$S_j^+ = \left(S_1^+, S_2^+, \ldots, S_n^+ \right) = \left\{ \max S_{ij} \mid j = 1, 2, \ldots\ldots, n \right\} \tag{10}$$

$$S_j^- = \left(S_1^-, S_2^-, \ldots, S_n^-\right) = \left\{\min S_{ij} \mid j = 1, 2, \ldots\ldots, n\right\} \tag{11}$$

(3) Determine the Euclidean distances of the standardized vectors of the indicators for each assessment object to the ideal and least - favorable solutions, respectively:

$$D_i^+ = \sqrt{\sum_{j=1}^{n}\left(S_j^+ - S_{ij}\right)^2} \tag{12}$$

$$D_i^- = \sqrt{\sum_{j=1}^{n}\left(S_j^- - S_{ij}\right)^2} \tag{13}$$

(4) Compute the relative proximity of each program

The computation of the Euclidean distance can additionally result in the relative proximity of the evaluation entity:

$$C_i = \frac{D_i^-}{D_i^+ + D_i^-} \tag{14}$$

Based on the size of the calculated relative proximity, it is possible to rank the objects of the assessment, the larger the value of the relative proximity of the objects of the assessment, the better the object of evaluation, the lower the risk, and vice versa.

2.3 Analysis of Development Level Measurement

This current study assesses the level of development of the digital economy and the scope of high - quality regional economic growth across China's provincial - level administrative areas during the time frame from 2014 to 2023.This goal is achieved through the devising of one assessment index framework for the digital economy and one assessment index framework for high-standard regional economic development.After that, this research carries the integration of real-world data from province and city indicators, and thus utilizes the entropy weight-TOPSIS method.

2.3.1 Degree of Digital Economy Development

The illustration in Figure 1 showcases the growth stages of the sub - aspects within the digital economy spanning from 2014 to 2023. Over this period, from 2014 to 2023, the development levels of all three sub - dimensions witnessed a substantial increase.The infrastructure development level experienced the most rapid growth. It soared from 0.292 in 2014 to 1.617 in 2023, representing a 454% increase. Next is the application level,this value was promoted from 0.406 in the year 2014 to 1.839 in the year 2023, it displays a growth rate that is 353%. Finally, the overall development level rose from 0.828 in 2014 to 3.087 in 2023, showing an increase ratio of 273%. Evidently, the implementation, underlying framework, and overall advancement of the digital economy have all witnessed substantial improvements. Over a ten - year span, the digital economy has achieved an aggregate growth rate of 447%. This serves to illustrate that the digital economy is presently in a phase of swift growth and holds extensive potential as well as significant room for future development.

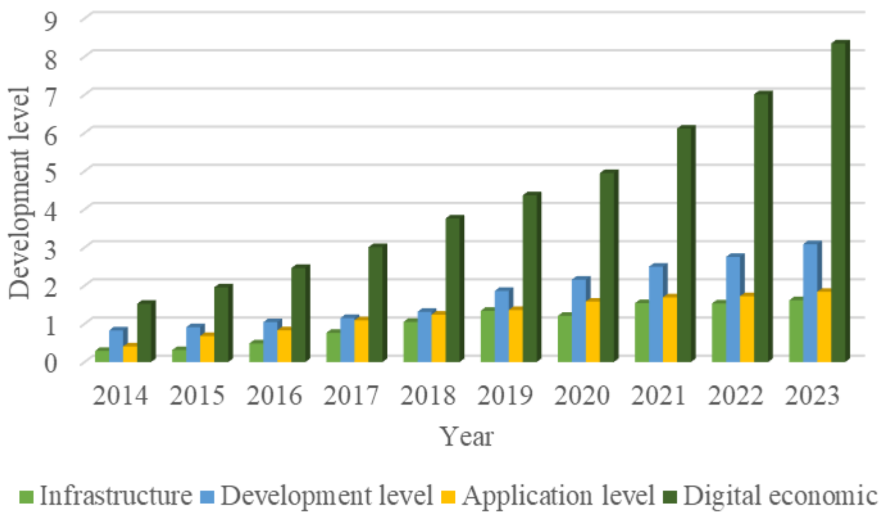

Figure 1: The advancement status of the sub - dimension within the economic realm

The condition of development of the digital economy in all different regions during 2014 to 2023 has been shown by Figure 2. Over this ten - year span (2014 - 2023), the digital economy witnessed substantial growth in most parts of China. In 2014, the mean score of China's digital economy was merely 0.061. However, by 2023, it had skyrocketed to 0.300. During the 2014 - 2023 timeframe, the digital economy in Beijing, Shanghai, Guangdong, and Zhejiang, and Jiangsu maintained a high - level development. Their average scores were 0.481, 0.369, 0.345, 0.248, and 0.285 respectively. Among them, Beijing, Shanghai, and Guangdong Regularly placed within the top three regarding the progress of the digital economic landscape.

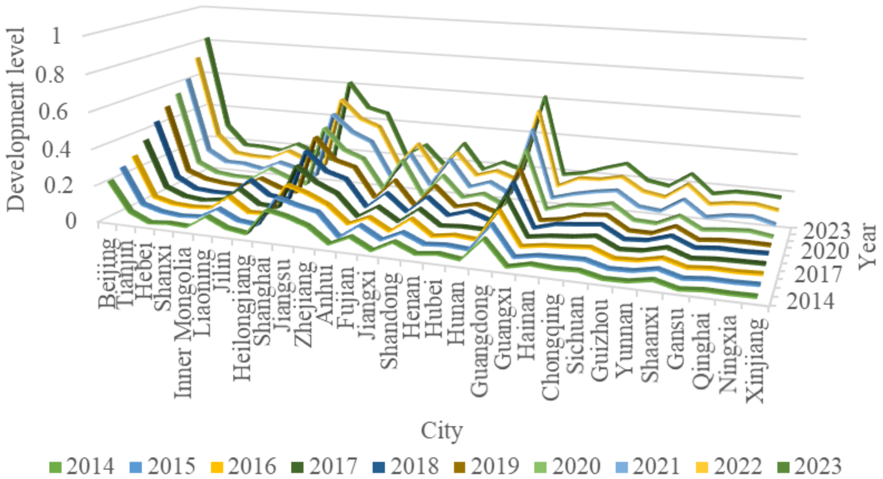

Figure 2: The extent of digital economic advancement across every region

Figure 3 shows us the growth condition of the digital economy in each sub-area from the year 2014 to the year 2023. In the entire time interval of 2014 to 2023, the eastern area, on average, has manifested the highest level of digital economy development progress.The mean value of its digital economy growth holds the position at 0.239. By comparison, the central and western areas showed relatively similar levels, the average values for digital economy development are 0.091 and 0.094 respectively.Within the year 2023, the eastern region possessed the highest mean development index. The western region was the next one, and the central region was placed at the last position. With regard to the growth speed of digital economy development, the western region has obtained the fastest growth, achieving a value of 836.36%.The growth speed we are discussing exceeded that of the eastern region, which was 736.36%. This outcome further verifies that since the implement of the western development strategy, the digital economic in the western region has obtained big promotion and obvious progress.

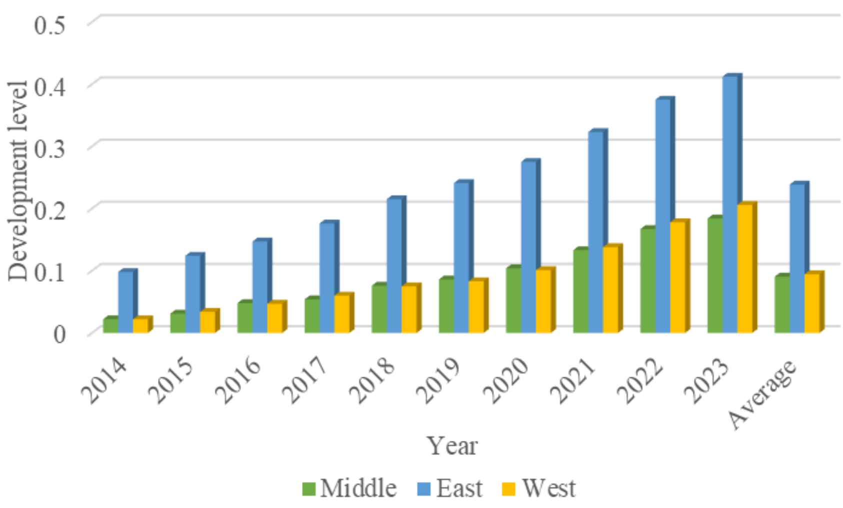

Figure 3: Regional digital economic development level

2.3.2 Level of advanced - standard advancement of the regional economic panorama

Figure 4 has shown the progress condition of the sub-parts in the deep development of the district economy in the time period from 2014 to 2023.In the time from 2014 to 2023, there occurred an 87.60 percent growth in the forward propulsion of the area's economic development. In these constituent parts, the high-quality characteristic of people's life level has obtained the most rapid growth. In the past decade, it experienced a qualitative improvement, with a growth rate of 222.22%. Next is the high - quality innovation and development. It advanced from 0.029 in 2014 to 0.079 in 2023, registering a growth rate of 172.41%. The standard of ecological civilization, which was of high quality, also demonstrated an upward trajectory. It rose from 0.012 in 2014 to 0.016, registering an increase of 34.48%. Regarding the high - quality economic growth, it went up from 0.058 in 2014 to 0.078 in 2023, achieving a ten - year growth rate of 33.33%.Evidently, there has been a significant enhancement in the standards of people's living, ecological civilization, innovation and development, and economic growth. The development of China's regional economies at a high level is becoming increasingly diverse, instead of simply depending on the growth of GDP. The level of people's living environments and the extent of innovation and development have offered important support for the high-quality growth of economy.

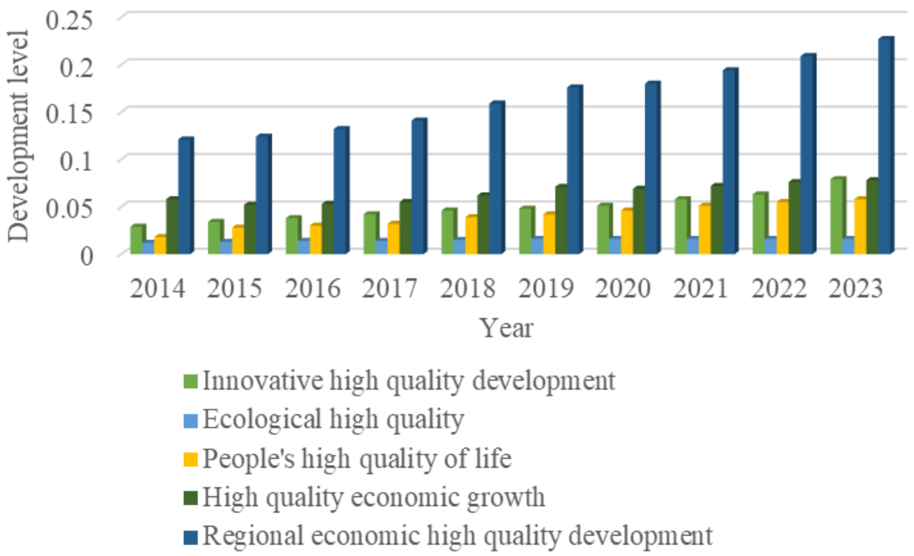

Figure 4: The extent of sub - aspects within the high - standard development of the regional economic landscape

We have calculated the whole score values of the high-criterion economic development degrees among 30 Chinese areas in the time period which covers the years from 2014 to 2023.Figure 5 has depicted the degrees of high-quality economic growth in these areas during this time period. During 2014 to 2023, which is a period of ten years, the high-quality economic development degrees of most among the 30 regions of China have the circumstance of getting better.As a matter of fact, within the past ten years, the degrees of high-quality economic development in these 30 regions have grown by 875.52 percent. In this whole ten-year period, areas like Peking, Tientsin, Shanghai, Chekiang, Kiangsu, and Kwangtung possessed the highest ranks of high-quality economic growth among all these 30 areas.The average values of the results of their high-quality economic development level were 0.498, 0.320, 0.381, 0.242, 0.271, and 0.275 separately. In the whole ten-year time span, Beijing together with Shanghai always occupied the first and the second places with regard to high-quality economic development degree.

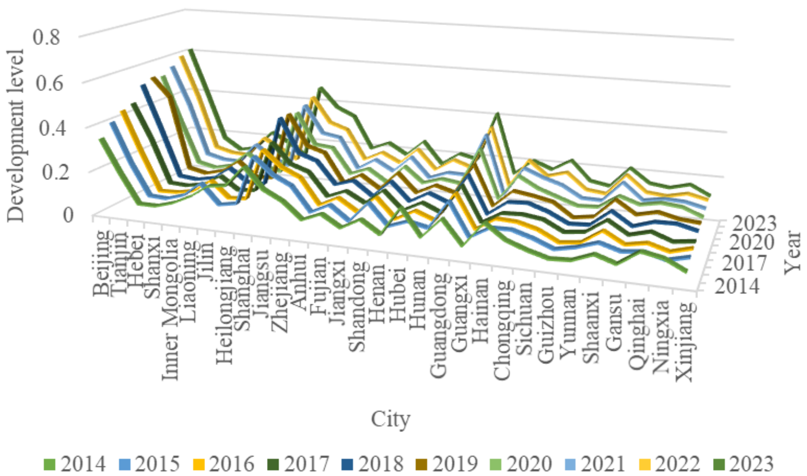

Figure 5: The level of high - quality development of the regional economy

Figure 5 shows the levels of high-quality economic development among 30 areas in China within a ten-year period that is from 2014 to 2023. These development degrees were gotten by the way of calculating combined scores. In this whole ten-year time, it can be seen that a notable promotion has occurred in the high-quality economic development degrees of most of these 30 Chinese regions.In the fact, the whole levels of high-quality economic development in these areas have seen a very big rise of 875.52%. In the whole ten-year time, from the 30 regions, Beijing, Tianjin, Shanghai, Zhejiang, Jiangsu, and Guangdong came out to be the persons who run in front in high-quality economic development.The average numerical values of their result indicators for high-requirement economic development are 0.498, 0.320, 0.381, 0.242, 0.271, and 0.275 separately. In addition, Beijing together with Shanghai year by year continuously maintain their places in the first two on the aspect of high-quality economic development degree.

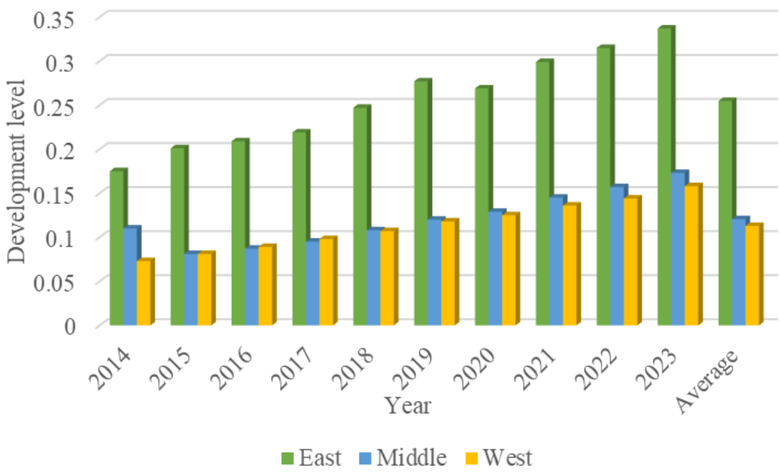

Figure 6: Diverse degrees of top - notch development in regional economic landscapes

3 Research Methodology Crucial

3.1 Research hypotheses

The digital economy boosts economic quality by promoting digital industries and enabling the digitalization of traditional sectors, thus supporting high - quality growth of the regional economy. The theoretical framework of this research is depicted in Figure 7. Taking into account both direct and indirect influences, we put forward the following assumptions:

Assumption H1: The digital economy has a substantial positive impact on the high - quality development of regional economies.

Assumption H2: Every core aspect of the digital economy, such as digital infrastructure, development status, and application range, makes a positive contribution to the high - quality development of regions.

Assumption H3: The digital economy mainly promotes the high - quality development of regions through the mediating function of technological innovation..

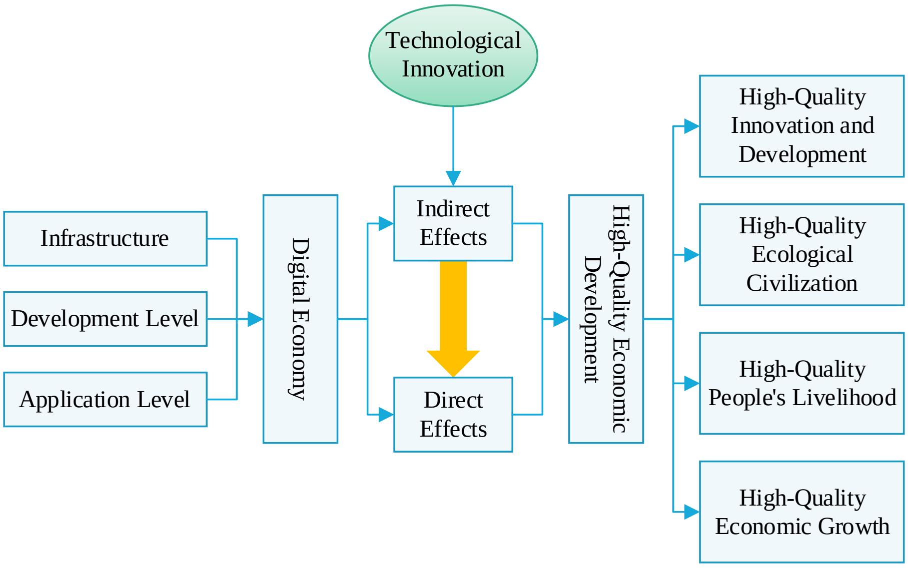

Figure 7: Theoretical research framework for this paper

3.2 Model Construction

3.2.1 Model Design

Regression modeling is among the multivariate statistical techniques, serving as an optimal instrument for examining and formulating the linear association between relevant and independent variables.To explore the mechanism by which the digital economy impacts the high - quality growth of the regional economy, this paper utilizes the multiple linear regression analysis technique to construct a model. Multiple linear regression (MLR) is a statistical technique that aims to develop a model depicting the association between the variables under examination and the dependent variable. It achieves this by utilizing linear equations founded on the observed data. The formula for the MLR model is:

$$Y_i = b_0 + b_1 \cdot x_{i1} + b_2 \cdot x_{i2} + ... + b_k \cdot x_{ik} + e_i \tag{15}$$

where Y_i is the dependent variable, b_0 is the intercept, x_{ik} is the independent variable, b_k is the vector of regression coefficients, and e_i is the residuals, i.e., the random error after removing the effect of k independent variables on Y, which is used to discriminate discrete outliers. An outlier is a discrete outlier if the residuals e_i of a set of data (x_i, y_i) in the constructed regression model Eq. (15) the residuals of these are significantly larger when compared to those of other data.. It is possible that the variables in some samples deviate significantly from the rest of the data due to specific reasons, such as sudden changes in experimental conditions or human error in recording. The diagnosis and treatment of outliers can improve the reliability of results, reduce analytical errors, and increase accuracy.

In this research, the Multiple Linear Regression (MLR) aims to reduce the total of squared differences between the observed and forecasted variables. The regression coefficients were calculated through employing the least squares method to make the Residual Sum of Squares (RSS) decrease to its minimal value. The RSS has the following characteristics:

$$RSS = \sum_{i=1}^{n} \left(y - b_0 - b_1 \cdot x_{i1} - b_2 \cdot x_{i2} - b_3 \cdot x_{i3} - \cdots - b_k \cdot x_{ik} \right) \tag{16}$$

Once the model has been built, it is necessary to conduct model validation.Model verification is arguably the most vital phase in the model - creation process. The verification process could entail evaluating the adequacy of the regression's fit, checking whether the residuals of the regression exhibit randomness, and confirming if the model's forecasting capability notably deteriorates when it is employed on data that was not utilized for model estimation.

The aptness of a regression line's match to the observed data is measured by the goodness - of - fit statistic. This metric quantifies the extent to which the regression line closely aligns with the actual observations. The fit coefficient, R^2, is a statistic used to measure the goodness-of-fit, i.e., the proportion (or percentage) of the y variance explained by the regression model to the y total variance, and ranges from 0 to 1. The closer the value of R^2 is to 1, the more effectively the regression straight line aligns with the observations, the better the fit. On the contrary, the lower the value of R^2, the poorer the alignment of the line with the observations.

The fitting coefficient R^2 is calculated as follows:

$$R^2 = 1 - \left(SS_{res} / SS_{tot} \right) \tag{17}$$

where SS_{res} the residual sum of squares has been given indication. It is the summation of the squared magnitudes of the differences between the real value and the predicted value,i.e. the error between the predicted value and the true value. SS_{tot} denotes the total sum of squares, reflecting the total error between the n observations of the dependent variable and its mean, indicating the degree of dispersion of the values, with larger values indicating greater dispersion. The SS_{res} / SS_{tot} denotes the SS_{res} exclusion of the effect of dispersion.

The expressions for SS_{res} and SS_{tot} are as follows:

$$SS_{res} = \sum_i \left(y_i - f_i \right)^2 \tag{18}$$

$$SS_{tot} = \sum_i \left(y_i - \overline{y} \right)^2 \tag{19}$$

$$\overline{y} = (\sum_{i=1}^{n} y_i) / n \tag{20}$$

where f_i denotes the true value and y_i denotes the predicted value.

In addition, the significance of the multiple regression equation is tested (F test) by constructing the statistic F, and if the value of p from the F test is less than 0.05, it means that, the overall regression is significant. Then:

$$F = \left(SS_{reg} / k \right) \Big/ \left(SS_{res} / n - k - 1 \right) \tag{21}$$

$$SS_{reg} = \sum_i \left(f_i - \overline{y} \right)^2 \tag{22}$$

where SS_{res} denotes the residual sum of squares and SS_{reg} denotes the regression sum of squares. The larger the F the more significant the existence of a linear relationship.

In addition, the smaller the residual variance S^2, the more accurately the regression equation is predicted, and the residual variance S^2 is equivalent to the error mean square error MSE, defined as:

$$MSE = SS_{res} / (n - k) \tag{23}$$

In this research, the initial step to assess the model's accuracy involved examining the regression's goodness - of - fit. After that, outliers were eliminated. Once the goodness - of - fit surpassed 90%, the regression equation was established. Subsequently, the microalgae data that were not employed in constructing the model were utilized for validation comparisons.

Consequently, a baseline panel regression model was developed in accordance with the assumptions put forth in this paper:

$$REHQD_{it} = \alpha_i + \beta_1 DE_{it} + \sum \beta_k X_{k,it} + \varepsilon_{it} \tag{24}$$

where $REHQD$ is the composite index of the level of high-quality development of the economy in the ith province in the tth year, and DE_{it} denotes the composite index of the level of development of the digital economy in the ith province in the tth year. $X_{k,it}$ denotes the set of control variables, and ε_{it} is the error disturbance term. β_1 and β_k are the coefficients of the core explanatory variables and the control variables, and in order to alleviate the problem of heteroskedasticity or skewness, both sides are taken to be logarithmic at the same time when performing specific model simulations.

3.2.2 Variable selection

(1) Dependent Variables

Regional High-Quality Economic Development (RHQED): The data which is shown here is obtained from the evaluation of the regional high-quality economic development condition that was conducted in Chapter 2.In this frame, the data which comes from the High-Quality Index of Innovative Development (HQIID) is utilized for indicating technological innovation in the research environment.

(2) Key Explanatory Variables

Digital Economy (DE): The data employed here are identical to those of the Digital Economy Composite Index gauged in Chapter 2. Moreover, the abbreviations IF, DL, and AI are utilized to represent the three aspects of assessing the digital economy, namely, infrastructure, development status, and application degree, respectively.

(3) Variables for controlIMPORTANT:- Supply solely the revised text- Refrain from including explanations, notes, or any form of meta - commentary- Guarantee that the revision is comprehensive and substantial, not just superficial alterations- The final text should be unidentifiable in its form yet identical in its essence to the original- Provide only English text without any extra information

Because of the concern toward problems in data gathering and the endogenous property of the model, the selections of control variables are comparatively few. According to the related researches, the below control variables are selected:

Financial Development Level (FL): This indicator is obtained through calculating the ratio that the total loan amount which has not been repaid of financial institutions accounts for in the Regional Gross Domestic Product.

Marketization Level (ML): The ratio that total retail sales of consumption goods accounts for in regional GDP is chosen as one assessment index.

External Openness (FDI): It is gauged by the total foreign direct investment divided by the GDP.

3.2.3 Data sources

This research carries out an experience-based inspection through using the board data of 30 province-level administrative bodies (including provinces, cities directly under the central government, and autonomous regions) in China which is from 2014 to 2023. The four areas of Tibet, Hong Kong, Macao, Taiwan are not got inclusion inside this sample.The data of concerned indicators are mainly acquired from National Bureau of Statistics, EPS data platform, statistic year-books, and yearly reports. Furthermore, a part of the measurement indexes has been computed according to the detail given in the previous section.

4 Empirical analysis

4.1 Basic regression analysis

This research paper utilizes Stata 16 software to perform an empirical analysis. First, without considering the endogeneity problem, a regression of the benchmark model is executed.The outcome of the Hausman test gives us that the null hypothesis must be rejected, hence hence hence this indicates that the fixed-effects model ought to be chosen. After that, we use the fixed-effects model in this paper's empirical testing part.To guarantee the reliability of the findings, Table 3 presents the outcomes of step - by - step regression analysis. In this analysis, control variables are added in a sequential manner. It should be noted that: * indicates statistical significance at the 1% level (p < 0.01), \\ at the 5% level (p < 0.05), and * at the 10% level (p < 0.1).As the control variables are gradually incorporated, the core explanatory variable, the digital economy (lnDE), maintains a positive and significant relationship at the 1% significance level across all model specifications.Specifically, a 1% growth in the digital economy index corresponds to a 0.196% to 0.318% increase in the regional high - quality development index. These results offer strong evidence, it is evident that the digital economy exerts a significant and favorable influence on the high - quality development of regions, thus confirming Hypothesis H1.

Table 3: Results of the benchmark regression

Variable	(1)	(2)	(3)	(4)
lnDE	0.318***	0.233***	0.249***	0.196***
	0.034	0.036	0.036	0.037
lnFL		-0.107*	-0.141*	-0.121*
		0.051	0.064	0.065
lnML			0.473*	0.409*
			0.218	0.212
lnFDI				0.077*
				0.051
Constant	-0.941***	-1.407***	-1.237***	-1.122***
	0.036	0.241	0.313	0.366
Observations	300	300	300	300
R-squared	0.657	0.662	0.695	0.751
FE	Yes	Yes	Yes	Yes

4.2 Multidimensional analysis

4.2.1 Impact of the elements of the digital economy

Previously acquired benchmark regression outcomes have examined the effect of the digital economy on the high - quality growth of the regional economy from an overarching view of regional digital economy development. Conversely, Table 4 emphasizes assessing the impact of each element of the digital economy on the high - quality progress of the regional economy. Among the various constituent parts of the digital economy, the computed coefficient values of infrastructure (IF), development condition (DL), and application condition (AI) all meet the 0.01 significance standard.This finding shows that promotions in the growing conditions of each aspect inside the digital economy can greatly push forward the high-quality development of the district economy.That is to say, it gives verification to the hypothesis H2 that was proposed in the previous section. It is worth pointing out that, among these four aspects, the estimated coefficient of the application degree (AI) is the largest, reaching 0.172. This indicates that the digital use is the most key factor. A coefficient value of 0.172 indicates that currently, the degree of digital application has a strong driving force on the high - quality progress of the regional economy. Therefore, in the subsequent development phases, this area should be given considerable attention. The estimation results of the remaining control variables are in line with those of the benchmark model, which further validates the reliability of the estimation outcomes.

Table 4: Regression outcomes of the digital economy across various

Variable	(5)	(6)	(7)
lnIF	0.142***		
	0.036		
lnDL		0.155***	
		0.037	
lnAI			0.172***
			0.043
lnFL	-0.154**	-0.175**	-0.177**
	0.097	0.091	0.081
lnML	0.328	0.387*	0.327*
	0.032	0.034	0.036
lnFDI	0.111***	0.128***	0.117***
	0.033	0.029	0.032
Constant	-1.122***	-1.127***	-1.132***
	0.067	0.064	0.071
Observations	300	300	300
R-squared	0.685	0.729	0.696
FE	Yes	Yes	Yes

4.2.2 Influence of technological advancement

Our research objective is to verify the function of the digital economy, which operates by way of technological innovation, in influencing the high-standard development of the regional economy. Just like what is displayed in Table 5,the results from the regression study on the effect of technical innovation show that, no matter whether control variables are added, the digital economy greatly promotes the innovative aspect of the high-quality development of the regional economy.The computed coefficients are 0.674 and 0.405 separately, and the p-value is lower than 0.01. This circumstance powerfully gives verification to Hypothesis H3 which was put forward in the foregoing section. Hypothesis H3 puts forward the view that the digital economy via technological innovation pushes forward the high-quality growth of the area economy.

Table 5: The regression result of technical innovation

Variable	(8)lnHQID	(9)lnHQID
lnDE	0.674***	0.405***
	0.082	0.087
lnFL		-0.518***
		0.124
lnML		0.797*
		0.305
lnFDI		-0.023
		0.073
Constant	-0.934***	-2.244***
	0.145	0.521
Observations	300	300
R-squared	0.665	0.722
FE	Yes	Yes

4.3 Examination of regional diversity

Table 6 has carried out an analysis about the differences of how the digital economy influences the high-quality development of the regional economy in eastern, central, and western regions. An all-round research about the area differences in the effect that the digital economy gives to high-quality regional economy growth has been carried out.In the provinces that lie across the eastern, the central, and the western regions, the digital economy has the very significant influence on the promotion of the high-quality economic growth. The coefficient numerical values in the eastern and central regions are higher than those in the western region, hence standing at 0.175, 0.163, and 0.157 respectively.The eastern region is more advanced in terms of communication infrastructure, digital technology, human resources, and materials. Leveraging these advantages, the digital economy can more effectively serve society and Improve the standard and effectiveness of economic growth in the eastern and central areas.Conversely, the western region is reaping the benefits of the inclination of national policies and resources. It is accelerating the advancement of the digital economic sphere. and steadily reducing the digital gap, Consequently, it propels high - standard economic development at the regional scale. If we hope our goal is to promote the influence of the nation’s digital economy to the high-quality growth of economy, therefore the western area is still the main region that we need to pay attention to.

Table 6: Regional heterogeneity analysis results

Variable	(10)East	(11)West	(12)Middle
lnDE	0.175***	0.157***	0.163***
	0.055	0.071	0.096
lnFL	-0.218***	-0.085	-0.126***
	0.059	0.053	0.045
lnML	0.322*	0.374	0.412**
	0.172	0.203	0.162
lnFDI	0.128***	0.085**	0.086***
	0.038	0.032	0.0243
Constant	-1.476***	-1.123***	-1.033***
	0.271	0.294	0.227
Observations	300	300	300
R-squared	0.803	0.773	0.766
FE	Yes	Yes	Yes

5 Conclusion

This research analyzes the growth of the digital economy and the high - quality economic development of 30 provincial regions in China from 2014 to 2023. Quantitative assessment models and regression analysis are employed to determine the inherent connection and transmission mechanism between them. The findings indicate that throughout the sample period, both the digital economy and high - quality development witnessed significant growth. The digital economy exerts a distinct positive influence on the high - quality development of regions. Infrastructure, industrial progress, and digital utilization all play effective roles in contributing to this development. Among them, the depth of digital application has the most potent promotional effect. At the same time, technological innovation serves as a crucial intermediate pathway. There is regional disparity in this regard; the driving force is the strongest in the eastern region, followed by the central and western regions. Consequently, three policy suggestions are put forward: fortify the digital economy to support high - quality development; implement region - specific policies to reduce development disparities; and refine the digital innovation environment to enhance technological capabilities.

About the Author

Feixiang Wang, bom in Bozhou,Anhui Province,P.R. China,in 1994.He studied in Business College of Guizhou University of Finance and Economics,where he obtained a Bachelor'sdegree in Economics. He then pursued and obtained a Master's degree in Science at GuizhouUniversity of Finance and Economics from 2018 to 2021. Now he is employed as a full-timeteacher at Xinjiang University of Technology. He has published a total of 6 research papers.His research interests are included Digital Economy and Economic Statistics.

Lihao Wu was bom in Zhengyang,Henan Province,P.R. China,in 1992.He obtained amaster's degree from Guizhou University of Finance and Economics in China.He is currentlystudying at Guizhou University of Finance and Economic.His main research direction is Political economy of socialism with Chinese characteristics.

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