ingegneria sismica
International Journal of Earthquake Engineering
Anno XLIII - Num. 2 - 2026

Digital Finance as an Economic Catalyst: Evidence of Model-Driven High-Quality Development in Shandong

Fenghui Zhu[1,*] *and Tonggong Zhang*[2]

[1] School of Accounting, Qingdao Vocational and Technical College of Hotel Management, Qingdao, Shandong, 266100, China
[2] School of Economics and Engineering, Qingdao University of Science and Technology, Qingdao, Shandong, 266061, China

SUMMARY: *Promoting coordinated regional development is a crucial pathway for building a new development paradigm and an inherent requirement for addressing imbalances and inadequacies in development. Based on theories of coordinated regional economic development and high-quality economic growth, this paper constructs an evaluation index system for Shandong Province's high-quality economic development by integrating the new development philosophy. Combining the entropy weight method with the TOPSIS method, we calculate Shandong's comprehensive score for high-quality economic development and introduce kernel density estimation to measure the spatial differentiation characteristics of this development. To explore the impact of digital finance on Shandong's high-quality economic development, a regression model was constructed using the digital inclusive finance index as the explanatory variable, supplemented by empirical analysis of data from 16 cities in Shandong. Findings reveal that from 2011 to 2024, Shandong's overall level of high-quality economic development increased by 1.25 times, with a notably high average annual growth rate during the study period. The impact of digital finance on Shandong's high-quality economic development exhibits a significant positive effect at the 1% significance level. Each 1% increase in digital finance correlates with a 0.583 percentage point rise in high-quality economic development levels. Moreover, the influence of digital finance demonstrates significant regional heterogeneity. Therefore, Shandong Province needs to further improve digital financial infrastructure across its cities to promote coordinated regional development and collectively advance the province's high-quality economic development.*

KEYWORDS: *high-quality economic development; Shandong Province; entropy weight method; TOPSIS method; kernel density; regression model*

1 Introduction

Benefiting from four decades of reform and opening up, China's economy has achieved remarkable accomplishments and made significant contributions to global economic stability. However, its past extensive growth model heavily relied on resource inputs, generated substantial pollution emissions, and led to a series of social issues such as widening urban-rural income gaps and insufficient innovation capacity. This approach is unsustainable in the long run [1-3]. In the new journey toward eliminating wealth disparities and achieving common prosperity, balancing the relationship between economic growth rate and growth quality is a

*penny0706@sina.cn
https://doi.org/10.65102/is2026642
Published: 30 April, 2026

crucial issue that modern nations must address [4, 5]. Relevant conferences have emphasized that high-quality development is the primary task in comprehensively building a modern socialist country. Against the backdrop of persistent global economic sluggishness, China's economy faces a complex convergence of three overlapping phases: a transition in growth momentum, structural adjustment pains, and the digestion of previous policy effects. It must achieve high-quality development characterized by innovation as the primary driver, coordination as an inherent feature, green development as the universal form, openness as the inevitable path, and shared benefits as the fundamental purpose. This will propel societal progress through transformations in quality, efficiency, and driving forces [6-9].

With the rapid advancement of internet technology, the digital economy—dominated by next-generation information technologies—has emerged as a vital pathway for effectively meeting market demands and smoothing the dual circulation of domestic and international markets. It has become a key driver and breakthrough point for high-quality development [10, 11]. As the financial sector provides capital support to other industries, it occupies a central position in the digital economy's evolution [12]. Digital finance is reshaping the landscape of traditional financial development. In its early stages, it has significantly enhanced the inclusiveness and precision of financial services, helping more market entities overcome information asymmetry issues in financing. This broadens funding channels for society, enterprises, and residents, strengthens societal resilience against financial risks, and elevates overall economic efficiency—all contributing to high-quality development across society [13-16].

As one of China's major economic provinces, Shandong's high-quality development has drawn significant attention. Chen et al. [17] evaluated Shandong's high-quality development level using the entropy weight method. By 2022, the province demonstrated relatively high development levels in innovation, sharing, and green development, while coordination and openness required improvement. In recent years, Shandong has consistently pursued high-quality development through a series of innovation-driven and transformation measures, including: transitioning from old to new growth drivers, developing the marine economy, advancing agricultural modernization, upgrading manufacturing, promoting technological innovation, expanding international cooperation, enacting environmental policies, and implementing ecological restoration projects [18-21]. Currently, Shandong actively integrates into national strategic frameworks, positioning high-quality development as the latest direction for the province's economic growth. Concurrently, the development of digital finance across various regions has injected new momentum into Shandong's traditional financial sector [22, 23]. As early as December 2017, Wulian County in Rizhao City, Shandong Province, pioneered a digital wealth management pilot program and collaborated with platforms like Alibaba to experiment with “digital wealth management,” which was rapidly promoted nationwide.

Subsequently, prefecture-level cities like Dezhou and Heze actively advanced inclusive digital finance development. Li et al. [24] analyzed the impact of inclusive digital finance on high-quality economic development using threshold and mediation models, finding positive effects primarily through facilitating consumption structure transformation. Yao [25] noted that inclusive digital finance development can narrow urban-rural income gaps in Shandong and promote balanced urban-rural development. Furthermore, Gao et al. [26] revealed that the inclusiveness of digital finance can promote high-quality development in regional real economies, achieved by stimulating and protecting entrepreneurial activities. Feng et al. [27] utilized panel data from various regions in Shandong Province to analyze that inclusive digital finance in Shandong can significantly optimize employment structures and drive the development of the tertiary sector, with this optimization being more pronounced in relatively

developed regions. Regarding infrastructure, Jinbo et al. [28] confirmed that digital infrastructure enhances Shandong's economic sustainability and social innovation while strengthening regional economic resilience. Shandong's financial digital infrastructure encompasses over 80,000 smart financial services and more than 10 financial data centers. Supported by technologies like blockchain and artificial intelligence, fintech facilities propel digital finance development, laying a solid foundation for financial inclusion and economic growth across the province [29, 30]. Through digital finance development, Shandong has further optimized its fiscal structure, elevated living standards, expanded financial service coverage, and advanced high-quality development. However, the current model of digital finance driving Shandong's high-quality development remains unclear and requires systematic clarification.

Investigating the impact of digital finance on Shandong's high-quality development level is crucial for comprehending regional imbalances and inconsistencies in development, thereby promoting Shandong's progression toward higher levels of quality and sustainability. This paper constructs an evaluation index system for Shandong's high-quality development level based on economic high-quality development theory and the new development philosophy, encompassing six dimensions: structural optimization, innovation, green development, openness, sharing, and coordination. Using panel data from 16 cities in Shandong Province from 2011 to 2024, the entropy-weighted TOPSIS method is introduced to measure the province's economic high-quality development level. Combined with kernel density estimation, the spatial differentiation characteristics of Shandong's economic high-quality development are analyzed. Additionally, the Peking University Digital Inclusive Finance Index is selected as an explanatory variable to construct a regression model exploring the impact of digital finance on Shandong's high-quality economic development level. Based on the findings, feasible recommendations for Shandong's high-quality development are proposed.

2 Measurement and Analysis of High-Quality Economic Development in Shandong Province

As a major industrial, agricultural, and populous province in China, Shandong has achieved significant breakthroughs in economic strength and industrial capabilities in recent years. However, alongside rapid economic growth, regional disparities have gradually emerged, with issues such as unbalanced and unsustainable development becoming increasingly prominent. Insufficient regional coordination severely limits the province's overall regional influence and fails to meet the demands of the new era's regional coordination strategy. Conducting an in-depth analysis of the evolving trends in Shandong's high-quality economic development is not only a new imperative for facilitating the transformation of old and new growth drivers—achieving the “replacing old industries with new ones, phoenix-like rebirth”—but also an urgent necessity for advancing the construction of a Beautiful Shandong and striving to realize the province's regional integration development.

2.1 Theoretical Foundations

2.1.1 Theory of Coordinated Regional Economic Development

Deeply implement the regional coordinated development strategy, major regional strategies, the main functional zones strategy, and the new urbanization strategy. Optimize the layout of major productive forces to build a regional economic structure and territorial spatial system characterized by complementary advantages and high-quality development. In accelerating the

formation of a new development paradigm during the new development stage and striving to promote high-quality development, the task of advancing high-quality regional economic development must be pursued. High-quality development has become the primary objective of regional economic growth, while coordinated regional development serves as a crucial pathway to achieving this goal.

High-quality development is the outcome of thoroughly implementing the new development philosophy and achieving efficiency gains, structural optimization, cultivation of new growth drivers, and improvements in people's living standards after economic growth has reached a certain stage. High-quality regional development can be regarded as an advanced state of regional advancement. It not only serves as a necessary foundation for advancing Chinese-style modernization but also constitutes a key driver for its implementation. Given the systemic nature of high-quality economic development, its standards exhibit distinct hierarchical levels: at the macro level, efficiency standards; at the meso level, structural standards; and at the micro level, market standards. Efficiency represents the macro-level benchmark for high-quality regional economic development, primarily centered on enhancing regional potential growth rates and factor utilization efficiency. At the meso level, the standard for high-quality regional economic development is structural, achieved by optimizing the regional industrial structure. At the micro level, the standard is market-based, meaning maximizing benefits according to market demand [31].

2.1.2 Theory of High-Quality Economic Development

High-quality economic development represents a comprehensive upgrade and reshaping of economic development models, pathways, and objectives as the economy enters a new phase. Under this concept, economic growth is no longer solely measured by GDP expansion but places greater emphasis on optimizing and upgrading economic structures. It highlights innovation-driven development as the primary engine of growth while pursuing ecological harmony and continuous improvement in social welfare and people's livelihoods.

Specifically, high-quality economic development requires deep structural adjustments to drive the transformation and upgrading of traditional industries. It emphasizes enhancing total factor productivity through technological and institutional innovation, promoting efficient resource allocation and circular utilization. Moreover, high-quality economic development prioritizes social equity and justice alongside enhanced public welfare, striving to establish mechanisms for sharing development outcomes. Consequently, the evaluation framework for high-quality development must embody its essence by adhering to the “Five Integrations” principle. This framework must intrinsically reflect the five development concepts—innovation, coordination, green development, openness, and sharing—along with their interdependent logical relationships. Only then can the economic and social development of various regions be assessed accurately and effectively[32].

2.2 Research Methods

2.2.1 Indicator System for High-Quality Economic Development

According to existing literature, economic quality can be further categorized into the quality of economic growth, the quality of economic development, and the quality of economic operations. The quality of economic development differs from the quality of economic growth; it represents a comprehensive assessment of the state of a nation's economic development, encompassing a much broader scope than the quality of economic growth. Generally, the criteria for measuring the quality of economic development should include the effectiveness, adequacy, coordination, innovation, sustainability, inclusiveness, and stability of economic development.

This paper establishes an evaluation index system for Shandong Province's high-quality economic development based on the new development philosophy of innovation, coordination, green development, openness, and sharing. Guided by principles of comprehensiveness, scientific rigor, systematic approach, and feasibility, the system is constructed across six dimensions: structural optimization, innovative development, coordinated development, green development, open development, and shared development, as shown in Table 1. The evaluation framework encompasses 18 indicators across these six dimensions, providing a comprehensive reflection of the evolving landscape of high-quality economic development in Shandong Province.

Table 1: Indicator system for the level of high-quality economic development

Primary index	Secondary index	Code
Structural optimization	Total economic volume	SO1
	Investment structure	SO2
	Demand structure	SO3
	Consumption structure	SO4
Innovative development.	Financial input	ID1
	Human capital	ID2
	Innovation output	ID3
Coordinated development	Urban-rural structure	CD1
	Financial structure	CD2
Green development	Energy consumption	GD1
	Degree of greening	GD2
Open development	Trade openness	OD1
	Open investment	OD2
Shared development	Income level	SD1
	Spiritual culture	SD2
	Educational resources	SD3
	Medical resources	SD4
	Infrastructure construction	SD5

Data primarily originates from the Shandong Statistical Yearbook, the China Urban Statistical Yearbook, and municipal statistical yearbooks. A minimal amount of missing data was imputed using either mean values or exponential smoothing. Positive indicators underwent positive normalization, while negative indicators underwent inverse normalization, simultaneously resolving dimensionality issues.

2.2.2 Entropy Weighted TOPSIS Method

The Entropy Weight TOPSIS method combines the entropy weight approach with the TOPSIS method. The entropy weight approach determines the weight values of evaluation indicators, effectively avoiding biases caused by subjective factors and achieving high reliability. The TOPSIS method (Two-Operator Partial Information System) primarily evaluates the quality of objects by measuring their distance from positive and negative ideal solutions, thereby ranking them to ensure objective and scientific evaluation outcomes [33]. Based on relevant References, the specific process is as follows:

(1) Construct the raw matrix $\{v_{ij}\}_{m\times n}$. Apply the range method to perform dimensionless processing on the raw data, yielding the standardized matrix $\{r_{ij}\}_{m\times n}$.

(2) Determine indicator weights using the entropy weight method. When calculating the indices for each subsystem, use the corresponding weights from w_1; when calculating the comprehensive index for Shandong Province's high-quality economic development level, use the weights from w_2 as the weights.

(3) To enhance the objectivity of evaluating Shandong Province's high-quality economic development level, the entropy weights w_i are used to construct the weight normalization matrix Y. That is:

$$Y = \begin{bmatrix} g_{11} & g_{12} & \cdots & g_{1n} \\ g_{21} & g_{22} & \cdots & g_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ g_{m1} & g_{m2} & \cdots & g_{mn} \end{bmatrix} = \begin{bmatrix} r_{11} \cdot w_1 & r_{12} \cdot w_1 & \ldots & r_{1n} \cdot w_1 \\ r_{21} \cdot w_2 & r_{22} \cdot w_2 & \ldots & r_{2n} \cdot w_2 \\ \vdots & \vdots & \vdots & \vdots \\ r_{m1} \cdot w_m & r_{m2} \cdot w_m & \ldots & r_{mn} \cdot w_m \end{bmatrix} \tag{1}$$

(4) Determine the positive and negative ideal solutions.

The set of positive ideal solutions is expressed as:

$$\{e_j^+\} = \{\max g_{il}, \max g_{i2} \ldots \max g_{im}\} \tag{2}$$

The set of negative solutions is expressed as:

$$\{e_j^-\} = \{\min g_{i1}, \min g_{i2} \ldots \min g_{in}\} \tag{3}$$

(5) Calculate the distances d_i^+, d_i^- between each evaluation object and the positive ideal solution and negative ideal solution using the Euclidean distance method. That is:

$$d_i^+ = \sqrt{\sum_{j=1}^{n} (g_{ij} - e_j^+)^2}; d_i^- = \sqrt{\sum_{j=1}^{n} (g_{ij} - e_j^-)^2} i = 1, 2, \ldots, m; 0 \le d_i^+, d_i^- \le 1 \tag{4}$$

(6) Calculate the proximity of the evaluation object to the ideal solution, T_i. Then:

$$T_i = \frac{d_i^-}{d_i^+ + d_i^-} i = 1, 2, \ldots, m; 0 \le T_i \le 1 \tag{5}$$

In the formula, T_i takes values between 0 and 1. The higher the value, the closer it is to the target, indicating a higher level of comprehensive high-quality economic development in Shandong Province.

2.2.3 Kernel Density Estimation Methods

To analyze regional disparities in Shandong Province's high-quality economic development and their origins, this paper employs kernel density estimation to examine the dynamic edge effects of high-quality economic development in Shandong. Kernel density estimation is a nonparametric method that examines data distribution characteristics directly from the data itself. This approach requires no prior model assumptions, offering advantages such as low model dependency and strong robustness. It is increasingly used to study distribution imbalances [34].

Let $f(x)$ denote the density function of a random variable X. This function can be estimated using the following equation:

$$f(x) = \frac{1}{Nh}\sum_{i=1}^{N} K(\frac{x_i - \overline{x}}{h}) \tag{6}$$

Here, $K(g)$ denotes a kernel function, x_i represents the sample values of a random variable, $\overline{x}$ is the sample mean, N is the sample size, and h indicates the bandwidth. The choice of bandwidth affects the estimation results: a smaller bandwidth yields higher estimation accuracy. This paper adopts the Gaussian kernel density function, defined as:

$$K(x) = \frac{1}{\sqrt{2\pi}}\exp(-\frac{x^2}{2}) \tag{7}$$

By comparing nuclear density curves across different periods, one can gain an intuitive understanding of the magnitude, patterns, and evolution of disparities in regional economic development.

2.3 Measuring the Level of High-Quality Economic Development in Shandong Province

2.3.1 Analysis of Overall Development Level

This study examines data from 16 prefecture-level cities in Shandong Province spanning 2011 to 2024. It measures the level of high-quality economic development using an evaluation indicator system developed earlier and the entropy-weighted TOPSIS method. The annual high-quality economic development levels of these 16 cities are averaged, with the cross-sectional mean representing Shandong Province's overall high-quality economic development level. This approach analyzes the longitudinal characteristics of the province's overall high-quality economic development. Figure 1 illustrates the longitudinal trend of Shandong Province's economic high-quality development level.

The figure reveals that from 2011 to 2024, the average level of high-quality economic development in Shandong Province exhibited a steady upward trend. The lowest value within the sample period occurred in 2011, with a high-quality economic development level of 0.354, while the highest value was recorded in 2024, reaching 0.796. From 2011 to 2024, the level of high-quality economic development increased by 1.25 times overall, with a notably high average annual growth rate within the sample period. The most prominent phase occurred between 2011 and 2012, when Shandong's high-quality economic development level rose from 0.354 to 0.397, achieving a year-on-year growth rate of 12.21%—the highest value within the sample period. The slowest growth phase occurred between 2016 and 2017, when Shandong's high-quality economic development level rose from 0.508 to 0.531, with a year-on-year growth rate of only 4.44%. The above data analysis reveals that Shandong's high-quality economic development level exhibited an overall upward trend within the sample period. The rate of increase was higher in the first half of the period than in the latter half, with the growth rate from 2016 to 2017 being the lowest within the sample period. This indicates that Shandong's development momentum has slowed in recent years, requiring strong impetus to further drive its high-quality economic development. Furthermore, to conduct a more detailed analysis of the longitudinal characteristics of Shandong's high-quality economic development, this paper further examines the longitudinal development features across the six dimensions of high-

quality economic development in Shandong Province. The research reveals that all six dimensions have undergone varying degrees of optimization within the sample period, indicating that the optimization of these six dimensions collectively promotes Shandong's high-quality economic development.

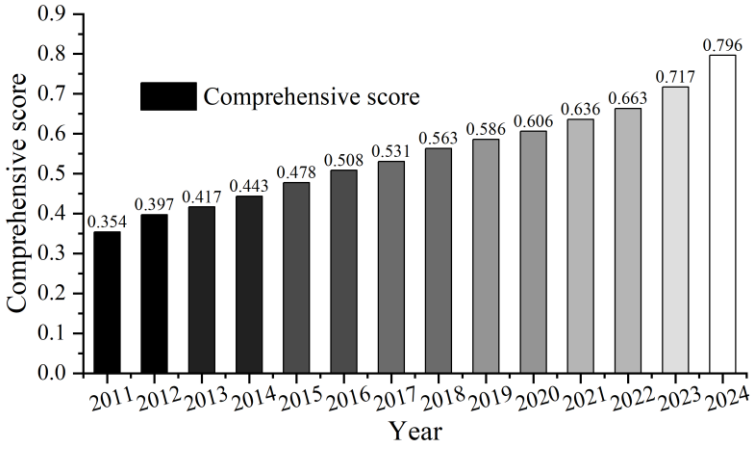


Figure 1: Overall development level analysis

2.3.2 Analysis of Development Levels in the Three Major Economic Circles

To provide a relatively clear picture of Shandong's high-quality economic development, this analysis examines the province's progress from three perspectives—the Provincial Capital Economic Circle, the Jiaodong Economic Circle, and the Southern Shandong Economic Circle—in conjunction with Shandong's accelerated regional economic development framework of "one cluster, two centers, and three circles," designed to "take the lead and forge new paths."

The "Provincial Capital Economic Circle" primarily encompasses seven prefecture-level cities: Jinan, Zibo, Dongying, Tai'an, Dezhou, Liaocheng, and Binzhou. It serves three major functional roles: a demonstration zone for ecological conservation and high-quality development in the Yellow River Basin, a regional hub for national kinetic energy transformation, and a new high ground for global civilizational exchange and mutual learning. Shandong's "Jiaodong Economic Circle" primarily encompasses five prefecture-level cities: Qingdao, Yantai, Weifang, Weihai, and Rizhao. It is positioned as a nationally significant shipping and trade hub, financial center, and model zone for marine ecological civilization, as well as a world-class core area for marine science and education and a cluster for modern marine industries. The "Southern Shandong Economic Circle" primarily encompasses four prefecture-level cities: Zaozhuang, Jining, Linyi, and Heze. It is positioned as a pioneer zone for rural revitalization, a new highland for transformative development, and an economic uplift zone within the Huai River Basin. Figure 2 illustrates the trends in high-quality development levels across these three economic circles.

Statistics reveal that from 2011 to 2024, Tai'an City consistently ranked among the top in the provincial capital economic circle in terms of comprehensive development quality scores. Tai'an's comprehensive development quality score was 0.301 in 2011 and reached 0.683 in 2024, representing an increase of approximately 126.91%. Zibo City's comprehensive development quality score remained relatively low overall. Its score was 0.375 in 2011 and 0.698 in 2024, representing an increase of approximately 86.13%. Overall, the comprehensive development quality scores within the Provincial Capital Economic Circle showed an upward trend, though the rate of increase varied significantly among different cities. From 2011 to 2024, the comprehensive development quality scores of cities within the Jiaodong Economic Circle

generally showed an upward trend, though differences among cities remained relatively large. Rizhao City maintained a leading position in the Jiaodong Economic Circle, with its comprehensive development quality score rising from 0.307 in 2011 to 0.685 in 2024, representing an overall increase of 123.13%. Additionally, from 2011 to 2024, the comprehensive development quality scores of cities within the Southern Shandong Economic Circle remained relatively close and generally trended upward, though they remained lower overall compared to the other two circles. Consequently, for Shandong Province's high-quality economic development, the provincial capital and Jiaodong economic circles demonstrate stronger momentum, while the Southern Shandong Economic Circle exhibits a relatively slower development trajectory. In pursuing high-quality economic development for Shandong Province, it is essential to prioritize the coordination among different economic circles to promote balanced regional development across the province.

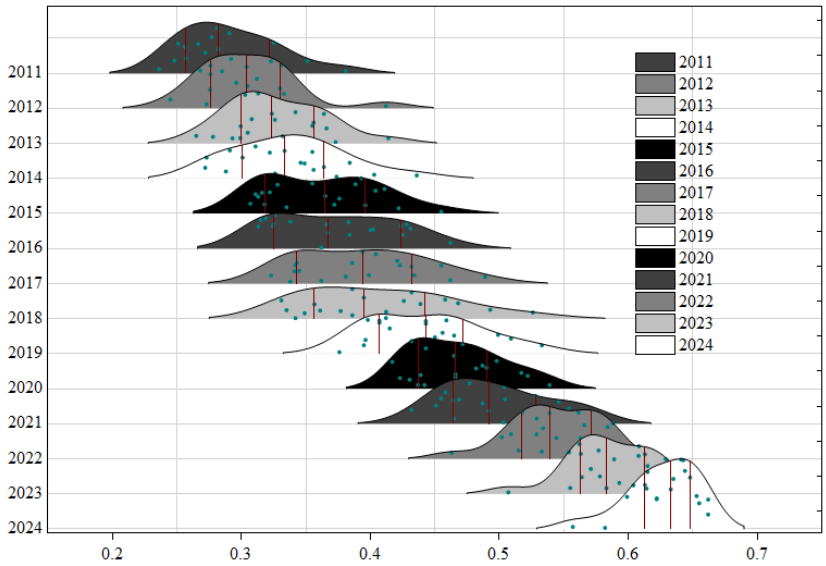


Figure 2: The development level of the three economic circle high quality

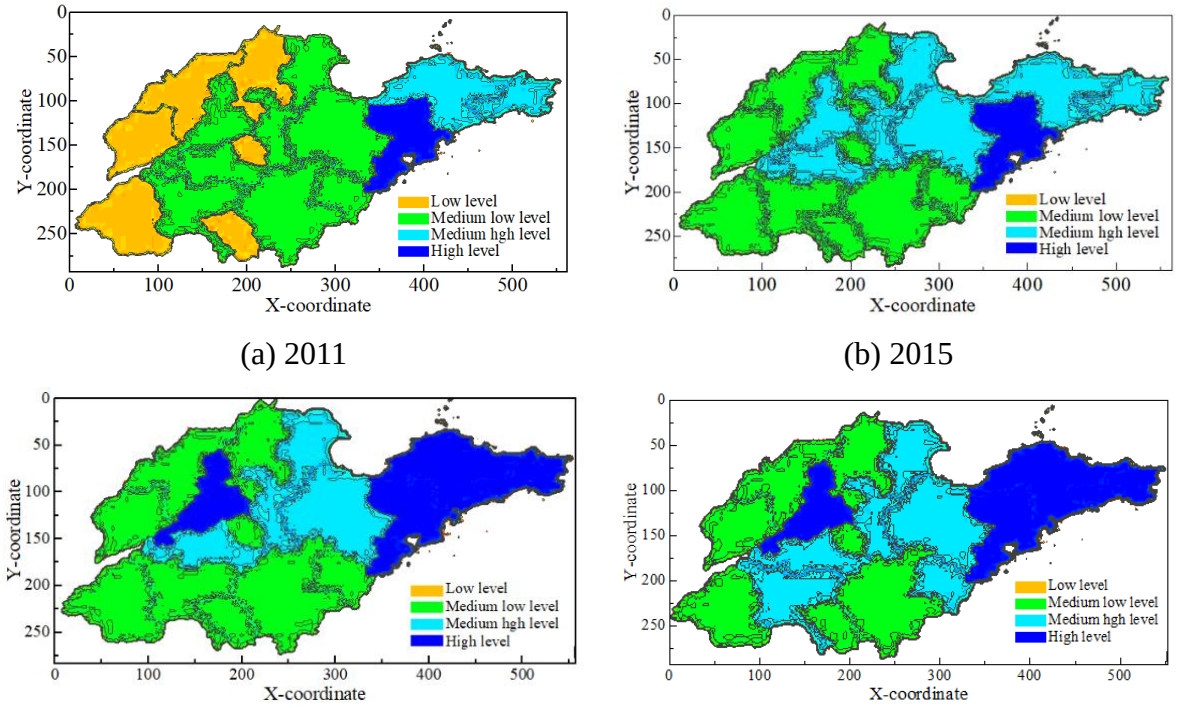
2.3.3 Spatial Differentiation Characteristics of High-Quality Economic Development

To further analyze spatial disparities in Shandong Province's high-quality economic development, this study selected four time points—2011, 2015, 2019, and 2024—and utilized ArcGIS software to generate graded spatial distribution maps of high-quality economic development levels across Shandong's cities. Based on the comprehensive high-quality economic development score, the province's development levels are categorized into four tiers: low level (0.00–0.30), lower-middle level (0.31–0.50), upper-middle level (0.51–0.65), and high level (above 0.65). The spatial distribution of Shandong's economic high-quality development across different periods is illustrated in Figure 3, where Figure 3(a) to (d) represent the distributions for 2011, 2015, 2019, and 2024, respectively.

The figures reveal pronounced regional disparities in Shandong's economic high-quality development from 2011 to 2024. Cities achieving high-level economic high-quality development remain scarce, with most cities situated at medium-high or medium-low levels. Overall, the high-quality economic development levels of various cities have progressively advanced toward medium-high and high levels, indicating a gradually improving trend. Specifically:

Regional disparities in Shandong's high-quality economic development are pronounced, gradually forming a point-axis layout pattern. Cities with similar high-quality economic

development levels exhibit a clustering trend characterized by “large clusters and small, scattered clusters.” In 2011, the spatial distribution of high-quality economic development levels showed a gradient pattern from east to central to west. Qingdao stands as Shandong's sole city at the high level of economic high-quality development, followed by Yantai and Weihai at the medium-high level. Central cities like Jinan, Zibo, and Dongying are at the medium-low level. The provincial capital Jinan exhibits limited radiating influence, while central-western cities such as Heze, Liaocheng, and Binzhou remain at the low level of economic high-quality development. By 2015, the spatial pattern primarily showed higher levels in the north and lower levels in the south. Qingdao remained the highest-level city for high-quality economic development within the study area. Cities previously at low levels advanced to higher levels. Jinan, Tai'an, Zibo, Dongying, and Weifang rose from medium-low to medium-high levels, while Jining, Linyi, and Rizhao remained at medium-low levels. By 2019, high-quality economic development exhibited a multipolar trend. Beyond Qingdao, Jinan, Yantai, and Weihai advanced from medium-high to high levels. As the provincial capital, Jinan enhanced its radiating influence, while other cities maintained stable development at medium-high or medium-low levels. By 2024, the level of high-quality economic development has further increased, with Qingdao and Jinan emerging as the regions with the highest levels of high-quality economic development, intensifying the trend of polarization. At this juncture, Qingdao, Jinan, Weihai, and Yantai remain at the high level of high-quality economic development. Beyond Zibo, Dongying, Weifang, and Tai'an, Rizhao and Jining have advanced from the medium-low level to the medium-high level. From 2011 to 2024, Shandong's high-quality economic development exhibited an east-high, west-low and north-high, south-low spatial pattern, with polarization trends gradually emerging. Notably, the completion and opening of the Qingdao-Rongcheng Intercity Railway strengthened connections between Qingdao, Yantai, and Weihai, laying the groundwork for the formation of the Qingdao-Yantai-Weihai high-quality economic development axis.



(a) 2011 (b) 2015

(c) 2018 (d) 2024

Figure 3: Spatial differentiation characteristics of high-quality development

To better analyze the dynamic characteristics of high-quality economic development in Shandong Province, this paper utilizes Stata software to obtain the kernel density distributions of Shandong's high-quality economic development for the years 2011, 2015, 2019, and 2024, as shown in Figure 4. Based on the trends in the kernel density changes depicted in the figure, the following conclusions can be drawn:

(1) The kernel density shifted overall to the right during the sample period, and the kernel density estimation curve transitioned from an initial left-skewed distribution to a right-skewed distribution, indicating an upward trend in Shandong's high-quality economic development level.

(2) The main peak of the kernel density estimation curve fluctuated downward compared to 2011, while the width of the main peak increased, suggesting a widening trend in regional disparities regarding Shandong's high-quality economic development level.

(3) The right tail of the high-quality economic development distribution has progressively lengthened, indicating an increasing number of cities achieving high levels of development. While the average level of high-quality economic development has risen annually, the gap in development levels has widened year by year.

(4) Only one major peak existed during the study period—Qingdao—reflecting a unipolar phenomenon. By 2019, the study area exhibited a less pronounced bipolar pattern.

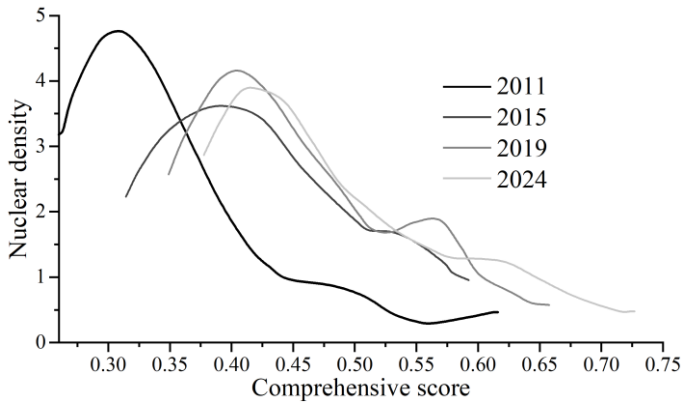


Figure 4: Kernel density estimation of high-quality economic development

3 Empirical Analysis and Recommendations on Digital Finance for High-Quality Development in Shandong

The development of digital finance presents new opportunities for China's high-quality economic growth. Shandong Province's economic development serves as a microcosm of China's broader economic trajectory, making it highly representative. Therefore, exploring the impact and trends of digital finance on Shandong's high-quality development, analyzing its specific pathways to influence economic growth and reduce disparities, and providing insights for formulating policies to promote the province's healthy and coordinated economic development holds significant theoretical and practical significance.

3.1 Research Hypotheses and Model Construction

3.1.1 Research Hypotheses

Based on a deep understanding of the essence and trends of high-quality development, this framework explores how digital finance can promote high-quality development in Shandong

Province from economic, structural, green, coordinated, and shared perspectives. Specific aspects are outlined below:

(1) In terms of economic efficiency, digital finance can enhance economic efficiency by lowering credit thresholds for operators, meeting their financing needs, supporting technological innovation, and facilitating mechanized and scaled production. This significantly boosts corporate output levels, leading to improved production quality and efficiency.

(2) Structural Optimization: Digital finance strengthens interdepartmental connections during enterprise development, enhances the mobility of production factors, and fosters efficient industrial chains. It also promotes the integration of primary, secondary, and tertiary industries in rural areas, guiding industrial structure optimization and upgrading.

(3) Regarding green development, digital finance facilitates the transmission of green development concepts by rationally allocating financial resources toward environmentally friendly projects and initiatives that improve ecological conditions. Additionally, leveraging government authorization, it provides funding for green ecological projects, enhancing credit accessibility and coverage for green industries. This effectively integrates modern finance's green development with green, organic, and pollution-free industries, thereby advancing industrial greening.

(4) Regarding coordination and sharing, digital finance not only supports enterprise development but also enables operators to gain operational profits, effectively expanding their income channels and potential. Furthermore, digital finance provides integrated financial services such as internet-based credit, investment, and insurance. By applying information technologies like big data to critical segments of the digital finance transmission pathway according to regional characteristics, it comprehensively elevates social living standards and achieves coordinated distribution in high-quality development.

Overall, digital finance can promote economic efficiency, structural optimization, green development, and coordinated sharing, ultimately contributing to high-quality economic development. Based on this, the following hypothesis is proposed:

H1: Digital finance significantly promotes high-quality economic development in Shandong Province.

3.1.2 Model Construction

This paper examines the impact of digital finance on high-quality economic development in Shandong Province using a panel model. Given the existing research foundation and data availability, the econometric model is specified as follows:

$$EHD_{i,t} = \beta_0 + \beta_1 DF_{i,t} + \beta_2 \sum Control_{i,t} + \varepsilon_{i,t} \tag{8}$$

In the equation, the subscript i denotes each prefecture-level city in Shandong Province, the subscript t denotes the year, and $EHD_{i,t}$ represents the comprehensive proxy variable for the level of high-quality economic development and its sub-dimension indicators in the i th prefecture-level city during the t th year. Its data is obtained using the entropy-weighted TOPSIS method described earlier. $DF_{i,t}$ denotes digital finance, primarily represented by the Peking University Digital Inclusive Finance Index. This index is calculated based on billions of micro-level data points from Ant Financial's Alipay, using three dimensions: coverage breadth, usage depth, and digitalization level. $Control_{i,t}$ denotes control variables, primarily including internet development level (INT), industrial structure level (IS), financial loan level (FLL), fiscal expenditure level (FOL), financial development level (FIN), economic

development level (AGDP), and urban-rural income gap (GAP). $\varepsilon_{i,t}$ denotes the random disturbance term, β_0 represents the constant term, and $\beta_1 \sim \beta_2$ are the regression coefficients for each variable.

3.2 Analysis of the Impact of Digital Finance

3.2.1 Correlation Analysis

Before conducting the empirical regression analysis in this chapter, this paper systematically performed correlation tests among variables to preliminarily observe their relationships. Figure 5 presents the correlation analysis results for the model variables.

As shown in the figure, the correlation coefficient between Digital Finance (DF) and Shandong Province's High-Quality Economic Development Level (EHD) is 0.352, significant at the 1% level. This indicates a statistically significant positive correlation, validating the theoretical hypothesis H1 of this paper. Additionally, the correlation coefficient between industrial structure level (IS) and Shandong Province's high-quality economic development level (EHD) is 0.527, significant at the 1% level. This indicates that improvements in industrial structure level positively promote Shandong Province's high-quality economic development. Notably, the correlation coefficient between financial loan levels (FLL) and EHD is -0.153. Although not statistically significant, it indicates a negative relationship. This may suggest that financial bandwidth alone has not directly promoted high-quality economic development and has yet to fully leverage its positive role in Shandong's economic growth. The correlation between fiscal expenditure level (FOL) and EHD is weak, with a coefficient of -0.034 that is not statistically significant. This may suggest that fiscal expenditure has not yet become a key driver in Shandong's current high-quality economic development. Furthermore, the correlation coefficient between financial development level (FIN) and EHD is 0.493, significant at the 1% level, indicating that enhancing financial development significantly promotes high-quality development. The correlation coefficient between the level of economic development (AGDP) and EHD is -0.182 and significant at the 10% significance level. This may be related to financial resources flowing more toward leading industries, resulting in insufficient financial supply in certain sectors. Overall, the correlation analysis results for the variables selected in this paper are mostly statistically significant, indicating that these variables hold research significance in regression analysis and can provide a reliable foundation for subsequent empirical analysis.

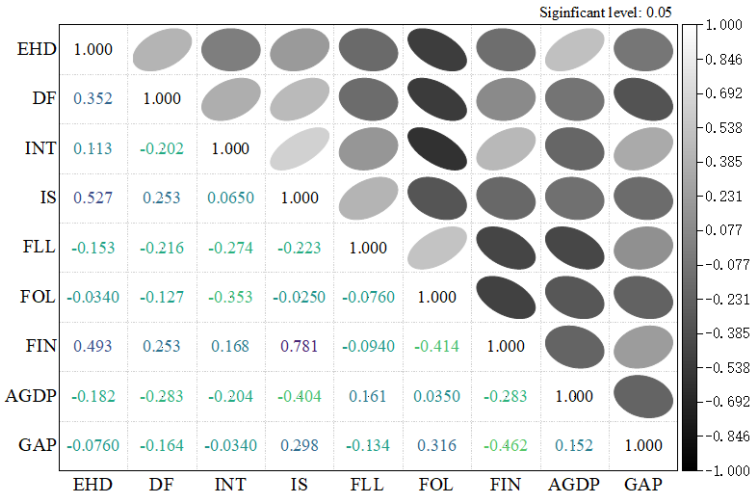


Figure 5: Correlation analysis results of model variables

Additionally, this paper introduces the variance inflation factor (VIF) to examine multicollinearity among model variables, with the specific testing structure shown in Table 2. The multicollinearity test indicates that the variance inflation factors (VIF) for all selected variables are below 6, falling within the safe threshold range. The maximum VIF value is 5.319, significantly lower than the critical value of 10, with an overall mean VIF of 2.530. This result indicates that no significant multicollinearity issues exist among the model variables, thereby eliminating the interference of collinearity. Consequently, the selected variables are suitable for subsequent regression analysis to ensure the reliability and validity of the research findings.

Table 2: Results of multicollinearity analysis

Variable	VIF	1/VIF	Variable	VIF	1/VIF
DF	1.527	0.655	FOL	2.463	0.406
INT	1.763	0.567	FIN	5.319	0.188
IS	5.076	0.197	AGDP	1.384	0.723
FLL	1.338	0.747	GAP	1.372	0.729
Means VIF			2.530		

3.2.2 Benchmark Regression Analysis

Selecting an appropriate measurement method for estimating panel data enhances the accuracy of results. This paper employs the F-test and Hausman test to determine the model type to be selected. The F-test results indicate rejection of the null hypothesis at the 1% significance level (p=0.001), supporting the selection of a fixed-effects model. The Hausman test, which assumes random effects, also rejects the null hypothesis at the 1% significance level (p=0.000). Consequently, the fixed-effects model is chosen based on the Hausman test results. After determining the required model, this study conducted a benchmark regression on the relationship between digital finance and Shandong Province's high-quality economic development. The regression results are presented in Table 3. In the table, ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. The values in parentheses represent robust standard errors, with the same notation applied throughout.

The regression results indicate that digital finance exerts a significant positive impact on Shandong Province's high-quality development. The coefficient of the core explanatory variable, the digital finance index, is 0.583, passing the test at the 1% significance level. This implies that a 1% increase in digital finance leads to a 0.583 increase in Shandong's high-quality economic development level, confirming that digital finance significantly promotes the province's high-quality economic development and validating H1. Regarding control variables, the coefficients for the impact of internet development level, industrial structure level, fiscal expenditure level, economic development level, and urban-rural income gap on high-quality development are 0.015, 0.627, 0.593, 4.814, and -4.227, respectively. Among these, internet development level, industrial structure level, and urban-rural income gap pass the significance test at the 1% level; economic development level passes at the 5% level; and fiscal expenditure level passes at the 10% level. This indicates that internet development level, industrial structure level, fiscal expenditure level, and economic development level promote high-quality economic development in Shandong Province, while the urban-rural income gap exerts a negative impact. These findings may stem from the fact that internet development level facilitates the growth of e-commerce, live-streaming sales, and contract farming, thereby boosting product operations and rural economic development. A more rational industrial structure drives coordinated development across primary, secondary, and tertiary industries, promotes tertiary industry integration, and thus positively influences development. A higher level of economic development indicates a stronger regional economy. Such economies typically possess

advanced infrastructure and a highly skilled workforce—essential prerequisites for high-quality economic development. Consequently, a higher level of economic development exerts a greater propulsive force on Shandong's high-quality economic growth.

Table 3: The benchmark regression results of the model

Variable	Coefficient	Standard deviation	T value	P value
DF	0.583***	0.013	1.975	0.000
INT	0.015***	0.002	3.168	0.001
IS	0.627***	0.195	3.206	0.000
FLL	-1.238	4.647	0.375	0.714
FOL	0.593*	0.307	1.933	0.053
FIN	0.006	0.051	0.135	0.892
AGDP	4.814**	0.002	2.337	0.023
GAP	-4.227***	1.165	3.581	0.000
(Con_)	0.306***	0.078	4.126	0.001
Hausman test		34.572***(6.157)		
Fixed-effect F-test		117.51***(5.832)		
R^2		0.5792		
F-test for fitting effect		8.331***(4.729)		

3.2.3 Robustness Test

To validate the validity of the regression results in this paper, we employed replacement samples and excluded the impact of special time periods. Simultaneously, we applied tail trimming at the 1% level for each variable, followed by conducting model robustness tests.

(1) Sample Replacement. In the sample replacement process, data from certain cities in Shandong Province were excluded. This exclusion was necessary because these cities often possess superior geographical, policy, and economic conditions in terms of economic development, financial systems, and policy implementation. Such factors could cause their performance in the sample to differ significantly from other regions. Therefore, removing these city samples helps ensure the regression results better reflect the general patterns observed elsewhere. Table 4 presents the robustness test results after sample substitution. The results show that the coefficient for the core explanatory variable, Digital Finance (DF), is 0.304 and passes the robustness test at the 1% significance level. This result aligns with the original regression model's conclusion, further validating the aforementioned findings. After excluding certain city samples, the regression coefficient remains significant and positive, indicating that the impact of digital finance exhibits consistency and robustness across different regions and sample configurations. This reflects the effectiveness of digital finance in promoting high-quality economic development in Shandong Province, with this conclusion possessing high reliability.

Table 4: Robustness Test: Replacement of Samples

Variable	Model (1)	Model (2)	Model (3)	Model (4)
DF	0.423***(3.147)	0.385***(3.021)	0.336***(2.847)	0.304***(2.493)
INT	-	0.017***(2.894)	0.017***(2.894)	0.015***(2.369)
IS	-	0.546***(3.793)	0.505***(3.289)	0.482***(3.005)
FLL	-	-	-1.226(0.576)	-1.176(0.527)
FOL	-	-	0.527*(1.327)	0.483*(1.064)
FIN	-	-	-	0.006(0.239)
AGDP	-	-	-	2.718**(3.574)
GAP	-	-	-	-1.594***(3.227)
(Con_)	0.414***(5.278)	0.405***(5.136)	0.388***(4.769)	0.359***(3.276)
Individual	YES	YES	YES	YES
Time	YES	YES	YES	YES
R^2	0.925	0.927	0.934	0.935

(2) Excluding exceptional periods. The COVID-19 outbreak at the end of 2019 imposed temporary disruptions on China's economic operations. During the pandemic control period, stringent containment measures led to temporary shutdowns in certain industries, with contact-intensive services like tourism and catering bearing the brunt. Consequently, economic activities in Shandong Province also experienced varying degrees of short-term suppression. To minimize pandemic interference, this study conducted a regression analysis after excluding 2020 observations. The results are detailed in Table 5. The table shows that after adjusting the study period, the coefficients of the core explanatory variables remained positive regardless of whether control variables were included, and they were statistically significant at the 1% level. This outcome aligns with the findings of the baseline regression, further validating the conclusions of this study.

Table 5: Robustness Test: Exclusion of Special Time Periods

Variable	Model (1)	Model (2)	Model (3)	Model (4)
DF	0.316***(2.934)	0.275***(2.576)	0.243***(2.117)	0.215***(2.067)
INT	-	0.012***(2.313)	0.012***(2.313)	0.011***(2.051)
IS	-	0.527***(3.281)	0.495***(2.293)	0.463***(2.182)
FLL	-	-	-1.115(0.472)	-1.106(0.438)
FOL	-	-	0.505*(1.269)	0.472*(1.153)
FIN	-	-	-	0.005(0.226)
AGDP	-	-	-	2.724**(3.603)
GAP	-	-	-	-1.276***(3.158)
(Con_)	0.436***(4.692)	0.382**(4.285)	0.375***(3.872)	0.342***(3.515)
Individual	YES	YES	YES	YES
Time	YES	YES	YES	YES
R^2	0.918	0.921	0.925	0.925

3.2.4 Heterogeneity Analysis

The impact of digital finance on Shandong Province's high-quality economic development may vary across different regions. To further analyze the regional differences in the influence of digital finance on high-quality development, this study conducted separate regressions for each city in Shandong. Figure 6 presents the regression coefficients and their 95% confidence

intervals for each region. The figure indicates that at a 95% confidence level, Linyi and Weihai are the two cities where digital finance most effectively promotes high-quality economic development in Shandong Province, with impact coefficients exceeding 2. Following these are Dongying, Rizhao, Binzhou, Jinan, Qingdao, Zibo, and Weifang, all exhibiting significantly positive coefficients. The cities with relatively low promotion effects of digital finance on high-quality development are Zaozhuang, Yantai, and Jining, where the significance is weaker. Dezhou, Tai'an, and Liaocheng show the lowest promotion effects of digital finance on high-quality development, with insignificant impacts. The impact coefficients for Dezhou and Liaocheng are even negative. This indicates that the promotion effects of digital finance on the level of high-quality economic development vary across different regions.

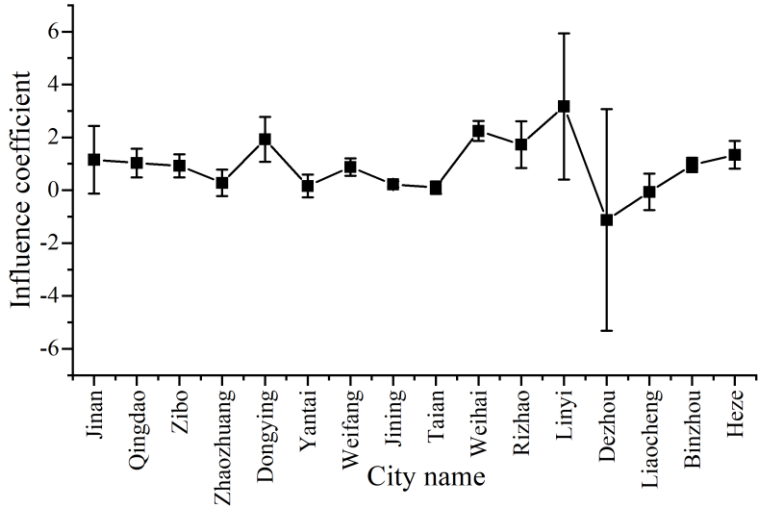


Figure 6: Regional heterogeneity analysis

4 Conclusion

This study measures the level of high-quality economic development in Shandong Province from both theoretical and empirical perspectives, utilizing panel data from 16 cities in Shandong from 2011 to 2024. It further analyzes the specific impact of digital finance on Shandong's high-quality economic development through panel model analysis. Findings reveal that Shandong's high-quality economic development level has shown a steady upward trend from 2011 to 2024, indicating robust overall economic momentum. Digital finance exerts a significant positive impact on Shandong's high-quality economic development at the 1% significance level, with its effects exhibiting pronounced regional heterogeneity. Based on these findings, the following specific recommendations are proposed for leveraging digital finance to advance Shandong's high-quality development:

(1) Given variations in economic development levels, resource endowments, and infrastructure across cities, demand for digital finance also differs. Therefore, governments at all levels should formulate tailored, differentiated policies based on local conditions to better leverage digital finance for high-quality development. For economically underdeveloped cities, efforts should focus on promoting digital financial services and improving infrastructure to broaden coverage and enhance digitalization. This will enable digital finance to serve a wider population, thereby improving financial efficiency and service levels in these regions. For relatively developed cities, attention should shift toward meeting the diverse demands for digital financial products by upgrading and innovating services to deepen usage.

(2) Promote the integrated development of digital finance and innovation capabilities,

focusing on building an innovation ecosystem. Strengthen the positive interaction between digital finance and innovation, gradually integrating cutting-edge technologies such as artificial intelligence, big data analytics, and data mining into financial markets. Guide investors with the intention to channel idle capital into economic sectors, providing reliable financing support for innovative development. Focusing on economic development, continuously enrich financial products, improve overall operational efficiency, strive to minimize financing transaction costs, expand the service boundaries of digital finance, and empower high-quality economic development through digital finance.

Funding

Shandong Provincial Natural Science Foundation Project (ZR2022MG080); Ministry of Education Humanities and Social Sciences Planning Project (23YJA880060).

References

[1] Green, F., & Stern, N. (2017). China's changing economy: implications for its carbon dioxide emissions. Climate policy, 17(4), 423-442.

[2] Ma, X., Wang, F., Chen, J., & Zhang, Y. (2018). The income gap between urban and rural residents in China: Since 1978. Computational Economics, 52(4), 1153-1174.

[3] Jain, R. (2017). China’s economic development policies, challenges and strategies, 1978-present: an overview. Indian Journal of Asian Affairs, 30(1/2), 65-84.

[4] Kakwani, N., Wang, X., Xue, N., & Zhan, P. (2022). Growth and common prosperity in China. China & World Economy, 30(1), 28-57.

[5] Zhao, L. (2022). China’s “economic miracle” and the universal modernization model. Modern China, 48(1), 53-72.

[6] Zhou, B., Zeng, X., Jiang, L., & Xue, B. (2020). High-quality economic growth under the influence of technological innovation preference in China: A numerical simulation from the government financial perspective. Structural Change and Economic Dynamics, 54, 163-172.

[7] Chen, L., & Huo, C. (2022). The measurement and influencing factors of high-quality economic development in China. Sustainability, 14(15), 9293.

[8] Wang, J., Han, Q., & Du, Y. (2022). Coordinated development of the economy, society and environment in urban China: A case study of 285 cities. Environment, Development and Sustainability, 24(11), 12917-12935.

[9] Morrison, W. M. (2019). China’s economic rise: History, trends, challenges, and implications for the United States. Current Politics and Economics of Northern and Western Asia, 28(2/3), 189-242.

[10] Zhang, M., & Luo, Q. (2022). A systematic literature review on the influence mechanism of digital finance on high quality economic development. Journal of Risk Analysis and

Crisis Response, 12(1).

[11] Wu, J., & Chen, T. (2022). Impact of digital economy on dual circulation: An empirical analysis in China. Sustainability, 14(21), 14466.

[12] Alekseyenko, L., Tulai, O., & Babii, S. (2023). Financial sector: regulatory and communication transformations in the digital economy. Ekonomichnyy analiz, 33(3), 222-231.

[13] Wang, Q., Yang, J., Chiu, Y. H., & Lin, T. Y. (2020). The impact of digital finance on financial efficiency. Managerial and Decision Economics, 41(7), 1225-1236.

[14] Li, Y., Zhang, Y., & Geng, L. (2024). Digital finance, financing constraints and supply chain resilience. International Review of Economics & Finance, 96, 103545.

[15] Feng, G., & Zhang, M. (2021). A literature review on digital finance, consumption upgrading and high-quality economic development. Journal of Risk Analysis and Crisis Response, 11(4).

[16] Risman, A., Mulyana, B., Silvatika, B., & Sulaeman, A. (2021). The effect of digital finance on financial stability. Management Science Letters, 11(7), 1979-1984.

[17] Chen, S., Zhou, Z., & Chan, W. K. V. (2025, March). Spatial and Temporal Analysis in High-Quality Development Level of Shandong Province. In 2025 7th International Conference on Software Engineering and Computer Science (CSECS) (pp. 1-6). IEEE.

[18] Liu, P., Liu, X., & Yang, H. (2019). Evaluation of the marine economic development quality in Qingdao based on entropy and grey relational analysis. Marine Economics and Management, 2(1), 29-38.

[19] Liu, Y., Shang, M., Xu, J., Zhang, L., & Hua, H. (2023). Value chain and the integrated development of manufacturing and modernized services: A case study of Shandong Province, China. Sustainability, 15(2), 1439.

[20] Jia, Y., Liu, C., Yin, C., & Zhu, Q. (2020). The construction of science and technology innovation policy design framework—take Shandong Province as an example. Journal of Industry-University Collaboration, 2(1), 34-48.

[21] Jiang, Z., Guo, F., Cai, L., & Li, X. (2021). Eco-province construction performance and its influencing factors of Shandong Province in China: From regional eco-efficiency perspective. Sustainability, 13(21), 12068.

[22] Wang, S., Lin, X., Xiao, H., Bu, N., & Li, Y. (2022). Empirical study on human capital, economic growth and sustainable development: Taking Shandong province as an example. Sustainability, 14(12), 7221.

[23] Liu, R., & Zhang, X. (2018, June). Research on the Difference of Regional Financial Agglomeration in Shandong Province of China. In 2018 2nd International Conference on Education, Economics and Management Research (ICEEMR 2018) (pp. 522-526). Atlantis Press.

[24] Li, E., Tang, Y., Zhang, Y., & Yu, J. (2024). Mechanism research on digital inclusive finance promoting high-quality economic development: Evidence from China. Heliyon, 10(3).

[25] Yao, R. (2023, October). A Study on the Impact of Digital Inclusive Finance on the Rural-Urban Income Gap in Shandong Province. In Proceedings of the 2023 3rd International Conference on Financial Management and Economic Transition (FMET 2023) (Vol. 262, p. 224). Springer Nature.

[26] Gao, J., Li, H., & Zhang, D. (2025). Exploring the mechanisms and regional variations in how digital financial inclusion drives high-quality real economic development across China. Finance Research Letters, 73, 106649.

[27] Feng, N., Zhou, X., & Yeon, S. J. (2025). The Impact of Digital Inclusive Finance in Shandong Province on the Optimization of Employment Structure—Research Based on the Perspectives of Regional Innovation and Entrepreneurial Activity. Academic Journal of Business & Management, 7(1), 211-218.

[28] Jinbo, W., Chaohui, L., & Chao, L. (2024, July). Empowering County Economy Development Resilience with Digital Infrastructure: An Empirical Study Based on 136 County Economies in Shandong Province. In West Forum on Economy and Management (Vol. 35, No. 4, pp. 1-16).

[29] Tian, L., & Kling, G. (2022). Financial inclusion and financial technology: finance for everyone?. The European Journal of Finance, 28(1), 1-2.

[30] Kireyeva, A. A., Kredina, A., Vasa, L., & Satpayeva, Z. T. (2021). Impact of financial technologies on economic development: Theories, methods and analysis. Journal of International Studies, 14(4).

[31] Jueping Xie,Canyang Xue,Jiaxin Zhou & Huaiying Lei. (2025). Digital economy on high-quality manufacturing development: a spatial spillover and regional coordination perspective. Finance Research Letters,85(PB),107928-107928.

[32] Shanshan Zhang. (2025). Analysis of the decoupling effect between water resource utilization and high-quality economic development in nine provinces (regions) of the Yellow River Basin. GeoJournal,90(5),215-215.

[33] Junfeng Zhu & Xiaozhen Zhou. (2023). Construction and Evaluation of a High-Quality Logistics Development System in Five Southeast Coastal Provinces under the Background of the Digital Economy. The Frontiers of Society, Science and Technology,5(8),

[34] Huan Zheng & Shaofan Wu. (2024). The spatial effect of financial openness on high-quality economic development: Evidence from provincial-level data in China. Socio-Economic Planning Sciences,95,101987-.