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Coupling and Coordination of Digital Economy and High-quality Agricultural Development: A Case Study of Shaanxi Province

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Abstract This study, taking Shaanxi Province as an example, systematically analyzed the coupling and coordination relationship between the digital economy and high-quality agricultural development from 2015 to 2024 by comprehensively employing the coupling coordination model and the entropy method. The findings reveal that both the digital economy and high-quality agricultural development indices in Shaanxi Province exhibit a consistent upward trend. The level of coupling coordination has progressively transitioned from a low degree of coupling to a coordinated development stage, establishing a virtuous interactive pattern characterized by "digital enabling agriculture" and "agriculture driving innovation". The driving force behind this coupling primarily stems from the synergistic interplay of a triple mechanism involving "policy guidance, technological breakthroughs, and industrial support". However, structural imbalances persist across regions and agricultural segments, chiefly manifested as the digital divide between the Guanzhong Plain and the Northern (Shaanbei) and Southern (Shaannan) regions, alongside insufficient integration depth of digital technologies in the latter stages of the agricultural industry chain. To address these challenges, the study proposes recommendations including building a "tri-chain integrated" technological ecosystem, optimizing a differentiated policy support mechanism, and implementing regionally targeted strategies. These measures aim to foster deep integration of the digital economy with the entire agricultural value chain across diverse regions, offering pathways for western agricultural provinces to bridge the digital divide and achieve rural revitalization.

Key words Digital economy, High-quality agricultural development, Coupling coordination

0 Introduction

Against the backdrop of China's deepening digital strategy, digital technologies are playing an increasingly crucial role in the organizational restructuring of the agricultural industry. Shaanxi Province, a pivotal region for the synergistic development of agriculture and the digital economy in western China, possesses a robust foundation in specialty agriculture. It hosts numerous distinctive agricultural industry clusters, including apples, kiwifruit, and tea. In 2024, the total output value of the province's fruit industry chain exceeded 200 billion yuan, with brands such as "Luochuan Apple" and "Meixian Kiwifruit" ranking among the top national regional public agricultural brands. Concurrently, the province's digital economy is experiencing vigorous growth. The construction of the Xi'an National Digital Economy Innovation and Development Pilot Zone is accelerating. In 2024, the added value of Shaanxi's core digital economy industries accounted for 8.2% of its GDP, and the total number of 5G base stations surpassed 120 000, providing substantial technological underpinning for the digital transformation of the entire agricultural industry chain. However, constrained by the ecological limitations of the Loess Plateau in Northern Shaanxi (Shaanbei), industrial agglomeration disparities in the Guanzhong Plain, and geographical barriers in the Qinling – Bashan Mountains of Southern Shaanxi (Shaannan), agricultural digitalization in Shaanxi exhibits characteristics of "regional imbalance and fragmented integration". The depth of fusion between digital technologies and key agricultural segments—production, processing, and distribution—remains insufficient. Therefore, systematically investigating the intrinsic mechanisms for the synergistic development of digital technologies and the agricultural industry holds significant practical importance for addressing the "digital divide" confronting major agricultural provinces in western China and solidly advancing rural revitalization. Shaanxi Province is an inland region of China, situated in the middle reaches of the Yellow River basin, with a total population of approximately 38.53 million and a land area of about 205 700 km^2. The province stretches long and narrow from north to south, featuring diverse topography that spans three climatic zones: subtropical, warm temperate, and mid-temperate. It can be divided into three distinct natural regions: the Loess Plateau region, the Guanzhong Plain region, and the Qinling – Bashan Mountain region. Shaanxi boasts not only a profound cultural and historical heritage but also rich ecological and resource diversity, underpinned by a deep-rooted agricultural foundation. The province's varied geography and climate types foster abundant germplasm resources. Specifically, Northern Shaanxi (Shaanbei) is a major potato-producing area and a significant base for specialty Chinese agriculture, goat farming, and minor grains. Weibei and southern Shaanbei host the world's largest contiguous cultivation area for high-quality apples. The Guanzhong region serves as the province's core area for grain production and protected agriculture, demonstrating pronounced advantages in its specialty industries.

1 Literature review and research hypotheses

1.1 Literature review Against the backdrop of digital technologies permeating all stages of agricultural production, distribution, and consumption, the coupling and coordination between the digital economy and high-quality agricultural development has

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emerged as a core pathway for addressing the "Three Rural Issues" (agriculture, rural areas, and farmers) and driving rural revitalization. Existing research has yielded substantial findings concerning their interaction mechanisms, evaluation of coupling coordination, regional variations in practice, and optimization strategies, providing crucial support for a deeper understanding of industrial synergy. At the theoretical level, scholars generally concur that the digital economy empowers high-quality agricultural development through three primary pathways: technological innovation, factor restructuring, and efficiency enhancement. Xu Xianchun *et al.* constructed a framework for measuring the scale of the digital economy, laying the groundwork for quantifying its penetration effects in agriculture. Zhang Wang *et al.* theoretically elucidated the coupling mechanism between the digital economy and rural revitalization, proposing a three-dimensional synergistic model encompassing technological empowerment, institutional safeguards, and market drivers. Regarding evaluation methods, the coupling coordination degree model has become the mainstream tool. Li Xiangling, Wang Han *et al.*, by constructing multi-dimensional indicator systems, empirically measured the coupling levels in provinces such as Hunan and Jilin, validating the model's applicability in regional studies. Practical research exhibits distinct regional variations. Domestic studies primarily concentrate on major agricultural provinces in eastern and central China; Wang Danyang, taking Yantai as a case study, analyzed the coupling relationship between the digital economy and green agricultural development. However, research focusing specifically on western provinces remains relatively scarce. Existing findings predominantly concentrate on the digital practices within single agricultural industries, lacking a systematic examination of whole-industry-chain synergy and regional differentiation characteristics. This gap underscores the significant academic value of this study in selecting Shaanxi Province as its research case. Overall, existing research has established a theoretical framework and methodological system for studying the coupling and coordination of the digital economy and high-quality agricultural development. Nevertheless, there remains scope for expansion in areas such as regional specificity, comprehensive coverage of the entire industry chain, and the mechanisms of factor flow.

1.2 Research hypotheses The coupling coordination model serves as an evaluation tool for synergistic development. Within this model, the coupling coefficient assesses the dynamic interconnections and constraining effects among various elements, while the coordination degree directly reflects the level of coordination. The formulas for calculating the coupling coordination degree of the two subsystems in this study are as follows:

$$C = \sqrt[2]{(E \times A)/(E + A)^2} \tag{1}$$

$$D = \sqrt{(C \times T)} \tag{2}$$

$$T = \alpha E + \beta A \tag{3}$$

where E and A represent the comprehensive evaluation scores of the digital economy and agricultural industry development, respectively; C is the coupling degree between the two; D is the coupling coordination degree; T is the coordination index; α and β are the contribution weights. Given the equal importance of both subsystems, α and β are both assigned a value of 0.5.

Furthermore, based on the research of Cheng Hui *et al.*, this study categorizes the coupling coordination degree into types as shown in Table 1.

Table 1 Classification of coupling coordination degree types

Coupling degree (C) interval	Coupling type	Coupling coordination degree (D) interval	Coordination type
[0,0.3]	Low-level coupling	[0,0.3]	Low coupling coordination
(0.3,0.5]	Antagonistic stage	(0.3,0.5]	Moderate coupling coordination
(0.5,0.8]	Running-in stage	(0.5,0.8]	High coupling coordination
(0.8,1]	High-level coupling	(0.8,1]	Extreme coupling coordination

2 Coupling analysis of digital economy empowering high-quality agricultural development

2.1 Temporal evolution of comprehensive levels of digital economy and high-quality agricultural development Utilizing the entropy weight method, the comprehensive evaluation values for the digital economy and high-quality agricultural development in Shaanxi Province from 2015 to 2024 were calculated. The results are presented in Fig. 1.

Overall, from 2015 to 2024, both the Digital Economy Development Index and the High-quality Agricultural Development Index in Shaanxi Province exhibited a marked upward trend. Specifically, in 2015, the Digital Economy Development Index stood at 0.149 and the High-quality Agricultural Development Index at 0.119. By 2024, these indices had risen to 0.478 and 0.45, respectively. This sustained growth can be attributed to policy support and structural optimization efforts in both the digital economy and high-quality agriculture within Shaanxi Province, fostering their synergistic advancement.

Stage-wise analysis:

(i) 2015 – 2017: The Digital Economy Development Index increased from 0.149 to 0.225, while the High-Quality Agricultural Development Index rose from 0.119 to 0.254. During this period, both indices grew relatively rapidly, with the High-Quality Agricultural Development Index registering a slightly higher growth rate than the Digital Economy Development Index. This phase benefited from Shaanxi Province's emphasis on agricultural infrastructure construction and agricultural science and technology investment, laying a foundation for high-quality agricultural development. Concurrently, preliminary exploration and application of the digital economy commenced in certain areas, such as the gradual emergence of e-commerce in agricultural product sales.

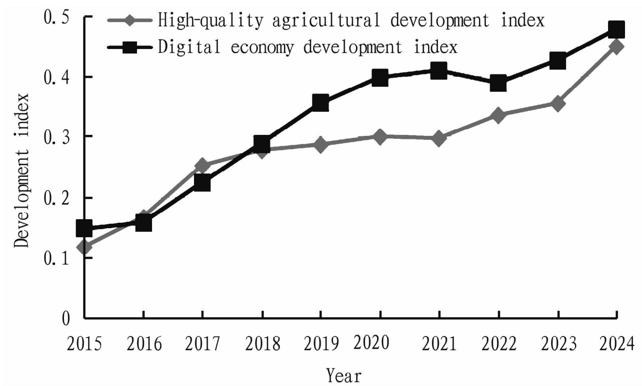

Fig. 1 Indices of digital economy and high-quality agricultural development

(ii) 2018 – 2020: The Digital Economy Development Index grew from 0.289 to 0.398, and the High-Quality Agricultural Development Index increased from 0.278 to 0.301. During this stage, the growth rate of the digital economy accelerated significantly, aligning with policy measures such as enhanced support for the digital industry and the promotion of digital technology integration with the real economy in Shaanxi Province. In contrast, the growth of the High-Quality Agricultural Development Index remained relatively stable. This stability stems from factors inherent to agriculture, such as dependence on natural conditions and longer adjustment cycles for industrial restructuring, which contribute to a degree of lag and steadiness in its development pace.

(iii) 2021 – 2022: The Digital Economy Development Index experienced a modest decline from 0.41 to 0.389, whereas the High-Quality Agricultural Development Index continued its steady growth from 0.298 to 0.336. The brief dip in the Digital Economy Development Index was primarily due to obstacles encountered by certain digital industries, influenced by technological bottlenecks, intensified market competition, and the impacts of the pandemic during this phase of digital economy expansion. Meanwhile, the persistent growth in the High-Quality Agricultural Development Index indicates that sustained investments and policy support in the agricultural sector within Shaanxi Province remained effective, driving continuous optimization of the agricultural industrial structure and gradual improvements in production efficiency and quality.

(iv) 2023 – 2024: The Digital Economy Development Index rose from 0.426 to 0.478, and the High-Quality Agricultural Development Index increased from 0.356 to 0.45. Both indices resumed their upward trajectory with notable growth rates. This signifies that, following the preceding adjustments, both the digital economy and high-quality agriculture in Shaanxi Province identified new growth drivers and momentum. The application of digital technologies in agriculture deepened further, and the synergistic effects of their joint development began to materialize.

2.2 Analysis of coupling coordination degree between digital economy and high-quality agriculture The coupling coordination degree between the digital economy and high-quality agricultural development, calculated using Formulas (1) – (3), is presented in Fig. 2.

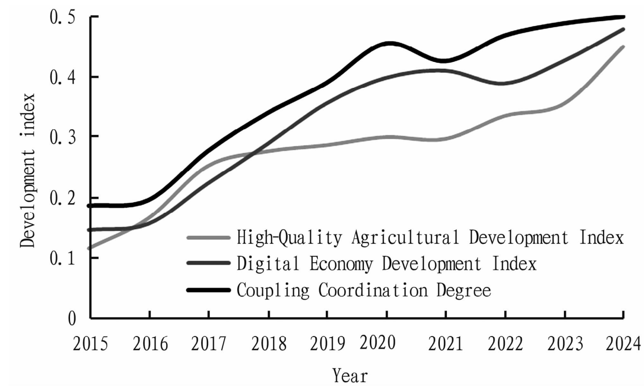

Fig. 2 Coupling coordination degree between digital economy and high-quality agricultural development

From 2015 to 2024, the Digital Economy Development Index, the High-Quality Agricultural Development Index, and their coupling coordination degree in Shaanxi Province all demonstrated a consistent upward trend. This indicates that during this period, the mutually reinforcing and synergistic development effect between the digital economy and high-quality agriculture in Shaanxi Province continuously strengthened, and the two are gradually forming a pattern of positive interaction.

The stage-specific characteristics are as follows:

(i) 2015 – 2017: The Digital Economy Development Index began a gradual ascent from a relatively low base, the High-Quality Agricultural Development Index also registered moderate growth, and the Coupling Coordination Degree increased incrementally from approximately 0.2. During this phase, the application of the digital economy in agriculture was in its nascent exploratory stage. For instance, some localities began experimenting with basic digital tools for agricultural production management and product sales. However, the overall level of integration remained low, the synergistic effects between the two sectors were not yet fully realized, and the improvement in Coupling Coordination Degree was consequently relatively slow.

(ii) 2018 – 2020: The growth rates of both the Digital Economy Development Index and the High-Quality Agricultural Development Index accelerated, leading to a corresponding rapid rise in the Coupling Coordination Degree. During this period, Shaanxi Province implemented a series of policies aimed at fostering the integration of the digital economy and agriculture. These included increased investment in digital agricultural infrastructure and the promotion of technologies like Agricultural Internet of Things (IoT). The application of digital technologies deepened progressively across agricultural production, distribution, and management processes. The enabling effect of the digital economy on high-quality agricultural development began to manifest more clearly, resulting in a significant enhancement of their Coupling Coordination Degree.

(ii) 2021 – 2022: The growth of both the Digital Economy Development Index and the High-Quality Agricultural Development Index moderated slightly, and the Coupling Coordination Degree underwent minor fluctuations and adjustments. This occurred as the process of digital-agricultural integration encountered challenges related to technology, market dynamics, or policy implementation, necessitating adjustments and optimization. For example, the outcomes of certain agricultural digitalization projects fell short of expectations, requiring refinements in technology application models or industrial layouts. Consequently, the Coupling Coordination Degree entered a temporary phase of readjustment during this stage.

(iii) 2023 – 2024: Both the Digital Economy Development Index and the High-Quality Agricultural Development Index resumed a faster growth trajectory, and the Coupling Coordination Degree continued its ascent, approaching 0.5. In this phase, following the preceding adjustments and refinements, the integration between the digital economy and high-quality agricultural development became more profound and mature. The application of digital technologies in agriculture became more extensive and efficient, exemplified by the use of big data analytics for precision farming and blockchain for agricultural product traceability. Simultaneously, high-quality agricultural development provided the digital economy with broader application scenarios and market demand. As a result, the Coupling Coordination Degree reached a relatively high level.

3 Conclusions and recommendations

3.1 Main conclusions

3.1.1 Coupling coordination level exhibits progressive ascent, entering overall coordinated development stage. From 2015 to 2024, the Coupling Coordination Degree between the digital economy and high-quality agricultural development in Shaanxi Province achieved significant growth, progressively advancing from initial low-level coupling to the moderate coordination range and nearing the high coordination range. This evolution closely paralleled the development progress of both systems: the Digital Economy Development Index surged from 0.149 to 0.478, and the smart agriculture market scale reached 8.9 billion yuan in 2024, with an average annual growth rate exceeding 15%; the High-Quality Agricultural Development Index rose from 0.119 to 0.45, with the output value of the apple and kiwifruit industry chains exceeding 140 billion yuan and 21.2 billion yuan, respectively. A virtuous cycle of interaction characterized by "digital technology empowering agricultural upgrading" and "agricultural demand driving digital innovation" has taken shape, significantly enhancing the stability and sustainability of coupling coordination.

3.1.2 Coupling dynamics exhibit a triple-driven characteristic: "policy guidance + technological breakthroughs + industrial support". At the policy level, provincial special funds and central government subsidies worked in concert, facilitating the construction of over a hundred Smart Agriculture Demonstration Parks and translating policy dividends into industrial practice. At the technological level, the smart agricultural machinery and equipment market reached 15 billion yuan, accounting for 43% of the national AI in agriculture market. Technologies such as IoT and drones were widely applied in orchard management and field crop cultivation. For instance, the Yangling Demonstration Zone achieved remarkable results, including water savings of 40% and a 25% reduction in chemical fertilizer usage. At the industrial level, the "Internet + Agricultural Products from Village to City" initiative yielded outstanding outcomes, with Shaanxi's online fruit retail sales exceeding 23 billion yuan in 2024. The deep integration of digital marketing with specialized agricultural industry chains provided a solid industrial foundation for their coupling and coordination.

3.1.3 Structural imbalances exist in coupling development, with notable regional and segment disparities. Regionally, leveraging Xi'an's digital industry cluster and Yangling's agricultural technology strengths, the Guanzhong Plain achieved a smart agriculture adoption rate of 35% in protected farming. In contrast, the adoption rate in the hilly areas of Northern Shaanxi (Shaanbei) and the mountainous regions of Southern Shaanxi (Shaannan) was merely 8%. This highlights a distinct "core-periphery" divergence in digital infrastructure deployment and technology application. Examining the industry chain segments, technologies like smart irrigation and drone-based pest control at the production end are relatively mature. For instance, in Ziyang County, drone pest control proved 20 times more efficient than manual methods. However, segments in the latter stages of the chain, such as big data traceability and smart cold chain logistics, remain underdeveloped. Concurrently, an import dependency exceeding 60% for core components like sensors and chips poses a major bottleneck hindering deeper technological integration.

3.2 Recommendations

3.2.1 Constructing a "triple-chain integration" technology ecosystem to overcome key coupling bottlenecks. First, a core technology breakthrough initiative is to be implemented. A provincial-level EDA R&D center will be established, leveraging Northwest A&F University (NWAFU) and the Qinchuangyuan Innovation Platform, focusing on critical "bottleneck" technologies such as agricultural sensors and specialized chips. The localization rate of core components is targeted to be raised to 30% by 2027. Compact, intelligent equipment suitable for the terrain of Shaanbei and Shaannan, specifically for mountainous orchards and terraced tea gardens, will be developed to address regional technology application gaps. Second, the technology transfer service system is to be enhanced. AI agriculture laboratories are to be jointly established between the Yangling Demonstration Zone and companies like Huawei, with the annual incubation of over 20 technology patents targeted. A three-tier transfer mechanism ("university R&D-park piloting-enterprise commercialization") will be constructed. Drawing lessons from the promotion of the Weibei apple water-saving model, provincial-level technical service teams are to be formed to provide targeted "point-to-point" on-ground support, thereby enhancing technology adoption efficiency. Third, an agricultural data sharing platform is to be constructed. Data resources from departments such as Agriculture and Rural Affairs, Meteorology, and Commerce will be integrated to build a unified "Shaanxi Agricultural Brain" platform. A blockchain traceability module will be embedded to achieve end-to-end data connectivity from production to sales. Data sharing and security management standards will be established, modeled after the Yangling approach.

3.2.2 Optimizing the policy support mechanism to strengthen institutional safeguards for coupling. Differentiated subsidy policies are to be innovated. Current fixed subsidies are to be shifted to a "performance-based" tiered incentive system. Dynamic rewards of up to 750 yuan/ha will be implemented for smart farms based on water-saving and yield-increase rates, with specific emphasis placed on Shaannan and Shaanbei regions. The scope of purchase subsidies for smart agricultural machinery is to be expanded, with new equipment such as drones and soil sensors comprehensively included in the subsidy catalog. A financial risk mitigation mechanism is to be established. "Smart Agriculture Insurance" products will be piloted, covering multiple risks including technology failure, data loss, and market volatility, thereby alleviating concerns among operators regarding digital investment. Financial institutions are encouraged to develop financing products based on "digital equipment collateral + data pledge" to ease the funding pressure on small and medium-sized enterprises. Industrial chain coordination policies are to be refined. The "provincial-level support for trillion-yuan chains, municipal-level for billion-yuan chains" industrial chain linkage mechanism is to be deepened, with priority given to the development of digital supply chains for characteristic industries like apples and kiwifruit. Smart agriculture open pilot zones are to be established in areas such as Jinghe New City and the Yangling Demonstration Zone to explore new models of cross-regional digital industrial chain collaboration.

3.2.3 Promoting regionally tailored strategies for balanced coupling development. A "Three-Belt Synergy" development framework is to be constructed. The Guanzhong region is focused on "Digital + High-End Agriculture", where clusters of smart greenhouses and digital marketing bases are to be built. Leveraging the experience of the Jitai Horticulture Industrial Park in Jinghe New City, the export of high-value agricultural products like fresh-cut flowers is to be promoted. In Northern Shaanxi (Shaanbei), "Digital + Dryland Agriculture" is prioritized, with technological models such as scientific seedling cultivation and smart irrigation from Dingbian County to be applied. Southern Shaanxi (Shaannan) is developed for "Digital + Eco-Agriculture", drawing on the experience of Ziyang's smart tea gardens to achieve precision and green production of selenium-enriched agricultural products. A digital infrastructure extension project is to be implemented. The extension of 5G networks to county-level agricultural production zones is prioritized. IoT monitoring backbone networks are to be constructed in key apple-producing areas of Shaanbei and tea-growing regions of Shaannan, aiming for comprehensive digital monitoring coverage in major production zones by 2027. County-level digital agriculture service centers are to be established, offering one-stop services such as technical training and equipment maintenance. A regional assistance mechanism is to be established. The "Guanzhong Digital Enterprise + Shaanbei/Shaannan Agricultural Base" cooperation model is to be promoted. Companies in locations like Xi'an Software Park are encouraged to develop compact, lightweight digital tools suitable for mountainous agricultural production. Through technology transfer and benefit-sharing mechanisms, the overall enhancement of coupling coordination levels across the province is to be driven.

References

[1] MA XP, YANG XH. Driving mechanism and path selection of digital economy for agricultural industry chain construction[J]. Agricultural Economy, 2024(7): 11-13. (in Chinese).

[2] XU XC, ZHANG MH. Research on the measurement of China's digital economy scale: Based on an international comparative perspective[J]. China Industrial Economics, 2020(5): 23-41. (in Chinese).

[3] ZHANG W, BAI YX. Theoretical construction, empirical analysis and optimization path of coupling between digital economy and rural revitalization[J]. China Soft Science, 2022(1): 132-146. (in Chinese).

[4] LI XL, LI WH. Spatio-temporal coupling analysis of digital economy and agricultural whole industry chain development in Hunan Province[J]. Agriculture and Technology, 2025, 45(16): 172-176. in Chinese).

[5] WANG DY. Coupling coordination analysis of digital economy and agricultural green development in Yantai City[J]. Guangdong Sericulture, 2025, 59(7): 66-68. (in Chinese).

[6] WANG H, JIN L. Analysis of coupling coordination degree between digital economy and high-quality agricultural development in Jilin Province under the background of new era[J]. Agricultural Industrialization, 2025 (8): 75-77, 81. (in Chinese).

[7] GONG R, XIE L, WANG YF. Interaction mechanism and empirical test between high-quality agricultural development and new urbanization[J]. Reform, 2020(7): 145-159. (in Chinese).

[8] ZOU YY, YUAN H, KONG LL, *et al.* Research on multiple configuration paths of digital economy enabling high-quality development of forestry [J]. Journal of Agrotechnical Economics, 2025, 24(2): 225-234. (in Chinese).

[9] WAN XY, LUO YQ. Measurement of digital economy development level and its impact effect on total factor productivity[J]. Reform, 2022(1): 101-118. (in Chinese).