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EVALUATION OF THE UTILITY OF VALUE CREATION IN THE AGRICULTURAL PRODUCT SUPPLY CHAIN EMPOWERED BY DIGITAL TECHNOLOGY

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ABSTRACT

In the context of rural revitalization and agricultural modernization development, the digital transformation of the agricultural product supply chain is an important means to increase the value of agricultural products. However, due to the diverse ways of digital technology empowerment and the significant differences among participants, the degree of technology adaptation is relatively low. Based on the perspective of digital technology empowering the value creation of agricultural product supply chains, this paper explores 20 evaluation indicators and 10 types of mainstream digital technologies as alternative options through SWOT analysis model and literature retrieval, obtains basic data with expert scoring and information fusion, and determines index weights using the CRITIC method Finally, the CoCoSo model is used for utility ranking and verification. The study found that satellite remote sensing technology was the most effective in enabling utility, while the good digital platform ecosystem and convenient circulation links were the main influencing factors, and the uneven infrastructure and talent shortage were the main constraints. The results can provide guidance for agricultural producers to choose appropriate technical means and for government departments to introduce targeted policies, promoting more refined and green development of supply chains.

1. Introduction

The country is now vigorously promoting agricultural modernization, emphasizing the construction of agricultural infrastructure and enhancing agricultural production capacity and level; At the same time, we should reform and improve the modern agricultural operation model to make the production and sale of agricultural products match. This will help achieve the goal of modernizing agriculture and rural areas and lay a good foundation for Chinese-style modernization. Recently, the Political Bureau of the Central Committee of the Communist Party of China held a meeting to review and adopt the "Opinions of the Central Committee of the Communist Party of China on Further Deepening Reform and Opening Up and Promoting Chinese-Style Modernization", which put forward systematic institutional designs for the production, circulation and storage of agricultural products, and will play a guiding role in the reform and long-term development of

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agricultural products in China in the coming period. In the process of implementing the rural revitalization strategy, both the production and sales of agricultural products must be taken into account. On the basis of ensuring the quantity of agricultural products, the quality and safety of agricultural products should be improved to make agriculture ecological and modern. On the other hand, attention should also be paid to enhancing the value of agricultural products by means of deep processing, brand building and digitalization, so that agricultural products can achieve higher value and farmers can increase their income and become prosperous. This also indicates that it is crucial to do a good job in the value creation and evaluation of the national agricultural product supply chain.

At present, China is gradually integrating a new generation of digital technologies such as artificial intelligence, big data, Internet of Things, cloud computing, Blockchain and 5G into the agricultural industrial chain, agricultural supply chain and agricultural value chain, thereby promoting the improvement of efficiency and value creation in all links of agricultural product production, circulation and consumption. These digital technologies are empowering agricultural products to reshape the economic structure system. The key for enterprises to manage the supply chain is value creation, which enables manufacturers, suppliers and consumer groups to cross regional, resource and information boundaries to integrate, construct and reconfigure supply chain resources, thereby enhancing supply chain value and promoting value creation for agricultural product enterprises. Value creation can be divided into models such as non-dominant digital technology adoption, agricultural product manufacturer-led digital technology adoption, and agricultural product retailer-led digital technology adoption, which reflect the diversity of value creation models and pose certain difficulties for different entities in the supply chain to choose appropriate development models, requiring the design of a utility evaluation framework for matching. However, in the context of value creation utility assessment with the rapid development of digital technology, the full integration of digital technology with the agricultural product supply chain leads to the diversity of its value creation models, and the endowments of different participants in the supply chain are heterogeneous, which requires the use of digital technology assessment for systematic judgment in the process of empowering the value creation utility assessment of the agricultural product supply chain. To determine the different degrees of effect corresponding to the different value creation utility assessment of each link in the agricultural product supply chain empowered by digital technology, thereby providing decision-making references for the utility assessment of value creation in the agricultural product supply chain and forming a systematic assessment method for optimizing the utility assessment of value creation in the agricultural product supply chain empowered by digital technology To facilitate the two-way integration of value creation utility assessment and digital technology in the agricultural product supply chain, and to identify value creation models that are in line with the development characteristics of different participants in the supply chain.

Based on the initial study of supply chain management and industrial Internet related professional knowledge, self-study of fuzzy decision-making, multi-attribute decision-making methods and uncertain decision-making related knowledge, read relevant literature materials, look for relevant data to explore its impact, and try to ensure the accuracy and validity of the conclusion.

1.1 Current Status Of Research On The Value Of Agricultural Supply Chains

Scholars at home and abroad have emphasized the value creation of the agricultural product supply chain. Due to the advantages of ASC (Agricultural Product Supply Chain), many studies and practices have shown that enhancing the value creation of ASC is a key strategy to promote the empowerment of digital technology in the construction of agricultural product system platforms, enabling them to effectively respond to risks and crises[1]. Typically, an ASC is often described as a supply chain that has the ability to proactively predict potential emergencies, respond promptly to disruptions, and recover effectively[2]. This approach not only helps mitigate the adverse effects of such crises and risks on vulnerable groups, but also contributes to achieving sustainable supply[3], fair access and efficient use[4] of agricultural products. Many countries are actively promoting the ASC concept in various fields, such as e-commerce[5], maritime[6] transport and artificial intelligence[7]. However, in practice, existing research has focused on analyzing the forms of stakeholder engagement. In the context of value creation driven by digital technology, there is a lack of research[8] on various aspects of ASC, such as the paths and mechanisms of digital collaborative operation between agricultural enterprises and farm base contractors, machinery manufacturers, intellectual resource cooperation agencies, and other stakeholders. In the actual implementation process, there are different characteristics of uncertainties, and clear decision-making information does not fully capture the information characteristics of ASC failures. Therefore, solving this problem is largely dependent on the knowledge and experience of experts. It is necessary to introduce fuzzy sets to transform the uncertain information expressed by experts into some actionable knowledge. In previous studies, fuzzy sets have been widely used to handle uncertain information in order to identify and prioritize the identification of implementation obstacles[9-10] in supply chain environments.

1.2 Current Status Of Research On The Application Of Digital Technology To Agricultural Supply Chains

Scholars at home and abroad have also emphasized the importance of how digital technology enables the utility of value creation to be efficiently selected in all links of the agricultural product supply chain, analyzed the basic principles and development status of the digital transformation model of the agricultural product supply chain, introduced digital technologies such as artificial intelligence, Internet of Things, and big data into the agricultural product industry, and optimized the entire process of the agricultural product supply chain. The realization of efficient and stable operation of the agricultural product supply chain reflects the crucial[11] role that digital transformation plays in every field. In recent years, agricultural enterprises have intensified empirical research[12-13] on strategic activities in the field of value creation utility assessment enabled by digital technology. In terms of how digital technology creates value, research has mainly focused on areas such as the optimization of agricultural product production services by big data technology, the scale of agricultural products through social e-commerce, the digital transformation and high-quality development of agricultural product enterprises, while the area of value creation in the agricultural product supply chain has been relatively scarce. In terms of value creation through digital technology, the integration of digital technology with agriculture, on the one hand, innovates the value chain of agricultural product supply from the perspective of sustainability, and improves the efficient operation and sustainable development[14] of the agricultural product supply chain; On the other hand, it creates, adds value and expands unattainable economic, social, ecological and cultural value on the basis of traditional agriculture, thereby reshaping the value creation and distribution system of modern agriculture. Of course, there are also studies based on the utility evaluation direction of blockchain technology empowering the value creation of agricultural product supply chains, which have evaluated the impact of blockchain technology on the food supply chain from an exploratory perspective and proposed a comprehensive conceptual framework with a wide range of performance dimensions, including efficiency, flexibility, responsiveness, food quality, and transparency of the supply chain[15].

1.3 Research Status Of The CoCoSo Method

In the context of how digital technology can empower the utility of value creation, to better conduct research on the agricultural product supply chain, relying solely on digital technology to empower the agricultural product supply chain is negligible. A more reasonable and efficient way to evaluate the utility of value creation is needed, and research methods to deal with the influence of unnecessary factors are proposed: Information processing method[16], IVSFS weighting calculation method[17], CoCoSo method. Here we focus on the CoCoSo method - on the one hand, the CoCoSo method can be applied to multi-attribute group decision model problems with probability interval dual hesitant fuzzy; On the other hand, this method is also used in combination with other fields, combining the intuitionistic language rough weighted Heronian average (ILRWHM) and intuitionistic language rough weighted geometric Heronian average (ILRWGHM) operators to improve the traditional CoCoSo method[18]. Also combined with new generalized orthogonal fuzzy set scoring functions, distance measures and generalized orthogonal fuzzy Einstein interactive ensemble operators, while proposing generalized orthogonal model CRITIC-ARAS multi-attribute group decision-making methods with completely unknown expert attribute weight information, The generalized orthogonal fuzzy CoCoSo multi-attribute group decision-making method[19] with completely unknown attribute weight information is used in many fields. As a result, the CoCoSo method can rank the comprehensive value of each alternative provided, measure the extent to which digital technology empowers the utility assessment of value creation in the agricultural product supply chain, and take into account the relationships[20] among different energy supply chain node enterprises.

In conclusion, the existing research on digital technology empowering value creation mainly focuses on exploring the influencing factors and driving elements, and rarely involves analyzing issues such as the utility evaluation indicators of value creation. Especially from the perspective of digital technology empowerment, examine the specific extent to which value creation affects the utility assessment of each link in the agricultural product supply chain. To this end, this project first identifies the utility of value creation enabled by digital technology based on existing literature, and at the same time establishes a model for evaluating the utility of value creation in the agricultural product supply chain. Based on this, combined with multi-attribute decision-making methods, analyze and construct a model for evaluating the value creation utility of agricultural product supply chains empowered by digital technology.

As shown in Fig 1, this study adopts a three - stage technical route of "theoretical construction - weight calculation - model evaluation" to establish an evaluation system for the value - creation utility of agricultural product supply chains empowered by digital technologies. Firstly, through literature retrieval and SWOT model analysis, an evaluation index system is constructed from the four dimensions of strengths, weaknesses, opportunities, and threats. A weighted average score matrix is formed by combining expert scores and information integration. Secondly, the CRITIC objective weighting method is used. By calculating the correlation coefficient, standard deviation, and information index, the weights of each evaluation index are scientifically determined. Finally, based on the CoCoSo multi - attribute decision - making model, the initial decision matrix is standardized. The weighted comparable sequence and the power - weighted comparable sequence of each alternative digital technology are calculated. The relative weights of the schemes are calculated through the comprehensive evaluation scores. The final values of the value - creation utility of different digital technologies are determined and ranked, realizing the quantitative evaluation of the empowerment effect of digital technologies and providing a scientific basis and decision - making reference for the digital transformation of agricultural product supply chains.

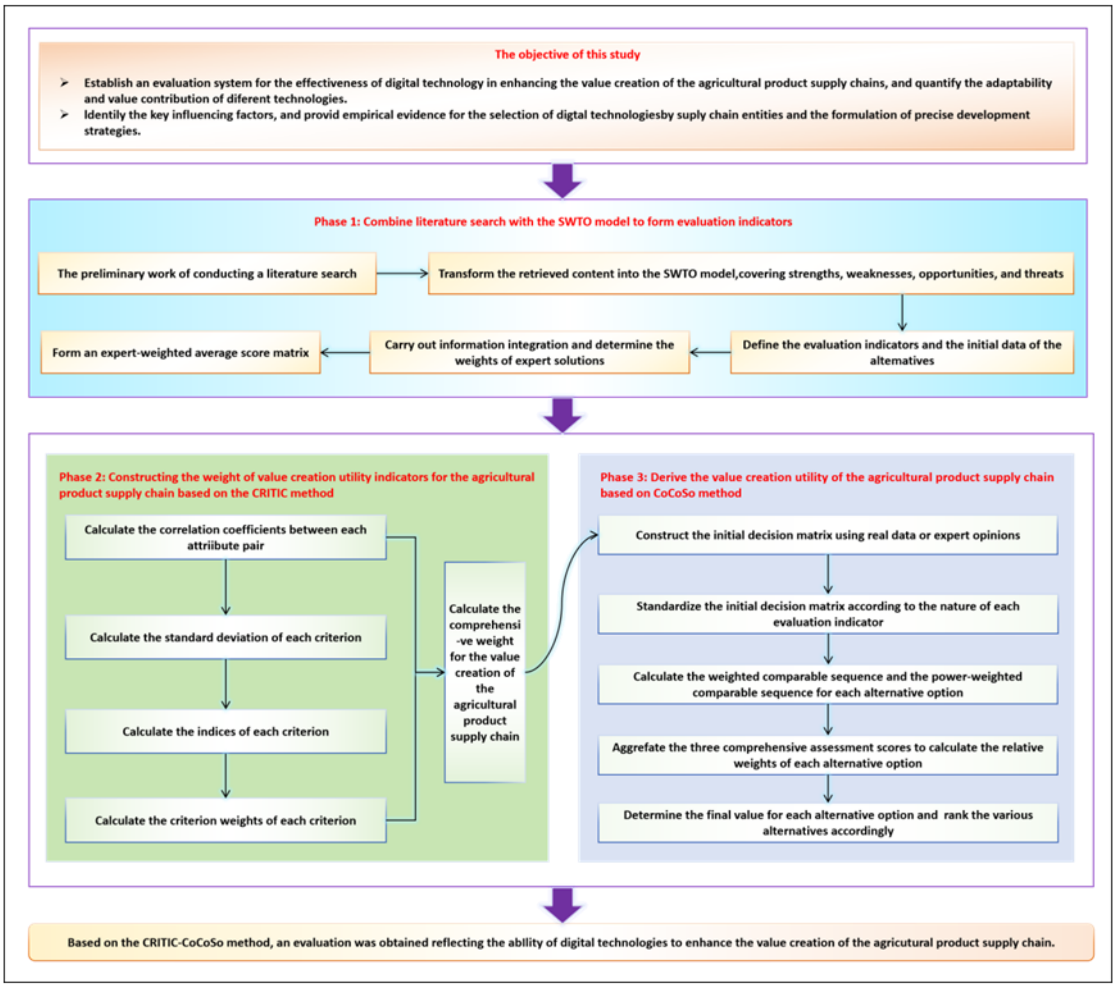

Fig. 1 Research Technical Roadmap for the Evaluation of the Value Creation Utility of Agricultural Product Supply Chains Empowered by Digital Technologies

2.Methodology

This paper mainly uses the SWTO model analysis to systematically select the evaluation indicators of the value creation utility of the agricultural product supply chain, providing decision-making references for the agricultural product industry to ensure the basic value creation utility selection of the agricultural product supply chain. Among them, the SWTO analysis model proposed by Heinz Weihrich, a professor at the University of San Francisco in the United States, is an analytical tool widely used in strategic planning and management decision-making, forming decisive conclusions[21]. The SWTO model has structured characteristics, mainly divided into four elements (S, W, T, and O), two parts (internal condition SW and external condition OT), and four strategies (S+O strategy, S+T strategy, W+O strategy, and W+T strategy), which are analyzed comprehensively to construct combinations that maximize the use of strengths, make up for weaknesses, seize opportunities, and respond to threats. Based on the bidirectional integration research literature on how digital technologies empower the evaluation of value creation utility in agricultural supply chains, select the construction of digital technology utility evaluation metrics.

2.1 Strengths Of Digital Technology Empowering Agricultural Product Value Creation Utility

2.1.1 Precisely allocate production factors to enhance production efficiency

Precision planting techniques can scientifically plan sowing schemes based on environmental conditions such as soil and climate; The Internet of Things smart irrigation system can precisely control water and fertilizer supply based on soil moisture and crop growth requirements, maximizing water and fertilizer utilization efficiency; Precision pesticide application technology can apply pesticides in a targeted manner based on the occurrence of pests and diseases, effectively reducing production costs; Advanced technologies such as sensors and machine vision can drive the optimal allocation of agricultural resources, avoid overuse or underuse, and improve the quality and safety of agricultural products[23]. As a result, the collaborative empowerment of various digital technologies in all aspects of agricultural production builds a systematic system for the precise allocation of agricultural production factors, providing key support for the precise and intelligent transformation of agricultural production models.

2.1.2 Optimize the circulation of agricultural products and enhance the value of commodities

Integrate Internet of Things and Blockchain technologies to build a full-chain traceability system from harvest coding, storage monitoring to consumption evidence, use traceability codes to enhance consumer trust, and open up premium space for quality agricultural products; The intelligent warehouse system relies on the environmental perception network and AI regulation algorithm to achieve dynamic balance of temperature and humidity, and the gravity sensing shelves automatically trigger replenishment warnings to reduce agricultural product loss; The intelligent distribution network, with the help of Spatio-Temporal big data, reduces transportation costs through path optimization algorithms; Cold chain Internet of Things technology ensures seamless connection from pre-cooling to delivery of fresh produce, improving circulation efficiency and quality[23]. In addition, digital technology also empowers the branding of agricultural products, enhancing consumers' trust in agricultural products through traceability systems, thereby increasing the commodity value and market competitiveness of agricultural products.

2.1.3 Empower agricultural big data to enhance market transparency

The enabling role of agricultural big data is reflected in two aspects: precisely matching market demands and avoiding operational risks. By conducting in-depth analysis of consumer market data, price fluctuation data, meteorological data, etc., and establishing information detection systems, agricultural producers can precisely predict market trends, adjust planting and breeding structures, avoid blind production leading to overstocking and losses, and enhance information transparency in the middle links of the supply chain. Digital technology builds a fairer and more transparent supply chain environment and legislates to regulate the trading behavior of agricultural products and combat unfair trade. Consumers can learn about the entire production process of agricultural products through information platforms and enhance their confidence in the quality of agricultural products; Producers can also get more timely market feedback, optimize production decisions, and drive the efficient operation[22,26] of the entire agricultural product supply chain.

2.1.4 Enhance platform service levels and promote intelligent operation

The new generation of information technology drives the digital transformation of agricultural operation and management services, and various agricultural service platforms provide all-round intelligent support for agricultural production and operation entities by integrating resources such as technology, talent and information. These platforms not only build multi-dimensional and three-dimensional resource exchange platforms through digital technology to achieve the interaction and circulation of online and offline resources, activate multiple elements in rural areas, but also enhance the service efficiency of digital technology; It also provides precise market insights and decision-making suggestions for operators through big data analysis, enhancing the efficiency of business decisions. At the same time, the platform's cultivation and introduction of digital talents can accelerate the application of the new generation of information technology in the agricultural sector, promote the innovation of agricultural business models, and shift[23-24] agricultural production and operation from traditional experience-driven to data-driven.

2.1.5 In line with the concept of green development, promote ecological sustainability

Digital technology has greatly contributed to the green development of agriculture in the process of promoting rural revitalization. Through technologies such as precise fertilization, intelligent irrigation, and green pest control, agricultural pollution can be effectively reduced and the efficiency of resource utilization can be improved. Digital technology also drives innovation in agricultural development models, creating a new form of agriculture that is smart, green, low-carbon and efficient, connecting production, consumption and the Internet. As a result, people, things, nature and technology can coexist in harmony and be integrated. This model not only enhances the ecological value of agricultural products and meets people's demand for green and organic agricultural products, but also lays a solid[26] foundation for sustainable agricultural development.

2.2 Weaknesses Of The Utility Of Digital Technology in Creating Value for Agricultural Products

2.2.1 Uneven coverage of digital infrastructure and prominent regional development imbalances

In rural areas of our country, especially in remote mountainous regions, the construction of digital infrastructure is still relatively weak. The distribution of resources such as network coverage, data centers, and Internet of Things devices is uneven, resulting in some places being unable to fully enjoy the convenience brought by digital technology. These deficiencies in infrastructure have led to significant disparities in the ability of farmers in different regions to access market information and use digital technology, thereby widening the gap in agricultural development between urban and rural areas and among regions, and hindering the realization of the value of agricultural products through digital technology nationwide.

2.2.2 Shortage of digital talents in agriculture and insufficient application of technology

The lack of digital talents in agriculture, the "walls" in traditional education methods, and the unfairness in rural education, as well as the shortage of talents who are proficient in both planting and digital technology, have prevented many advanced digital technologies from being implemented in agricultural production. Many farmers, especially middle-aged and elderly ones, are unfamiliar with the use of digital tools such as smart phones and big data platforms, and have a low level of understanding and acceptance of digital technology, which makes the application of digital technology only superficial and unable to play a good role, and has become an important obstacle[24]] to the realization of the value of agricultural products. Effective measures are urgently needed to solve this problem.

2.2.3 There are hidden dangers in data security and privacy protection, and the regulatory system is well established

In the process of digital technology empowering the production and circulation of agricultural products, a large amount of sensitive data involving production data, consumption data, personal information, etc. is collected and transmitted, and data security and privacy protection face severe challenges. Once the data is leaked or misused, it will not only harm the rights and interests of consumers, but also undermine the trust of agricultural producers in digital platforms and affect the stable operation of the entire agricultural supply chain. At the same time, the imperfection of relevant laws and regulations makes it difficult to hold accountable and prevent data security issues.

2.2.4 The digital platform ecosystem is imperfect and cross-subject collaboration efficiency is low

At present, many digital agriculture platforms have relatively single functions and lack cross-link and cross-subject collaboration capabilities. Data barriers still exist in production, processing, distribution and sales, making it difficult to form a complete value creation chain. The lack of uniform standards and incompatible interfaces between platforms leads to the emergence of information silos, reducing the overall efficiency of the supply chain. In addition, the profit models and benefit distribution mechanisms of the platforms are not yet mature enough to fully mobilize everyone's enthusiasm for participation, which restricts the healthy development of the platform ecosystem.

2.2.5 Constrained by traditional production and operation concepts and lacking impetus for digital transformation

Some agricultural producers are trapped by traditional ideas and are not clear about the specific benefits of digital technology, resulting in a lack of motivation and intention to change proactively. They are more inclined to rely on old experience and the original sales methods, and sometimes observe before drawing conclusions about the new production methods and market opportunities brought by digital technology, and sometimes directly oppose them. This mindset is out of step with The Times, causing a lot of trouble for the promotion of digital technology and making it difficult for agricultural products to increase in value quickly as a result.

2.3 Opportunities For Digital Technology To Empower Agricultural Product Value Creation Utility

2.3.1 Policy support has been strengthened to create a favorable development environment

In a series of Central Document No. 1 issued by the state in 2026 to support the modernization of agriculture and rural areas, it is mentioned that financial insurance, fiscal subsidies and other means should be strengthened to create favorable conditions for digital technology to increase the value of agricultural products from aspects such as capital input, technology research and development, and talent cultivation, and stimulate the enthusiasm of farmers and agricultural workers. The document also proposed to increase the application of technologies such as drones, the Internet of Things and robots in agricultural production based on actual conditions. Local governments have also responded positively to the call and taken the initiative, such as establishing a number of digital agriculture demonstration bases and popularizing agricultural Internet of Things technology, to accelerate the process of the integration of digital technology and agriculture. These policies not only reduce the cost for farmers and agricultural business entities to apply digital technology, but also provide favorable policy conditions for the development of digital agriculture enterprises, greatly promoting the application of digital technology in the agricultural field.

2.3.2 Driven by consumption upgrade, there is a strong demand for green and high-quality agricultural products

As people's living standards rise, consumers are demanding more about the quality, safety and traceability of agricultural products. The demand for green, organic and traceable quality agricultural products has been growing. Digital technology precisely meets this trend of consumption upgrade. Technologies such as traceability systems and quality inspection can ensure that the appearance and quality of agricultural products are guaranteed, and the quality can be traced, providing consumers with transparent and reliable information about agricultural products. As a result, the expectations and confidence of end consumers in quality agricultural products have increased, and the unit price and sales of agricultural products have also gone up. At the same time, digital platforms have opened up broader sales channels for high-quality agricultural products, combining online and offline channels to help producers precisely identify high-end markets and thereby increase[22,26] the value of agricultural products.

2.3.3 Technological iteration is accelerating and enabling means are constantly innovating

The new generation of information technologies such as artificial intelligence, big data, Blockchain and 5G are developing rapidly and constantly being updated, which enables digital technologies to better help create value for agricultural products. For instance, Blockchain technology can track the entire process of agricultural products from production to sale, giving consumers more peace of mind; Artificial intelligence can intelligently identify and control pests and diseases, improving the production efficiency of agricultural products; 5G technology provides high-speed data transmission channels for Internet of Things devices. When combined, these technologies will continue to expand the application scenarios of digital agriculture and push the value creation of agricultural products to a deeper level. In the context of the deepening of the "Digital China" strategy, we should seize this important opportunity to vigorously promote the application of digital agricultural technologies and turn them into real productive forces. By strengthening the empowerment of digital technology, we will deeply integrate data elements with traditional production factors such as labor, land and seeds, as well as environmental factors such as pesticides and fertilizers, to fully leverage the value potential of agricultural data, accelerate the development of smart agriculture, and promote the transformation and upgrading[24] of traditional agriculture to modern agriculture.

2.3.4 Continuously innovate the supply chain model to enhance the resilience of the cycle

Digital technology is transforming the supply chain model of agricultural products from the traditional one-line approach to a more diverse and networked model. By developing short-chain supply chains and diversifying models, agricultural products can keep up with market changes more quickly, reduce reliance on a single channel, and make supply chains more flexible and resilient. Digital technology also helps agricultural producers find new trading partners and open up domestic and international markets, thereby enhancing the resilience and value creation capacity[25] of agricultural supply chains.

2.3.5 Industrial integration deepens to expand the space for value creation

Digital technology is accelerating the integration of agriculture with processing, logistics, tourism, finance and other industries, creating greater value space for products and helping to build an ecosystem of data sharing, enabling deeper collaboration between upstream and downstream of the industrial chain. For instance, the Internet of Things connects data from production, processing and sales; Machine learning can predict market trends and achieve "produce as much as you need"; Blockchain builds trusted trading platforms, and smart contracts reduce trading risks; AI can unlock the potential for collaboration among all parties, and digital twin technology provides a reference for decision-making - all of these are driving agriculture towards a more integrated and intelligent direction, with a stronger[23] overall ability to create value. For example, the "agriculture + e-commerce" model enables produce to be sold faster and farther; The "agriculture + tourism" model enhances the brand value of agricultural products by developing leisure agriculture and rural tourism; The "agriculture + finance" model provides financial support for agricultural production through services such as digital credit and agricultural insurance. The integration of these industries not only extends the agricultural industrial chain but also increases the added value of agricultural products, opening up new paths for the creation of agricultural product value.

2.4 Threats To The Utility Of Digital Technology In Creating Value For Agricultural Products

2.4.1 Cyber security risks are escalating, threatening supply chain stability

As digital technology is deeply embedded in the agricultural supply chain, security incidents such as cyber attacks and data breaches occur frequently. Once key digital agricultural platforms and Internet of Things devices are compromised, a chain reaction will be triggered, including the destruction of production data, the disruption of logistics links, and the distortion of market information, directly impacting the order of supply chain operations; At the same time, security incidents will undermine consumers' trust in digital agricultural products and damage their market reputation and value base.

2.4.2 Intensified market competition and increased survival pressure on small and medium-sized producers

Digital technology has lowered the market entry threshold in the agricultural sector, attracting a large amount of social capital, Internet enterprises and large agricultural groups to enter the agricultural digital field. The competition in the agricultural product market is becoming increasingly fierce. Large agricultural enterprises and digital platforms, with their advantages in technology, capital, channels, brands, etc., quickly integrate agricultural resources to form a dominant position in the market and gain an advantage in agricultural product pricing, channel layout, resource acquisition, etc. Small and medium-sized agricultural producers, due to shortcomings such as insufficient digital technology endowment, limited financial strength and weak brand influence, are in a clearly disadvantaged position in the market competition. They not only face the problem of squeezed market share, but also face the predicament of low purchase prices of agricultural products and single sales channels, and the survival pressure continues to rise. This imbalance in market competition will also lead to an uneven distribution of agricultural product value and restrict the sustainable development of the agricultural industry.

2.4.3 The supporting laws and regulations are lagging behind, and there are regulatory gaps

Digital agriculture, as an emerging form of agricultural development, has developed at a much faster pace than the construction of supporting laws, regulations and regulatory systems, resulting in many regulatory gaps and institutional loopholes in the process of digital technology empowering the value creation of agricultural products. At present, China's laws and regulations in areas such as data security, privacy protection, definition of responsibilities for digital platforms, standards for digital traceability of agricultural products, and norms for online transactions of agricultural products are not yet complete, making it difficult to effectively regulate the new contradictions and problems in the development of digital agriculture. The lagging system provides opportunities for some illegal acts, such as false traceability information, uneven quality of online agricultural products, and unfair competition among platforms, which not only disrupt the normal market order but also harm the legitimate rights and interests of consumers and agricultural producers, and restrict the healthy development of digital technology empowering the creation of agricultural product value.

2.4.4 The degree of dependence on technology has deepened and the ability to resist risks has weakened

Agricultural production is increasingly dependent on digital technology, but unexpected situations such as technical failures, network disruptions, and power shortages can paralyze production and supply chains, significantly reduce the system's resilience to risks, and make it more sensitive to external disturbances. At the same time, the "choke point" problem of core technologies restricts the independent development of digital agriculture and affects the stable creation of agricultural product value.

2.4.5 Cultural inheritance faces challenges and agricultural civilization is weakened

While digital technology is promoting agricultural modernization, it also poses challenges to the inheritance of traditional agricultural civilization. If there is an excessive reliance on digital technology and standardized production models, traditional farming skills, rural culture and ecological wisdom may gradually be diluted or even forgotten. The values and ways of cognition contained in agricultural civilization are an important part of the cultural value and brand connotation of agricultural products. If these inheritances encounter difficulties, the multiple values of agricultural products will be weakened.

2.5 Integrated Strategic Options For Digital Technology To Empower The Utility Of Value Creation In Agricultural Products

2.5.1 S+O Strategy: Leverage core strengths, seize external opportunities, and proactively expand value creation space

Leverage the strengths of digital technology in precise production, efficient circulation, big data application and platform services, and catch up with the external opportunities such as national policy support, consumption upgrade, technological update and industrial integration to form a "advantage + opportunity" synergistic development model and proactively explore the value creation space of the agricultural product supply chain. On the one hand, use digital technology to precisely seize the momentum of consumption upgrade, focus on the production and development of green, high-quality and traceable agricultural products, open up the high-end consumer market through agricultural digital platforms, make agricultural products of high quality and high price, and increase added value; On the other hand, taking advantage of national policy support and the iteration of digital technology, lay out diversified and short-chain agricultural product supply chain models, build an innovative ecosystem of digital agriculture, promote the deep integration of agriculture with processing, culture and tourism, finance and other industries, turn the core advantages of digital technology into market competitiveness, and maximize the value creation of the agricultural product supply chain.

2.5.2 S+T Strategy: Relying on technological advantages, strengthening risk prevention and control, and enhancing core competitiveness

In the face of external threats such as cyber security, market competition, and technological dependence, we need to give full play to the strengths of digital technologies, such as intelligent management, data analysis, and precise regulation, to build a risk defense system of "quality against risk" and enhance the risk-resistance capacity and core competitiveness of the agricultural product supply chain. Specifically, technologies such as big data and artificial intelligence can be used to enhance cyber security protection, improve data security management, and ensure the data security and system stability of the supply chain; Through big data analysis technology, accurately predict market competition situations, provide market information and decision support to small and medium-sized agricultural producers, and help them improve market adaptability and competitiveness; In addition, relying on digital technology to promote the integration of traditional farming civilization and modern agriculture, and using digital technology to record and pass on traditional farming skills and local culture, can strengthen the cultural value and brand connotation of agricultural products, form unique competitive advantages in the market, and effectively respond to the challenges of market competition and cultural inheritance.

2.5.3 W+O Strategy: Make up for development shortcomings, leverage external opportunities, and accelerate the digital transformation process

In response to internal weaknesses such as uneven digital infrastructure, shortage of digital talents, and incomplete platform ecosystem, actively seize external opportunities such as national policy support, technological iteration, and industrial integration, implement the "make up for weaknesses and leverage strengths" development strategy, and accelerate the digital transformation process of the agricultural product supply chain. By seeking national policy and financial support, we will intensify the construction of digital infrastructure in rural areas, improve network coverage and the layout of Internet of Things devices in remote areas, and narrow the gap in regional digital development; Based on the opportunities of agricultural digital platforms and technological iterations, carry out a combination of online and offline digital technology training to cultivate local agricultural digital talents and enhance the digital technology application capabilities of agricultural producers; Take advantage of the opportunities of industrial integration, introduce high-quality external resources, technologies and enterprises to participate in the construction of the agricultural digital platform ecosystem, improve the platform functions and benefit distribution mechanism, break down data barriers, enhance the efficiency of cross-subject collaboration in the supply chain, and transform internal disadvantages into development momentum.

2.5.4 W+T Strategy: Control dual risks, Build a safeguards system, drive Sustainable transformation

In the face of the dual pressure of internal disadvantages and external threats, build a dual guarantee system of "prevention and control + transformation" to promote the sustainable digital transformation of the agricultural product supply chain. On the one hand, strengthen institutional building and improve the regulatory system, fill the legal and regulatory gaps in the field of digital agriculture, clarify regulatory requirements in terms of data security, platform responsibility, quality standards, etc., and prevent various risks such as data security, market competition, and technology dependence; On the other hand, we will strengthen publicity and guidance as well as education and training to encourage agricultural producers to change their traditional production and operation concepts, enhance their willingness and ability for digital transformation, and at the same time establish a diversified technical support system, increase investment in core technology research and development, enhance the autonomy and controllability of digital agriculture technology, and reduce reliance on single technology and external equipment. Ensure the stability of agricultural production and supply chain operations, and achieve the transformation of the agricultural product supply chain from "passive response to risks" to "active transformation and development".

2.6 Construction Of AUtility Evaluation Model For Value Creation In Agricultural Product Supply Chains Based On The CoCoSo Method

2.6.1 Determine the evaluation metrics of the evaluation model and the initial data of the alternative options

Through the SWOT analysis of digital technology empowering the utility of agricultural product value creation in Part II and the bidirectional integration research literature on how digital technology can empower the assessment of the utility of agricultural product supply chain value creation, multiple influencing factors of digital technology empowering the assessment of the utility of agricultural product supply chain value creation can be identified from four aspects: strengths, weaknesses, opportunities, and threats (see Table 1) Combine these twenty evaluation indicators （$A_1, A_2, A_3, \cdots, A_{20}$）. Meanwhile, by reading the research literature, select ten digital technologies applied in the agricultural product supply chain (see Table 2) and define them as $(B_1, B_2, B_3, \cdots, B_{10})$.

Table 1

Evaluation Metrics for assessing the value creation utility in agricultural supply chains empowered by digital technologies

Dimensions	Contents of Evaluation Indicators
Strengths	Precise allocation of factors of production to enhance productivity (A_1)
	Optimize the circulation of agricultural products and increase the value of commodities (A_2)
	Empower agricultural big data to enhance market transparency (A_3)
	Enhance platform service level and promote intelligent operation (A_4)
	Align with the green development concept and promote ecological sustainability (A_5)
Weaknesses	Uneven digital infrastructure coverage and prominent regional development imbalances (A_6)
	Shortage of digital talents in agriculture and insufficient technical application

	capabilities (A_7)
	There are risks in data security and privacy protection, and the regulatory system is improved (A_8)
	The digital platform ecosystem is imperfect and cross-agent collaboration efficiency is low (A_9)
	Constrained by traditional production and operation concepts, lacking impetus for digital transformation (A_{10})
Opportunities	Greater policy support to create A favorable development environment (A_{11})
	Driven by consumption upgrade, there is A strong demand for green and high-quality agricultural products (A_{12})
	Accelerated technological iteration and continuous innovation in enabling methods (A_{13})
	Supply chain models continue to innovate to enhance circular resilience (A_{14})
	Industrial integration deepens to expand value creation space (A_{15})
Threats	Cyber security risks increase, threatening supply chain stability (A_{16})
	Intensified market competition and increased survival pressure on small and medium-sized producers (A_{17})
	The supporting laws and regulations lag behind and there are regulatory gaps (A_{18})
	Greater reliance on technology and weakened resilience (A_{19})
	Cultural heritage is challenged and agricultural civilization is weakened (A_{20})

Table 2
Application of Digital Technology in the Agricultural Product Supply Chain

Serial Numbers	Applied technology	Serial Number	Applied technology
1	Drone technology	6	Cloud computing
2	Satellite remote sensing	7	Cold chain Internet of Things technology
3	Big data	8	Internet of Things
4	Ai algorithms	9	Blockchain
5	Machine learning algorithms	10	Digital twin

2.6.2 Information Fusion

Firstly, to match the measurement framework constructed in this paper, five senior experts $\left(D_1, D_2, D_3, D_4, D_5\right)$ with relevant professional backgrounds were selected for evaluation in the group assessment. The evaluation indicators for the value creation utility of the agricultural product supply chain were quantitatively scored in the application of different digital technologies in the agricultural product supply chain. As a result, the quantifiable matrices corresponding to the five experts $\left(D_1, D_2, D_3, D_4, D_5\right)$, namely the initial evaluation matrices of the experts, $\tilde{X}_p$ are obtained, where $A_i(i=1,2,\cdots,20)$ and $B_j(j=1,2,\cdots,10)$ are the elements in the matrix. In this paper, considering the opinions of the k-bit experts comprehensively, the formula for calculating the expert weights is as follows:

$$\gamma_d = \frac{\left|G(F_d)\right|}{\left|\sum_{d=1}^{k} G(F_d)\right|}, d = 1, 2, \cdots, k. \tag{1}$$

Here, d refers to the number of experts. In this paper, the number of experts is 5, so $d = 5$; $\sum_{d=1}^{k} G(F_d)$ refers to the total amount of information, $G\left(\tilde{X}_{p_{ij}}^{d}\right)$ referring to the amount of information per expert respectively, as follows:

$$G(F_d) = G\left(\tilde{X}_{p_{ij}}^{d}\right) = \sum_{i=1}^{m}\sum_{j=1}^{n} \tilde{X}_{p_{ij}}^{d}. \tag{2}$$

Based on formulas (1) and (2) and experts 1-experts 5 in the annex, it is concluded that: $G(F_1) = 1032$, $G(F_2) = 923$, $G(F_3) = 994$, $G(F_4) = 1059$, $G(F_5) = 1093$, $\sum_{d=1}^{k} G(F_d) = 5101$。

Secondly, after calculation, the weights of the five experts $(D_1, D_2, D_3, D_4, D_5)$ in this paper are 0.202,0.181,0.195,0.208 and 0.214 respectively.Finally, in order to construct a more practical information fusion method, the weights of all five experts were set to 0.2, and the weighted average operator was used for calculation. It is possible to analyze the interrelationships among the input parameters and form an information system integration method for each node of value creation, utility selection and utility evaluation in the agricultural product supply chain, resulting in the weighted average score matrix in Table 3.

Table 3
Weighted average Score matrix

Options	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9	B_{10}
A_1	5.8	6.6	6.2	6.4	5.6	5.8	6.2	5.6	5.8	5.8
A_2	5.4	5.6	6.0	6.6	5.6	5.2	6.4	5.8	5.6	5.4
A_3	4.6	5.4	6.0	5.8	4.6	5.6	4.8	5.2	5.0	5.4
A_4	6.2	5.8	5.6	5.2	5.2	5.4	5.2	5.8	5.2	6.2
A_5	5.6	4.6	5.6	5.4	5.4	5.6	4.8	5.4	5.0	4.8
A_6	5.8	5.2	5.2	4.6	4.8	5.4	4.2	4.6	5.2	5.6
A_7	5.6	5.2	4.6	4.8	5.2	5.2	4.2	4.8	5.0	5.4
A_8	4.8	4.4	5.0	4.0	6.2	5.0	4.0	4.6	5.0	4.4
A_9	4.6	4.8	5.0	4.8	4.6	4.8	4.4	4.6	4.8	5.6
A_{10}	5.4	4.6	4.8	4.4	5.2	5.2	4.2	4.4	4.8	4.6
A_{11}	6.2	5.0	5.4	6.0	5.0	4.6	5.2	4.8	5.6	5.2
A_{12}	6.0	5.2	5.4	5.2	5.8	5.0	5.4	5.0	4.8	5.4
A_{13}	6.0	6.0	5.4	6.0	5.0	5.4	5.4	5.4	5.2	5.4
A_{14}	6.0	5.4	5.0	5.2	5.8	4.8	5.2	5.2	5.2	5.2
A_{15}	5.8	5.2	5.8	5.6	5.4	5.4	5.2	4.6	4.6	5.6
A_{16}	4.4	5.0	4.4	4.4	6.0	5.0	5.2	5.0	5.2	5.4
A_{17}	5.6	4.8	4.6	4.6	4.6	5.0	4.8	4.8	5.2	5.2
A_{18}	4.8	5.0	5.4	5.0	5.2	4.8	4.6	5.4	5.4	5.2
A_{19}	4.4	4.8	5.0	4.4	5.0	4.4	3.6	4.2	5.0	5.0

A_{20}	3.6	4.6	3.8	3.6	3.4	3.0	3.8	3.4	3.4	3.8

2.6.3 Construct utility index weights for value creation in agricultural supply chains based on the CRITIC approach

Calculate the correlation coefficients of the attribute pairs using formula (4) as ρ_{ik} shown in Table 4.

$$\rho_{ik} = \frac{\sum_{j=1}^{m}\left(\pi_{ij} - \bar{\pi}_i\right)\left(\pi_{ik} - \bar{\pi}_k\right)}{\sqrt{\sum_{j=1}^{m}\left(\pi_{ij} - \bar{\pi}_i\right)^2 \sum_{j=1}^{m}\left(\pi_{ij} - \bar{\pi}_k\right)^2}} \tag{3}$$

In the formula, $\bar{\pi}_i$ and $\bar{\pi}_k$ is the average of the i th and k th attributes, k and i is not equal to any other index. $\bar{\pi}_i$ is obtained using formula (4) and $\bar{\pi}_k$ in the same way:

$$\bar{\pi}_i = \frac{1}{n}\sum_{j=1}^{n}\pi_{ij}, \quad i = 1, 2, \ldots, m. \tag{4}$$

Table 4
Correlation coefficients for the format pairs of the score matrix

ρ_{ik}	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	A_{11}	A_{12}	A_{13}	A_{14}	A_{15}	A_{16}	A_{17}	A_{18}	A_{19}	A_{20}
A_1	1	0.8213	0.7524	0.8845	0.7012	0.6537	0.6328	0.5841	0.6029	0.5517	0.8034	0.8126	0.8347	0.8259	0.7831	0.7245	0.6823	0.7516	0.6038	0.4529
A_2	0.8213	1	0.8015	0.8527	0.7234	0.6842	0.6635	0.6128	0.6319	0.5824	0.8316	0.8425	0.8637	0.8548	0.8132	0.7541	0.7126	0.7825	0.6327	0.4836
A_3	0.7524	0.8015	1	0.7836	0.7625	0.7234	0.7025	0.6531	0.6728	0.6237	0.7926	0.8035	0.8247	0.8158	0.7736	0.7325	0.6924	0.7635	0.6528	0.5037
A_4	0.8845	0.8527	0.7836	1	0.7326	0.6837	0.6628	0.6135	0.6327	0.5836	0.8537	0.8646	0.8858	0.8769	0.8347	0.7736	0.7325	0.8036	0.6538	0.5038
A_5	0.7012	0.7234	0.7625	0.7326	1	0.7836	0.7627	0.7138	0.7329	0.6837	0.7538	0.7647	0.7859	0.7768	0.7347	0.6936	0.6525	0.7238	0.6839	0.5347
A_6	0.6537	0.6842	0.7234	0.6837	0.7836	1	0.9236	0.8747	0.8938	0.8447	0.7039	0.7148	0.7359	0.7268	0.6847	0.6436	0.6025	0.6738	0.7349	0.5857
A_7	0.6328	0.6635	0.7025	0.6628	0.7627	0.9236	1	0.8948	0.9139	0.8648	0.684	0.6949	0.716	0.7069	0.6648	0.6237	0.5826	0.6539	0.715	0.5658
A_8	0.5841	0.6128	0.6531	0.6135	0.7138	0.8747	0.8948	1	0.9349	0.8858	0.6341	0.645	0.6661	0.657	0.6149	0.5738	0.5327	0.604	0.7651	0.616
A_9	0.6029	0.6319	0.6728	0.6327	0.7329	0.8938	0.9139	0.9349	1	0.9059	0.6542	0.6651	0.6862	0.6771	0.635	0.5939	0.5528	0.6241	0.7852	0.6361
A_{10}	0.5517	0.5824	0.6237	0.5836	0.6837	0.8447	0.8648	0.8858	0.9059	1	0.6043	0.6152	0.6363	0.6272	0.5851	0.544	0.5029	0.5742	0.7353	0.6062
A_{11}	0.8034	0.8316	0.7926	0.8537	0.7538	0.7039	0.684	0.6341	0.6542	0.6043	1	0.9444	0.9655	0.9566	0.9145	0.8534	0.8123	0.8846	0.7044	0.5345
A_{12}	0.8126	0.8425	0.8035	0.8646	0.7647	0.7148	0.6949	0.645	0.6651	0.6152	0.9444	1	0.9766	0.9677	0.9256	0.8645	0.8234	0.8957	0.7155	0.5456
A_{13}	0.8347	0.8637	0.8247	0.8858	0.7859	0.7359	0.716	0.6661	0.6862	0.6363	0.9655	0.9766	1	0.9877	0.9467	0.8856	0.8445	0.9168	0.7366	0.5667
A_{14}	0.8259	0.8548	0.8158	0.8769	0.7768	0.7268	0.7069	0.657	0.6771	0.6272	0.9566	0.9677	0.9877	1	0.9378	0.8767	0.8356	0.9079	0.7277	0.5578
A_{15}	0.7831	0.8132	0.7736	0.8347	0.7347	0.6847	0.6648	0.6149	0.635	0.5851	0.9145	0.9256	0.9467	0.9378	1	0.8357	0.7946	0.8658	0.6857	0.5167
A_{16}	0.7245	0.7541	0.7325	0.7736	0.6936	0.6436	0.6237	0.5738	0.5939	0.544	0.8534	0.8645	0.8856	0.8767	0.8357	1	0.8558	0.8047	0.6458	0.4868
A_{17}	0.6823	0.7126	0.6924	0.7325	0.6525	0.6025	0.5826	0.5327	0.5528	0.5029	0.8123	0.8234	0.8445	0.8356	0.7946	0.8558	1	0.7658	0.6059	0.4479
A_{18}	0.7516	0.7825	0.7635	0.8036	0.7238	0.6738	0.6539	0.604	0.6241	0.5742	0.8846	0.8957	0.9168	0.9079	0.8658	0.8047	0.7658	1	0.696	0.527
A_{19}	0.6038	0.6327	0.6528	0.6538	0.6839	0.7349	0.715	0.7651	0.7852	0.7353	0.7044	0.7155	0.7366	0.7277	0.6857	0.6458	0.6059	0.696	1	0.6581
A_{20}	0.4529	0.4836	0.5037	0.5038	0.5347	0.5857	0.5658	0.616	0.6361	0.6062	0.5345	0.5456	0.5667	0.5578	0.5167	0.4868	0.4479	0.527	0.6581	1

4.3.2 Calculate the standard deviation σ_i, index C_i, and criterion weights w_i for each criterion

Step 1.1 Use Formula (5) to calculate the standard deviation σ_i of each indicator:

$$\sigma_i = \sqrt{\frac{1}{n-1}\left(\sum_{j=1}^{n}\left(\pi_{ij} - \overline{\pi}_i\right)^2\right)}, \quad j = 1, 2, \ldots, n. \tag{5}$$

Step 1.2 Calculate the index C_i using Formula (6) :

$$C_i = \sigma_i \sum_{k=1}^{m}\left(1 - \rho_{ik}\right), \quad j = 1, 2, \ldots, n. \tag{6}$$

Step 1.3 Calculate the index weights w_i according to Formula (7) :

$$w_i = \frac{C_i}{\sum_{i=1}^{m} C_i} \tag{7}$$

As a result, the results are shown in Table 5.

Table 5

Standard deviations σ_i, indices C_i, weights w_i for each indicator

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20
σ_i	0.3690	0.6165	0.4732	0.3900	0.3600	0.5200	0.4800	0.7500	0.1800	0.4200	0.4720	0.2710	0.3770	0.3400	0.4200	0.5300	0.3800	0.2900	0.4500	0.1000
C_i	4.5555	7.4741	5.6199	4.6848	4.244	5.8419	5.4459	8.3426	1.9822	4.6615	1.6310	0.6357	0.4654	0.4575	1.9185	3.0098	2.5798	1.4142	4.0055	1.3457
w_i	0.0702	0.1152	0.0866	0.0722	0.0654	0.0900	0.0840	0.1286	0.0306	0.0718	0.0251	0.0098	0.0072	0.0071	0.0296	0.0464	0.0398	0.0218	0.0617	0.0207
Sorting	8	2	4	6	9	3	5	1	14	7	15	18	19	20	13	11	12	16	10	17

Therefore, results show 20 sort of weights of evaluation indexes: A_8、A_2、A_6、A_3、A_7、A_4、A_{10}、A_1、A_5、A_{19}、A_{16}、A_{17}、A_{15}、A_9、A_{11}、A_{18}、A_{20}、A_{12}、A_{13}、A_{14}. Among them, A_8 has the highest weight at 0.1286, indicating that it has a high degree of data dispersion, weak correlation with other schemes, and the largest amount of information. A_{13}、A_{14} weight is at least about 0.007, indicating that it is highly relevant to most schemes and has the least amount of information.

2.6.4 Produce supply chain value creation utility based on the CoCoSo method

Step 2.1 Construct the initial decision matrix using real data or expert opinions (see Table 3).

Step 2.2 Standardize the initial decision matrix based on the nature of each evaluation index.

$$r_{ij} = \frac{\pi_{ij} - \min_i \pi_{ij}}{\max_i \pi_{ij} - \min_i \pi_{ij}} \quad \text{,for the benefit criterion.} \tag{8}$$

$$r_{ij} = \frac{\max_i \pi_{ij} - \pi_{ij}}{\max_i \pi_{ij} - \min_i \pi_{ij}} \quad \text{,based on cost criteria.} \tag{9}$$

As a result, the normalized, and range results are shown in Table 6, and the normalized decision matrix is shown in Table 7.

Table 6

Shows the range of $\min \pi_{ij}$ 、 $\max \pi_{ij}$ and range after standardized treatment

Scheme	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
$\min \pi_{ij}$	3.6	3.6	3.8	4	3.4	3	3.6	4.2	4.6	3.8
$\max \pi_{ij}$	6.2	6.6	6	6.6	6.2	5.6	6.4	5.8	5.8	6.2

Range	2.6	3	2.2	2.6	2.8	2.6	2.8	1.6	1.2	2.4

Table 7
Normalized Decision Matrix

Scheme	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9	B_{10}
A_1	5.8	6.6	6.2	6.4	5.6	5.8	6.2	5.6	5.8	5.8
A_2	5.4	5.6	6	6.6	5.6	5.2	6.4	5.8	5.6	5.4
A_3	4.6	5.4	6	5.8	4.6	5.6	4.8	5.2	5	5.4
A_4	6.2	5.8	5.6	5.2	5.2	5.4	5.2	5.8	5.2	6.2
A_5	5.6	4.6	5.6	5.4	5.4	5.6	4.8	5.4	5	4.8
A_6	5.8	5.2	5.2	4.6	4.8	5.4	4.2	4.6	5.2	5.6
A_7	5.6	5.2	4.6	4.8	5.2	5.2	4.2	4.8	5	5.4
A_8	4.8	4.4	5	4	6.2	5	4	4.6	5	4.4
A_9	4.6	4.8	5	4.8	4.6	4.8	4.4	4.6	4.8	5.6
A_{10}	5.4	4.6	4.8	4.4	5.2	5.2	4.2	4.4	4.8	4.6
A_{11}	6.2	5	5.4	6	5	4.6	5.2	4.8	5.6	5.2
A_{12}	6	5.2	5.4	5.2	5.8	5	5.4	5	4.8	5.4
A_{13}	6	6	5.4	6	5	5.4	5.4	5.4	5.2	5.4
A_{14}	6	5.4	5	5.2	5.8	4.8	5.2	5.2	5.2	5.2
A_{15}	5.8	5.2	5.8	5.6	5.4	5.4	5.2	4.6	4.6	5.6
A_{16}	4.4	5	4.4	4.4	6	5	5.2	5	5.2	5.4
A_{17}	5.6	4.8	4.6	4.6	4.6	5	4.8	4.8	5.2	5.2
A_{18}	4.8	5	5.4	5	5.2	4.8	4.6	5.4	5.4	5.2
A_{19}	4.4	4.8	5	4.4	5	4.4	3.6	4.2	5	5
A_{20}	3.6	4.6	3.8	3.6	3.4	3	3.8	3.4	3.4	3.8

Step 2.3 Calculate the weighted comparability sequence and the power-weighted comparability sequence for each alternative according to the following formula.

$$S_j = \sum_{i=1}^{m} (w_j r_{ij}) \tag{10}$$

$$P_j = \sum_{i=1}^{m} \left(w_j\right)^{r_{ij}} \tag{11}$$

Thus, the results are shown in Table 8.

Table 8
For each evaluation index S_j 、 P_j

Scheme	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9	B_{10}
S_j	0.7215	0.7832	0.6987	0.7124	0.6893	0.6751	0.7026	0.6948	0.6825	0.6912
P_j	3.1245	3.2156	3.0872	3.1023	3.0789	3.0654	3.0987	3.0865	3.0721	3.0812

Step 2.4 Calculate the relative weights of each alternative by adding up the scores of the three comprehensive evaluations.

$$M_{ja} = \frac{P_i + S_i}{\sum_{i=1}^{m}(P_i + S_i)} \tag{12}$$

$$M_{jb} = \frac{S_i}{\min_i S_i} + \frac{P_i}{\min_i P_i} \tag{13}$$

$$M_{jc} = \frac{\lambda(S_i) + (1-\lambda)(P_i)}{\lambda \max_i S_i + (1-\lambda)\max_i P_i}, \quad 0 \le \lambda \le 1. \tag{14}$$

Formula (12) represents the arithmetic mean of the total score, formula (13) represents the sum of the relative scores compared to the best alternative, and formula (14) represents the calculation of a balanced compromise score, λ with values ranging from 0 to 1, selected by decision-makers and experts, and the results are shown in Table 9.

Table 9

Evaluation indicators M_{ja}、M_{jb}、M_{jc}

Scheme	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9	B_{10}
M_{ja}	0.1032	0.1065	0.101	0.1021	0.1005	0.0998	0.1018	0.1009	0.1002	0.1007
M_{jb}	5.7821	5.9876	5.6789	5.7234	5.6542	5.6213	5.7125	5.6678	5.6345	5.6598
M_{jc}	0.9765	1.000	0.9623	0.9701	0.9587	0.9532	0.9689	0.9615	0.9568	0.9599

Step 2.5 Determine the final value of each alternative solution through Equation (15), and rank each alternative solution accordingly.

$$M_j = \left(M_{ja}M_{jb}M_{jc}\right)^{\frac{1}{3}} + \frac{1}{3}\left(M_{ja} + M_{jb} + M_{jc}\right) \tag{15}$$

Table 10

Final values and ranking of each alternative

Scheme	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9	B_{10}
M_j	3.2876	3.3654	3.2432	3.2651	3.2154	3.1982	3.2589	3.2367	3.2067	3.2289
Ranking	2	1	5	3	8	10	4	6	9	7

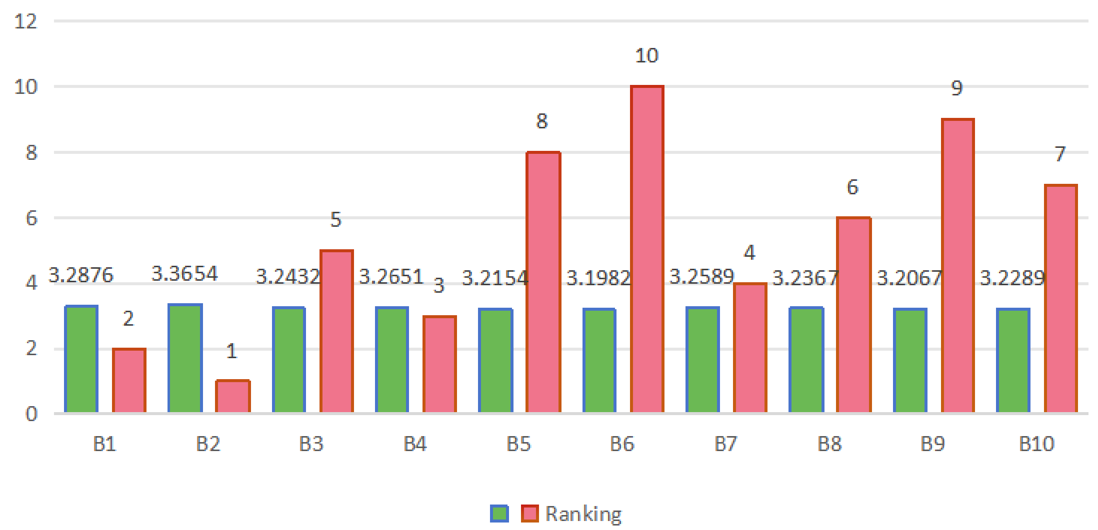

Fig. 2 The final numerical values and ranking bar charts of each alternative solution

Therefore, as calculated by formula (15),the ranking is shown in Table 10 and Fig 2. The last ranking is $M_2 \approx 3.3654$. Thus, it can be seen that the best evaluation metric is B_2, which is high in both the weighted sum and the power-weighted score, and ultimately ranks first. The worst metric is B_6, which has the lowest original score among all metrics and thus the smallest final score. B_2 and B_7, with weights of 0.1159 and 0.1095 respectively, had the greatest impact on it. On these two options, B_2 scored higher and had the most significant advantage.

3.Result

3.1 Result Analysis

This study, based on the results obtained from the CRITIC- CoCoSo method, reflects the evaluation of the ability of digital technology to empower the value creation of the agricultural product supply chain. From the perspective of the weights of the evaluation indicators, the imperfect digital platform ecosystem (A_8) ranks first with a weight of 0.1286, indicating that the low efficiency of cross-agent collaboration is the main obstacle to digital technology empowerment at present. Due to the scattered data and low correlation with other indicators, this indicator contains the most information and has the greatest room for improvement. Optimizing the circulation of agricultural products (A_2) has a weight of 0.1152, ranking second. It can be seen from the standardized matrix that technologies such as satellite remote sensing (B_2) and unmanned aerial vehicle (B_1) receive high scores in aspects such as circulation traceability and warehousing, indicating that digitalization of the circulation links has a significant promoting effect on creating value. However, the weight of technological iteration acceleration (A_{13}) and supply chain model innovation (A_{14}) is only around 0.007, mainly because these two are highly correlated with indicators such as precision production and policy support. Therefore, technological innovation must be combined with other aspects in order to fully exert its role.

Based on the ranking of alternative options, satellite remote sensing technology (B_2) scored 3.3654 in the first place, achieving higher scores of 0.5455 and 1.0000 respectively in circulation optimization (A_2) and green development (A_5), indicating its significant contribution to the effective monitoring of the production process and to the ecological environment. Cloud computing (B_6) ranked last (3.1982), mainly due to its poor performance in digital platform ecosystem (A_8), data security (A_3), etc., indicating that it cannot exchange information well with other relevant entities and cannot guarantee personal information security well. The mid-tier technologies such as artificial intelligence algorithms (B_4) and cold chain Internet of Things (B_7) have score gap mainly due to their suitability for small and medium-sized enterprises. These technologies play an important role for large agricultural enterprises, but their role in rural remote areas has not been fully demonstrated due to reasons such as the shortage of digital talents (A_7) and uneven infrastructure (A_6). On the other hand, there are significant differences between regions and entities. Large-scale farms in the eastern plains are willing to embrace advanced technologies such as digital twins and blockchain, while small-scale farmers in the central and western regions are more likely to use simple and cost-effective technologies such as drones and big data, which also confirm what we mentioned above about "uneven coverage of digital infrastructure" and "constraints of traditional concepts".

3.2 Suggestions For Enhancing The utility Of Value Creation

Based on the assessment of the main issues identified, based on the SWOT comprehensive strategy selection, propose four different improvement measures in different directions. First, in response to the most prominent deficiencies, strengthen the construction of digital infrastructure and platforms. Government departments should provide financial support for networks and Internet of Things devices in poverty-stricken areas and carry out related engineering construction to achieve balanced development of digital infrastructure nationwide and reduce the digital divide between urban and rural areas and between eastern and western regions; Second, formulate unified rules for open data of agricultural product supply chains, break down information silos in production, processing and transportation, form a digital platform ecosystem involving "government - enterprises - farmers", and on this basis, define the platform's revenue and profit-sharing methods, and improve the level of multi-party cooperation.

At the same time, enhance technical fit and implement differentiated and hierarchical promotion methods. Promote the application of advanced technologies such as digital twins and artificial intelligence algorithms for large agricultural producers, and build digital farms throughout the entire industrial chain on this basis to create economies of scale; For small and medium-sized agricultural producers, provide easy-to-use digital products such as simplified versions of big data market analysis apps and drone usage tutorials to reduce the difficulty of using the technology. And build a talent cultivation system that combines online and offline, and cooperate with universities and enterprises for order-based training mechanisms, focusing on practical issues such as the application ability of digital products and the security protection ability of data to address the shortage of talents.

Secondly, strengthen risk prevention and improve institutional and technical support measures. Accelerate the formulation of regulations and systems related to agricultural production data security and digital traceability, clarify the security responsibilities and accountability mechanisms of digital platforms, and prevent problems such as data leakage and false traceability; In terms of technology, efforts should be made to increase independent research and development of key technologies, reduce reliance on external technologies, and build emergency plans for digital technology to enhance the resilience of the entire industrial chain and supply chain against network disruptions and technical failures.

Finally, strengthen cooperation among industries to discover more possibilities. "Digital technology + agriculture + tourism/finance", creating characteristic agricultural product brands based on Blockchain traceability, developing "agriculture + e-commerce" to expand market channels; Seize the opportunity to establish digital agriculture demonstration zones that integrate production and sales, processing, transportation and other functions to achieve a conscientious cycle of "technology research and development - application promotion - value recovery", while digitizing traditional farming methods to promote the common development of modern agriculture and farming civilization.

4.Conclusion

4.1 Research Conclusions

The study in this paper constructs a reasonable evaluation model, but there is still room for improvement. This study screened out key influencing factors through the SWOT analysis model and literature retrieval, established the CRITIC- CoCoSo evaluation model, combined with 20 evaluation indicators and actual data from 10 digital technologies, and drew the following core conclusions.

First, digital technology has "two cores" for value creation in the agricultural product supply chain, namely optimizing circulation links and improving the digital platform ecosystem are the most important forces, which together account for 24.38%, while technological progress and model innovation need to be combined with other aspects to play a role due to the large amount of information duplication.

Second, the effects of different digital technologies vary greatly. Technologies such as satellite remote sensing and unmanned aerial vehicles (UAVs) work best because they facilitate precise production and traceability, but cloud computing and digital twins cannot fully play their roles due to the lack of corresponding talents and infrastructure. In general, high-end technologies are more in line with the needs of large-scale agricultural producers, while lightweight technologies are more in line with the needs of small-scale farmers, showing a stratified feature.

Third, the application of digital technology faces three major problems: First, in some places the infrastructure is not well-developed, and it is difficult to use the relevant technology in these places; Second, there is a lack of people who understand both technology and agriculture, making it difficult for advanced science and technology to be applied to agricultural production; Third, there are problems of unclear data security and platform responsibilities due to the lack of corresponding legal system support.

Fourth, there are significant differences among entities and regions. Large farmers and developed eastern regions are more willing to adopt technology and achieve good results; Small-scale farmers and the central and western regions, due to limited resources, are more inclined to choose low-cost and easy-to-implement technologies. This also affects the overall effectiveness of digital technology to some extent.

In general, digital technology can enhance the value of agricultural supply chains through precise production, efficient circulation, and data management, but it needs to address the three major problems of "weak links, insufficient synergy, and poor compatibility". The potential of digital technology can only be fully realized by using differentiated strategies to precisely match technology, entities and regions.

4.2 Research Outlook

The research in this article, although merely establishing a relatively appropriate evaluation model, still has room for improvement. It could be explored in three areas in the future.

First, expand research metrics and value dimensions. The current research indicators mainly focus on values at the economic and social levels and can be expanded in the future, such as the green and cultural values reflected in carbon reduction efficiency, the protection and development of rural culture, etc., to form a four-dimensional evaluation standard of "economy - society - ecology - culture"; In addition, economic evaluation indicators such as the application cost of technology and the return on investment could be added to make the evaluation results more in line with the actual needs of agricultural producers.

Second, improve research methods and data sources. In the future, machine learning methods such as random forests and neural networks can be used to calculate the weights of indicators, thereby improving the model 'ability to handle complex data. At the same time, intensify field research, select different regions and different types of agricultural product supply chains as samples for analysis, and collect first-hand data on production and circulation to make the model more general and authentic; In addition, the fuzzy decision-making method can be used to address some uncertainties in the process of technology application, such as price fluctuations, natural disasters, etc., in order to obtain more accurate results.

Third, strengthen the application areas and related research work. In the future, personalized technology research and development can be carried out for different types of agricultural entities, such as family farms, agricultural cooperatives, and large agricultural enterprises, to form targeted technology promotion plans. On the other hand, keep up with the pace of digital technology development, explore the possibility of integrating new technologies such as 5G and quantum computing with the agricultural product circulation field, and grasp the changing trends of future value creation methods. In addition, international comparative analysis can be conducted. Based on the application of digital technology in developed agricultural countries such as the United States, Europe and Japan, and in light of China's actual situation, relevant policies and measures can be improved to provide more practical suggestions for the digital transformation of China's agricultural product supply chain.

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References:

[1] Riccardo Rialti, Anna Marrucci, Lamberto Zollo & Cristiano Ciappei. (2022). Digital technologies, sustainable open innovation and shared value creation: evidence from an Italian agritech business. British Food Journal, 124(6), 1838-1856. https://doi.org/10.1108/BFJ-03-2021-0327.

[2] Mancuso Ilaria, Messeni Petruzzelli Antonio & Panniello Umberto. (2023). Innovating agri-food business models after the Covid-19 pandemic: The impact of digital technologies on the value creation and value capture mechanisms.Technological Forecasting & Social Change,190,122404. https://doi.org/10.1016/J.TECHFORE.2023.122404.

[3] Rashi Sharma, Devika Kannan, Jyoti Dhingra Darbari & P.C. Jha. (2024). Group decision making model for selection of performance indicators for sustainable supplier evaluation in agro-food supply chain.International Journal of Production Economics,277,109353.https://doi.org/10.1016/J.IJPE.2024.109353.

[4] Danyal Aghajani, Hasti Seraji, Harpreet Kaur & Jyri Vilko. (2024). A sustainable integrated model for multi-objective planning of an agri-food supply chain under uncertain parameters: A case study. Computers and Chemical Engineering,188,108766. https://doi.org/10.1016/J.COMPCHEMENG.2024.108766.

[5] Prajapati Dhirendra, Zhou Fuli, Dwivedi Ashish, Singh Tripti, Lakshay Lakshay & Pratap Saurabh. (2022). Sustainable Agro-Food Supply Chain in E-Commerce: Towards the Circular Economy.Sustainability,14(14), 8698. https://doi.org/10.3390/SU14148698.

[6] Sagareishvili Nino. (2021). The role of maritime logistics and supply chain in stimulating the export of agricultural products.MATEC Web of Conferences,339,https://doi.org/10.1051/MATECCONF/202133901008.

[7] El Bhilat El Mehdi, El Jaouhari Asmae & Hamidi L. Saadia. (2024). Assessing the influence of artificial intelligence on agri-food supply chain performance: the mediating effect of distribution network efficiency.Technological Forecasting & Social Change,200,123149.https://doi.org/10.1016/J.TECHFORE.2023.123149.

[8]Chen, I. J., & Small, M. H. (1994). Implementing advanced manufacturing technology: an integrated planning model.Omega,22(1), 91-103.https://doi.org/10.1016/0305-0483（94）90010-8.

[9] Vern Priyanka, Panghal Anupama, Mor Rahul S, Kamble Sachin S., Islam Md. Shamimul & Khan Syed Abdul Rehman. (2023). Influential barriers to blockchain technology implementation in agri-food supply chain.Operations Management Research,16(3), 1206-1219.https://doi.org/10.1007/S12063-023-00388-7.

[10] Pongen Imnatila, Ray Pritee & Gupta Rohit. (2024). Evaluating the barriers to e-waste closed-loop supply chain adoption.Benchmarking: An International Journal,31(9), 2871-2896. https://doi.org/10.1108/BIJ-01-2023-0032.

[11] Cook Simon, Jackson Elizabeth L., Fisher Myles J., Baker Derek & Diepeveen Dean. (2022). Embedding digital agriculture into sustainable Australian food systems: pathways and pitfalls to value creation.International Journal of Agricultural Sustainability,20(3), 346-367. https://doi.org/10.1080/14735903.2021.1937881.

[12] Schoneveld George C. &Weng Xiaoxue. (2023). Smallholder value creation in agrifood chains: Value network approach.Land Use Policy,131,https://doi.org/10.1016/J.LANDUSEPOL.2023.106676.

[13] R. Manigandan & J. Naga Venkata Raghuram. (2024). Impact of digital technologies adoption on firm performance: the mediating role of social value creation and the moderating role of entrepreneurial marketing in Indian SMEs.International Journal of Information Systems and Change Management,14(2), 198-229. https://doi.org/10.1504/IJISCM.2024.140621.

[14] Stefanella Stranieri, Federica Riccardi, Miranda P.M. Meuwissen & Claudio Soregaroli. (2021). Exploring the impact of blockchain on the performance of agri-food supply chains.Food Control,119.https://doi.org/10.1016/j.foodcont.2020.107495.
[15] Corallo Angelo, De Giovanni Martina, Latino Maria Elena & Menegoli Marta. (2024). Leveraging on technology and sustainability to innovate the supply chain: a proposal of agri-food value chain model.Supply Chain Management: An International Journal,29(3), 661-683.https://doi.org/10.1108/SCM-12-2022-0484.
[16]Wang, H., & Zhang, F. (2022). Interaction power Heronian mean aggregation operators for multiple attribute decision making with T-spherical fuzzy information.Journal of Intelligent & Fuzzy Systems,42(6), 5715-5739.https://doi.org/10.3233/JIFS-212149.
[17] Aydoğdu Ali, Gül Sait. (2021) New entropy propositions for interval-valued spherical fuzzy sets and their usage in an extension of ARAS (ARAS-IVSFS). Expert Systems, 39 (4): 12898. https://doi.org/10.1111/EXSY.12898.
[18] Rong Yuan. (2021). A study on the multi - attribute group decision - making method based on the generalized orthogonal fuzzy set (Master's thesis, Xihua University). Master. https://doi.org/10.27411/d.cnki.gscgc.2021.000058.
[19] Wang Haolun. (2024). A selection model for waste power battery recycling technologies based on the Intuitionistic Linguistic Rough CoCoSo - H. Chinese Journal of Management Science, 32 (05), 24 - 37. https://doi.org/10.16381/j.cnki.issn1003 - 207x.2021.0319.
[20] Shupeng Huang, Hong Cheng & Meiling Luo. (2024). Comparative Study on Barriers of Supply Chain Management MOOCs in China: Online Review Analysis with a Novel TOPSIS-CoCoSo Approach.Journal of Theoretical and Applied Electronic Commerce Research,19(3), 1793. https://doi.org/10.3390/JTAER19030088.
[21] Liu Dan. (2011). SWOT analysis of ideological and political education in colleges and universities in the strategic management model. China Economist, (05), 94 - 95. [22] Zong Yixiang, Wang Xu & Sun Yuzhu. (2024). Governance practices and experience enlightenment of the EU's agricultural product supply chain under emergencies. Agricultural Outlook, 20 (04), 87 - 92.
[23] Chen Dongping. (2025). A study on the impact of digital technology diffusion on value creation in the agricultural industrial chain of Luxi County. Agricultural Technology & Equipment, (06), 71 - 73.https://doi.org/10.3969/j.issn.1673-887X.
[24] Chen Xiaoxia & Chen Jianhong. (2024). Realistic obstacles and innovative paths for the development of digital agriculture platforms. Journal of Southwest Petroleum University (Social Sciences Edition), 26 (06), 45 - 52.https://doi.org/10.11885/j.issn.1674 5094.
[25] Li Haiyan. (2022). The formation mechanism and implementation path of the digital agriculture innovation ecosystem. Issues in Agricultural Economy, (05), 49 - 59. https://doi.org/10.13246/j.cnki.iae.20220328.003.
[26] Miao Wenqing. (2024). The essential attributes and value creation of digital agriculture. Administration & Law, (01), 106 - 118.