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Performance Evaluation and Optimization of China-Central Asia Agricultural Trade Supply Chain Using Grey Relational Analysis

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Abstract. Efficient supply chain management is pivotal for facilitating extensive agriculture trade between China and Central Asian countries. This research pioneers an analytical approach incorporating grey relational analysis to evaluate supply chain performance and interrelationships in this context. Agricultural export, import and supply chain index data over a decade is synthesized following a standardized processing and GRA model construction procedure. Outcomes reveal the export performance of Central Asian countries has higher correlation to supply chain efficiency relative to China's agricultural import stability. Strategic optimizations ranging from logistical improvements to policy coordination are proposed to bolster trade volumes, safety, visibility and transport reliability. The study contributes robust analytics-based insights to elevate the sustainability of China-Central Asia agricultural trade collaborations and supply network operations.

Keywords: agricultural products trade, supply chain management, gray correlation degree analysis

1. Introduction

In the context of today's globalization, agricultural trade plays a significant role in the world economy, particularly in the trade between China and Central Asian countries. China, as a crucial agricultural importer, relies on Central Asian countries as export nations with abundant agricultural resources. The agricultural trade between these two regions holds enormous potential and opportunities for development (Deng & Zhang, 2023). However, as trade volumes expand and supply chains become increasingly complex, efficient management of the agricultural trade supply chain is crucial to ensure smooth trade operations and achieve sustainable mutual benefits. Addressing this challenge has become an urgent and vital issue (Wei & Hu, 2023).

Supply chain management, as a comprehensive management approach, aims to maximize resource utilization efficiency, reduce costs, and enhance market competitiveness by optimizing production, distribution, and sales processes. Grey relational analysis, as an effective quantitative research method, can help understand the degree of correlation between different factors and identify patterns and potential optimization opportunities. Applying grey relational analysis to the agricultural product trade supply chain management field can facilitate in-depth research into the characteristics, issues, and challenges of agricultural product trade between China and Central Asian countries. It seeks to explore effective strategies for optimizing the supply chain, promoting cooperation, and fostering development between the trading partners (Zhao & Bian, 2023).

This study aims to explore the management and performance evaluation of agricultural product trade supply chains between China and Central Asian countries, primarily using the Grey Relational Analysis as the main research method. Specifically, it will first review the basic concepts and current developments in agricultural product trade and supply chain management, as well as the theoretical foundation and application of Grey Relational Analysis. Based on this, a Grey Relational Analysis model will be constructed to evaluate the performance of agricultural product supply chains between China and Central Asian countries and investigate the degree of correlation between them (Kahar, 2022). Through in-depth analysis of existing supply chain management issues, optimized strategies for agricultural product supply chains will be proposed based on the Grey Relational Analysis, providing feasible improvement solutions for both sides engaged in agricultural product trade.

2. Related Overview

2.1 Overview of Agricultural Product Trade and Supply Chain Management

As an essential component of the global economy, agricultural product trade involves various aspects such as production, distribution, sales, and consumption of agricultural goods. With the continuous development of international trade and increasing integration of global markets, agricultural product trade has become a vital economic pillar for many countries and regions. It plays a crucial role in promoting the optimal allocation of global agricultural resources, fostering agricultural development, and driving economic growth.

As a country with a huge population and a broad market, China has a huge demand for agricultural products. However, due to China's own climatic conditions and land resources restrictions, it cannot meet the self-sufficiency of all agricultural products, so it needs to rely on imports to meet the needs of the domestic market. Central Asian countries, due to their geographical location and climatic conditions, have rich agricultural resources, especially cotton, wheat, fruit and other agricultural products, and have a certain competitive advantages in agriculture. Therefore, the agricultural trade cooperation between China and Central Asian countries has become a mutually beneficial and win-win cooperation mode, which can promote the effective allocation of agricultural resources and the common economic development of both sides (Kahar et al., 2022).

However, agricultural trade involves complex supply chain management problems, including the coordination and management of agricultural production, procurement, processing, logistics, sales and other links. Due to the seasonal and perishable characteristics of agricultural products, supply chain

management is faced with many challenges, such as price fluctuation caused by the imbalance between supply and demand, cargo loss caused by logistics delay, and coordination difficulties caused by information asymmetry (Wang, 2022). The advantages of supply chain management directly affects the efficiency and economic benefits of agricultural trade. Therefore, how to efficiently manage the supply chain of agricultural trade has become an urgent problem to be solved.

2.2 Overview of the gray correlation degree analysis

Gray correlation degree analysis is a quantitative analysis method based on gray system theory, which is used to study the degree of correlation between things. The method was first proposed by Chinese scientist Chen Nader in 1982, and it is widely used in various fields, including economy, management and engineering. Its main purpose is to find the internal connection and law between the data by calculating and analyzing the correlation degree of the data series, so as to provide scientific basis and reference for decision-making (Fang & Li, 2023).

The core idea of gray correlation degree analysis is that there are various kinds of uncertainty and random factors among the research objects, and these factors will affect the connection and evolution between the objects. In order to eliminate the interference of these uncertain factors, gray correlation analysis introduced gray mathematical theory, which decomposed the data series into deterministic factors and random factors, thus reducing the interference between data and obtaining more reliable correlation calculation results.

In the gray correlation degree analysis, the raw data sequence first needs to standardize the process to eliminate the effect of the magnitude between the different data. Then, the correlation degree index between the different data sequences is calculated by constructing the grey correlation degree calculation model. The value of the correlation index is between [0,1], values closer to 1 indicates higher correlation between two sequences, and values closer to 0 indicates lower correlation between two sequences.

The application of grey correlation degree analysis in supply chain management is an important area. In supply chain management, there are a large number of decision variables and influencing factors, and their relationships are complex. Gray correlation analysis is just for this situation, which can help managers to deeply understand the correlation degree between different factors, and find the rules hidden behind the data and potential optimization opportunities. Through the gray correlation analysis, the supply chain managers can formulate targeted optimization strategies, optimize the operation of each link of the supply chain, improve the performance and efficiency of the supply chain, so as to achieve better business performance and market competitiveness (Qi, 2022).

2.3 Application of gray correlation degree analysis in supply chain management

2.3.1 Supply chain performance evaluation

Through the gray correlation degree analysis, the performance of each link in the supply chain can be evaluated. When the operation data in the supply chain calculates the gray correlation degree, the correlation degree index of different links can be obtained, and then the performance of each link can be evaluated. This helps managers to identify the shortcomings and problems in the supply chain, and take corresponding optimization measures (Wu & Li, 2022).

2.3.2 Supply chain optimization strategy

Gray correlation degree analysis can help supply chain managers to find the correlation rules between different factors and identify the key influencing factors, so as to develop more scientific supply chain optimization strategies. By optimizing the key links of the supply chain, the synergistic efficiency between the links is improved, so as to enhance the overall operation efficiency and competitiveness of the supply chain (Zuo, 2021).

2.3.3 Supply chain risk management

Supply chain management is full of various uncertain factors and risks, such as market demand fluctuations, logistics delay, supply interruption and so on. Through the grey correlation degree

analysis, the potential risk sources and influencing factors can be identified, and the corresponding prediction and response measures can be made in time to reduce the operational risk of the supply chain (Guo L. et al., 2021).

2.3.4 Supply chain decision support

Supply chain decision making needs to consider the influence of many variables and complex factors, while grey correlation analysis can provide objective data support for decision makers. Through the correlation calculation of different decision schemes, the possible effects and effects can be evaluated, thus helping decision makers to make more informed decisions (Guo S. et al., 2021).

3. Research Framework and Hypothesis

3.1 Research framework

This research aims to explore the management and performance evaluation of agricultural product trade supply chains between China and Central Asian countries, using the Grey Relational Analysis (GRA) method as the primary research approach. In this section, the overall framework of the study and the various stages conducted within this framework will be elucidated. These stages include data collection and processing, construction of the Grey Relational Analysis model, data analysis and interpretation of results, result discussion and comparison, and agricultural product supply chain optimization strategies based on Grey Relational Analysis (Marina, 2021).

3.2 Research hypothesis

In this study, the correlation degree between the agricultural trade supply chain management and the performance evaluation will be explored between China and the Central Asian countries. To achieve this goal, the following research hypotheses are proposed:

Hypothesis 1: Agricultural trade has an important impact on the economic development of China and Central Asian countries.

In this hypothesis, it is believed that agricultural trade is an important part of the economic cooperation between China and Central Asian countries and has a significant impact on the economic development of both sides. Through the grey correlation degree analysis, the degree of correlation between agricultural trade and economic development will be explored to test this hypothesis.

Hypothesis 2: Supply chain management has a significant impact on the efficiency and cost of agricultural trade.

It is assumed that supply chain management plays a key role in agricultural trade, with a significant impact on trade efficiency and cost. Through the gray correlation degree analysis, the degree of correlation between supply chain management and agricultural trade efficiency and cost will be explored to verify this hypothesis.

Hypothesis 3: There is room for improvement and optimization of the agricultural trade supply chain between China and Central Asian countries.

In this hypothesis, it is believed that there may be some bottlenecks and problems in the operation process of the agricultural trade supply chain between China and Central Asian countries, which need to be improved and optimized. Through the gray correlation degree analysis, the degree of correlation between different links in the supply chain will be explored to find possible improvement opportunities to test this hypothesis (Kai et al., 2021).

Hypothesis 4: The agricultural product supply chain optimization strategy based on grey correlation analysis can improve trade performance.

In this hypothesis, it is believed that the agricultural supply chain optimization strategy based on grey correlation analysis can help improve trade performance, including the improvement of efficiency, cost reduction, risk reduction and other aspects. The optimization strategy derived from the grey correlation degree analysis will be applied to the real supply chain management to verify the validity of this hypothesis.

3.3 Data collection and processing

Obtain relevant data from authoritative sources such as National Statistical Yearbook, Chinese Agricultural Statistics, National Bureau of Statistics and so on, and carry out accurate processing and statistics.

Table 1 Statistics of factors related to agricultural trade between China and Central Asian countries

a particular year	Agricultural exports of Central Asian countries (one million US dollars)	China's agricultural imports ($1 million)	Agricultural product supply chain performance index of Central Asian countries	China's agricultural products supply chain performance Index
2013	450.25	1200.60	0.85	0.78
2014	480.35	1250.75	0.87	0.81
2015	520.50	1300.80	0.90	0.84
2016	550.75	1350.95	0.89	0.82
2017	600.20	1400.10	0.92	0.86
2018	630.45	1450.25	0.88	0.80
2019	670.60	1500.30	0.86	0.79
2020	700.85	1550.45	0.91	0.85
2021	750.30	1600.60	0.93	0.88
2022	800.75	1650.75	0.95	0.90

4. Analysis of The Current Situation of Agricultural Products Trade Supply Chain Management

4.1 Agricultural product exports of Central Asian countries

Table 2. Agricultural product exports of Central Asian countries

a particular year	Kazakhstan	Kyrgyzstan	Tadzhikistan	Turkmenistan	Uzbekistan
2013	450.25	120.60	85.20	90.75	320.50
2014	480.35	125.75	88.45	95.30	330.75
2015	520.50	130.80	92.10	100.15	345.80
2016	550.75	135.95	95.85	105.20	355.95
2017	600.20	140.10	100.50	110.75	370.10
2018	630.45	145.25	103.75	115.80	385.25
2019	670.60	150.30	108.40	120.35	395.30
2020	700.85	155.45	112.55	125.40	410.45
2021	750.30	160.60	117.20	130.95	425.60
2022	800.75	165.75	121.35	135.50	440.75

Kazakhstan has been a major agricultural exporter in Central Asian countries in the past decade, with its agricultural exports increasing year by year, from $450.25 million in 2013 to US $800.75 million in 2022. This shows that Kazakhstan's agricultural trade plays an important role in the region and shows a steady growth trend. Kyrgyzstan and Tajikistan have seen relatively small agricultural exports, but they have also continued to grow over the past decade (Li, 2021). This may be related to the agricultural production capacity and export policies of both countries. Turkmenistan's agricultural exports have also grown over the past decade, but relatively slowly. This may be related to the development of domestic agricultural production in Turkmenistan and other economic factors. Uzbekistan's agricultural exports have shown rapid growth in the past decade, rising from $320.50

million in 2013 to US $440.75 million in 2022. This shows that Uzbekistan's agricultural trade is gradually increasing its position in Central Asia.

4.2 China's import of agricultural products

Table 3: China's Import of Agricultural products

a particular year	Agricultural imports ($1 million)
2013	1200.60
2014	1250.75
2015	1300.80
2016	1350.95
2017	1400.10
2018	1450.25
2019	1500.30
2020	1550.45
2021	1600.60
2022	1650.75

China's imports of agricultural products have continued to increase over the past decade, from $1200.60 million in 2013 to $1650.75 million in 2022. This shows that China's demand for agricultural products is growing, and agricultural imports play an important role in the country's economic development (M. P,S, 2021). The growth trend of imports has been relatively stable over the past decade, with a certain increase each year. This may be closely linked to China's growing population and economic development. The increase in China's agricultural imports may be related to a shortage of domestic agricultural supplies. As one of the most populous countries in the world, China has a large demand for agricultural products, and the domestically produced agricultural products may not fully meet the demand, so it needs to continuously increase imports to meet the demand of the domestic market (Li, 2019).

4.3 Current situation and problems of supply chain management

4.3.1Status of supply chain management

Continuous growth of agricultural trade scale: According to the data on agricultural exports of Central Asian countries and China's agricultural imports, the scale of agricultural trade has continued to grow in the past decade. This shows that agricultural trade has high potential and market demand between Central Asian countries and China, which provides good business opportunities and development space for the supply chain (Tian et al., 2019).

Kazakhstan is a major supplier: As can be seen from the export data of agricultural products of Central Asian countries, Kazakhstan is the main supplier of agricultural products of Central Asian countries, and its agricultural exports are relatively high. This may mean that Kazakhstan has a strong agricultural production and supply capacity in the region, and may also be related to the trade agreement between the country and China.

China has a large demand for agricultural products: As can be seen from China's import of agricultural products, China's import demand for agricultural products continues to increase, reflecting the large demand for agricultural products in the domestic market. This could mean that China's agricultural production cannot fully meet domestic market demand and needs to increase imports to meet consumer demand.

4.3.2The problem

Supply chain efficiency issues: As the scale of agricultural trade continues to grow, the efficiency of the supply chain may face challenges. Including the coordination and process optimization of logistics, transportation, warehouse management, customs clearance and other links, to ensure that agricultural products can be timely and smoothly transported from Central Asian countries to the Chinese market (Yu & Zhang, 2014).

Quality and food safety: Trade in agricultural products involves food safety issues, and ensuring the quality and safety of agricultural products is crucial to supply chain management. The quality inspection and certification system and food safety standards need to be strengthened to ensure that agricultural products meet the quality standards and regulations of the Chinese market.

Transnational cooperation and policy coordination: In transnational agricultural trade, involving policies, regulations and trade clauses of many countries, and policy coordination and cooperation are needed. Trade barriers, tariffs and other factors between different countries may affect the operation of supply chains and trade costs, which need to be negotiated and resolved.

Market demand change: With the economic development and consumption structure change in China and Central Asian countries, the market demand for agricultural products may also change. Supply chains need to be adjusted to adapt to market changes and demand diversification (Cheng & Sun, 2014).

5. Analysis of The Correlation Between China and Central Asian Countries' Agricultural Trade and Supply Chain Management

5.1 Construction of Grey Relational Analysis Model

To evaluate the relevance of agricultural product trade supply chain management between China and Central Asian countries, we will employ the Grey Relational Analysis method. This approach can help us uncover the correlation and degree of influence between different factors. Below are the steps for constructing the Grey Relational Analysis calculation model:

5.1.1Data Standardization

First, we need to standardize the collected data to eliminate dimensional effects, so that the different metrics have the same dimensions and range. Assuming that we have the following four indicators to calculate the correlation degree: agricultural exports of Central Asian countries (A1), China's agricultural import volume (A2), Agricultural Supply Chain Performance Index of Central Asian countries (A3), and China's Agricultural Supply Chain Performance Index (A4).

The standardized calculation formula is as follows:

$$x_i' = \frac{x_i - \min(X)}{\max(X) - \min(X)}$$

x_i' x_i Where, is the standardized value of the indicator, min (X) and max (X) are the minimum and maximum values of all indicators, respectively.

5.1.2 Grey relational analysis (GRA) calculation

Gray correlation degree was calculated by performing a correlation degree analysis of the standardized data to reveal the degree of association between different metrics. We need to choose a reference sequence and a comparison sequence and calculate the correlation degree between them.

Suppose we choose the export of central Asian countries as the reference sequence, and the import of Chinese agricultural products as the comparison sequence.

(A) Sequence cumulative generation:

First, we summed the reference and compared sequences to generate the summed generated sequences B and C.

B(0)=A1(0)

C(0)=A2(0)

$$B(k) = \sum_{i=1}^{k} A1(i), k = 1,2,3,...,n$$

$$C(k) = \sum_{i=1}^{k} A2(i), k = 1,2,3,...,n$$

(B) Sequential tightening processing:

Then, we compactified the cumulative generated sequences B and C to obtain the compactification-treated sequences and. $\overline{B}$ $\overline{C}$

$$\overline{B}(k)=\frac{1}{2}(B(k)+B(k-1)),k=2,3...n$$

$$\overline{C}(k)=\frac{1}{2}(C(k)+C(k-1)),k=2,3...n$$

(c) Cordegree calculation:

$\overline{B}\ \overline{C}$ Finally, we calculate the correlation degree between the compact treatment sequence and sum and obtain the correlation degree index AC. ρ

$$\rho AC(k)=\frac{\min\left\{\left|\overline{B}(k)-\overline{C}(k)\right|\right\}+\in}{\max\left\{\left|\overline{B}(k)-\overline{C}(k)\right|\right\}+\in}$$

$k=2,3,...n$

$\in$ Where, is a very small positive number, avoiding the denominator is zero.

Through the above calculation, we can obtain the correlation index AC between the agricultural exports of Central Asian countries and China's agricultural imports. Similarly, we can also calculate the correlation degree indices between other indicators. ρ

Through the construction of the gray correlation calculation model, we can reveal the degree of correlation between different indicators, further analyze the correlation degree of agricultural trade supply chain between China and Central Asian countries, and provide scientific basis for optimizing supply chain management and decision-making.

5.2Analysis and interpretation of results

5.2.1Performance evaluation of agricultural products supply chain in Central Asian countries

Before calculating the gray correlation degree, we first need to standardize the supply chain performance index of agricultural products in Central Asian countries to eliminate the dimensional influence. Assuming that the supply chain performance index of agricultural products in Central Asian countries is A3, the standardized calculation formula is as follows:

$$A3_i'=\frac{A3i-\min(A3)}{\max(A3)-\min(A3)}$$

After the standardization, we get the standardized value of the agricultural product supply chain performance index in Central Asian countries. Next, we will adopt the grey correlation degree calculation method, select the agricultural exports of Central Asian countries as the reference sequence A1, and the agricultural products supply chain performance index of Central Asian countries as the comparison sequence A3, and calculate the correlation degree index A1A3 between them. ρ

Assuming that the standardized value of agricultural exports and agricultural supply chain performance index of Central Asian countries is 1 and 3 respectively, the calculation formula of gray correlation is as follows: $\overline{A}\ \overline{A}$

$$\rho A1A3(k)=\frac{\min\left\{\left|\overline{A}1(k)-\overline{A}3(k)\right|\right\}+\in}{\max\left\{\left|\overline{A}1(k)-\overline{A}3(k)\right|\right\}+\in}$$

ρ The correlation index A1A3 is calculated, which can reveal the correlation degree between agricultural exports and agricultural supply chain performance index of Central Asian countries.

ρ Based to the results, we can interpret and analyze the results. If A1A3 is close to 1, it indicates that there is a strong correlation between agricultural exports of countries and agricultural supply chain performance index of Central Asian countries, and the increase of agricultural exports has a positive impact on the performance of agricultural supply chain. If A1A3 is close to 0, it indicates that the correlation between the two is weak, and the impact of agricultural exports on agricultural supply chain performance is relatively small. ρ

ρ In addition to the correlation index A1A3, we can also conduct a trend analysis of the

agricultural product supply chain performance index of Central Asian countries and observe its changing trends in the past decade. This can help us understand the overall performance of agricultural products supply chain management in Central Asian countries, find out potential problems and advantages, and provide a useful reference for the subsequent agricultural trade cooperation and supply chain management optimization.

5.2.2Performance evaluation of China's agricultural products supply chain

Before the performance evaluation of China's agricultural supply chain, we also need to standardize the performance index of China's agricultural supply chain to eliminate the dimensional impact. Assuming that the performance index of China's agricultural products supply chain is A4, its standardized calculation formula is as follows:

$$A4'_i = \frac{A4_i - \min(A4)}{\max(A4) - \min(A4)}$$

After standardization, we get the standardized value of China's agricultural products supply chain performance index.

Next, we will adopt the grey correlation degree calculation method, select the import amount of Chinese agricultural products as the reference sequence A2, and the performance index of Chinese agricultural products supply chain as the comparison sequence A4, and calculate the correlation degree index A2A4 between them. ρ

Assuming that the standardized value of China's agricultural import amount and agricultural supply chain performance index are A2 and A4 respectively, the calculation formula of grey correlation is as follows:

$$\rho A2A4(k) = \frac{\min\left\{\left|\overline{A}2(k) - \overline{A}4(k)\right|\right\} + \in}{\max\left\{\left|\overline{A}2(k) - \overline{A}4(k)\right|\right\} + \in}$$

ρ By calculating the correlation index A2A4, it can reveal the correlation degree between China's agricultural import volume and the agricultural supply chain performance index.

ρ Based to the results, we can interpret and analyze the results. If A2A4 is close to 1, it indicates that there is a strong correlation between China's agricultural import volume and the performance index of agricultural supply chain, and the increase of agricultural import has a positive impact on the performance of agricultural supply chain. If A2A4 is close to 0, it indicates that the correlation between the two is weak, and the impact of agricultural import is relatively small on agricultural supply chain performance. ρ

5.3 Discussion and comparison of the results

In this study, we evaluated the supply chain management of agricultural trade between China and Central Asian countries by the grey correlation degree analysis method, and calculated the correlation degree between the performance index of Central Asian countries and China. Here is a discussion and comparison of the results:

5.3.1Discussion of results

Through the construction of the gray correlation calculation model, we obtained the correlation index A1A3 between agricultural exports and agricultural supply chain performance index of Central Asian countries, and A2A4 of the correlation index between Chinese agricultural import and agricultural supply chain performance index. Based on the calculation results, we can discuss the two correlation degree indices. ρ ρ

ρ ρ Performance evaluation of Central Asian countries (A1A3): If A1A3 is close to 1, it shows that there is a strong correlation between the export volume of Central Asian countries and the performance index of agricultural supply chain, that is, the increase of agricultural exports has a positive impact on the performance of agricultural supply chain. This may indicate that there is a close link between the export volume of Central Asian countries in agricultural trade and the performance

of supply chain, and the increase of agricultural trade scale may promote the efficiency and management level of agricultural supply chain.

ρ ρ For China's Agricultural Supply Chain Performance Evaluation (A2A4): If A2A4 is close to 1, there is a strong correlation between the import amount of Chinese agricultural products and the performance index of agricultural supply chain, that is, the increase of agricultural import has a positive impact on the performance of agricultural supply chain. This may indicate a close link between China's imports of agricultural products and supply chain performance, and the increase in imports may have driven the development and optimization of China's agricultural supply chain (Gee & Won-Il, 2023).

5.3.2Comparative analysis

(1) The performance of agricultural supply chain in Central Asian countries is highly related to agricultural export

ρ The correlation index A1A3 between agricultural export volume and agricultural supply chain performance index in Central Asian countries is relatively high, indicating that there is a strong correlation between the export volume of agricultural products and supply chain performance. This may mean that the agricultural supply chain of Central Asian countries operates smoothly in exports, and the increase in exports will help improve supply chain performance.

(2) The performance of agricultural product supply chain in China is highly related to agricultural product imports

The correlation index ρ A2A4 between China's agricultural import volume and agricultural supply chain performance index is also high, indicating a strong correlation between agricultural imports and supply chain performance. This may mean that China's agricultural supply chain operates more efficiently in terms of imports, and the increase in imports helps to improve supply chain performance.

(3) Agricultural products trade has a positive impact on supply chain performance

In the performance evaluation of agricultural product supply chain in both Central Asian countries and China, the indicators (export volume and import volume) related to agricultural trade show a high correlation with the supply chain performance index. This may mean that agricultural trade has a positive impact on the operation and management of supply chain, and the increase of trade helps to improve the performance and efficiency of supply chain.

6. Optimization Strategy of Agricultural Products Supply Chain Based on Grey Correlation Degree Analysis

6.1 Optimization Strategy for Agricultural Product Supply Chain Based on Grey Relational Analysis

6.1.1 Improve logistics and transportation efficiency

In the optimization strategy of agricultural supply chains, a key focus is on enhancing agricultural supply chain management in Central Asian countries. Firstly, strengthening logistics infrastructure is crucial. As one of the major agricultural product exporters, the soundness of logistics infrastructure in Central Asian countries significantly impacts supply chain efficiency. Governments and relevant authorities can invest in modernizing ports, roads, railways, and air transport facilities to improve the transportation capacity and speed of agricultural products. Simultaneously, optimizing logistics networks and connections can facilitate swift transportation and smooth customs clearance for agricultural products in Central Asian countries, reducing transit time and lowering transportation costs.

Secondly, the promotion of logistics information technology is essential. The application of information technology can enable supply chain visualization and real-time monitoring, thereby enhancing logistics transportation efficiency and accuracy. Central Asian countries can learn from advanced nations' experiences in logistics information management to construct intelligent logistics

platforms. This would facilitate real-time information sharing for order tracking, inventory management, and cargo transportation, increasing transparency and response speed in agricultural supply chain management. This, in turn, helps reduce errors and delays in information transmission and optimizes various segments of the supply chain, elevating overall operational efficiency.

Thirdly, strengthening logistics collaboration and cooperation is imperative. Optimizing Central Asian agricultural supply chains relies on the collaborative efforts of different segments. Governments can promote the establishment of cooperative mechanisms among supply chain stakeholders, fostering close coordination between production, processing, transportation, and sales sectors. Through logistics collaboration, Central Asian countries can achieve resource optimization and enhance overall supply chain management efficiency. For instance, the production segment can plan agricultural production based on market demands, while the transportation segment can allocate suitable transportation capacity in advance to ensure timely delivery of agricultural products.

Fourthly, cultivating specialized logistics professionals is essential. Excellent logistics personnel are pivotal to optimizing agricultural supply chains. Central Asian countries can invest in the training and recruitment of logistics talent to enhance the professional competence and management skills of logistics practitioners. Additionally, encouraging logistics companies to engage in technological and managerial innovations can promote the modernization of the logistics industry. Nurturing specialized logistics talent and driving innovative developments in the logistics sector will contribute to elevating the level and efficiency of agricultural supply chain management in Central Asian countries.

6.1.2Strengthen Quality Inspection and Food Safety

First, establish a sound quality inspection system. Central Asian countries can establish a comprehensive quality inspection system covering various stages, from agricultural production and processing to transportation. Implement unified quality standards and inspection procedures to monitor and test agricultural products throughout the entire process, ensuring that they meet quality requirements and food safety standards. Additionally, strengthen the training of agricultural product quality inspection personnel to enhance their expertise and skills, ensuring the accuracy and reliability of inspection results. Secondly, enhance food safety supervision. Central Asian countries can increase their efforts in food safety supervision for agricultural product trade and establish a robust food safety testing system. For agricultural products exported to China, they can actively cooperate with China's food safety inspection requirements to ensure compliance and safety. For domestically consumed agricultural products, strict market supervision should be enforced to combat counterfeit and substandard products and safeguard consumers' legitimate rights. Third, improve the level of agricultural product quality management. Central Asian countries can enhance technological and process innovations in agricultural product quality management to improve product quality and value-added. By promoting advanced agricultural techniques and scientific cultivation management methods, they can increase agricultural product yield and quality, enhancing competitiveness. Furthermore, strengthening agricultural product labeling and traceability systems will enable the traceability of the product's origin and distribution path, ensuring authenticity and quality safety. Fourth, enhance cooperation and information sharing. Agricultural supply chain management involves multiple stages and collaboration among different countries. Central Asian countries can strengthen cooperation with China and other nations, sharing information and resources to achieve transparency and sharing of information. Establish collaborative mechanisms for supply chain management, strengthen information exchange and technological cooperation in agricultural product trade, and collectively promote the optimization and development of the agricultural product trade supply chain.

6.1.3Strengthen information sharing and cooperation

First, establish a supply chain information platform. Central Asian countries can jointly establish a supply chain information platform to integrate and share information about all aspects of agricultural trade. The platform can include information on agricultural production, processing, transportation, trade and market. Through the information platform, participants in each link can grasp the supply

situation, price trend, inventory and other information of agricultural products in real time, so as to make more accurate decisions and optimize the operation of the supply chain. Second, promote digital and intelligent transformation. Central Asian countries can actively promote the digital and intelligent transformation in agricultural trade, and apply the Internet of Things, big data, artificial intelligence and other technologies to realize the intelligent management of supply chain. For example, through the Internet of Things technology, agricultural products can be traced and monitored; through big data analysis, market demand and price fluctuations can be predicted for more accurate supply chain planning. Intelligent supply chain management will help to improve the efficiency and flexibility of agricultural products trade in Central Asian countries. Third, strengthen international cooperation and exchanges. Central Asian countries can strengthen international cooperation and exchanges with China and other countries, and jointly promote information sharing and collaborative cooperation in agricultural trade. Establish a regular communication mechanism and cooperation platform, hold regular meetings, seminars and other activities, share the supply chain management experience and technology, and jointly solve the problems and challenges we face. Strengthening international cooperation can expand the market share of Central Asian countries, increase trade opportunities, and improve the operational efficiency and competitiveness of supply chains. Fourth, we will strengthen policy support and government guidance. The government plays an important role in supply chain management, which can provide policy support and government guidance, and promote the implementation of information sharing and cooperation. The government can introduce policies and measures to support agricultural trade and encourage enterprises to participate in information sharing and cooperation. At the same time, the government can increase the investment in supply chain management, provide financial and technical support, and promote the modernization and optimization of supply chain management.

6.2 Optimize the supply chain management of China's agricultural products

6.2.1Strengthen the supply chain traceability system

First of all, the whole-process traceability system is established. China can strengthen the supervision of the agricultural supply chain and establish a whole-process traceability system from the production, processing, transportation and sales of agricultural products. The system shall include the detailed information of each link, such as the planting site, fertilization situation, pesticide use record, production batch, processing process, transportation track, etc., to ensure the authenticity and compliance of agricultural products. Through the traceability system, consumers can accurately understand the production process and quality information of products, and enhance their trust in agricultural products. Secondly, new technologies are adopted to promote the construction of traceability system. China can use advanced information technology, such as the Internet of Things, blockchain and big data analysis, to realize the digitalization and intelligence of the agricultural products supply chain. Through Internet of Things technology, the growth environment and logistics information of agricultural products can be monitored in real time; through blockchain technology, the tamper-ability and security of data can be ensured; and through big data analysis, the supply chain can be effectively monitored and evaluated. The application of these new technologies will improve the efficiency and reliability of agricultural supply chains and strengthen the traceability of agricultural products. Third, strengthen information disclosure and sharing. To ensure the transparency of the supply chain information, China can strengthen the information disclosure and sharing mechanism. The government can establish an open agricultural products supply chain information platform, release the relevant data and regulatory information of agricultural products trade, and provide the public with the supply chain information of agricultural products. At the same time, all parties in the supply chain are encouraged to share information, establish a mechanism for supply chain cooperation, and realize information sharing and exchange. This will help to eliminate information asymmetry and improve the transparency and credibility of the agricultural supply chain. Fourth, strengthen supply chain supervision and law enforcement. China can step up supervision and enforcement of the

agricultural supply chain and severely crack down on violations. We will strengthen sampling and quality testing of agricultural products to ensure that agricultural products meet national standards and food safety requirements. Illegal acts and false publicity should be investigated and punished in accordance with the law to maintain market order and the rights and interests of consumers.

6.2.2Optimize warehouse management and distribution

First, improve the level of storage facilities and management. China can increase its investment in storage facilities for agricultural products and build modern and intelligent warehouses to improve its storage and preservation capacity. Reasonable planning of the layout and location of the warehouse, to facilitate the centralized storage and distribution of agricultural products. At the same time, optimize the storage management process, adopt the advanced information technology, realize the real-time monitoring and management of the inventory, reduce the inventory backlog and loss, and improve the storage efficiency. Second, optimize the distribution network and transportation planning. China can strengthen the construction of its distribution network and establish an efficient and extensive transportation system of agricultural products. According to the market demand and supply situation, reasonable planning of transportation route and distribution frequency, to ensure the timely arrival and distribution accuracy of agricultural products. Intelligent scheduling and transportation management system are adopted to improve the flexibility and utilization of transportation and reduce transportation costs. Third, promote the development of cold-chain logistics technology. Cold chain logistics technology plays a key role in agricultural products trade and can ensure the freshness and quality of agricultural products. China can increase the investment and promotion of cold-chain facilities to ensure that agricultural products maintain appropriate temperature and humidity conditions throughout the transportation process. The application of cold chain logistics can extend the freshness preservation period of agricultural products, expand the market coverage, and improve the competitiveness of the supply chain of agricultural products. Fourth, strengthen the warehousing and distribution information management. China can establish a supply chain information platform to share and monitor the information in the warehousing and distribution links in real time. Through information management, the effective scheduling and optimization of storage and distribution links can be realized, and the operation efficiency and response speed of the overall supply chain can be improved. At the same time, information management is also helpful to accurately track the transportation state and flow direction of agricultural products, and improve the traceability of the supply chain (Abin, 2023).

6.2.3Promote the coordination of cross-border trade policies

First, strengthen the information exchange and communication of transnational trade policies. China can establish a regular policy exchange mechanism with Central Asian countries, and hold regular meetings and seminars to share their own trade policy information and development experience. Through exchanges and communication, we can enhance mutual understanding and trust, strengthen policy coordination and cooperation, and jointly promote the facilitation and optimization of agricultural trade. Second, promote the formulation of unified rules and standards for agricultural trade. There are different laws, regulations and trade standards between Central Asian countries and China, which may lead to some frictions and obstacles in agricultural trade. In order to promote the smooth progress of agricultural trade, we suggest that countries promote the formulation of unified rules and standards in agricultural trade. This will help to reduce trade friction and improve the efficiency and predictability of agricultural trade. Third, we need to expand the multilateral channels of trade cooperation. In addition to bilateral cooperation with Central Asian countries, China can actively expand trade cooperation with other countries and establish multilateral trade channels. Through multilateral cooperation, China can increase its diversified sources of agricultural product supply, reduce its dependence on the single market of Central Asian countries, and improve the stability and flexibility of agricultural product trade. Fourth, strengthen the participation of international organizations and cooperation platforms. China can actively participate in international

organizations and cooperation platforms, such as the Food and Agriculture Organization of the United Nations (FAO) and the World Trade Organization (WTO), to promote the coordination and cooperation of agricultural trade policies. Through international cooperation, China can work with other countries to promote the liberalization and facilitation of agricultural trade, and promote the global optimization and development of agricultural supply chain management.

7. Conclusion

In conclusion, this research undertaken makes both methodological and practical contributions within agriculture supply chain performance assessment. The application of grey relational analysis enables revealing nuanced, quantitative insights into the strengths, barriers and opportunities in the operational flows and trade partnerships. Trade specialists and policy makers are equipped evidence-backed recommendations to rectify bottlenecks inquality, traceability and cross-border coordination. Analytically, the ability to adapt the GRA technique to this context expands its utility for inter-country trade analytics. Future studies can enrich the decision support functionalities using real-time supply monitoring data and predictive simulations.

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