SCIENTIFIC OASIS

Decision Making: Applications in Management and Engineering

Journal homepage: www.dmame-journal.org
ISSN: 2560-6018, eISSN: 2620-0104

Performance Evaluation of Intelligent Agricultural Supply Chain Based on Structural Equation Model

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ARTICLE INFO

Article history:
Received 24 August 2023
Received in revised form 21 January 2024
Accepted 1 February 2024
Available online 8 February 2024

Keywords:
SC Function; Structural equation model; Digital technology; Information sharing; Big data.

ABSTRACT

To solve the problems of unstable chain and poor supply chain (SC) function in the China's agriculture industry, the relevant study is carried out on the function evaluation of the sustainable agricultural SC by structural equation modelling (SEM) under the background of digital technology. Primarily, the analysis is implemented on the research status of the sustainable SC and SC function. Then, starting with the relationship among big data (BD) application, information sharing, and sustainable SC function of agricultural production, a function evaluation model is implemented for the sustainable SC of SEM-based agricultural production. Next, a questionnaire is designed for the research on the impact of BD applications on the function of the sustainable agricultural SC. Ultimately, the statistical analysis of the obtained data reveals the correlation between the interaction and influence among the BD application, information sharing, and sustainable SC function of agricultural production. The results show that the BD application dimension, information sharing dimension, and all sub-dimensions have is beneficial to the function of the agricultural sustainable SC. The application of multidimensional cloud technology in BD has no obvious relationship with the dimensionality and level of information sharing, and the relationship between other corresponding dimensions shows a significant positive impact. A referenceable method is provided for the practice of sustainable SC management of agricultural production.

1. Introduction

Sustainable development is a progressive model that ensures current needs are met while safeguarding the survival and development of future generations. The sustainable development of the global economy will pose a challenge to humanity in the future, as the Earth can only provide finite resources. It is paramount for enterprises to formulate strategies for developing a sustainable supply chain (SC) by Barbosa-Póvoa *et al.,* [1].

It was focused on IT Governance (ITG) mechanisms in Small and Medium-sized Enterprises (SMEs) in southern Minas Gerais, Brazil by Maia *et al.,* [2]. ITG mechanisms play a pivotal role in aligning IT with business objectives, a crucial factor for SMEs. However, SMEs face unique challenges in

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https://doi.org/10.31181/dmame722024930

implementing ITG, including resource constraints and technological complexities. The study explores how the deployment of ITG mechanisms can enhance business value through IT and identifies areas for improvement. It was delved into the concept of creating a resilient supply chain, a critical need in today's complex business environment by Aliahmadi *et al.,* [3]. Resilience in the supply chain is essential for overcoming uncertainties and disruptions. The study focuses on how Artificial Intelligence of Things (AIoT) technologies can enhance supply chain resilience. Understanding the impact of AIoT on a resilient smart supply chain is crucial for modern supply chain organizations. It was discussed the advantages of blockchain technology in the supply chain for processed foods by Mankawade *et al.,* [4]. Blockchain technology enhances transparency and safety in the supply chain while reducing the risk of fraud. Additionally, it provides efficient tracking of food products, vital for ensuring food safety. Implementing blockchain technology in supply chains offers numerous benefits, both to consumers and the industry. It was addressed the challenge of designing a reliable and sustainable supply chain for blood distribution in healthcare systems by Eslamipoor and Nobari [5]. Ensuring an efficient blood supply chain is crucial for meeting the demands of healthcare facilities. The research explores a multi-objective model that considers cost, environmental impacts, and reliability to create a sustainable blood supply chain. Employing advanced techniques like the ε-constraint approach and imperialist competitive algorithms, this study contributes to healthcare supply chain optimization. The research mentioned above addresses critical aspects of supply chain management and IT governance mechanisms, emphasizing the role of technology in enhancing business value, improving supply chain resilience through AI and IoT technologies, leveraging blockchain technology for processed food traceability, and designing sustainable supply chains for healthcare. These topics are essential in the context of evolving business environments and challenges.

In China's sustainable supply chain (SC), whether in concept or management, it is still in its infancy. There is only a relatively low overall environmental awareness and a limited sense of social responsibility among enterprises [6]. With the advent of globalization, supply chain management has gradually come into people's view and attracted their attention. Along with information technologies such as network communication and manufacturing technology constantly improving, integration and competition among enterprises have become significantly decisive in the global market. As competition intensifies, the seller's market transforms into a buyer's market, stimulating the diversification of customer requirements. In response, manufacturers are accelerating product innovation and shortening production cycles [7-8]. However, while e-commerce brings benefits to global economic development, it also gives rise to environmental and social problems that cannot be ignored. Therefore, in the current competitive environment and faced with these challenges, enterprises must pay more attention to the impact on the environment and society to enhance their competitive advantage. This is also a challenge to traditional enterprises [9].

As China's economy accelerates its development, the country's agricultural industry is also growing rapidly. The "13th five-year plan" period is a crucial phase for China to build a well-off society comprehensively. As a result, the party and the government are placing great importance on poverty alleviation, and "three rural" issues are receiving significant attention from society at large [10]. Meanwhile, the current economic and social development has entered a new period of rapid change, structural optimization, and dynamic transformation. Agricultural development is also facing the challenge of modernization. Agriculture, as the mainstay of national economic and social development, continues to play a crucial role [11]. However, most of the competition in agricultural product markets is concentrated in agricultural product supermarkets. Due to the traditional sales model, the entire supply chain has a complex structure and experiences significant resource waste and losses. Agricultural production is often region-specific and seasonal. Even with low costs, the end consumers have substantial purchasing power and can still have a positive consumption experience.

The agricultural production industry faces instability in its supply chain, resulting in relatively poor supply chain (SC) function and management defects. It is essential to explore how the application of big data (BD) can optimize the management of sustainable agricultural SC. Therefore, this article analyzes the interactions among BD applications, information sharing, and SC function to construct a theoretical model and reveal the relationships through statistical data analysis. The aim is to provide a referenceable method for the practice of sustainable SC management in agricultural production.

This article's contributions are as follows: (1) Identification of Key Challenges in Agricultural Supply Chains: The article recognizes the challenges associated with unstable agricultural supply chains and the poor SC function within the rapidly developing agricultural industry in China. This identification highlights critical issues that require attention and solutions; (2) Utilization of Structural Equation Modeling (SEM): The article employs structural equation modeling (SEM) as a research methodology, offering a robust and systematic approach to assess and model the relationships among various factors influencing the sustainability and functionality of agricultural supply chains; (3) Statistical Analysis of Relationships: Through statistical analysis of the collected data, the study reveals the correlation between BD applications, information sharing, and the sustainable SC function in agricultural production. This empirical evidence strengthens the theoretical model and enhances our understanding of these relationships. In summary, this article makes a valuable contribution by not only identifying critical challenges in agricultural supply chains but also by proposing a solution-oriented approach through the integration of digital technology, empirical research, and the development of a theoretical model. It provides a structured framework for understanding and improving agricultural supply chain management, aligning with the goals of sustainable development and efficient SC function.

2. Research Status of Sustainable SC

It was discussed the application of Hesitant Fuzzy Sets (HFSs) to address the complexities of decision-making in uncertain environments by Farnam and Darehmiraki [12]. HFSs provide a flexible framework for modeling decision-making in cases where uncertainties and differences in opinions among decision-makers exist. The study demonstrates how Hesitant Fuzzy Linear Programming (HFLP) can be applied to solve hesitant fuzzy multi-objective problems, with potential applications in various fields, particularly in supply chain management. It was focused on the pivotal role of agriculture in India and the challenges it faces, including decreasing crop yields due to industrialization, pesticide use, and water scarcity by Zhou [13]. To address these issues, the study proposes the implementation of Wireless Sensor Networks (WSNs) in Smart Agriculture. WSNs are highlighted as a solution to monitor environmental parameters like moisture, temperature, soil humidity, and pH, contributing to increased crop volume and quality. This approach not only aids in resource conservation but also advances the concept of Smart Agriculture. Ehsani *et al.,* [14] explored the impact of technology capability drivers on the supply chain performance of automotive companies. The study employs fuzzy hierarchical analysis to identify and prioritize these drivers, crucial in an ever-evolving technological landscape. It identifies specific areas of technology capability, such as "strategic technology capability" and "product technology capability," that have the most significant influence on supply chain performance. This research provides a valuable framework for decision-makers in the automotive industry. Sıcakyüz [15] presented a bibliometric analysis of the use of Data Envelopment Analysis (DEA) in Supply Chain Management (SCM) over the years. It offers insights into research trends, the geographical distribution of authors, working areas, journals, and the content of studies related to DEA in SCM. The findings suggest that DEA is a valuable tool for assessing and improving the efficiency of supply chain operations, with potential applications in addressing sustainability concerns in SCM. These articles collectively highlight the importance of advanced methodologies and technologies, such as fuzzy sets, wireless sensor networks, and data analysis, in addressing complex challenges in decision-making, agriculture, technology management, sustainability, and supply chain performance. They provide a comprehensive overview of recent developments in these fields, offering guidance for future research and practical applications.

With the increasing focus on sustainability in the field of the supply chain (SC), more experiences and concepts have emerged in published articles. Khan *et al.,* [16] analyzed the driving factors and obstacles in sustainable SC. The research results indicate that this field primarily relies on a research method known as "multi-criteria decision-making" and focuses on enterprise-level research. Globalization has made SC management and control more challenging. Blockchain technology, with its prominent features of distribution, is designed to ensure transparency, traceability, and security in the transaction process, potentially addressing some global SC management issues.

Saberi *et al.,* [17] conducted critical research on blockchain technology and smart contracts, discussed their potential applications in SC management, and identified four types of barriers to the adoption of blockchain technology, namely inter-organizational, intra-organizational, technical, and external barriers. Koberg and Longoni [18] contributed by identifying configuration and governance mechanisms as key elements of global SC sustainable management and by integrating their relationship with sustainability outcomes. The trend of considering SC sustainability without addressing sustainability risks may impact the future of enterprises. Asamoah *et al.,* [19] investigated how the use of inter-organizational systems affected an organization's SC management capability and SC function. Drawing from the resource-based view theory, the study examines two crucial mechanisms for enhancing SC function: (a) the effective external utilization of network partners through inter-organizational systems and (b) maximizing the organizational management capability of inter-organizational systems in SC management. The results reveal that the use of inter-organizational systems has dual effects on improving SC function, SC management ability, and the intermediary role of SC management ability. Effective data management and employee capabilities support enable enterprises to leverage big data analysis and enhance sustainable SC management results.

In summary, early research in sustainable SC has been introduced since its inception. However, studies on sustainable SC function remain insufficient. Furthermore, these studies often overlook the correlation between sustainability and SC function uncertainty, which is essential for integrating sustainable development and SC function. Therefore, the use of information sharing can facilitate quicker information transmission between node enterprises, enabling enterprises to adapt rapidly to market changes, enhance consumer satisfaction levels, and ultimately improve overall SC function.

3. Establishing the Function Evaluation Model of the Sustainable Agricultural SC by the Structural Equation Modeling

3.1 Establishment of the Theoretical Model

Information sharing in the supply chain (SC) involves the process of transmitting and exchanging information among all enterprises within the entire SC on an information platform. The adoption of an information-sharing mechanism contributes to enhancing the level of SC management [20].

(1) Production information: In the traditional agricultural SC structure, agricultural producers often obtain valuable production and operational information at a high cost, involving numerous intermediate links. This lack of information sharing between production and sales leads to

information asymmetry, resulting in inefficiencies within the agricultural production distribution chain [21].

(2) Demand information: Some agricultural products are challenging to store, and information asymmetry can cause the bullwhip effect. Therefore, effective demand information feedback from downstream SCs to upstream enterprises is crucial for predicting market demand, adjusting production plans, enhancing risk mitigation capabilities, and ultimately improving the operational efficiency of agricultural SCs [22].

(3) Inventory information: Among the members of the SC, sharing inventory information is a crucial aspect of information-sharing agreements. Inventory information sharing reduces the inventory levels of all parties involved, minimizing product waste. Sharing inventory information among agricultural product operators, upstream and downstream enterprises, logistics service providers, and consumers helps reduce inventory costs [23].

(4) Logistics information: Logistics efficiency is a critical factor in the agricultural SC. The quality of agricultural products depends on logistics efficiency. High logistics efficiency ensures swift delivery of agricultural products to customers, reducing the likelihood of product damage and enhancing the overall shopping experience for consumers.

(5) Quality information: The quality of agricultural products within the SC relies on the quality of inputs provided by upstream suppliers. Timely information transmission from upstream suppliers to downstream suppliers is essential in case of quality issues with agricultural products. This allows downstream suppliers to formulate necessary countermeasures, reducing losses and unnecessary costs [24].

The significance of information sharing lies in enabling cooperation between node enterprises within the SC, thereby achieving comprehensive information sharing throughout the SC. This cooperation facilitates more rapid responses to diverse customer needs and ultimately elevates the SC's competitive edge [25-26]. Information sharing enhances SC responsiveness, customer satisfaction, and SC functionality. It leverages its advantages to foster connectivity between enterprises and the SC, culminating in a highly integrated SC system that boosts SC functionality [27]. Figure 1 illustrates the primary role of information sharing within the SC.

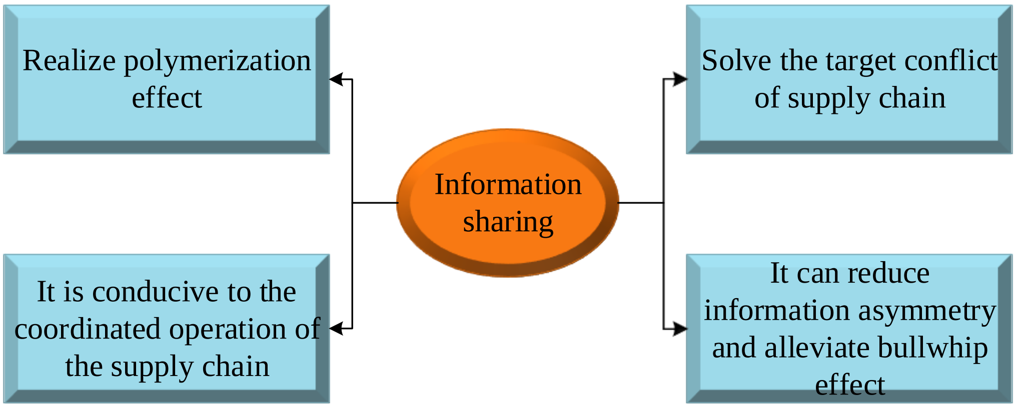

Fig. 1. Functions of information sharing on the SC

The integration of Big Data (BD) applications and data processing models can meet varying information processing needs, subsequently enhancing Supply Chain (SC) functionality and advancing information-sharing reform [28]. The utilization of BD among SC node enterprises is effective in optimizing the information-sharing platform [29]. BD application effectively enhances SC functionality by enabling node enterprises to acquire information more accurately and rapidly through efficient information transmission, thereby mitigating the "bullwhip effect" and elevating SC performance [30]. BD applications contribute to improving service quality and, in conjunction with industrial SC characteristics, ultimately optimize SC functionality. Figure 2 illustrates the theoretical model established herein, showcasing the relationships between BD application, information sharing, and SC function.

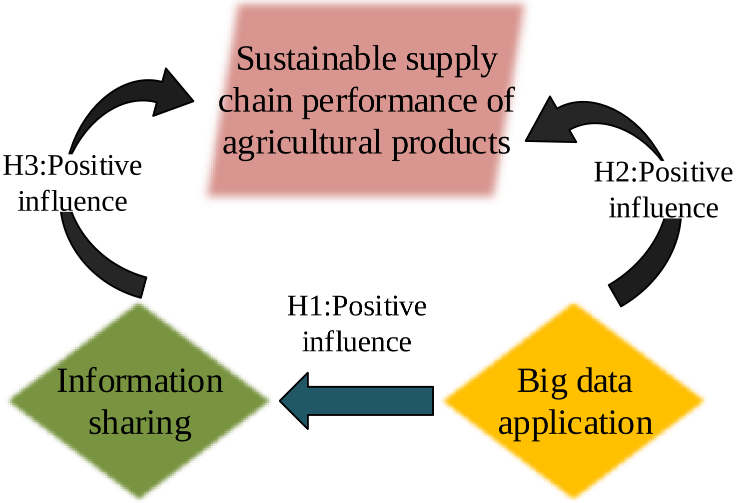

Fig. 2. Theoretical model of BD application, information sharing, and SC function

3.2 Assumptions on the impact of BD application and information sharing on the function of sustainable agricultural SC

The quality of information sharing is a critical factor in SC functionality. On one hand, as participants in the process of information sharing, SC node enterprises can significantly reduce production lead times and enhance the development of the SC information system, which aids in mitigating the "bullwhip effect" [31]. On the other hand, information sharing can also enhance inventory turnover rates, optimize SC resource allocation, elevate the service level of the entire SC, and make the SC more adaptable in responding to market changes [32]. The quality of information shared between upstream and downstream enterprises in the SC can influence consumer demand predictions and enterprise responsiveness to market changes, consequently impacting SC functionality.

In summary, for the interaction mechanism between BD application, information sharing, and the sustainable SC function of agricultural production, Table 1 presents the proposed assumptions.

Table 1
Assumptions

Grade	research hypothesis
H1	BD technology plays an important role in the sustainable SC function of agricultural production
H11	Data mining can cause a positive influence on the function of the agricultural sustainable SC
H12	The application of cloud technology has a significant positive impact on the function of the sustainable agricultural SC
H2	Information sharing can positively affect the function of the agricultural sustainable SC
H21	The effectiveness of information sharing determines the function of the agricultural sustainable SC
H22	Improving the shared information content is beneficial to the function of the agricultural sustainable SC
H23	The quality of shared information casts a positive influence on the function of the agricultural sustainable SC

Grade	research hypothesis
H3	BD applications have a significant positive impact on information sharing
H31	Data mining casts a positive influence on information sharing
H32	Data mining has a significant positive impact on the level of information sharing
H33	Data mining casts a positive influence on the content of shared information
H34	Data mining casts a positive influence on the quality of shared information
H35	Cloud technology has a significant positive impact on information sharing
H36	Cloud technology is conducive to improving the level of information sharing
H37	Cloud technology casts a positive influence on shared information content
H38	Cloud technology can positively affect the quality of shared information

Combined with the previous theoretical models and relevant assumptions, the hypothesis test is conducted on BD application, information sharing, and sustainable SC function of agricultural production established here. Figure 3 illustrates its model, and the arrow direction in Figure 3 represents a positive impact.

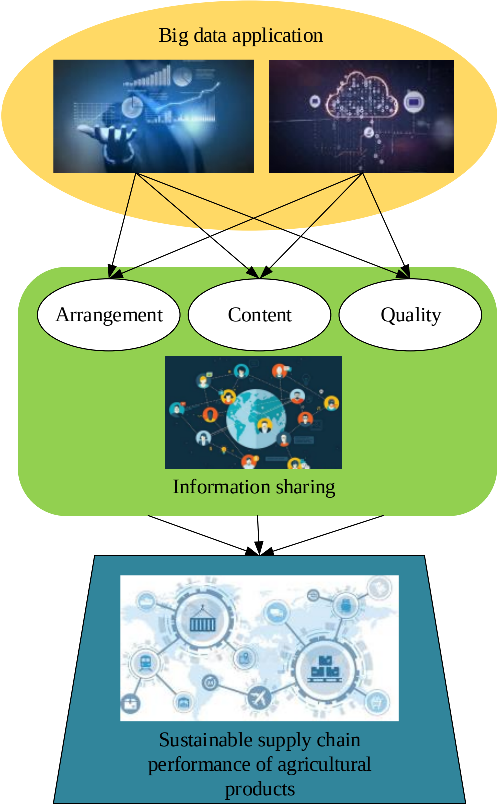

Fig. 3. Hypothesis test model of BD application, information sharing, and SC function

3.3 Structural equation modeling

Structural equation modeling, is abbreviated as SEM, which is also known as covariance structural model, or causal model. An SME can be used for both qualitative and quantitative analysis. It includes two parts of calculation:

(1) Measurement equation: the measurement equation reflects the correlation between multiple measurement variables and latent variables, such as the relationship between indicators such as process fairness and organizational commitment. Equations (1) and (2) demonstrate the calculation.

$$x = \Lambda_x \xi + \delta \tag{1}$$

$$y = \Lambda_y \eta + \varepsilon \tag{2}$$

(2) Structural equation: the structural equation expresses the correlation between potential variables, such as the relationship between the construction of advantageous disciplines and the core competitiveness of colleges and universities, the relationship between BD application, information sharing, and SC function. Equation (3) refers to its specific form.

$$\eta = B\eta + \Gamma\xi + \zeta \tag{3}$$

In Equations (1)-(3), ξ and η represent exogenous and endogenous variables respectively, and x and y stand for the observed exogenous and endogenous variables respectively; Λx denotes the direct relationship between the observed exogenous variables and exogenous latent variables; Λy indicates the direct relationship between the observed endogenous variables and endogenous latent variables; δ and ε are both error terms; B and Γ are both path coefficients; ζ is the residual term of structural equation [33].

4. Research and design on the impact of BD application on the function of sustainable agricultural SC

According to the principles of questionnaire design and the needs of the present work, this questionnaire survey includes two parts. The first part is the basic information, including the Department, position, working time, description of the basic situation of the enterprise, etc.; the second part is the measurement items, a total of 27 questions, as shown in Table 2.

Table 2

Measurement items of each dimension of BD application, information sharing, and SC function

Dimension	Grade	Measurement topic
Data mining	SJ1	The enterprise has a data information processing department.
	SJ2	Enterprises attach great importance to data information analysis.
	SJ3	Enterprises' decisions refer to integrated data information.
	SJ4	Enterprises have different mathematical methods for different structural data.
Cloud technology	YJ1	Enterprises have communication devices to access remote databases.
	YJ2	Enterprises apply digital archives management.
	YJ3	Enterprises share data information through the network platform.
Shared information hierarchy	GC1	SC node enterprises share operation-level information.
	GC2	SC nodes share management information among enterprises.
	GC3	SC nodes share strategic information among enterprises.
Share information content	GN1	Production planning information is shared among node enterprises in the SC.
	GN2	Production capacity information is shared among node enterprises in the SC.
	GN3	Inventory information is shared among node enterprises in the SC.
	GN4	Demand forecasting information is shared among node enterprises in the SC.
	GN5	SC nodes share sales information among enterprises.
	GN6	Order processing information is shared among node enterprises in the SC.
Shared information quality	GZ1	The information shared between node enterprises in the SC is accurate.
	GZ2	The information shared between node enterprises in the SC is complete.

Dimension	Grade	Measurement topic
	GZ3	The information shared between node enterprises in the SC is timely.
	GZ4	The information shared between node enterprises in the SC is sufficient.
	GZ5	The information shared between node enterprises in the SC is reliable.
Sustainable SC function of agricultural production	GJ1	The enterprise SC can adjust products in time to meet customers' requirements.
	GJ2	The enterprise can effectively produce new products and put them into the market with the help of the SC.
	GJ3	The information transmitted by the enterprise SC is effective.
	GJ4	The enterprise SC can deliver goods on time.
	GJ5	The enterprise SC can quickly respond to market changes.
	GJ6	The service level that customers get from the enterprise's SC is relatively high.

The options for each topic are determined using a Likert scale with 5 items, where 1 signifies "totally disagreed," 2 indicates "disagreed," 3 represents "indifferent," 4 signifies "agreed," and 5 corresponds to "totally agreed." Data collection primarily targets participants in the agricultural Supply Chain (SC), including cooperatives, production bases, leading agricultural enterprises, dealers, wholesalers, brands, agricultural product processing enterprises, retail terminals, e-commerce platforms, and third-party logistics companies involved in agricultural production. The focus is primarily on staff from these enterprises, including enterprise managers. Questionnaires are distributed both online and offline. A total of 300 questionnaires are distributed to on-the-job personnel in the Shaanxi production base and relevant enterprises, and all of them are collected. The number of effective questionnaires is 289, resulting in a recovery rate of 96.3%.

5. Results and discussion

5.1 Descriptive statistical analysis of survey data

5.1.1 Descriptive statistical analysis of samples

The descriptive statistical analysis is conducted on the research objects to obtain research results. Figures 4-8 signify the descriptive statistical analysis results of the samples.

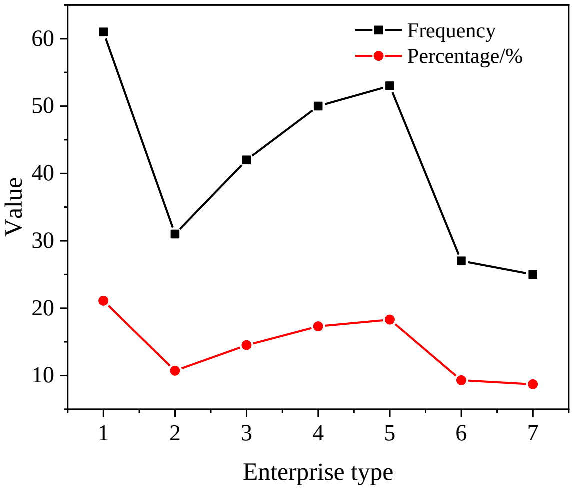

Fig. 4. Distribution of sample enterprise types (abscissa 1-7 respectively refer to agricultural product production base, agricultural leading enterprises, agricultural processing enterprises, intermediate distributors of agricultural production, retailers, third-party logistics companies related to agricultural production, and e-commerce platforms related to agricultural production)

Figure 4 reveals that among the enterprise types, the proportion of agricultural product production bases is 21.1%, which is the highest. The index of "retailers" ranks second, accounting for 18.3% and the index "agricultural intermediate distributors" ranks third, accounting for 17.3%. The e-commerce platforms involving agricultural production have the least proportion.

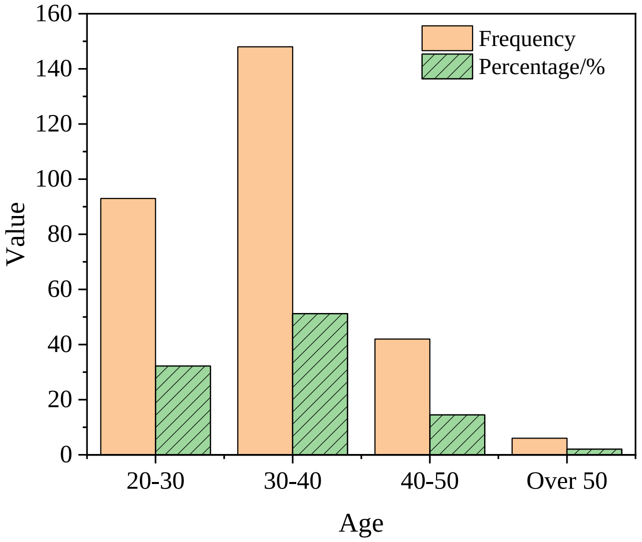

Fig. 5. Distribution of samples' ages

Figure 5 indicates that the distribution of samples' ages is mostly concentrated between 20-40 years, of which the largest proportion is 30-40 years, accounting for 51.2%; the second is 20-30 years, accounting for 32.2%; the proportion over 50 years is the least, only accounting for 2.1%. Because among the staff of the enterprise, the staff aged between 20 and 50 belong to the middle force, which is widely distributed horizontally and vertically. A perception of the actual situation of the enterprise helps to reflect the credibility of the data.

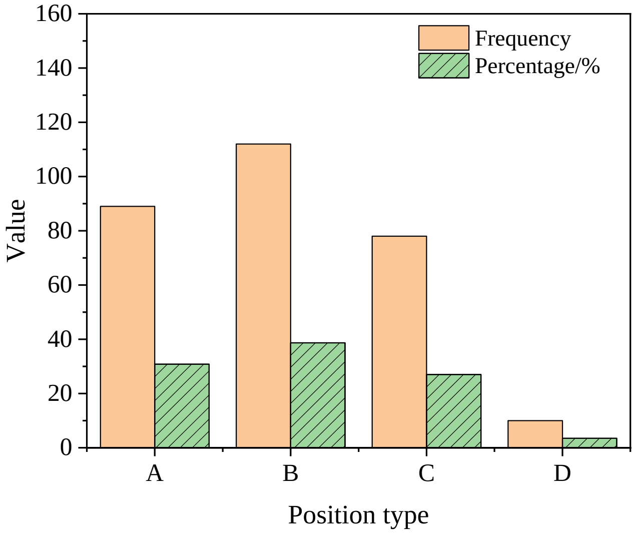

Figure 6 Distribution of sample positions (A: ordinary employees; B: grass-roots managers; C: middle managers; D: senior managers)

Figure 6 implies that the highest percentages of the sample job grades are grass-roots managers and ordinary employees, accounting for 38.7% and 30.8% respectively, and the middle managers account for 27%. In daily work, middle managers, grass-roots managers, and ordinary employees are more familiar with the business of the enterprise, so they meet the purpose of the survey.

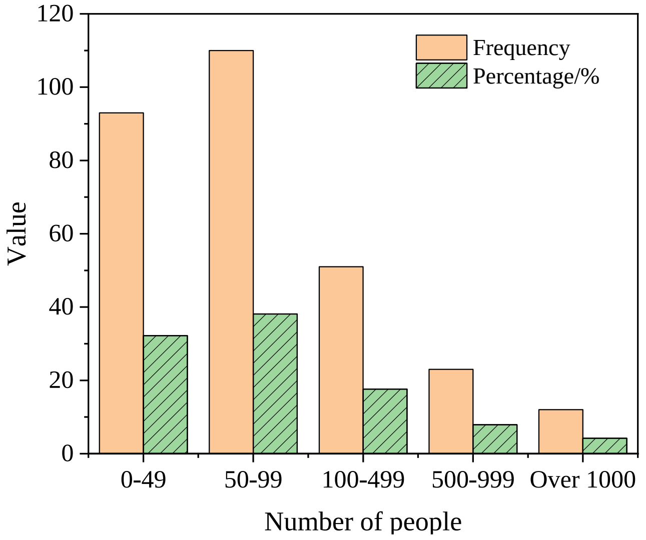

Fig. 7. Distribution of the sample enterprises' size

Figure 7 suggests that the number of enterprises with 50-99 employees accounts for the largest proportion, with a value of 38.1%; the number of enterprises with 0-49 employees accounts for 32.2%; the number of enterprises with 100-499 employees accounts for 17.6%, and the least proportion is the number of enterprises with more than 1000 employees. Generally, the overall distribution of enterprise-scale of the sample is relatively uniform.

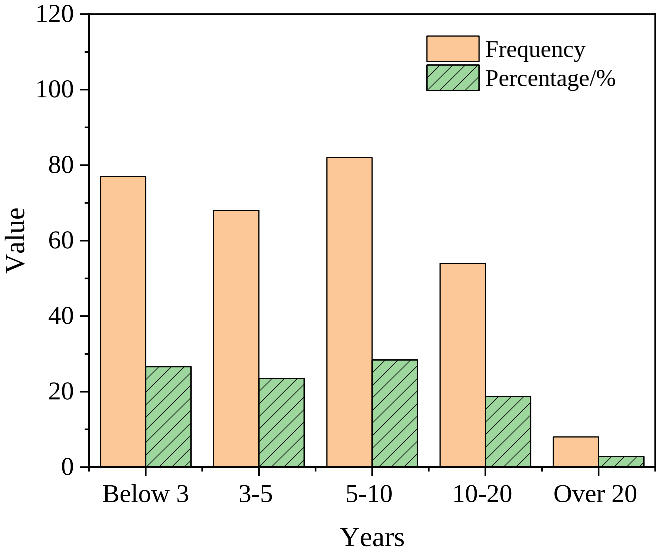

Fig. 8. Time distribution of sample enterprises participating in the SC

Figure 8 reveals that the proportion of enterprises participating in the SC is 26.6% for less than 3 years, 23.5% for 3-5 years, 28.4% for 5-10 years, 18.7% for 10-20 years, and 2.8% for more than 20 years. Among them, the enterprises participating in the SC for 5-10 years have the highest proportion, while the enterprises participating in the SC for more than 20 years have the lowest proportion.

5.1.2 Descriptive statistical analysis of each dimension

SPSS 21.0 is used to make statistics on the data items of each dimension of the obtained sample data. Figure 9 displays the basic statistical results of the question items of each dimension and their sub-dimensions.

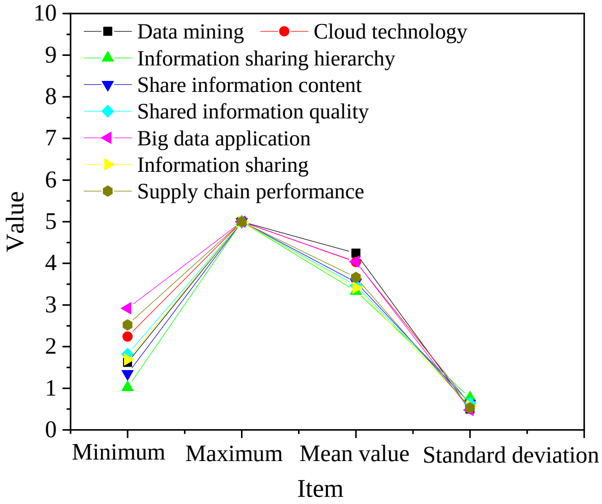

Fig. 9. Descriptive statistics of variables

Figure 9 demonstrates that the average values of data mining and cloud technology are relatively high, with values of 4.2453 and 4.0335 respectively, which shows that there is enough recognition of the importance of agricultural product production base for data information processing; the average value of all sub-dimensions of the information sharing dimension is about 3.5, which shows that there is a lack of use of information sharing in the sustainable SC management of agricultural production, so it is necessary to strengthen the exchange of information; the average value is 3.7624 for the sustainable SC function of agricultural production. The results suggest that there is a good overall level of sustainable SC function of agricultural production, but there is still room for improvement. The standard deviation of all dimensions is close to 0.5, indicating that the dispersion is suitable for further research and analysis.

5.2 Reliability and validity analysis of the questionnaire

Figure 10 indicates the reliability analysis results of each variable and related dimensions.

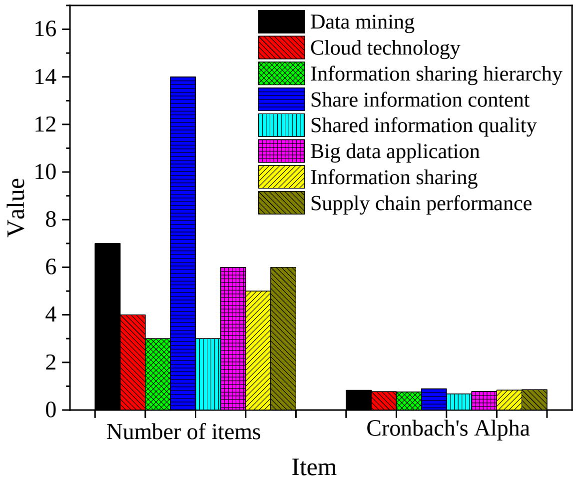

Fig. 10. Reliability analysis results of variables and related dimensions

Figure 10 manifests that the alpha coefficient value is 0.831 for the total dimension of BD application; the alpha coefficient value is 0.896 for the total dimension of information sharing; the alpha coefficient value is 0.856 for the sustainable SC function of agricultural production. These three values are greater than 0.8, and the alpha coefficient value of each sub-dimension is more than 0.7, which shows that the reliability of the items of each dimension designed in this survey is relatively good and need not be modified.

Table 3 expresses the results of the KMO and Bartlett spherical test for all variables.

Table 3
KMO and Bartlett spherical test results for all variables

Measurement dimension	KMO value	Approximate chi-square	Freedom	Sig.
BD application	0.842	571.561	43	0.001
information sharing	0.873	1236.753	89	0.001
sustainable SC function of agricultural production	0.883	542.673	27	0.000

Table 3 reveals that the approximate chi-square values of Bartlett's test for BD application, information sharing, and sustainable SC function of agricultural production are 571.561, 1236.753, and 542.673 respectively, the significance levels are 0.001, 0.001, and 0.000 respectively, the significance level is less than 0.05, and the KMO value is higher than 0.8, so the validity of the questionnaire is relatively good.

5.3 Confirmatory factor analysis

An SEM is established between each dimension for confirmatory factor analysis. Figure 11 presents the results of confirmatory factor analysis of each variable.

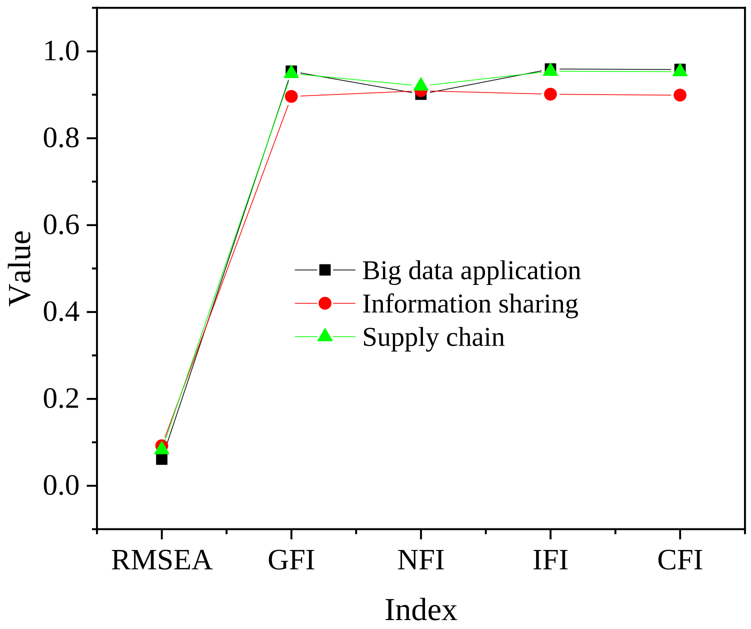

Figure 11 Confirmatory factor analysis results of various variables (RMSEA stands for the root mean square of approximation error; GFI means the goodness of fit index; NFI denotes the standard fitting index; IFI indicates the value-added fitting index; CFI represents the comparative fitting index)

Figure 11 illustrates that the index values of RMSEA for BD application, information sharing, and sustainable SC function of agricultural production are less than 0.8, meeting the requirements; the values of IFI, CFI, NFI, and TLI meet the requirements, and the values have reached more than 0.9. Therefore, the fitness fitting index of each item of BD application, information sharing, and agricultural product SC function has reached the specified standard, and the fitting degree is relatively good.

5.4 Correlation analysis

The Pearson correlation coefficient is used to analyze the correlation of each dimension variable studied. If the Pearson correlation coefficient is higher than 0.8, it is considered as high correlation, if the Pearson correlation coefficient is lower than 0.4, it is considered as low correlation, and if the Pearson correlation coefficient is between 0.4 and 0.8, it is considered as medium correlation. SJ represents data mining; YJ represents cloud technology; GC denotes information sharing level; GN represents the content of shared information; GZ refers to the quality of shared information; DS represents BD application; XG stands for information sharing and GJ means the sustainable SC function of agricultural production. Table 4 reveals the correlation analysis matrix of each variable.

Table 4
Correlation analysis matrix of each variable

	SJ	YJ	GC	GN	GZ	DS	XG	GJ
SJ	1							
YJ	0.468**	1						
GC	0.387**	0.422*	1					
GN	0.419*	0.624**	0.524*	1				
GZ	0.431*	0.519**	0.501**	0.643**	1			
DS	0.819*	0.873*	0.445**	0.623**	0.563**	1		
XG	0.462**	0.612**	0.829*	0.842*	0.845*	0.639**	1	
GJ	0.434**	0.451**	0.461**	0.468**	0.471*	0.518**	0.551**	1

Table 4 manifests that the Pearson correlation coefficients of all dimensions included in BD application, information sharing, and sustainable SC function of agricultural production are mostly between 0.4 and 0.8, which are moderately correlated, and most are significantly correlated at the level of 0001. The calculated R2 value for the model is 0.875, and the adjusted R2 value is 0.882. This indicates that the model has a good explanatory power.

5.5 Test results of hypotheses

Table 5 exemplifies the test results of the hypotheses proposed here.

Table 5
Test results of hypotheses

Research hypotheses	Is it established
H1	yes
H11	yes
H12	yes
H2	yes
H21	yes
H22	yes
H23	yes

Research hypotheses	Is it established
H3	yes
H31	yes
H32	yes
H33	yes
H34	yes
H35	yes
H36	no
H37	yes
H38	yes

Note: Table 1 presents the specific research hypotheses.

Table 5 indicates that all dimensions of BD application have a significantly positive impact on the sustainable SC function of agricultural production, confirming the validity of all hypotheses (H1, H11, and H12). Similarly, all dimensions of information-sharing level have a significantly positive impact on the sustainable SC function of agricultural production, validating all hypotheses (H2, H21, H22, and H23). BD has a notably positive impact on the overall variables of information sharing. Nevertheless, there is no significant effect of data mining and cloud technology on the level of information sharing.

Data mining has a notably positive impact on the function of the sustainable agricultural SC. In-depth data mining by enterprises within the sustainable agricultural SC provides other partners with more information about market changes and customer demand, thereby enhancing the SC's function. Cloud technology also significantly improves the sustainable SC function of agricultural production. Enterprises at each node in the SC can leverage advanced cloud technology to enhance information transmission efficiency, contributing to improved sustainability in the SC function of agricultural production. However, it's important to note that the information-sharing hierarchy dimension contains shared information content, and these two concepts are sometimes indistinguishable when filling out questionnaires. Therefore, cloud technology may appear to have a reverse effect on the information-sharing hierarchy during data analysis.

6. Conclusion

The research has focused on the complexities and significant losses in agricultural product markets, primarily driven by the traditional sales model prevalent in agricultural product supermarkets. It conducts an analysis of the interplay between Big Data (BD) application, information sharing, and supply chain (SC) functionality. A theoretical model is developed to encompass these three factors. Through statistical data analysis, the study reveals the interactive and influential relationships among these factors, providing a methodological reference for the practical implementation of sustainable supply chain management in agricultural production.

The findings underscore the positive impact of data mining on the functionality of sustainable agricultural supply chains. In-depth data mining within agricultural supply chain enterprises enhances the availability of market dynamics and customer demand information, contributing to the overall effectiveness of the supply chain. Furthermore, cloud technology is found to significantly boost the sustainability of agricultural supply chain functions. Implementing advanced cloud technologies across the supply chain nodes improves information transmission, thus enhancing the sustainability of agricultural production supply chains. Sharing levels positively affect the sustainability of agricultural production supply chains. BD applications exhibit a strong positive influence on the overall variables related to information sharing. However, it is notable that data mining and cloud technology do not significantly impact the information sharing levels.

A limitation of the present study is that it primarily explores the mechanisms through which BD applications and information sharing influence the sustainability of agricultural supply chains. Future research endeavors should delve deeper into the impact of other variables and factors on the functionality of sustainable agricultural supply chains.

Based on the above research, several managerial implications can be found: (1) Embrace Data Mining: Managers in the agricultural supply chain should recognize the value of data mining. Investing in data mining tools and expertise can significantly enhance the supply chain's functionality by providing crucial market insights and customer demand information. (2) Enhance Information Sharing: Promoting higher levels of information sharing among supply chain partners can positively impact the sustainability of agricultural production supply chains. Managers should foster collaborative efforts to share critical data and insights. (3) Maximize BD Applications: Leveraging Big Data applications is crucial for enhancing information sharing and overall supply chain functionality. Managers should explore the full potential of BD applications to optimize their supply chain operations. These managerial implications provide a practical guide for industry professionals to improve the sustainability and efficiency of agricultural supply chains.

Author contribution

Conceptualization, Z.Y. and L.N.; methodology, Z.Y.; software, Z.Y.; validation, Z.Y., L.N. and Z.Z.; formal analysis, Z.Y.; investigation, Z.Y.; resources, Z.Y.; data curation, Z.Y.; writing—original draft preparation, Z.Y.; writing—review and editing, Z.Y.; visualization, Z.Y.; supervision, Z.Y.; project administration, Z.Y.; funding acquisition, L.N. All authors have read and agreed to the published version of the manuscript.

Funding

This research received no external funding.

Data Availability Statement

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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