Research Article

Tracing Information for Agricultural Product and Identifying Key Regulatory Decisions towards Eco-Economics Sustainability

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Information traceability of agricultural products is of vital importance in the supply chain in the ongoing wave of big data relying on a group of advanced technologies, such as blockchain. This paper investigates how to effectively supervise and manage the agricultural supply chain with regard to information traceability. Starting from establishing a system framework for tracing and querying information by applying BigchainDB, this paper combines Decision Making Trial and Evaluation Laboratory (DEMATEL) and Analytic Network Process (ANP) to identify and assess the key regulatory decisions for the government for both economic and ecological purposes. The final results obtained by DEMATEL and ANP are consistent. The vital role of the planting link in eco-economics sustainability is affirmed. Through analyzing the demands of supply chain practitioners, as well as both economic and ecologic views of key points, the qualification information is attached significance. And the preservation and storage processes also deserve attention.

1. Introduction

Fresh agricultural products play an increasingly important role in the health level of the general public and have been attached notable attention by consumers, industrial practitioners, and government regulators involved in the agricultural supply chain (ASC, hereafter). Appropriate regulatory policies of the government for agricultural products are of great significance to the economy and social community [1]. As a special type of product that is highly perishable with circulative loss and obvious seasonal and regional characteristics, the freshness of the agricultural product has a great impact on its quality, by which the price and market demand fluctuate [2]. Moreover, the freshness of the agricultural product is time-sensitive, which puts much stricter requirements from the farmland to the dining table, throughout the entire supply chain such as planting, picking, shortage, transportation, and selling. Various agriculture-related members are expected to collaborate, share information, and wisely allocate resources without

any waste in all activities. Therefore, tracing information for agricultural products has become a vital issue in ASC.

With the development of advanced technology, tracing agricultural products has been widely seen around the world. The European Union took the lead in establishing the traceability system at the legal level in the 1990s. Since then, Japan, America, and China successively promoted the development of relevant traceability systems in ASC. Several technologies have been applied, such as radio-frequency identification (RFID) [3], QR code [4], and NFC. Among them, Blockchain is a technology that can be used to achieve transparency and reliability with its unique proof-of-work system that allows two parties to trade without a third party involved, avoiding problems that data are easy to tamper with, and data chains are easy to be broken. Evidence has shown its advantages of application in information tracing, and this technology has been used in many fields like medical care, cloud computing, and public services [5]. For information flow in the supply chain, which requires timely transmission accompanied by being processed and updated,

diverse new technologies bring potential to tracing and tracking [6], which gives a new chance for better supervision.

Along with the mode diversity, the addition of multiple entities makes the agricultural supply chain development show longitudinal extension, which is easy to result in poor quality and repeated treatments. Meanwhile, the competition within supply chains becomes fiercer. Although the development of e-commerce could speed up information sharing, profit orientation triggers malpractices like transmitting wrong information for price pushing. As the behavior of practitioners has a direct impact on final products and the development of the supply chain, the attention of regulators deserves to be shifted from final products to how people behave in the supply chain. On the other hand, the resources are gradually worn out, and the release of pollution is swiftly increasing. In addition, because of the improvement of living standards, people are more likely to pursue eating "healthier" and "more diverse." The trend of demand changing drives products with characteristics such as "out-of-season," "ecological," and "additive-free" to market hotspots that an increasing group of people is willing to pay more for environment-friendly products [7]. The new market demand and realistic problems raise new challenges to the operation of the supply chain, making it a crucial indicator to judge the quality of the supply chain as whether "sustainable enough." And the goal to be more environmental-friendly makes the targets of supervision change from only focusing on food safety to the balance of eco-economics based on quality guarantee. The upgrade calls for more information transparency and accuracy, which puts more pressure on data collecting and processing [8].

To bridge the gap between industrial practice and academia, this paper aims to trace agricultural products and identify the key regulatory decisions for both economic and ecological purposes. By applying BigchainDB, a database with Blockchain characteristics, this paper establishes a system framework to trace the information of agricultural products, based on which we identify and assess the key regulatory decisions of the government. To be specific, this paper mainly addresses the following research questions:

(1) How to apply the new technology to address the problem that data is easy to be tampered with during the process of information tracking;

(2) The specific information input of the whole agricultural supply chain traceability system, divided by different links;

(3) How to identify the key regulatory points among supply chain information points, especially taking "eco-economics' as the goal.

This paper analyzes the demands from the perspectives of different supply chain entities and establishes a conceptual model and an information flow figure for the supply chain information storage and traceability system based on decentralized databases with the strengths of blockchain. To determine the weights of the importance, the Decision Making Trial and Evaluation Laboratory (DEMATEL) and Analytic Network Process (ANP) methods are applied to the processes of obtaining views of actual participants in the field. From the key point results, the link which plays a vital role in the eco-economics sustainable development of the agricultural supply chain can be concluded, and based on which targeted suggestions could then be proposed.

The section arrangement is as follows: Section 1 introduces the background of the issue proposal that the development of the agricultural supply chain as well as social requirements triggers the demand for information tracing and eco-economics sustainability supervision, and the current technologies applied to this field. And this part shortly introduces the general framework of this paper. Section 2 summarizes the existing research statutes. In Section 3 a tracing system is established based on blockchain technology, and the main points to be considered are stated from different perspectives. Section 4 mainly combines DEMATEL and ANP methods to identify the key control points and concludes with a regulatory flow diagram based on critical control points obtained. Section 5 concluded the findings and points out some limitations of this paper for future improvement.

2. Literature Review

The role of supervision in the supply chain is gradually attached more significance in both practice and research. Scholars like Sahim et al. [9] have confirmed the positive effects of supervision on supply chain performance in practical cases. New methods, policies, and technologies to better regulate the operation of the supply chain are being researched. Chen et al. [10] applied NFC Technology to build a real-time traceability monitoring system for agricultural product supply chain and verified its effectiveness. Wen et al. [11] targeted quality issues in remanufacturing the supply chain with nonwaste returns, proposing different quality regulation policies to explore the impacts on supply chain performance, and pointed out that adjusting the quality regulation probability was more efficient than adjusting the penalty for inferior products. Song et al. [12] established the quality and safety traceability system of agricultural products based on the multiagent method to provide a systematic evaluation basis for the quality supply. Due to the special nature of perishable food as the final product, the supervision in this field is mainly in the dimension of food quality and safety. With the developing trend, more researchers have noticed the supervision on ecology dimension. Zhao et al. [13] took strategies selected by manufacturers to reduce the life cycle environmental risk of materials and carbon emissions as the research contents, exploring their optimal decision under government policies. Qu et al. [14] explored the issue of multiparty collaborative governance of energy conservation and emission reduction under the perspective of the low-carbon supply chain. However, there are still more researches on the macro system construction than on the specific regulatory link, more on the application of information technology than on the specific regulatory contents, and the eco-economics related contents are far from enough, failing to meet the practical demands.

To achieve the traceability in supply chain, many scholars have talked about it from technology and mechanism aspects.

Feng et al. [15] talked about the strengths, challenges, and developing methods of food traceability systems based on blockchain, pointing out a revised structure for better application. Behnke and Janssen [16] used a template analysis method to research on four cases of food supply chain, identifying 18 boundary conditions in the commercial, regulatory, quality, and traceability categories to improve supply chain traceability. Besides helping break the boundaries between supply chain entities and establish more efficient cooperation mechanisms, blockchain is also beneficial to government regulation. As Jabbar et al. [17] said, the application of blockchain in governance and services could allow for the transformation of government roles and functions. Yong et al. [18] developed a "Vaccine Blockchain" system based on blockchain and machine learning technology, which was designed to support vaccine traceability and smart contract features that could be used to address the issues of expired vaccines and falsifying vaccine records. However, researches on the application of blockchain technology in the supply chain field are still insufficient, and most of them are focused on supply chain finance, information security, and quality security. Few researchers paid attention to the potential application of blockchain technology to supply chain behavior supervision, and researches on information supervision based on blockchain technology for agricultural supply chain are even fewer, not to mention the ecological problems in ASC.

In researches that talk about decision-making and comparing influential factors, many methods were applied. Because the judging processes are subjective, and the degree is hard to describe, it worked out in reality by comparing indicators in pairs to identify the important factors deserving attention. The most commonly used method is the Analytic Hierarchy Process (AHP) method [19, 20], and it has been improved by integrating with other analyzing and calculating methods [21, 22]. However, the shortcomings such as high subjectivity and ignorance of the interplay among influential factors of AHP method are obvious. Therefore, the Decision Making Trial and Evaluation Laboratory (DEMATEL) and Analytic Network Process (ANP) methods are applied to studies on the influential factors and performance evaluation. Scholars such as Govindan and Van Horenbeek have taken advantage of these two methods to make evaluations in specific fields [23, 24], and the two methods are gradually combined to explore the internal mutual effects among indicators [25–27], in order to better improve the performance of decision-making and evaluation by reducing the error probability of interactions [28].

Previous literature has contributed a lot to the supervision of ASC, but there are still some gaps to be filled. The differences between the existing research and this paper are as follows: (1) as the majority of researches that talk about supervision in ASC are product quality-oriented or economics-oriented, this paper takes the eco-economics sustainability as the goal, to combine demands from different dimensions; (2) few researches study both the technology applied and the contents of regulations in the supply chain, but more concentrating on one part. This paper puts forward more practical thinking regarding, based on a specific blockchain database, what is the concrete system like and how to decide the key points; (3) faced with a large amount of information, this paper applies DEMATEL and ANP methods together to achieve the identification of key points, based on which we are to put forward specific suggestions. The combination of analyzing methods is an innovation compared to previous relative researches.

3. Constructing a Tracing Information System for the Agricultural Supply Chain System Based on Blockchain

To identify the key control points for supervision, a system to achieve the whole supply chain information input is a basis. In this part, by analyzing the features of the products as well as supply chain operations to obtain the practical requirements, a storage and traceability system is established based on the BigchainDB database. And then, the whole processes of the product circulation in ASC are divided into four parts, and the main source data are proposed.

3.1. Storage and Traceability System of Agricultural Supply Chain Based on BigchainDB. The current mode of supply chain information tracing is mainly focused on food safety. It creates a unique identifiable identification code for products, with the help of RFID, QR code, and other similar technologies to realize the information traceability of the whole processes of production and establish the system through three steps, namely, product identification, information collection, and terminal query. Data in the traditional information system of supply chain are relatively isolated and limited and are mainly source data and quantitative data that reflect product ownership. In the current cases, data are stored separately, hard to reflect the whole processes of the supply chain. The uniqueness of the identification codes would cause the loss of information and the interruption of traceability once new products are produced or processed during circulation. Furthermore, the "one-to-one" transmission mechanism makes the whole process of information in the supply chain unable to be open and transparent, and members of the supply chain are prone to make decision-making mistakes due to information asymmetry and other reasons. In addition, the centralized structure of the existing supply chain information traceability systems makes it vulnerable to external attacks and information tampering, and the misinformation transmitted will eventually lead to the economic and even health damage to consumers. In general, high centralization of structure, data vulnerable to tampering, and difficulty in verifying the integrity of tampered data have become the three major pain points for information traceability and market supervision.

Blockchain technology, with the characteristics of decentralization, distribution, immutability, and consensus mechanism, can solve the problem of information credibility when it is applied to information traceability. It makes the information source of supply chain members no longer solely from the previous links, and its diverse and comprehensive input of information can help supply chain
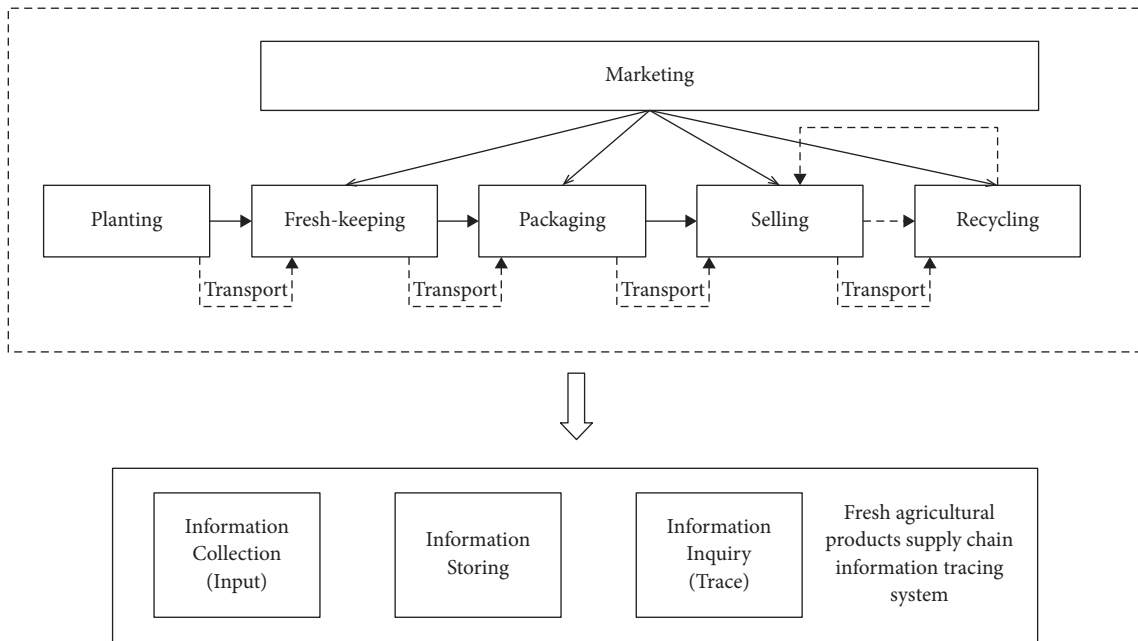
Figure 1: Conceptual model of information traceability system of agricultural supply chain.

members and end consumers make more scientific decisions, rather than just taking price or experience as the decision-making guide.

The agricultural supply chain contains links of planting, storing, fresh-keeping, packaging, selling, recycling, and transporting, and only through transmitting real data of all these links, the quality of products can be guaranteed [29]. Figure 1 shows the main links of an agricultural supply chain that an information tracing system should contain and the main functions of the system. Based on the characteristics of this kind of products, the requirements of information tracing can be drawn:

3.1.1. It Involves Many Subjects and Complicated Processes. Products in other fields are mostly from raw materials to treatments and then to sales. There are no excessive processing procedures, and their forms will not change greatly. Because fresh agricultural products undergo complex and lengthy processing procedures, their appearance and quality will change with time. The whole supply chain involves many entities, including not only farmers and sellers, but also processing and outsourcing enterprises [30].

3.1.2. High Information Correlation. Because the whole processes of the fresh agricultural supply chain, from planting to selling, all have impacts on the quality of the final products, especially freshness, the operation of each link matters to the decision-making of the next link. The high information correlation requires high accuracy and authenticity of the information.

3.1.3. Many Query Ports. As mentioned above, the operation of every link will affect the following decision-making, so the

problems that information asymmetry and distrust among supply chain members would occur if only providing information query ports at supply chain terminals. Multiple query ports allow practitioners to acquire information throughout the whole chain, so they can timely grasp the chances of decision-making, achieving better cooperation.

BigchainDB is a distributed database with blockchain characteristics. It has decentralized control. Data stored cannot be tampered with, and assets can be created and transmitted without the help of central nodes. The data can be guaranteed to be real and effective, responsibilities can be clearly checked, and the whole supply chain information can be input and queried under the protocol specifications.

According to the characteristics of information traceability in the supply chain of fresh agricultural products, the following requirements for an information traceability system can be obtained:

(1) Set up information collection, storage, and query for the whole process from planting to the final market.

(2) Open the multiagent port; the input information cannot be modified to ensure the authenticity of the information, to quickly locate the problem when it happens, and responsibility.

(3) Establish the correlation between information, and get through each link of the whole supply chain.

Figure 2 shows the information transmission process in a storage and traceability system and presents the information owner and importer.

The users of the agricultural supply chain information traceability system are mainly farmers, market parties (online platforms/offline stores), government regulatory departments, and consumers. The four types of users are given different rights in the information traceability system
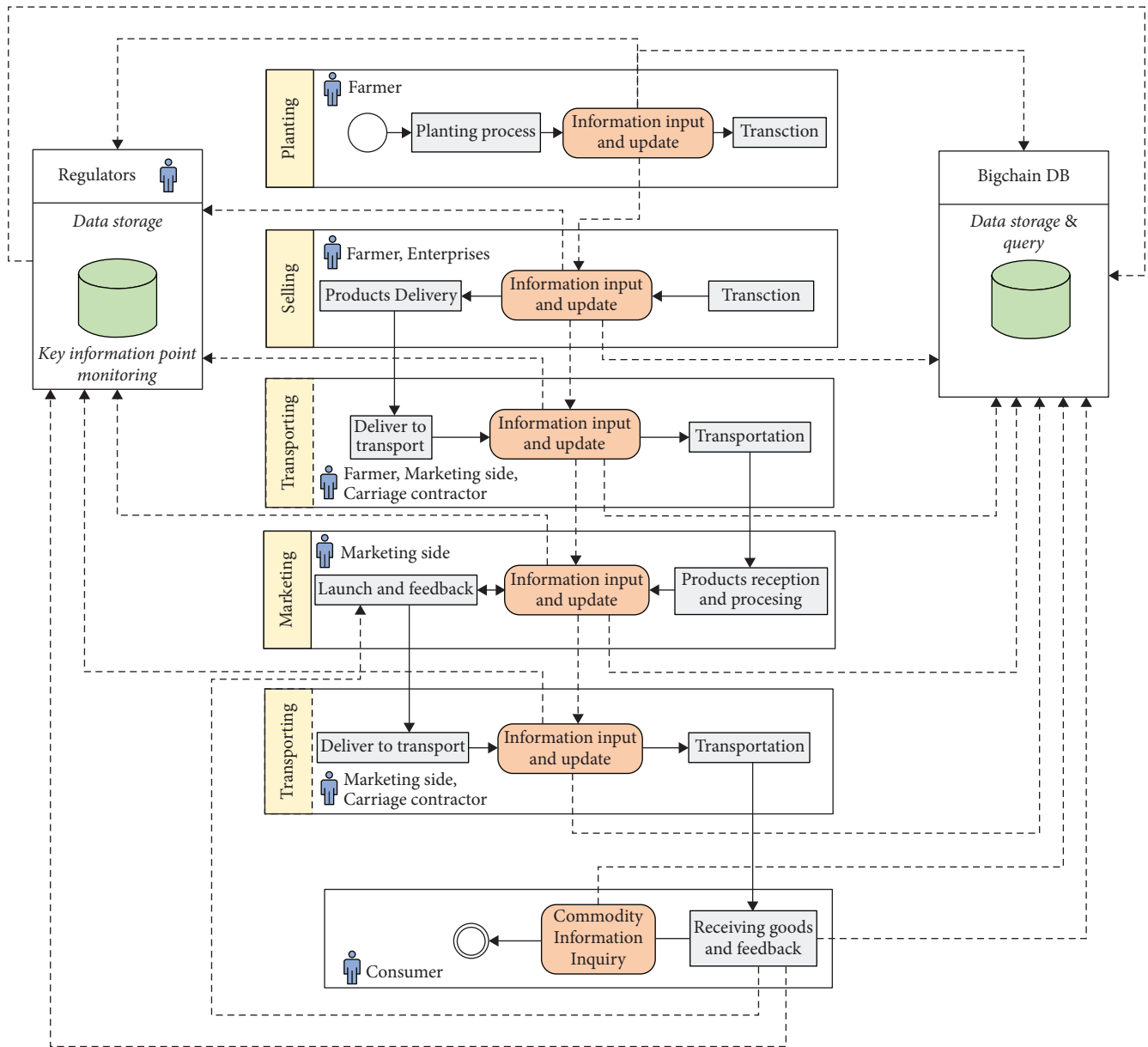
FIGURE 2: Information flow diagram of agricultural supply chain information storage and traceability system.

according to the overall supply chain specifications and their own needs.

Farmer: as the source of the supply chain, farmers need to take the role of importer of planting information, which can serve as the basis for the behavior of subsequent supply chain members and even consumers and can also be used for the review, evaluation, and accountability by government regulatory authorities. Farmers have the right to inquire about the subsequent product processing behavior and marketing behavior, so that they can better understand the latest market demand and product position, to reasonably adjust their planting plan instead of blindly relying on experience to make decisions. Moreover, in the process of bargaining with the market side, farmers often lack a specific cognition of the real product price because of the lack of knowledge of market sales strategy. Through the inquiry of the market side's previous sales data, farmers can also make a more reasonable valuation of their products.

Marketing side: the data that the marketing side needs to input is mainly its own behavior after production, including storage, fresh-keeping, processing, transportation, and sales. Compared with farmers, the information is more complex, and it is the key object that the government regulatory authorities need to supervise. Since the behaviors of the marketing side are directly related to the quality of the goods purchased by the consumers in the final market, the authenticity and effectiveness of its input data are vital. The marketing side should not be completely profit-oriented but also take social and environmental responsibilities into

account and adopt certain ecological protection measures. Additionally, because the farmer is the products' information source of the marketing side, sellers used to be at an information disadvantage and often suffer losses due to false information or misjudgment of experience. By querying farmers' planting information, the marketing side can have a comprehensive understanding of the planting details and make reasonable behavior decisions and price negotiations.

Government regulatory authority: in addition to supply chain information, government regulatory departments need to input legal provisions and regulatory standards that supply chain members need to abide by, to release all the information that supply chain members need to know in real-time. In the meanwhile, for the government regulatory authority, the supply chain information traceability system is more important for information inquiry and inspection, so that the regulatory authority can be directly associated with all information data from planting to final sale, and the errors caused by the multisubject transmission of information can be reduced. Because the environmental performance of products is the combined output of all operation processes involved, the behaviors in the supply chain should be evaluated more comprehensively and standardized.

Consumer: the main demand of market consumers in the supply chain information traceability system of agricultural products is information inquiry. According to their own requirements for the characteristics of the product, they can query a series of information about the product from planting to the final product to make a trade-off in mind, considering quality and price, to avoid being misled by the market side's false propaganda. Furthermore, the feedback from consumers will also be input into the traceability system, which will serve as the evaluation criteria for the regulatory authorities.

3.2. Main Process Analysis and Source Data Entry. According to the entities involved in the agricultural supply chain, this paper divides the main links of the supply chain into the planting link and the marketing link, supplemented by the transportation link as the intermediate link and the supervision link as the external constraint.

3.2.1. Planting. The information owner is the farmer. The sublinks include not only the selection and treatment of seeds, but also a series of processes including sowing, fertilization, irrigation, and harvest. The planting process decides the products' basic quality and quantity. Furthermore, the operation of the farmer has a vital effect on the following action of subsequent links.

3.2.2. Transaction. The transaction link is the process in which farmers negotiate the price on the marketing side and determine the order quantity. In this link, both parties will conduct a game with the goal of "maximizing revenue" according to their own needs and the information they have mastered, to reach the final subscription agreement. Therefore, in this link, the information owners are the farmers and the marketing side.

3.2.3. Marketing. The information owner of this link is the marketing side, specifically, all kinds of e-commerce platforms of online channels and physical stores such as shops and supermarkets of offline channels. The sublinks are relatively more complex. In addition to marketing, they also include intermediate links such as product storage, preservation, processing, and packaging, as well as recycling links after the sales process.

3.2.4. Transportation. Transportation exists in the whole process of the supply chain as an intermediate link connecting the main behaviors of supply chain members. At the end of the planting process, the fresh products produced by the farmer need to be transported to the storage location on the marketing side. Whether the farmer or the market is responsible for this transport depends on the purchase agreement between the two parties. In the market segment, the warehoused products are sent to the market for sale, and the marketing side takes on the transportation costs. The input data in the transportation process are mainly distance, time, transportation mode, and partner's qualification information, so that the subsequent members of the supply chain can judge the quality, maintenance, and deterioration of fresh agricultural products.

3.2.5. Supervision. The information ownership of the supervision link is government regulatory departments. The main input information is the policy issued by the regulatory authority, so that supply chain members know the standards of conduct they should abide by. It also includes the result information obtained from the active qualification audit of supply chain members by the regulatory authorities, as well as the spot check and audit of link operations and output products.

According to the analysis of five links of the agricultural supply chain, we can conclude with an information flow diagram consistent with the producing, processing, and selling procedures of agri-food products. The dimensions of information input are considered from time (time point/period/frequency), place, environment (condition), equipment, method, information of entities, quantity, price, etc. The flow diagram of the whole processes of the agricultural supply chain is shown in Figure 3:

4. Identifying Key Regulatory Decisions towards Eco-Economics Sustainability in This Agricultural Supply Chain

A supply chain that provides goods or services without harming the environment can be regarded as sustainable [31]. However, profit-orientation is more likely to be the
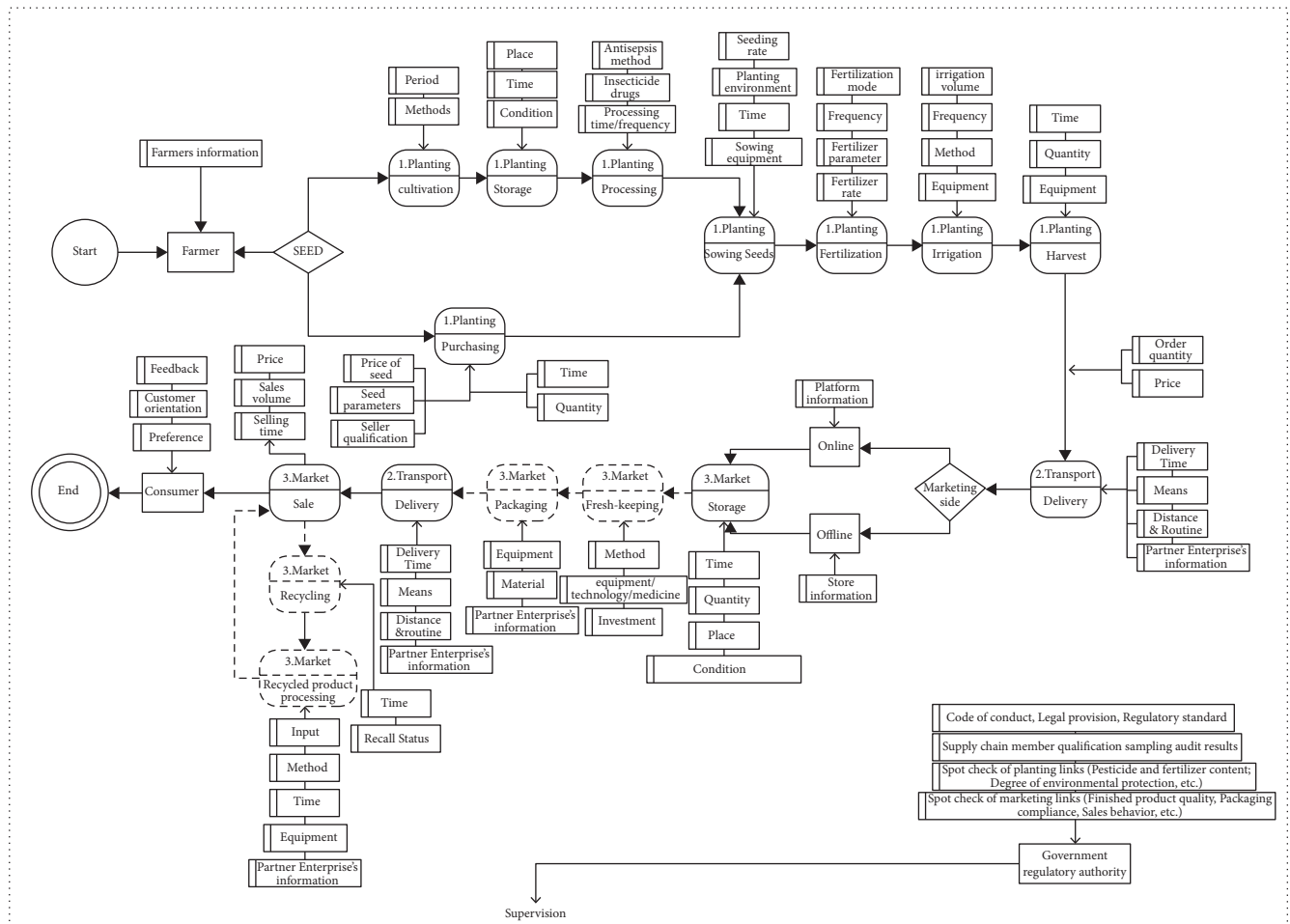
FIGURE 3: Agricultural supply chain flow diagram.

priority of supply chain entities. To achieve the balance between ecology and economy, specific demands and processes should be analyzed to identify key control points in the agricultural supply chain. Table 1 shows the main stage links as well as corresponding information input according to the goals and requirements of each link.

It is necessary to clarify key regulatory points, carrying out scientific supervision in a targeted way. For better exploring the relationship among links and information points, this paper establishes a DEMATEL-ANP model, to first determine the interrelationships between primary indicators and then calculate sublinks' weights. Then, based on the DEMATEL-ANP model, key regulatory points can be concluded, in order to achieve comprehensive supervision. A case study is presented to show how this model is applied to agricultural supply chain.

4.1. The Establishment of First-Stage Link Influence Relation Based on DEMATEL Method

4.1.1. Formation of Direct Relation Matrix.
We invite 5 supply chain researchers, 5 industry experts from agrifood enterprises, 5 farmers who plant fruits and vegetables, and 5 market participants working as the managers of the processing

company, to fill out the questionnaire prepared. Through evaluation of the answers to the questionnaire, the validity of the questionnaire reached 85%. They are required to judge and grade the strength of the influence index U_i on U_j, taking environmental influences into account, where 0 represents no effect, 1 represents a slight effect, 2 represents an effect, 3 represents a high effect, and 4 represents an extremely strong effect. The direct relation matrix is obtained by using arithmetic mean method.

$$M = \begin{array}{c} \\ U_1 \\ U_2 \\ U_3 \\ U_4 \end{array} \overset{\begin{array}{cccc} U_1 & U_2 & U_3 & U_4 \end{array}}{\begin{pmatrix} 0 & 3.500 & 3.125 & 2.000 \\ 2.125 & 0 & 2.500 & 2.000 \\ 3.000 & 2.750 & 0 & 1.500 \\ 1.000 & 0.750 & 1.750 & 0 \end{pmatrix}}. \tag{1}$$

4.1.2. Calculate Standardized Direct Relation Matrix and Comprehensive Influence Matrix

(1) We can get $\lambda = 0.1159$ by applying the following formula:

TABLE 1: The identification system of key points of government supervision.

First stage link	Second stage link	Goal	Information input
Planting U_1	Basic information of farmer U_{11}	Farmers have good qualifications and reputations.	The information of farmer
	Seed cultivation U_{12}	Cultivate high quality and high emergence rate of the seed; The process is as environmentally friendly as possible.	Cultivation period, Cultivation method
	Seed storage U_{13}	Extend the service life and use quality of seeds as much as possible.	Storage location, Storage time, Storage condition, Antisepsis method, Insecticidal drugs
	Seed processing U_{14}		Processing time/frequency
	Seed purchase U_{15}	Pursuing high-quality seeds under the premise of high-cost performance.	The price of seed, Seed parameters (variety), Qualification of the seller, Purchasing time, Purchasing quantity
	Sowing U_{16}	Realize the high yield and high-quality growth of subsequent crops.	Planting environment, Sowing time, Sowing equipment/method, Sowing quantity
	Fertilization U_{17}	Increase crop yield, improve crop quality and soil fertility, avoid unnecessary waste of fertilizer resources and excessive damage to the soil.	Fertilizing frequency, Fertilizer parameters (variety), Fertilizer dosage, Fertilization pattern
	Irrigation U_{18}	Ensure the normal growth of crops, obtain high and stable yield.	Irrigation frequency, Irrigation method, Irrigation equipment, Irrigation volume
	Harvest U_{19}	Ensure the best quality and quantity of crop output.	Harvest time, The total harvest, Harvest equipment
Transaction U_2	Transaction between farmers and enterprises U_{21} Transaction among farmers, enterprises and contractors U_{22}	Each party obtains the ideal profit in the transaction process.	Order quantity Price

TABLE 1: Continued.

First stage link	Second stage link	Goal	Information input
	Basic information of marketing side U_{31}	Enterprises have good qualifications and reputations.	Platform information, etc. Shop information, etc.
	Storage U_{32}	Minimize the rate of fresh produce spoilage through proper storage to ensure high-quality products for sale.	Storage time; Storage quantity; Location of warehouse; Condition of warehouse; Method of fresh-keeping
	Fresh-keeping U_{33}	Try to keep fresh produce as fresh as possible and ready for market.	Fresh keeping equipment/technology; Fresh keeping investment
	Packaging U_{34}	Enhance product's added value through high-quality packaging.	Packaging machinery; Packaging material; Packaging partner information
Marketing U_3	Selling U_{35}	Maximize revenue.	Market price; Sales volume; The selling time; Recycling time; The state of the product recalled
	Recycling and Reprocessing U_{36}	Take full advantage of the residual value of the product.	Reprocessing investment; Reprocessing method; Reprocessing time; Reprocessing equipment; Processing partner information
	Customer information U_{37}	Fully understand the target customer preferences, grasp the market trends.	Customer group; Customer preferences; Product feedback (consumer input)
Transportation U_4	Delivery of products U_{41}	Deliver the goods to the destination quickly and well.	Delivery time; Delivery method; Delivery distance; Transportation partner information
	Delivery of commodities U_{42}		

$$\lambda = \left\{ \frac{1}{\max\limits_{1\leq i\leq n}\left(\sum_{j=1}^{n} M_{ij}\right)}, \frac{1}{\min\limits_{1\leq j\leq n}\max\limits_{1\leq j\leq n}\left(\sum_{i=1}^{n} M_{ij}\right)} \right\}. \tag{2}$$

(2) Then, calculate X according to the following formula:

$$X = \lambda \times M,$$

$$X = \begin{pmatrix} 0 & 0.4058 & 0.3623 & 0.2319 \\ 0.2464 & 0 & 0.2899 & 0.2319 \\ 0.3478 & 0.3188 & 0 & 0.1739 \\ 0.1159 & 0.0870 & 0.2029 & 0 \end{pmatrix}. \tag{3}$$

(3) Comprehensive influence matrix T can be obtained by formula (3), and I represents fourth order identity matrix.

$$T = X(I - X)^{-1},$$

$$T = \begin{pmatrix} 0.8092 & 1.1898 & 1.1832 & 0.9012 \\ 0.8421 & 0.7122 & 0.9553 & 0.7584 \\ 0.9816 & 1.0466 & 0.8186 & 0.7866 \\ 0.4821 & 0.4992 & 0.5892 & 0.3300 \end{pmatrix}. \tag{4}$$

4.1.3. Calculate Centrality and Causality. Row sum calculation by the following formula:

$$D_i = \sum_{j=1}^{n} t_{ij}, \quad i = 1, 2, \cdots, n. \tag{5}$$

Line sum calculation by the following formula:

$$R_j = \sum_{i=1}^{n} t_{ij} \, (j = 1, 2, \cdots, n). \tag{6}$$

Centrality calculation by the following formula, which reflects the degree of factors' effect.

$$D_i + R_j = \sum_{i=1}^{n} t_{ij} + \sum_{j=1}^{n} t_{ij} \quad (i = 1, 2, \cdots, n; j = 1, 2, \cdots, n). \tag{7}$$

Causality calculation by the following formula:

$$D_i - R_j = \sum_{i=1}^{n} t_{ij} - \sum_{j=1}^{n} t_{ij} \quad (i = 1, 2, \cdots, n; j = 1, 2, \cdots, n). \tag{8}$$

If $D_i - R_j > 0$, it means that this factor is a causal factor and has an impact on other indicators.

If $D_i - R_j < 0$, then this factor is an affected factor and has a lot of room for improvement.

The calculated centrality and causality are shown in Table 2.

TABLE 2: Centrality degree and cause degree of the first-stage link.

j	i						
	U_1	U_2	U_3	U_4	D_i	$D_i + R_j$	$D_i - R_j$
U_1	0.809 2	1.189 8	1.183 2	0.901 2	4.083 4	7.198 4	0.968 4
U_2	0.842 1	0.712 2	0.955 3	0.758 4	3.26 8	6.715 8	−0.179 8
U_3	0.981 6	1.046 6	0.818 6	0.786 6	3.633 4	7.179 7	0.087 1
U_4	0.482 1	0.499 2	0.589 2	0.33	1.900 5	4.676 7	−0.875 7
R_j	3.115	3.447 8	3.546 3	2.776 2			

4.1.4. Draw the Cause-and-Effect Diagram. According to the direct relation matrix M calculated by DEMATEL, based on whether the elements in the matrix interact, the relationship is set as 1, and no relationship is set as 0, which can form a binary matrix D.

$$\begin{matrix} & U_1\ U_2\ U_3\ U_4 \\ D = \begin{matrix} U_1 \\ U_2 \\ U_3 \\ U_4 \end{matrix} & \begin{pmatrix} 0 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 \end{pmatrix}. \end{matrix} \tag{9}$$

Add the matrix to its transpose, $D\prime$, to form the matrix P.

$$P = D + D' = \begin{pmatrix} 0 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 \end{pmatrix} + \begin{pmatrix} 0 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 \end{pmatrix} = \begin{pmatrix} 0 & 2 & 2 & 2 \\ 2 & 0 & 2 & 2 \\ 2 & 2 & 0 & 2 \\ 2 & 2 & 2 & 0 \end{pmatrix}. \tag{10}$$

According to the following rules,

(i) $C_{ij} = 0$: Indexes i and j have no influencing relationship.

(ii) $C_{ij} = n\ d$: Index i has no effect on index j but j has effects on i.

(iii) $C_{ij} = 1$: Index j has no effect on index i but i has effects on j.

(iv) $C_{ij} = 2$: Indexes i and j have an interactive relationship.

Then, we can get

$$C = P = \begin{pmatrix} 0 & 2 & 2 & 2 \\ 2 & 0 & 2 & 2 \\ 2 & 2 & 0 & 2 \\ 2 & 2 & 2 & 0 \end{pmatrix}, \tag{11}$$

based on which the cause-and-effect diagram is drawn in Figure 4.

We can conclude that planting link U_1 and marketing link U_3 are causal in that they have major impacts on other links because the major producing and processing happen within these two links, which conforms to the existing conclusions of researches. The transaction link U_2 and transportation link U_4 are result links. These two links mainly represent the circulation process in the supply
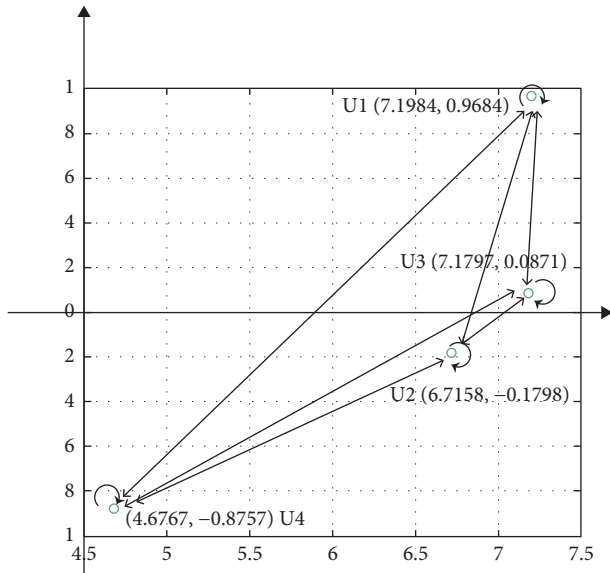
FIGURE 4: Causality diagram of the first-stage link.

chain. The technical input and planting methods carried out by farmers in the planting process are directly related to the cost paid and emissions produced. The warehousing, preserving, and selling methods used by the marketing side also determine the wholesale price boundary of the product they are willing to pay. The market feedback obtained from the selling process has a guiding role in the formulation of price agreements and wholesale quantity between farmers and market parties as well as the sustainable behaviors affected by consumers' environmental tendencies. The quality of the products produced in the planting process and the efforts of the marketing side to keep the products fresh and store the products greatly affect the final state of the finished products delivered to the market and the degree of sustainability of the whole supply chain, thus affecting the market demand and influencing the next order decisions. Correspondingly, it also put forward a series of requirements on the transportation conditions.

According to the ranking of center degree, the ranking of importance among the four links can be obtained, which shows $U_1 > U_3 > U_2 > U_4$. Planting link is a key link in the output of fresh agricultural products, and its results directly determine the decisions of the following three links, so it deserves more attention.

As the information points within the four links are interdependent and influential, it is necessary to further explore their internal relations to determine the key points of government supervision.

4.2. The Weight Determination of Secondary Information Points Based on ANP Method.

Based on the logical relationship between links defined by DEMATEL method, in order to better explore the interrelation of information points within the links, ANP network analytic hierarchy process is used to determine the weight of information points. The correlation and structure network

relationships based on ANP method can be found in Table 3 and Figure 5.

The Delphi method is adopted to conduct a questionnaire survey on the importance of regulation of each point. 20 interviewees in Section 4.1 were invited in DEMATEL method in three groups, namely, the planting aspect, the marketing aspect, and the ecology, to score the importance of information points. It is not hard to understand that the two former aspects' results are collected from entities in supply chain, which are inevitably greatly affected by profits orientation. And results from the ecology aspects are more likely to be cost-irrespective. The software Super Decisions was used for input and weight calculation. Each significant degree comparison step must pass the consistency test. Different perspectives determine their different preferences for key points of regulation. If the government wants to regulate comprehensively, it is required to consider the preferences of all parties.

The weights calculated according to scores given from different perspectives are shown in Table 4.

4.3. Key Control Point Analysis.

According to the importance degree weights of 20 subdivided information points of four links, namely, planting, trading, marketing, and transportation, obtained from the perspectives of maximizing the interests of farmers and market, as well as from the perspectives of ecology and quality orientation, it can be concluded that:

(1) The results of the first-stage link influence relation based on DEMATEL method are basically consistent with the importance ranking obtained from the second-stage information points of ANP, and the four links have interactive relationships. For all intents and purposes, the planting process is considered the most important. From an economic point of view, as the planting link is the main process of commodity output; it plays a decisive role in the quality of the final product. The macroscopic supply and demand relationship, as well as the wholesale price and quantity negotiated by farmers with the marketing side according to the harvest situation, has a certain degree of decisive effect on the market price of the final product put on the market, and the quality of product output will put forward the corresponding requirements for subsequent transportation and storing conditions. Therefore, the completion of planting links has a crucial impact on the interests of supply chain members. From an ecological point of view, every subdivision of the planting process is closely related to the ecological environment such as water and soil. The major producing and processing are both within this link. Therefore, no matter from any aspect of view to score the importance, information points in this link are more likely to be given more attention. In addition, compared with other links, this link is more applied to the cultivation and planting of plants through

Table 3: Correlation of secondary information points based on ANP.

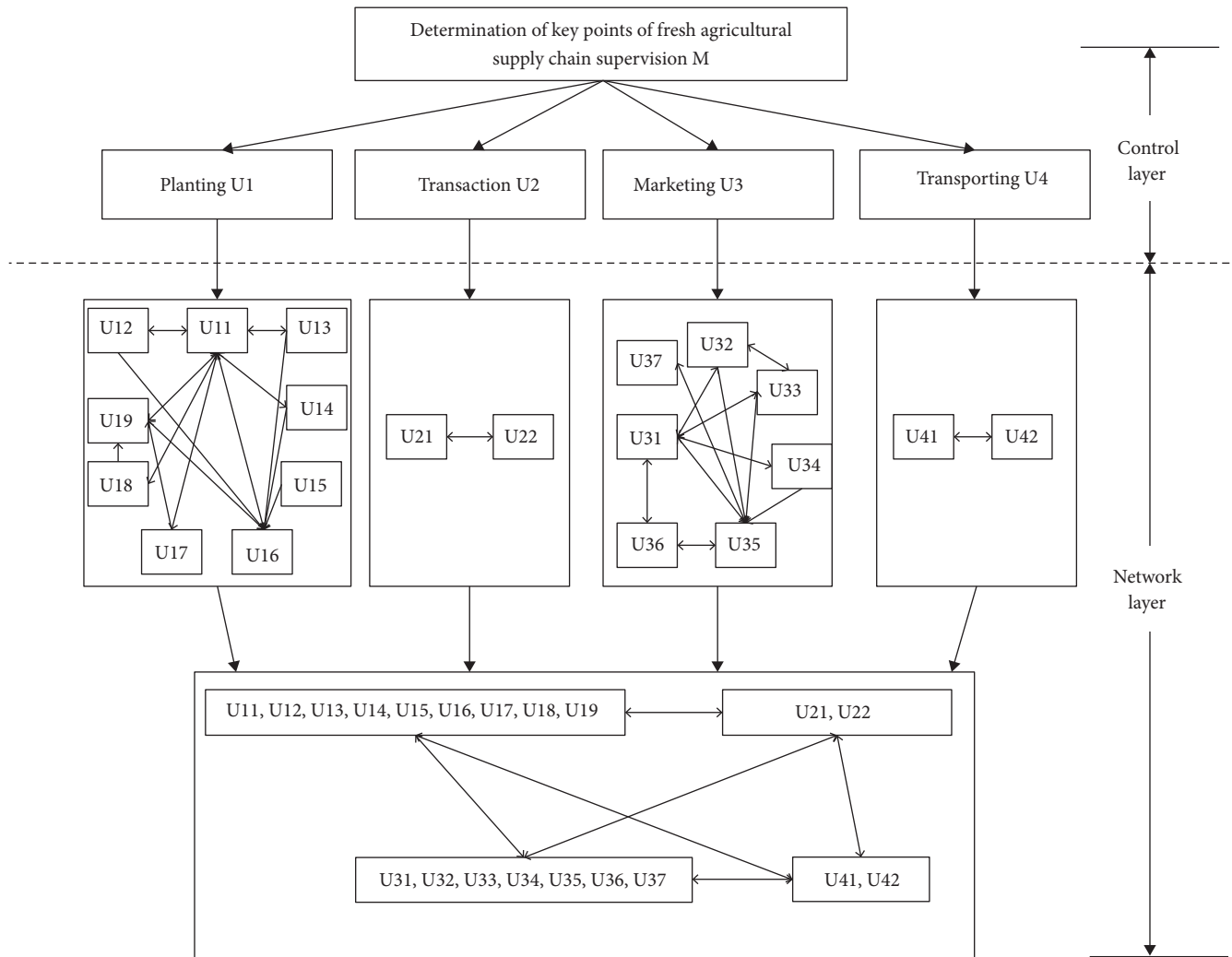|	Planting U1									Transaction U2		Marketing U3							Transportation U4	
	U11	U12	U13	U14	U15	U16	U17	U18	U19	U21	U22	U31	U32	U33	U34	U35	U36	U37	U41	U42
U11																				
U12	✓																			
U13	✓																			
U14	✓																			
U15																				
U16	✓																			
U17	✓																			
U18	✓																			
U19	✓						✓	✓												
U21		✓	✓	✓	✓				✓											
U22						✓			✓											
U31										✓	✓									
U32												✓								
U33											✓	✓	✓							
U34											✓	✓	✓							
U35		✓	✓		✓						✓	✓	✓				✓	✓		
U36												✓				✓				
U37																✓				
U41	✓												✓	✓	✓	✓				
U42													✓	✓		✓			✓	

Figure 5: ANP network structure.

Table 4: Subdivide index weights.

Farmer-oriented			Sort	Enterprise-oriented			Sort	Ecology-oriented			Sort
U1 0.666 208 759	U11	0.170 22	1	U1 0.725 121 7	U11	0.204 1	2	U1 0.549 581 495	U11	0.169 403	1
	U12	0.083 12	6		U12	0.051 071	6		U12	0.026 392	12
	U13	0.028 09	9		U13	0.009 256	17		U13	0.006 534	19
	U14	0.028 09	9		U14	0.009 256	17		U14	0.010 325	17
	U15	0.086 04	5		U15	0.065 189	5		U15	0.036 827	10
	U16	0.113 5	4		U16	0.096 658	4		U16	0.065 253	6
	U17	0.015 48	13		U17	0.034 91	8		U17	0.057 468	8
	U18	0.015 39	14		U18	0.034 91	8		U18	0.054 691	9
	U19	0.126 28	3		U19	0.219 765	1		U19	0.122 693	2
U2 0.099 918 415	U21	0.039 19	8	U2 0.068 787	U21	0.022 212	11	U2 0.038 772 486	U21	0.009 419	18
	U22	0.060 73	7		U22	0.046 575	7		U22	0.029 354	11
U3 0.217 949 174	U31	0.012 26	16	U3 0.160 398 4	U31	0.013 69	13	U3 0.375 472 317	U31	0.102 947	3
	U32	0.011 28	17		U32	0.011 9	16		U32	0.059 997	7
	U33	0.018 89	12		U33	0.013 629	15		U33	0.086 658	4
	U34	0.003 75	20		U34	0.003 627	20		U34	0.019 871	15
	U35	0.130 53	2		U35	0.096 72	3		U35	0.078 708	5
	U36	0.013 2	15		U36	0.007 153	19		U36	0.022 98	13
	U37	0.028 04	11		U37	0.013 684	14		U37	0.004 305	20
U4 0.015 931 964	U41	0.008 58	18	U4 0.045 697 2	U41	0.028 048	10	U4 0.036 173 619	U41	0.015 593	16
	U42	0.007 35	19		U42	0.017 649	12		U42	0.020 581	14

microorganisms, so it has a higher weight in ecological importance.

(2) From the perspective of farmers and the marketing side, the three information points with the highest importance are as follows: farmer qualification, sales, and harvest information. In the same way that the importance of the planting process is the highest, the farmer's qualification means the corresponding technical foundation, planting experience, product reputation, and sustainability awareness, so for the market side, this information point not only is an important basis for establishing cooperation, but also has a significant correlation with the final product quality. Farmers themselves will also work to build a better reputation for their qualifications, which in turn will bring in more purchase orders. Sales on the marketing side and harvest on the farmer's side are the end links of the planting and marketing processes. These two links are directly connected with product trading and, therefore, are directly related to the income results of both sides. And though it is set that "sustainability" should be taken into consideration, practitioners in the supply chain inevitably tend to think about profits when asked about the importance of regulatory points. Therefore, introducing the third group to evaluate the importance of supply chain information from an ecological perspective is vital.

(3) From the perspective of "ecology," it can be found that more attention is paid to the qualification information, as well as the link processes such as storage, preservation, fertilization, and irrigation. Qualification information reflects entities' senses of social responsibility, not only from products' quality, but also from sustainability. Profit-oriented supply chain behaviors often lead to frequent violations at the expense of the ecological environment. Therefore, grasping the process points that are most directly related to the environment can effectively regulate the behaviors of supply chain members, conduct comprehensive supervision, and realize the balanced development of the whole supply chain.

According to the identification and analysis of ecological critical control points from different perspectives, it can be concluded that the comprehensive supervision of government departments not only needs to take into account the profit-oriented behaviors of supply chain members, but also needs to control from a macro perspective, to realize the simultaneous maintenance of economic behaviors, ecological environmental protection, and consumer food health.

4.4. Policy Suggestions on Government Supervision.

According to the obtained critical control points and the basic characteristics of agricultural supply chain information storage and traceability system, we put forward the following suggestions on government supervision policy:

(1) Give full play to the regulatory role of the government, unify the economic, ecological, and quality regulatory standards of the same fresh agricultural products in each region, and clarify the code of conduct, norms and punishment measures of different subjects in the supply chain. Different regulatory policies must cooperate and coordinate with each other well.

(2) Strengthen the supervision of the ecological behavior of supply chain members. Focus on the qualification information of supply chain members and the output link of products, give full play to the advantages of Blockchain and other advanced technologies to collect comprehensive and true information, and focus on supervision and review. Once the defective link is detected by supervision, the government department should immediately correct the fault and order the rectification until the members of the supply chain meet the standards.

(3) Compared with other products, the supervision of the supply chain of fresh agricultural products should pay more attention to timeliness. To attach importance to the performance of supply chain supervision, the first step is to shift the focus of supervision from economic behavior to ecological behavior. The improvement of the system plays a certain role in promoting the improvement of the supply chain ecosystem and environmental quality, but if it lags behind the technical level, it cannot play the interactive effect between the two. Therefore, government departments must attach importance to the role of supervision, take the degree of "sustainability' of supply chain as the goal, regulate the economy-oriented behaviors of supply chain members, and encourage and support supply chain members to adopt more environmentally friendly and quality-first behaviors and measures by policy means.

(4) Both macroscopic and microscopic perspectives should be taken into account. In addition to the overall benefits of supply chain, government supervision departments also need to consider the collection of opinions from individual supply chain subjects. Supply chain participants tend to provide more realistic data and information to assist in overall supervision. At the same time, the regulatory standards set by the government departments should be combined with the actual situation and demand and should not set too high a threshold to bring burdens to members of the supply chain.

(5) Punishment means, as well as reward and subsidy measures, should be included. In addition to setting regulatory standards and corresponding punitive measures, the government should take incentives, subsidies, and other measures to encourage supply chain members to increase ecological investment in production and sales behavior and guide them to establish reasonable cooperation among members
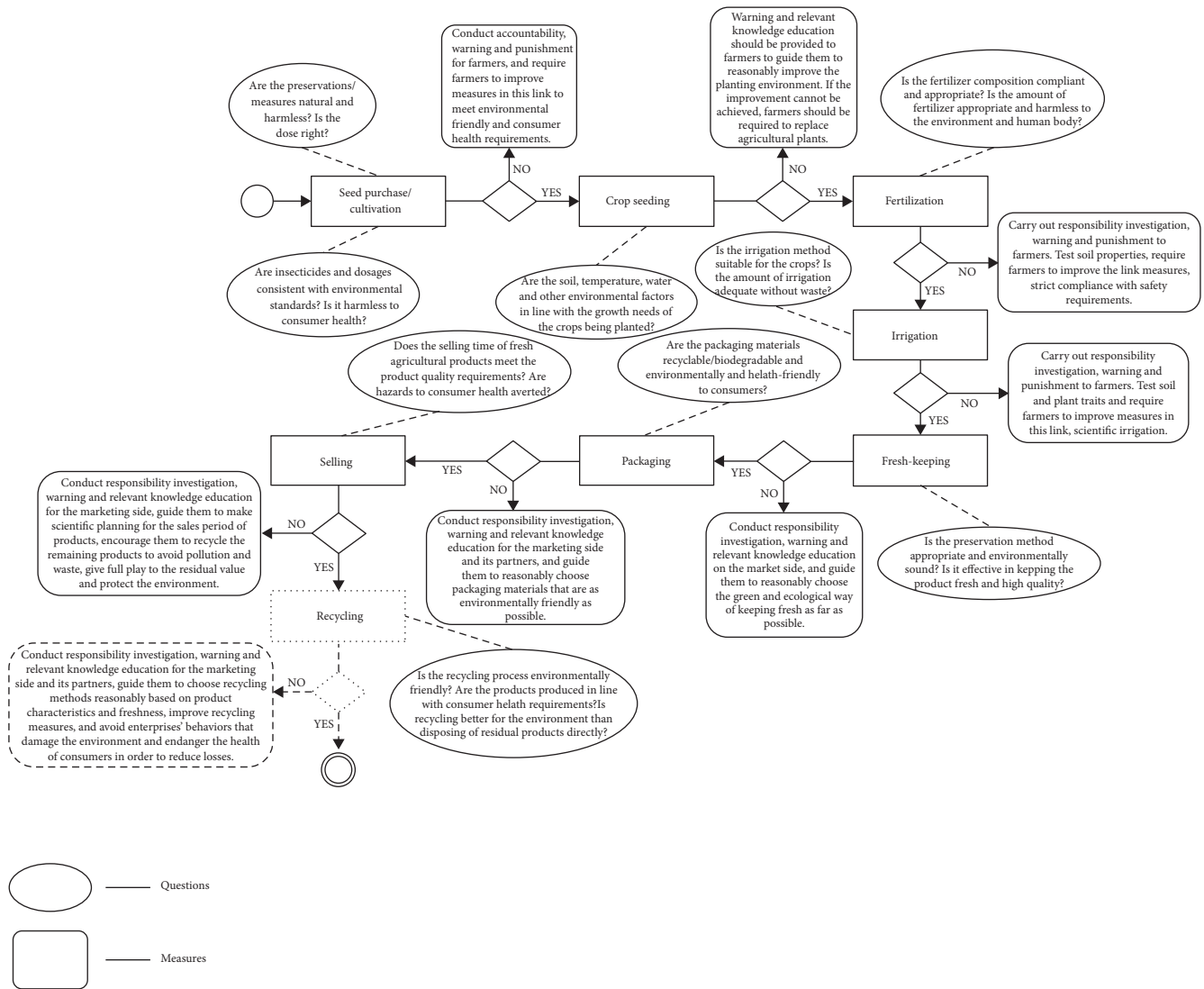
FIGURE 6: Regulatory flow diagram under critical control points.

with the guidance of "sustainable development of supply chain."

(6) Through the intervention of blockchain and other technologies, the behavior of supply chain members and the authenticity of reported information should be more standardized. Focus on key links and information point monitoring for "early discovery, early punishment, early correction." Regulatory information should be timely fed back in the supply chain member qualification information to play a certain warning role.

Combined with the supply chain process and key points of information input, this paper puts forward the following suggestions on the regulatory flow diagram as Figure 6:

5. Conclusion

Based on the characteristics of the agricultural supply chain and the advantages of the decentralized database, this paper established the system architecture of agricultural supply chain information storage and traceability. At the same time, in order to achieve comprehensive and sustainable supervision, this paper starts from several core links, discusses the main information points worth attention in each link, and applies the theoretical method of DEMATEL + ANP from the perspectives of farmers, marketing side and the whole supply chain ecology in the form of expert inquiry. With the two methods applied, the interrelationships among indicators are shown, and the causal and result factors are identified to better locate the key points. The critical control points with the goal of "maximizing the benefit of supply chain members" and "optimizing the ecological quality of supply chain are determined, respectively. Finally, according to the analysis of the critical control points and the traceability system architecture, the corresponding suggestions for supply chain supervision are put forward.

The application of blockchain in the agricultural supply chain in actual practice is still at the early stage, and this paper only puts forward the vision of how to take advantage of blockchain's strength, to better apply methods of

management science to assist supply chain operation. However, it fails to point out how to put the traceability system into practice, and it should be explored in the following research.

Data Availability

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

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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