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Original scientific paper

Examining the Supply Chain Management Models for Agricultural Products Under the Context of E-Commerce

Weiqing ZHANG, Jiaxin LI, Yajie HE*

Abstract: Agricultural products market changes constantly along with the thriving of e-commerce and agricultural products e-commerce keeps growing as an innovative industry; however, there are still many loopholes in the management of the supply chain from beginning to end. In order to effectively address these issues, this paper utilizes the dynamic requirement forecasting method based on SVM (support vector machine) to identify and fit the secular trend in and potential cyclical fluctuation factors for the market requirements for agricultural products. The supply chain coordination decision center is established by integrating the collaborative supply management component and other components. XML technology and CORBA technology are adopted to construct the integrated management model of agricultural products supply chain in e-commerce environment. For its relatively high management level, the model established can promote both agricultural consumption and agricultural economic output, strengthen the competitiveness of enterprises in agricultural products market and realize maximization of profit targets.

Keywords: agricultural products; e-commerce; market requirements forecasting; supply chain management model

1 INTRODUCTION

The information technology and network technology with their rapid and vigorous development have brought about fundamental transformation to world economy and a new economic era has begun. This era, mainly featuring globalization, informatization, networking and digitalization, has derived new environmental characteristics [1-4]. The design, production, distribution and other links of all kinds of products are faced with new challenges in such economic environment [5], and the relationship between consumers and retailers has also changed [6-7]. Various advanced technologies have the chance for extensive application in order to better adapt to the evolution of economic environment [8]. To build e-commerce platforms based on information technology has become an effective tool for most enterprises in handling market environment changes by integrating all effective resources to speed up transportation in all aspects and strengthen enterprise competitiveness [9-10]. The advantage of e-commerce business model becomes more and more obvious for it can not only break the limits of thinking but also simplify communication links and thus promote both effectiveness and efficiency of business activities [11-13]. On e-commerce transaction platforms, enterprises can ensure unimpeded logistics according to the dynamic information of capital flow and information flow [14-16]. Such transaction form can prevent information delay and distortion from the source by virtue of high-efficiency and low-cost network development approaches [17-19]. The onrush of the Internet and e-commerce technology diverts more and more enterprises to alignment. They adopt e-commerce platforms as technological means and establish integrated supply chain systems to realize network-based management of supply chains [20-22]. This management mode consists of manufacturers as well as upstream and downstream enterprises. Upstream and downstream enterprises are organically integrated through the Internet e-commerce technology with manufacturers at the core. Upstream enterprises include raw material producers and suppliers and downstream enterprises include distributors, providers and correspondence banks [23]. This customer-oriented e-commerce supply chain aims to cut transportation costs and speed up response to customer requirements so as to yield twice the result with half the effort [24].

With the increasing popularity and advancement of the Internet, more and more people have accepted e-commerce products, and agricultural products have also found a place on various e-commerce platforms. Increasing items of agricultural and sideline products such as vegetables, soy products, seasonal fruits, meat, poultry and eggs can not only enrich e-commerce platforms, but also gain more customers. Therefore, this paper targets agricultural products and forms a supply chain coordination decision center using the collaborative requirements management component, the collaborative production planning and scheduling component and other components. With the supply chain coordination decision center at the core, the integrated agricultural products supply chain management model is designed on e-commerce platforms by adopting the business function layer, the unified data layer and the information infrastructure layer. The establishment of this model is practically meaningful mainly in that it can actively promote the circulation of agricultural products on e-commerce platforms, enrich the perspectives of supply chain optimization researches, and practically help e-commerce platforms involved in agricultural products industry to improve their supply chain management level.

2 LITERATURE REVIEW

Many experts and scholars have made different definitions to the concept of supply chain and they have done studies on supply chain management in different directions. Reference [25] assessed the benefits brought by implementing ERP technology and green supply chain management to the operational performance of manufacturing industries under the current constraints of environmental protection and COVID-19 pandemic, the results of which could enrich current researches on supply chain management. Reference [26] explored how the application of blockchain technology could improve global marine conservation and fisheries supply chain management. The utilization of automatic consensus protocols enabled verification and permanent storage of data transmitted over the network and reduced the risk of data corruption to near zero. Reference [27] discusses the importance of sustainability to supply chain management based on the novel DEA approach. Reference [28] adopted a theoretical extension approach for concept development and took Concurrent Engineering as the "Method" to explore the core process in supply chain. The research results provided the conceptual framework and research agenda for researchers and practitioners dedicated to adjusting current supply chain processes to support CE implementation. Reference [29] developed a multi-item questionnaire by applying the quantitative model. Structural equation modelling was used to test research hypotheses. The management of supply chain quality could promote agility and innovative capability and further improve performance. Reference [30] integrated blockchain into supply chains and designed a digital supply chain based on blockchain technology for logistics and supply chain management in the real world. In reference [31], Internet service platforms and big data marketing were regarded as an independent game theme and integrated into the dynamic closed-loop supply chain system. Bellman's continuous dynamic programming theory was utilized to get the optimal feedback strategies for price and big data marketing efforts, brand goodwill, return on used products and corporate profits in three business models. Reference [32] made a systematic review of previous researches and elucidated the potential contribution of blockchain technology to manufacturers as well as to the economic, environmental and social performance of their supply chains. The results extended the understanding of blockchain application in sustainable manufacturing and sustainable supply chains.

To sum up, current mainstream literatures mainly include researches on the optimization of supply chains for industrial and consumer goods, usually starting with the less efficient links in the supply chain. However, there are few researches on supply chains for agricultural products, especially on e-commerce-based ones. And even when there are, the exploration on supply chain management of such products is not deep enough. The integrated management model of agricultural products supply chain in the e-commerce environment constructed in this paper will effectively compensate for the shortcomings of current research.

3 AGRICULTURAL PRODUCTS SUPPLY CHAIN MANAGEMENT MODEL

3.1 Architecture of the Supply Chain Coordination Decision Center

The core of the integrated supply chain management model in e-commerce environment is defined by the information infrastructure layer, the unified data layer, the business function layer and the information presentation layer. The framework of the coordination decision center shown in Fig. 1 is composed of multiple components including the requirements management component, the supply management component, the production planning and scheduling component, the partner evaluation and selection component, the relationship management and restructuring component and the supply chain performance evaluation component. Each component is implemented as described in the following figure.

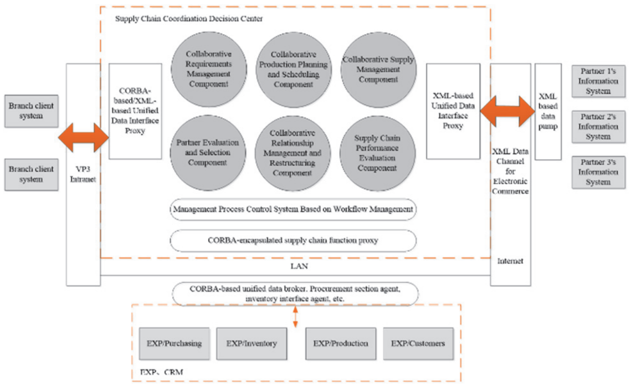


Figure 1 Coordination decision center

(1) The requirements management component. The function of this component is mainly to forecast market requirements. To provide a basis for the modelling and trend forecasting of supply chain market requirements, a dynamic agricultural products requirements forecasting method based on SVM is established to identify and fit the potential cyclical fluctuation factors and secular trend in the market requirements for agricultural products. The designed forecasting method divides real risk into empirical risk and confidence risk, the former being the error of the forecasting method based on given samples and the latter being the error of the forecasting method based on unknown samples. The confidence risk is subject to two factors, namely the Vapnik-Chervonenkis dimension of the sample data and the total sample number. Generally speaking, the larger the VC dimension or the smaller the number of training samples, the greater the confidence risk, and vice versa. Assuming that real risk is $R(C)$ and empirical risk and confidence risk are $R_{emp}(C)R(C)$ and $\phi(n/h)$ respectively, and that minimizing the sum of the two risks is minimizing the SVM of structural risk, the mathematical expression of structural risk is:

$$R(C) \le R_{emp}(C) + \phi(n/h) \tag{1}$$

Given that the sample number is n, the forecasted target object value is d_i, and the input sample data vector is x_i, the sample data set is.

$$D = \{(d_i, x_i)\}_{i=1}^{n} \tag{2}$$

If the nonlinear mapping relationship between input vector x and high-dimensional feature space is $\phi(x)$, the regression function expression of SVM is.

$$y = f(x) = w\phi(x) + b \tag{3}$$

where, w and b are the weight coefficient and the correction parameter respectively.

Hence the minimization objective function of structural risk is obtained as follows.

$$\text{Minimize: } R(C)=\frac{1}{2}\|w\|^2+C\frac{1}{n}\sum_{i=1}^{n}L_3(d_i,y_i) \tag{4}$$

In this function, C is an arbitrary constant the function of which is to balance $\frac{1}{2}\|w\|^2$ (the measurement of the geometric margin between support vectors) and $L_3(d,y)$ (the error term). If the error parameter is set as ε, the conditional expression of the value of the error term $L_3(d,y)$ is.

$$L_3(d,y)=\begin{cases}0 & |d-y|<\varepsilon\\ |d-y|-\varepsilon & |d-y|\geq\varepsilon\end{cases} \tag{5}$$

Add slack variables ζ and ζ^* to minimization of objective Eq. (4) to obtain the following objective function to calculate the values of w and b.

$$\text{Minimize: } R(w,\zeta,\zeta^*)=\frac{1}{2}\|w\|^2+C\sum_{i=1}^{n}L_3(\zeta_i+\zeta_i^*) \tag{6}$$

The constraints of this objective function are as follows.

$$\text{Subjected to: }\begin{cases}d_i-w\phi(x_i)-b\leq\varepsilon+\zeta_i\\ w\phi(x_i)+b-d_i\leq\varepsilon+\zeta_i^*\\ \zeta_i,\zeta_i^*\geq 0\end{cases} \tag{7}$$

According to Lagrange duality principle, dual variables are introduced and the non-negative condition is satisfied [33]. Then.

$$\alpha_i,\alpha_i^*,\eta_i,\eta_i^*\geq 0 \tag{8}$$

The function is constructed as follows.

$$\begin{aligned}L&=\frac{1}{2}\|w\|^2+C\sum_{i=1}^{n}(\zeta_i+\zeta_i^*)-\sum_{i=1}^{n}\alpha_i(\varepsilon+\zeta_i-d_i+\\&+w\phi(x_i)+b)-\sum_{i=1}^{n}\alpha_i^*(\varepsilon+\zeta_i^*+d_i-w\phi(x_i)-b)-\\&-\sum_{i=1}^{n}(\eta_i,\zeta_i+\eta_i^*,\zeta_i^*)\end{aligned} \tag{9}$$

According to the saddle point condition of Lagrange function in optimization theory, let the respective partial derivative of function L to variables (w,b,ζ_i,ζ^*) be 0 [34]. Using Wolfe-type dual technique, the following equation is obtained [35].

$$\begin{aligned}&\text{max i mize: } R(\alpha_i,\alpha_i^*)=-\frac{1}{2}\sum_{i,j=1}^{n}(\alpha_i-\alpha_i^*)(\alpha_j-\alpha_j^*)\cdot\\&\cdot\langle\phi(x_i),\phi(x_j)\rangle-\varepsilon\sum_{i=1}^{n}(\alpha_i-\alpha_i^*)+\sum_{i=1}^{n}d_i(\alpha_i-\alpha_i^*)\end{aligned} \tag{10}$$

$$\text{Subjected to: }\begin{cases}\sum_{i=1}^{n}(\alpha_i-\alpha_i^*)=0\\ \alpha_i,\alpha_i^*\in[0,C]\end{cases} \tag{11}$$

The precision of agricultural products market requirements forecasting is subject to the kernel function. Therefore, the following radial basis function is selected.

$$K(x,x_i)=\exp\left(-|x-x_i|^2/\sigma^2\right) \tag{12}$$

Hence, objective Eq. (8) and its influencing factor Eq. (9) turn to.

$$\begin{aligned}&\text{max i mize: } R(\alpha_i,\alpha_i^*)=-\frac{1}{2}\sum_{i,j=1}^{n}(\alpha_i-\alpha_i^*)(\alpha_j-\alpha_j^*)\cdot\\&\cdot K(x_i,x_j)-\varepsilon\sum_{i=1}^{n}(\alpha_i+\alpha_i^*)+\sum_{i=1}^{n}d_i(\alpha_i-\alpha_i^*)\end{aligned} \tag{13}$$

$$\text{Subjected to: }\begin{cases}\sum_{i=1}^{n}(\alpha_i-\alpha_i^*)=0\\ \alpha_i,\alpha_i^*\in[0,C]\end{cases} \tag{14}$$

The above two formulas are adopted to conduct integration training during the SVM-based agricultural products market requirements forecasting process, before which, however, the training samples should be generated. First, influencing factors for requirement change and historical sales data are smoothed, and singular values are eliminated. Then training samples are obtained after fuzzification and normalization processing. Eq. (13) and Eq. (14) are solved through SVM, and the solutions of α_i and α_i^* are obtained, of which $i = 1, 2, \ldots, n$. Substitute the above parameters into the following variation of regression Eq. (3) to forecast future market requirements for agricultural products based on the samples.

$$y=f(x,\alpha_i,\alpha_i^*)=\sum_{i=1}^{n}(\alpha_i-\alpha_i^*)K(x_i,x_j)+b \tag{15}$$

(2) The production planning and scheduling component. This component mainly aims to provide production planning and scheduling service for all partners in the supply chain on the premise of meeting customer demands. Specific work content includes making various plans such as production plans, procurement plans and so on. This opponent can realize unified inventory management through the overall management of all links along the agricultural products supply chain.

(3) The supply management component. The function of this component is to manage suppliers' goods supply and optimize the different stages of iintroduction, development, maturity and decline in the whole life cycle of agricultural products. With the support of extensible functional components, all types of procurement-related information are managed in a comprehensive manner.

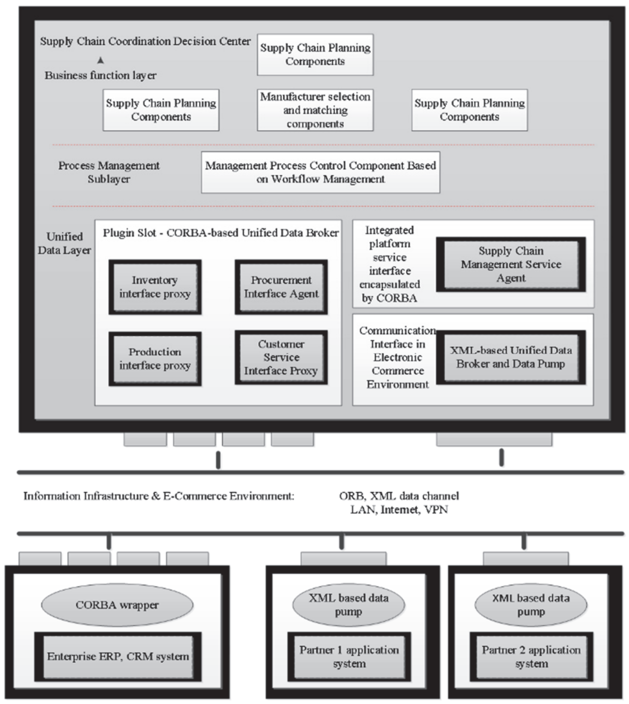
(4) The partner evaluation and selection component. Partners selected can directly influence the operation of supply chains. This is mainly because the purpose of establishing a supply chain partnership is to reduce the total inventory of the entire supply chain products, reduce costs and improve the operation performance of the entire supply chain by improving the level of information sharing. Partner evaluation includes three stages, namely, the establishment stage, the operation stage and the post-operation stage.

(5) The relationship management and restructuring component. The fundamental goal of agricultural products supply chain is to share benefits and risks among enterprises so that the cooperation of all parties can achieve common profits. Inequitable distribution of benefits will lead to cooperation structure imbalance and cause unpredictable consequences. Based on the dynamic characteristics of agricultural products supply chain, this component makes continuous evaluation and adjustment during the operation process so as to keep the supply chain in the optimal state as far as possible. It is used for benefit distribution, risk sharing, risk control, restructuring and optimization. Core technologies to support supply chain establishment and reorganization include the bidding mechanism and the negotiation mechanism between partners.

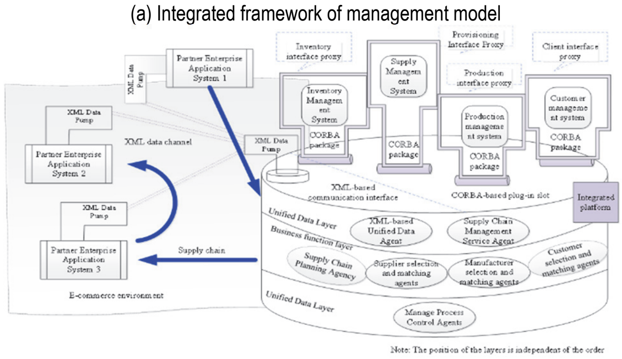
(6) The performance evaluation component. Supply chains are constantly changing. Maximization of the profit and value of agricultural products supply chains requires rapid adjustment to the links of supply chains according to market requirement changes. The key to achieve this optimal goal is to develop effective performance evaluation and optimization methods.This requires setting up reasonable performance evaluation dimensions, such as whether it meets the actual needs of the market, whether it can keep up with the update speed of products, and whether it can minimize costs.

3.2 Framework of Supply Chain Management Model Based on Coordination Decision Center

To make the supply chain management model more applicable, the functions of the coordination decision center should be properly simplified and reorganized in a scientific manner to ensure that the reorganized coordination decision center can implement the core idea of agricultural products supply chain management all along. The supply chain management model should be advanced in operability in order for extensive application. Based on the position and function of the coordination decision center, the core functions of the coordination decision center in the supply chain management model are simplified. The agricultural products supply chain management model is established consisting of multiple components including those for supply chain planning, supplier distribution and selection, producer distribution and selection, client distribution and selection and so on, so that suppliers, producers and clients of agricultural products can flexibly share information and that enterprises can optimize the agricultural products supply chain from an overall perspective. The supply chain management can become more coordinated in general through realizing the functions of the process management module. Fig. 2a shows the agricultural products supply chain management model after the reorganization of the coordination decision center, and the operating environment of the model is as shown in Fig. 2. As shown in Fig. 2a, the agricultural products supply chain management model in e-commerce environment is mainly composed of the business function layer, the unified data layer and the information infrastructure layer. Its core is still the coordination decision center and its structure is based on the information infrastructure layer. The model adopts Extensible Markup Language (XML) technology and Common Object Request Broker Architecture (CORBA) technology respectively to integrate the applications between various partners and those between heterogeneous systems. This can not only provide sound technical supports for the target's heterogeneous system environment in the supply chain but also provide more flexible and efficient manners for establishing agricultural products supply chains so as to implement information management and control between enterprises and suppliers, producers and clients.



(a) Integrated framework of management model



(b) Operating environment of management model

Figure 2 Framework and environment of management model in e-commerce environment

On the premise of the control of logistics, information flow and capital flow, the overall supply chain is managed to realize the ultimate goal of supply chain management, that is, to reduce the inventory of agricultural products, to accelerate the turnover of all flows and the circulation of agricultural products, to expand the market prospect of agricultural products and to improve the competitiveness of enterprises.

4 EVALUATION OF THE MANAGEMENT LEVEL OF THE AGRICULTURAL PRODUCTS SUPPLY CHAIN MODEL

Select a second-tier city with well-developed logistics industry and do experiments on the agricultural products supply chains in multiple areas. Apply the agricultural products supply chain management model established in this paper to Areas No. 1 and No. 2 to explore the management level of the model.

4.1 Data and Index Selection

A number of indexes are selected from the perspectives of agricultural economic development, consumption, logistics systems, industrial chain supporting facility development, social labor force and innovation level to evaluate the level of the agricultural products supply chain in each area with reference to previous studies related to logistics supply chains. Specific data are as shown in Fig. 3. Another reason for selecting these indexes is that these indexes can be publicly obtained in their provincial statistical yearbooks. They are the key data for evaluating the development trend of social macro-economy and are important references for evaluating the management level of the agricultural products supply chain in each area.

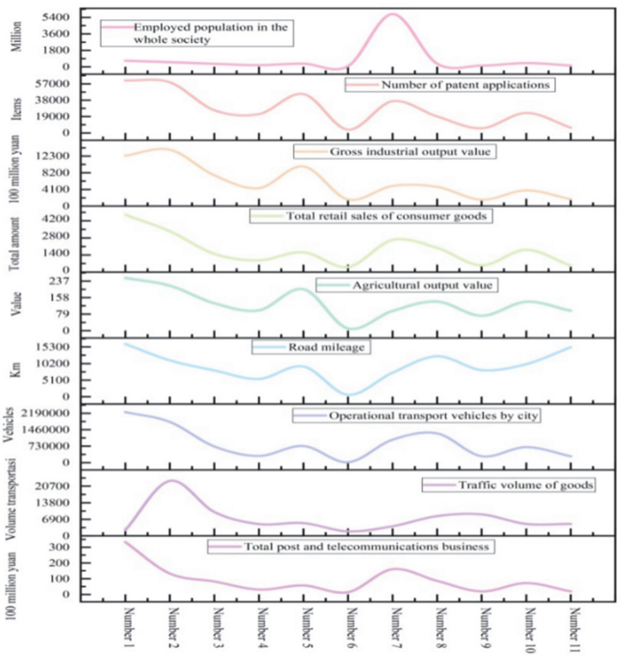
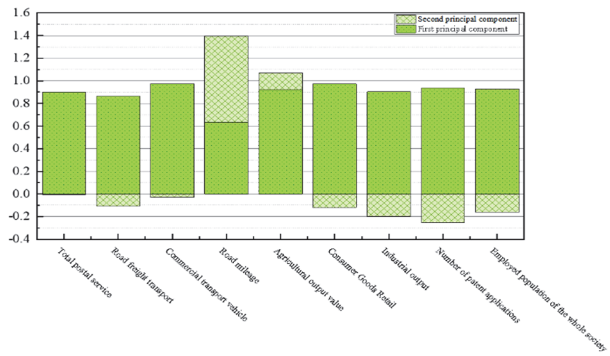


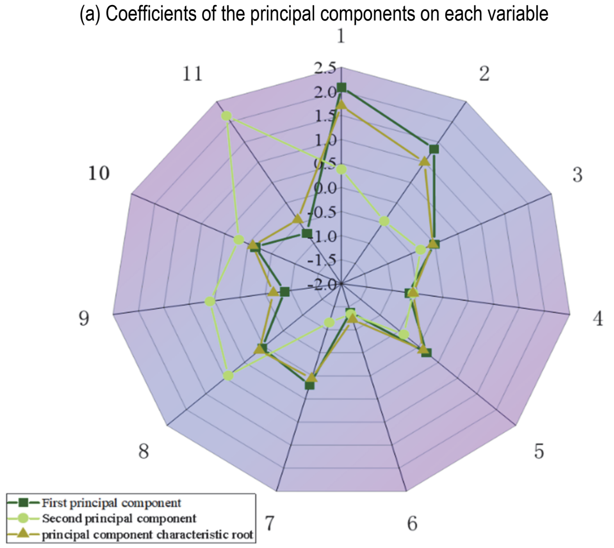
Figure 3 Selected index data

4.2 Management Level Based on Principal Component Analysis

Principal component analysis is carried out on the above indexes, and two components are selected. The variance contribution rate of the first principal component is 79.1%, which basically explains most of the data variation, while the variance contribution rate of the second principal component is 9.4%. Fig. 4a shows the coefficients of the two principal components on each variable. It can be observed that the coefficients of the first principal component are basically very large and they are positive, meaning that this principal component can reflect the overall supply chain management level in corresponding areas. However, the coefficients of the second principal component show remarkable differences on the variables. The road mileage coefficient 0.785 shows that besides reflecting the supply chain management level of the study area, the second principal component can also illustrate the logistics and traffic management of the area. Based on the coefficients of the principal components on each variable as shown in Fig. 4a, the principal component analysis method is utilized to evaluate the management level of the agricultural products supply chain in each area. The specific results are as shown in Fig. 4b. It can be seen that Areas No. 1 and No. 2 which adopt the management model in this paper keep staying in the first echelon. The level indexes of the first principal component and the characteristic root of Area No. 1 are 2.13 and 1.698 respectively. The level indexes of the first principal component and the characteristic root of Area No. 2 are 1.279 and 1.418 respectively. The supply chain management level of other areas is obviously lagging behind with all indexes below 1. In addition to management mode, the influencing factors and decisive factors for the comprehensive level of agricultural products supply chain management also include social and economic development and the transportation level.



(a) Coefficients of the principal components on each variable



(b) Management level indexes

Figure 4 Evaluation of the model management level based on principal component analysis

Cluster analysis is carried out to improve the reliability and persuasiveness of experimental results. Euclidean mean square distance and inter-class connection method are utilized to express similarity and inter-class distance respectively. After cluster analysis of supply chain management models adopted by multiple study areas, the dimensionless index results are obtained through normalization processing of the evaluation index data of each area. The following tree-like clustering results are obtained as shown in Fig. 5. Through the analysis of clustering results, the 11 target areas in the study city are divided into three categories according to their agricultural products supply chain management levels:

(1) Category I: Area No. 1, Area No. 2.

(2) Category II: Area No. 3, Area No. 5, Area No. 7, Area No. 8, Area No. 10.

(3) Category III: Area No. 4, Area No. 6, Area No. 9, Area No. 11.

The first category of agricultural product supply chain management level is significantly stronger than other types. Compared with the other two categories of supply chain management, the first category has obvious advantages in terms of the total social retail sales and the gross agricultural output value. It can be observed that the results of cluster analysis once again validate the results of principal component analysis. This also illustrates directly the reliability and internal consistency of the e-commerce management model.

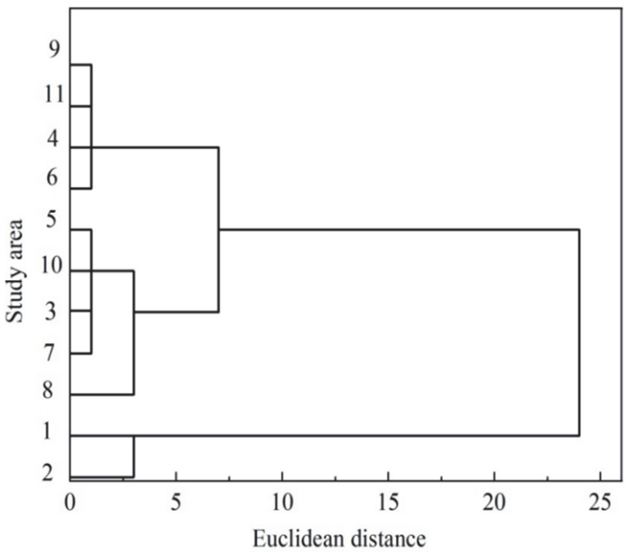


Figure 5 Evaluation of model management level based on cluster analysis

To sum up, there are significant differences in the level of agricultural products supply chain management in different areas. By giving full play to the maximum efficiency of the supply chain, Areas No.1 and No. 2 take the top two positions all along in terms of the management level. Both the total retail sales (470276 billion yuan and 342148 billion yuan) and the gross agricultural output value (24604 billion yuan and 21177 billion yuan) of the two areas can prove that the management model in this paper can promote both agricultural consumption and agricultural economic output value. In addition, the large e-commerce company in Area No. 1 endows this area with unique advantages of the Internet industry in developing the e-commerce supply chain mode for agricultural products. Moreover, as the political, economic, cultural, transportation and even science and technology center of the target city, this area also promotes the management model with its unique advantages. In terms of e-commerce + agricultural products supply chain system + intelligent development, Area No. 1 takes fresh produce e-commerce and chain supermarkets as the main body and actively promotes the management model. Area No. 2 also benefits positively from its proximity to Area No. 1. Especially, after adopting the management model established in this paper, the agriculture, forestry, animal husbandry and fishery industries in the primary industry have risen significantly, with the output value increasing by as much as 24.94%. The above data constantly verify the significance of the integrated management model of agricultural products supply chain in e-commerce environment.

5 DISCUSSION AND CONCLUSION

Based on the characteristics of difficult modeling and complex calculation of the theoretical model of requirements forecasting, this paper establishes a dynamic requirements forecasting method for agricultural products based on SVM. This method is applied to the collaborative requirements management component. This component is combined with the collaborative supply management component, the supply chain performance evaluation component and so on to obtain the supply chain coordination decision center. With the support of XML technology and CORBA technology and through proper simplification and reorganization of the functions of the coordination center, this paper establishes the integrated agricultural products supply chain management model in e-commerce environment. The evaluation results of the agricultural products supply chain management level of multiple areas verify that the level indexes of the first principal component and the characteristic root of Area No. 1 are 2.13 and 1.698 respectively and the level indexes of the first principal component and the characteristic root of Area No. 2 are 1.279 and 1.418 respectively. It can be seen that Areas No. 1 and No. 2 which adopt the management model in this paper keep staying in the first echelon. In terms of e-commerce + agricultural products supply chain system + intelligent development, Area No. 1 takes fresh produce e-commerce and chain supermarkets as the main body and actively promotes the management model. Area No. 2 also benefits positively from its proximity to Area No. 1. The agriculture, forestry, animal husbandry and fishery industries in the primary industry have risen significantly, with the output value increasing by as much as 24.94%.

In conclusion, this paper establishes the integrated agricultural products supply chain management model in e-commerce environment. Compared with the traditional agricultural product supply chain management model, this model has unique advantages. It is because the model emphasizes the integration effect of "e-commerce + agricultural products supply chain system + intelligent", and highlights the function of the business function layer, the unified data layer and the information infrastructure layer. In this way, the supply chain of agricultural products can be more flexible and efficient, and the turnover of logistics and the circulation of agricultural products will be higher, which can improve the competitiveness of agricultural enterprises. Therefore, this model is more suitable for market demand, and has more promotion value.

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Contact information:

Weiqing ZHANG, Lecturer
Hebei Vocational University of Industry and Technology,
Shijiazhuang, Hebei, China, 050000
E-mail: hbgzdzwq@hbcit.edu.cn

Jiaxin LI
Central University of Finance and Economics, 010000
E-mail: zycjlijiaxin@163.com

Yajie HE, Lecturer
(Corresponding author)
Hebei Vocational University of Industry and Technology,
Shijiazhuang, Hebei, China, 050000
E-mail: hbgzdhyj@hbcit.edu.cn