

Analysis of Risk Factors of Fresh Agricultural Product Supply Chain Based on Grey Correlation Degree – Take Chengdu as an Example

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Abstract. The purpose of this paper is to provide a reference for risk assessment and prevention of the fresh agricultural product supply chain in Chengdu. The risk factors of fresh agricultural products supply chain in Chengdu are empirically analyzed by using the grey correlation method, and the screening and sorting are carried out. According to the calculation results, it is concluded that the main risk factors are supply risk, logistics risk, demand risk, production risk, cooperation risk, etc., and the reference value provided can meet the status quo.

Key words. Fresh agricultural products, supply chain risk, risk factors, grey correlation degree

1. Introduction

Fresh agricultural products refer to the primary products produced by the agricultural sector without or with a little processing that cannot be stored for a long time at room temperature. Fresh agricultural products are generally divided into vegetables, fruits, meat, aquatic products and other types [1]. Fresh agricultural products have their own characteristics of freshness, seasonality, and perishability, coupled with the price fluctuations and uneven supply and demand of the agricultural product market itself, which lead to higher risks of fresh agricultural products and fragility and risk of the supply chain of fresh agricultural products.

Chengdu has produced a huge supply and demand market of fresh agricultural products. Although Chengdu has made a lot of efforts in the construction of fresh agricultural product supply chain in recent years, and achieved certain results, in the context of complex and changeable supply chain risks, as well as the emergence of new technologies and new models, quality and safety of fresh agricultural products and supply chain risks still occur from time to time [2]. Therefore, it is particularly important to identify and prevent supply chain risks.

A literature review was conducted on CNKI with the keyword "risk of supply chain of fresh agricultural products". Scholars have made certain achievements in the

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identification of risk factors in the supply chain of fresh agricultural products, mainly covering the use of various methods to identify risk influencing factors. In terms of risk factor identification, Kramer et al. [3] defined the quality and safety risks of fresh fruit and vegetable supply chains as the following four: biological risks, chemical risks, physical risks, microbial risks; Deep et al. [4] used scenario planning to define future stable risks and analyze risk development; Siegel et al. [5] believed that the supply chain of agricultural products is derived from climate change, price fluctuation, quality issues, etc.; Juan et al. [6] concluded that the risk sources of emergencies are natural risk, market risk and production risk on the basis of analyzing the emergencies of fresh agricultural products. Willersinn et al. [7] believes that wholesalers, processors and retailers are the key to causing quantitative and quality risks in the Swiss potato supply chain. Li et al. [8] used the SCOR model and bibliometrics to identify risk factors in the supply chain of fresh agricultural products. Murtono et al. [9] used the Rapid Agricultural Supply Chain Risk Assessment (RapAgRisk) method to identify the risk of onion in the supply chain of fresh agricultural products; Peyman et al. [10] used the Failure Mode and Effects Analysis (FMEA) method to identify risk factors in the agricultural supply chain with three types of judgment indicators: severity, incidence, and detectability; Ming et al. [11] analyzed the risk factors affecting the supply chain of fresh agricultural products under "agricultural-supermarket docking" mode and "Internet +" mode. In the application of grey correlation degree to the identification of influencing factors of supply chain, Cheng et al. [12] identify the main influencing factors of agricultural product logistics by using grey relational degree; Ting et al. [13] used grey model to identify the risk factors of tourism supply chain; Yan et al. [14] used grey correlation degree to explore the influencing factors of agricultural product logistics in Shaanxi Province; Ge et al. [15] analyzed the influencing factors of the supply chain of fresh agricultural products by using gray correlation; Kun et al. [16] used ANP and grey correlation to identify the main influencing factors of the prefabricated building supply chain.

To sum up, although scholars have done a lot of research on the identification of risks in the supply chain of fresh agricultural products, they generally focus on subjective identification of risk sources or based on text statistics, and lack quantitative data analysis to determine risks. Combined with the grey model, this paper quantitatively analyzes the influencing factors of supply chain risk, sorts the risk factors, and summarizes the key risk factors affecting the supply chain.

Grey correlation analysis is one of the research methods of grey system theory [17], the main idea is to measure the degree of correlation of development trends among various factors [18]. In the development process of the system for a certain period, if the development trend and degree of the factors are closer, the degree of correlation of factors will be higher. Compared with other research methods, the data requirements for fresh agricultural products are higher, therefore, this paper uses the grey correlation method to determine the main risk factors among many risk factors according to the results of the correlation degree of each factor.

2. Risk factor analysis

This paper is based on the selection of factors affecting the supply chain of agricultural products by Yan et al. [19], Ming et al. [20], Rong et al. [21], and the current situation of the fresh agricultural product supply chain in Chengdu. The selection of indicators is based on systematic and scientific principles and selecting 34 indicators to analyze the

risk factors of the supply chain. This paper takes 2011 as the starting point and selects the data about 10 years for analysis. Taking the transaction volume of fresh agricultural products market in Chengdu as the reference sequence, Resident population, Gross Agricultural Product, Agricultural product logistics volume, Online retail sales of agricultural products and other indicators as the comparison sequence.

The main steps of grey correlation analysis are as follows:

(1) Determine the data analysis sequence; if there are m elements in the gray system, each element has n index attributes. Then the reference sequence is $Y=Y(k)|k=1,2,\dots,m$; the comparison sequence is $X_i=X_i(k)|k=1,2,\dots,m, i=1,2,\dots,n$.

(2) Dimensionless processing of data; in this paper, the extreme value method is used to normalize the data of different dimensions in the system, and the formula is as follows: $Y = \frac{k - \min(k)}{\max(k) - \min(k)} \quad k=1,2,\dots,m; X_i = \frac{k - \min(k)}{\max(k) - \min(k)} \quad k=1,2,\dots,m, i=1,2,\dots,n$

(3) Find the difference sequence; the formula is: $\Delta_i(k) = |Y^0(k) - X_i^0(k)|$. The difference between the two poles is: $\Delta_{\max} = \max_i \max_k \Delta_i(k); \Delta_{\min} = \min_i \min_k \Delta_i(k)$

(4) Find the correlation coefficient; the formula is: $\xi_i(k) = \frac{\Delta_{\min} + \rho \Delta_{\max}}{\Delta_i(k) + \rho \Delta_{\max}}$

(5) Calculate the degree of association; the formula for the degree of association r_i is: $r_i = \frac{1}{n} \sum_{k=1}^m \xi_i(k), i=1,2,\dots,n$

(6) Sorting the correlation degree; sort the comparison sequence $X_1 - X_n$ according to the calculation result of the correlation degree.

The Windows version of MATLAB (version R2018b, 9.5.0.944444) was used to load the data, write the code according to the model calculation formula in the MATLAB environment, and display the final calculation result.

3. Results and analysis

After dimensionless processing of the data, the correlation coefficients between the sequences calculated by the software are shown in Table 1.

The grey correlation degree of each risk factor to the risk of fresh agricultural product supply chain in Chengdu is shown in Table 2.

From the calculation results, the grey correlation degree of each risk influencing factor is between 0.70 and 0.98, above 0.9 are 19, and above 0.8 are 11, indicating that each risk influencing factor has an obvious effect on supply chain risk.

(1) Analysis of main influencing factors

Gross agricultural production has the greatest impact with a grey correlation of 0.98, ranking first, indicating that in the fresh agricultural product supply chain, the production and supply of products is very crucial.

The grey correlation degree of agricultural product logistics volume is 0.975, ranking second, in addition, trucks ranked fourth (0.96), freight turnover ranked eighth (0.938), and road mileage ranked ninth (0.934), which is enough to show that the circulation of fresh agricultural products is the most important part of the supply chain, there is also the storage scale of cold chain logistics (0.92) with a high degree of correlation, which is the key point of the circulation of fresh agricultural products [22].

The grey correlation degree of the total retail sales of consumer goods is 0.973, ranking third, in addition, the fifth-ranked per capita disposable income of residents (0.96) and the sixth-ranked permanent population (0.95) indicate that the market sales of

Table 1. Correlation coefficients between reference and comparative sequences of risk influencing factors

Risk factors	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Resident population (X1)	0.9422	0.9359	0.9300	0.9841	0.9994	0.9772	0.9513	0.9414	0.9354	0.9396
Resident per capita disposable income (X2)	0.9799	0.9987	0.9339	0.9103	0.9407	0.9948	0.9593	0.9767	0.9935	0.9607
Consumer Price Index (X3)	0.8618	0.8673	0.8644	0.9212	0.9412	0.9807	0.8975	0.8726	0.8598	0.8509
Commodity retail price index (X4)	0.8612	0.8685	0.8649	0.9199	0.9428	0.9800	0.8922	0.8746	0.8610	0.8543
Gross Agricultural Product (X5)	0.9956	0.9854	0.9802	0.9823	0.9928	1.0000	0.9817	0.9676	0.9775	0.9915
Production of fresh agricultural products (X6)	0.8852	0.8782	0.8941	0.9425	0.9514	0.9688	0.8962	0.8867	0.8764	0.8709
Cargo volume (X7)	0.8304	0.7748	0.8714	0.9534	0.9784	0.9195	0.8554	0.8556	0.8664	0.8820
Cargo turnover (X8)	0.9426	0.8959	0.9369	0.9502	0.9684	0.9614	0.9060	0.9123	0.9455	0.9692
Agricultural product logistics volume (X9)	0.9860	0.9802	0.9627	0.9850	0.9912	0.9823	0.9567	0.9799	0.9503	0.9815
Truck (X10)	0.9991	0.9792	0.9431	0.9794	0.9888	0.9630	0.9143	0.9562	0.9968	0.9362
Highway Mileage (X11)	0.9301	0.9139	0.9039	0.9535	0.9706	0.9992	0.9208	0.9201	0.9088	0.9223
Warehouse scale of cold chain logistics (X12)	0.9271	0.9313	0.9527	0.9519	0.8494	0.9714	0.9955	0.9978	0.9639	0.7025
Basic information on post and	0.8062	0.8251	0.8425	0.8500	0.8753	0.8652	0.7992	0.8921	0.6878	0.5573
Number of comprehensive retail markets for	0.9220	0.8743	0.8106	0.8428	0.8726	0.9415	0.8855	0.8260	0.7917	0.7965
Internet users (X15)	0.9839	0.9596	0.9456	0.9900	0.9923	0.9819	0.9277	0.9282	0.9259	0.8945
The number of mobile phones used (X16)	0.9397	0.9082	0.8913	0.9571	0.9744	0.9766	0.9395	0.9483	0.8863	0.9199
Agricultural Science and Technology										
Expenditure (X17)	0.9976	0.9541	0.8791	0.9237	0.8941	0.9562	0.9085	0.8880	0.9325	0.9578
Crop Affected Area (X18)	0.5850	0.5997	0.5355	0.9737	0.8098	0.7874	0.6619	0.7189	0.6677	0.7327
Rainfall (X19)	0.8821	0.9564	0.7682	0.9389	1.0000	0.9614	0.8757	0.9604	0.8722	0.9248
Sunshine Hours (X20)	0.9216	0.8922	0.9782	0.3336	0.8834	0.8282	0.7798	0.7672	0.6986	0.7117
Fiscal Expenditure on Transportation (X21)	0.9034	0.8199	0.8217	0.7947	0.7944	0.9676	0.8436	0.8099	0.8673	0.8075
Government investment in agricultural science										
and technology (X22)	0.9294	0.9061	0.8247	0.9442	0.9232	0.9924	0.8810	0.9860	0.9526	0.9842
Agricultural and livestock products wholesale										
enterprises (X23)	0.8937	0.9486	0.8878	0.9204	0.9197	0.9160	0.7973	0.7793	0.9915	0.8602
Income from agricultural and sideline food										
processing industry (X24)	0.9478	0.9274	0.8807	0.9243	0.9213	0.8979	0.9534	0.8256	0.8234	0.8499
Number of college graduates (X25)	0.9390	0.9330	0.8965	0.9305	0.9425	0.9727	0.9270	0.9143	0.9054	0.9234
Total power of agricultural machinery (X26)	0.9375	0.9230	0.8965	0.9227	0.9365	0.9961	0.9349	0.8896	0.9005	0.8940
Grain primary processing machinery (X27)	0.9142	0.9065	0.9004	0.9535	0.9785	0.9754	0.9357	0.9191	0.8970	0.8820
Total inventory of agricultural products at the										
end of the year (X28)	0.8306	0.8749	0.9484	0.9491	0.9637	0.9428	0.8870	0.8531	0.9025	0.9764
Online retail sales of agricultural products (X29)	0.7874	0.8122	0.8178	0.8273	0.9605	0.9473	0.9122	0.8971	0.7809	0.5766
Price index of agricultural production tools										
(X30)	0.8301	0.8493	0.8773	0.9268	0.9513	0.9647	0.8859	0.8882	0.8347	0.8601
Total retail sales of social consumer goods (X31)	0.9259	0.9670	0.9914	0.9887	0.9947	0.9834	0.9875	0.9830	0.9454	0.9705
Agricultural fertilizer application (X32)	0.7806	0.7746	0.7667	0.8152	0.8241	0.8773	0.8079	0.7865	0.7590	0.7408
Pesticide usage (X33)	0.8396	0.8470	0.8576	0.9176	0.9457	0.9834	0.9139	0.8739	0.8269	0.7963

Table 2. Grey correlation degree of risk factors affecting fresh agricultural product supply chain in Chengdu

Risk factors	X1	X2	X3	X4	X5	X6	X7
Correlation	0.954	0.965	0.891	0.891	0.985	0.905	0.878
Risk factors	X8	X9	X10	X11	X12	X13	X14
Correlation	0.939	0.976	0.965	0.934	0.924	0.8	0.856
Risk factors	X15	X16	X17	X18	X19	X20	X21
Correlation	0.953	0.934	0.929	0.707	0.914	0.78	0.843
Risk factors	X22	X23	X24	X25	X26	X27	X28
Correlation	0.932	0.891	0.895	0.928	0.923	0.926	0.912
Risk factors	X29	X30	X31	X32	X33		
Correlation	0.832	0.887	0.973	0.793	0.88		

fresh agricultural products and consumption of fresh agricultural products by residents have a greater impact on supply chain risks.

(2) Screen for risk factors

After analyzing the grey correlation degree of 34 risk factors, considering the data and its actual situation, the last three rankings (X32, X20, X18) were eliminated with a correlation lower than 0.8. The remaining 31 risk factors that are closely related can be used as a reference for the secondary index system for risk assessment and prevention of fresh agricultural product supply chain in Chengdu.

In addition, according to the meaning represented by the index data, this paper summarizes the risk factors X1-X4 as demand risk, X5-X6 as supply risk, X7-X12 as logistics risk, X13-X17 as information risk, X18-X20 as environmental risk, X21-X22 as policy risk, X23-X25 as cooperation risk, X26-X27 as production risk, X28-X31 as market economic risk, and X32-X33 as quality risk. The findings are closely related to

studies such as Qing [23], Cui [24]. On this basis, the average value of the correlation degree of each classification index is calculated and ranked, and the first-level discriminant index of the supply chain risk of fresh agricultural products in Chengdu is obtained, as shown in Table 3.

Table 3. The first-level discriminant index of risk in the supply chain of fresh agricultural products

First-level indicator	Risk factors	Correlation	Ranking
supply risk	X5-X6	0.95	1
Logistics risk	X7-X12	0.94	2
demand risk	X1-X4	0.93	3
production risk	X26-X27	0.92	4
Cooperation risk	X23-X25	0.91	5
Market economic risk	X28-X31	0.90	6
information risk	X13-X17	0.89	7
policy risk	X21-X22	0.89	8
quality risk	X32-X33	0.84	9
Environmental risk	X18-X20	0.80	10

4. Conclusion

On the basis of existing research, this paper collects relevant data on the supply chain of fresh agricultural products in Chengdu, uses the grey correlation model to analyze the risk factors, and selects and sorts the risk factors according to the results. According to the calculation results, it is concluded that the main risk factors are supply risk, logistics risk, demand risk, production risk, cooperation risk and so on.

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