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Research on transaction scale prediction of fresh e-commerce industry based on MLR-GM(1,1,r) model

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Abstract

Aiming at the problem of complex factors influencing the scale of fresh e-commerce transactions and the small amount of data that can be collected, this paper combines the GM(1,1,r) model with the multiple linear regression model. Firstly, the independent variables are determined according to the size of the gray correlation degree and stepwise regression of each influencing factor, and then the GM(1,1,r) model is established for the independent variables to obtain the predicted values, and finally the predicted values of the independent variables are substituted into the multiple linear regression model to obtain the predicted values of the transaction scale of fresh e-commerce. The conclusion shows that the registration volume of fresh e-commerce related enterprises and the scale of the cold chain logistics market are closely related to the transaction scale of the fresh e-commerce industry, and the transaction scale of the fresh e-commerce industry will reach 661.280 billion yuan in 2023.

Keywords

Fresh food e-commerce, Grey association, Multiple linear regression analysis, GM(1,1,r) model.

1. Introduction

With the rapid development of e-commerce enterprises, e-commerce platforms are becoming more and more mature, which has promoted the development of fresh e-commerce to a certain extent. Since 2011, fresh food e-commerce has risen rapidly, and different types of fresh food e-commerce platforms such as Tmall, JD.com, Meituan, and Hema Fresh have sprung up, and consumers' demand for fresh products has gradually changed from quantity demand to quality pursuit. In addition, the quarantine measures during the epidemic forced consumers to change their consumption habits, which brought unexpected development opportunities to fresh food e-commerce companies, and fresh food e-commerce is bound to usher in explosive growth. However, the dangers faced by the fresh e-commerce industry cannot be ignored, and the bankruptcy restructuring of Daily Youxian and the quiet withdrawal of Aunt Qian in the market all show the pressure and difficulties faced by the fresh e-commerce industry. In this context, scientific prediction of the scale of fresh e-commerce transactions is fully necessary and reasonable.

Relevant scholars have conducted research on fresh food e-commerce from different perspectives. Lin Qiang et al[1] explored the sales mode of the two parties under the difference in fresh product quality by constructing a two-stage game model between suppliers and e-commerce platforms under the "quality-price" competition. In order to further reduce the risk of cold chain logistics disconnection in the front warehouse of fresh e-commerce, Shen Xiaoyu et al[2] established a system of factors affecting the risk of cold chain logistics disconnection of fresh e-commerce front warehouse cold chain logistics based on "man-thing-management-machine-technology-ring", which provides a theoretical basis for the risk management and

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control of cold chain logistics in the front warehouse of fresh e-commerce enterprises. Due to the various storage and delivery requirements of fresh products and the complex ambient temperature within long express delivery distances, the packaging scheme of fresh products is very challenging, and Yin Li et al[3] propose a packaging design system in fresh e-commerce logistics to meet these challenges. Bai Shizhen[4] et al established a fresh e-commerce supply chain model consisting of an online retailer and a third-party logistics provider for the large number of quality and quantity losses of fresh products during transportation, and examined the impact of double losses on decision-making and profits. Han Jingshu[5] explores the impact of fresh food e-commerce platform quality and perceived quality on consumers' repurchase behavior. In order to clarify the influencing factors of consumer satisfaction in the e-commerce of fresh produce under the background of the new crown pneumonia, Guan Gaofeng[6] proposed a hybrid method based on LDA-SEM-XGBoost through research online reviews, and gave suggestions for sustainable production and sales of fresh produce. In order to solve the problem that the development of self-built logistics cannot meet the development of fresh e-commerce, Wang Xinxin[7] established a collaborative distribution optimization model for the goals of lowest distribution cost of fresh agricultural products, maximum customer satisfaction and maximum freshness, and designed the corresponding genetic algorithm based on examples, and proposed a coordinated distribution strategy between self-built logistics and third-party logistics.

For the forecast of fresh e-commerce, it mainly focuses on the demand for fresh products and the demand forecast of cold chain logistics. In view of the fact that the sample size of sales data collected from fresh products is usually small, Zhang Yanliang[8] analyzed and predicted the sales volume of four fruits on the Ganfuyuan platform for 24 consecutive days based on the fractional gray prediction model. Ma Jiayu[9] and others constructed an ARIMA-SVM combination prediction model based on the Sharp value weight allocation method, and analyzed the sales volume of fresh e-commerce agricultural products from the first quarter of 2015 to the third quarter of 2019 and predicted the sales volume of fresh e-commerce agricultural products in a farm in Qingdao City by constructing the demand forecast index system of fresh agricultural products. Li Kun[10] took potato as an example and used time series theory to establish several potato demand fluctuation forecasting models to provide reference for enterprise procurement.

In summary, the existing research on fresh e-commerce mainly focuses on supply chain, cold chain logistics, and factors influencing consumers' purchase intention, and there are relatively few research on the prediction of its transaction scale. As the "last blue ocean" in the e-commerce field, the prediction of the transaction scale of fresh food e-commerce is conducive to exploring the internal development law of fresh e-commerce and providing reference for e-commerce platforms. Based on this, starting from the influencing factors affecting the development of fresh e-commerce industry, this paper uses gray correlation analysis and combines multiple linear regression analysis with GM(1,1,r) model to predict the transaction scale of fresh e-commerce, in order to provide solutions for the prediction of fresh e-commerce transaction scale.

2. Research method

Fresh food e-commerce is an emerging complex system, and its transaction size is affected by many factors. Whether it is a qualitative predictive model or a quantitative predictive model, each has its own advantages and disadvantages. Since each predictive model reflects part of the information of the system from different angles, and each prediction model is not mutually exclusive, in order to improve the utilization rate of information and the predictive accuracy of

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the model, this paper proposes a combined forecasting model, that is, coupling different forecasting models to establish a new combinatorial forecasting model.

Compared with the classical GM(1,1) model, the GM(1,1,r) model has a better fitting effect on the uncertainty system of "small data and poor information" because of its flexibility of power exponential value. Therefore, combining the GM(1,1,r) prediction model with other models can not only complement the functions of the model, improve the prediction accuracy, but also solve the problem of less data in fresh e-commerce.

Multiple linear regression models (MLR models) mainly study the linear relationship between multiple variables. Due to the complex factors affecting the scale of fresh e-commerce transactions, and the degree of influence of different factors is also different, if all factors participate in regression, the model is complex and does not conform to the actual situation, which will affect the accuracy of the model.

Therefore, according to the size of the gray correlation between factors and the multiple linear regression method, this paper determines the main factors (i.e. model independent variables) of the regression model and establishes the regression prediction model. At the same time, the GM(1,1,r) model is established for each independent variable to obtain the predicted value, and the prediction value of each independent variable is substituted into the regression model for prediction, so as to obtain a more accurate combined prediction model.

2.1. Grey correlation analysis

The basic idea of grey correlation analysis is to judge whether sequence curves are closely related based on how similar they are. The closer the curves, the greater the correlation between the corresponding sequences, and vice versa.

Correlation coefficient:

$$\xi_i(k)=\frac{\min\limits_i\min\limits_k|\Delta_i(k)|+\rho\max\limits_i\max\limits_k|\Delta_i(k)|}{|\Delta_i(k)|+\rho\max\limits_i\max\limits_k|\Delta_i(k)|} \tag{1}$$

Absolute difference:

$$\Delta_i(k)=|X_0(k)-X_i(k)| \tag{2}$$

Equal weight correlation degree:

$$\gamma_i=\frac{1}{n}\sum_{k=1}^{n}\xi_i(k) \tag{3}$$

Weighted correlation degree:

$$\gamma_i^{'}=\sum_{k=1}^{n}W_j(k)\xi_i(k) \tag{4}$$

Where, $\xi_i(k)$ is the correlation; ρ is the resolution coefficient, generally $\rho=0.5$; $\Delta_i(k)$ is the difference sequence between index sequence and comparison sequence; $W_j(k)$ is the weight of each character index; γ_i is equal weight correlation degree; $\gamma_i^{'}$ is the weighted correlation degree.

2.2. GM(1,1,r) Model

Let the non-negative original sequence be $X^{(0)}=(x^{(0)}(1),x^{(0)}(2),...,x^{(0)}(N))$,whose primary accumulation generates a sequence of $X^{(1)}=(x^{(1)}(1),x^{(1)}(2),...,x^{(1)}(N))$,where $x^{(1)}(k)=\sum_{i=1}^{k}x^{(0)}(i)$, $k=1,2,...,N$,noting the background values $z(k)=\frac{1}{2}(x^{(1)}(k)+x^{(1)}(k-1))$, $k=1,2,...,N$ 。

Definition 1 The grey differential equation for the GM(1,1,r) model is

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$$x^{(0)}(k)+az(k)=b(z(k))^r,\quad k=2,3,...,N$$

Where:is the power exponent, a, b are constants.

Definition 2 The whitening equation for the GM(1,1,r) model is

$$\frac{dx^{(1)}(t)}{dt}+ax^{(1)}(t)=b(x^{(1)}(t))^r$$

When $x^{(0)}(1)=x^{(1)}(1)=\hat{x}^{(1)}(1)$,the time response function is

$$\hat{x}^{(1)}(t)=\left\{\frac{b}{a}+e^{a(r-1)(t-1)}\left[(x^{(1)}(1))^{(1-r)}-\frac{b}{a}\right]\right\}^{\frac{1}{r-1}} \tag{5}$$

Following the least squares method for the grey differential equation, we obtain, of which

$$\boldsymbol{B}=\begin{bmatrix}-z(2) & (z(2))^r\\ -z(3) & (z(3))^r\\ \vdots & \vdots\\ -z(N) & (z(N))^r\end{bmatrix}\qquad \boldsymbol{Y}=\begin{bmatrix}x^{(0)}(2)\\ x^{(0)}(3)\\ \vdots\\ x^{(0)}(N)\end{bmatrix}$$

Power exponent r, which is generally found by optimization methods. Combining a, b, and r substitute into formula (1). The simulated value of the original sequence is obtained by $\hat{x}^{(0)}(k)=\hat{x}^{(1)}(k)-\hat{x}^{(1)}(k-1)$, $k=2,3,\cdots,N$. The predicted value of the q-step of the original non-negative sequence is obtained by $\hat{x}^{(0)}(k)=\hat{x}^{(1)}(k)-\hat{x}^{(1)}(k-1)$, $k=N+1,N+2,\cdots,N+q$.

2.3. Multiple linear regression model

A multiple linear regression model is a statistical method used to estimate the linear relationship between 2 or more independent variables and 1 dependent variable. The population regression model is represented mathematically as : $Y_i=\beta_1+\beta_2X_{1i}+\beta_3X_{2i}+\beta_4X_{3i}+\mu_i$ 。

The most widely used method for regression analysis is the ordinary least squares method, which is based on the principle that the selected sample regression function minimizes the sum of squares of the difference between the estimated and true values of all Y. Expressed in mathematical form as: $\min\sum e_i^2=\sum(Y_i-\hat{Y}_i)^2$.

3. MLR-GM(1,1,r) model of fresh e-commerce industry transaction scale forecast

Index selection

There are many factors affecting the transaction scale of the fresh e-commerce industry, combined with the research of previous scholars and the feasibility of data collection, this paper considers starting from the three first-level indicators of consumer consumption level, enterprise development level and technological development level, and selects 14 quantifiable secondary indicators to achieve the research purpose. The breakdown of specific indicators is shown in Table 1:

Consumer consumption level: The increase in consumer consumption level will lead to the expansion of the total demand of society, and the demand for online shopping will also increase accordingly, which in turn will affect the transaction scale of the fresh food e-commerce industry. Consumer consumption levels are affected by the country's economic and social development. Per capita disposable income is the comprehensive average of various types of household income, reflecting the living standards of Chinese consumers. GDP can reflect the scale of the country's economic development and judge the speed of economic development. Per capita consumption expenditure is composed of daily consumption, residential consumption, medical and health consumption, etc., which can reflect the consumption power

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of consumers. The total retail sales of social sales products can reflect the total consumption demand of residents for physical goods. At the same time, since fresh e-commerce mainly focuses on fresh products, this paper selects per capita meat consumption, per capita vegetable consumption, per capita aquatic product consumption, and per capita consumption of dried fresh melons and fruits as secondary indicators to judge consumer consumption level.

Enterprise development level: With the continuous popularization and deepening of e-commerce, the penetration rate of fresh food e-commerce in various fields continues to rise. As a branch of e-commerce, the development of fresh e-commerce is not only affected by itself, but also closely related to the overall development of the e-commerce industry. Based on this, this paper selects the number of e-commerce enterprises, the investment amount of fresh e-commerce industry, and the registration volume of fresh e-commerce related enterprises as secondary indicators to measure the development level of enterprises.

Technology development level: fresh products are products with immediate demand, thin profits, large losses, in order to obtain revenue, we must pay attention to the development of cold chain logistics. At the same time, fresh food e-commerce relies on the Internet to achieve operation, and its development and growth are inseparable from the Internet. Therefore, this paper selects the scale of the cold chain logistics market, the revenue of express delivery business, and the number of Internet users as secondary indicators reflecting the level of technological development.

Table1 Factors influencing the transaction scale of the fresh food e-commerce industry

Target layer	First-order index	Secondary index	Reference scholar
Fresh e-commerce industry transaction scale	Consumer consumption level	Per capita disposable income gross domestic product per capita consumption expenditure Total retail sales of social sales goods Per capita meat consumption Per capita vegetable consumption Per capita consumption of aquatic products Per capita consumption of dried fresh melons and fruits	Wang Yangyang[11], Chen Ying[12],Gao Xin[13],Yao Xuerui[14],Lu Yong[15],Liu Ran[16]
	Enterprise development level	Number of e-commerce enterprises Fresh electricity business industry investment amount Fresh electricity business related enterprise registrations	Liu Xuan[17],Wang yexiang[18]
	Developing level of science and technology	Cold chain logistics market size Express revenue Number of Internet users	Zhang Dequan[19], Wang Jian[20]

(2) Grey relational degree solution

Based on 14 quantifiable secondary indicators, this paper collects data from 2015 to 2021 from iMedia Consulting, NetEconomics, National Bureau of Statistics, Mob Research Institute, China Business Industry Research Institute, Prospective Industry Research Institute, China IoT Cold Chain Committee, and Huajing Industry Research Institute. The specific values are shown in Table 2.

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Table2 Raw data of influencing factors

Sequence	Index	2015	2016	2017	2018	2019	2020	2021
X0	Fresh e-commerce industry transaction scale /100 million yuan	542	914	1403	1950	2555	3641	4658
X1	per capita disposable income /yuan	21966	23821	25974	28228	30733	32189	35128
X2	gross domestic product /100 million yuan	685571	742694	830946	915244	983751	1005451	1138807
X3	per capita consumption expenditure /yuan	15712	17111	18322	19853	21559	21210	24100
X4	Total retail sales of social sales goods /100 million yuan	286588	315806	347327	377783	408017	391981	440823
X5	Per capita meat consumption /KG	26	26	27	30	27	25	33
X6	Per capita vegetable consumption /KG	98	100	99	96	99	104	110
X7	Per capita consumption of aquatic products /KG	11	11	12	11	14	14	14
X8	Per capita consumption of dried fresh melons and fruits /KG	45	48	50	52	56	56	61
X9	Number of e-commerce enterprises /enterprises	87436	102761	92122	99035	109410	124552	139074
X10	Fresh electricity business industry investment amount /100 million yuan	69	149	72	221	40	326	64
X11	Fresh electricity business related enterprise registrations / enterprises	1781	2910	3270	4241	4908	5478	1801
X12	Cold chain logistics market size /100 million yuan	1800	2250	2550	3035	3780	4850	5699
X13	Express revenue /100 million yuan	27696466	39743601	49571089	60384254	74978235	87954342	103323162
X14	Number of Internet users /10000 people	68826	73125	77198	82851	90359	98899	103195

The transaction scale of fresh e-commerce industry (X_0) was used as the reference sequence, and the influencing factors (X_1-X_{14}) were used as the marker series for gray correlation analysis. It is generally believed that when $0.5 \leq$ correlation degree <0.6, there is a moderate correlation between the two factors; When $0.6 \leq$ correlation degree < 0.7, there was a moderate correlation between the two factors. When $0.7 \leq$ correlation degree < 0.8, there is a strong correlation between the two factors. When $0.8 \leq$ correlation degree < 1, there is a very strong correlation between the two factors. The specific values are shown in Fig 1:

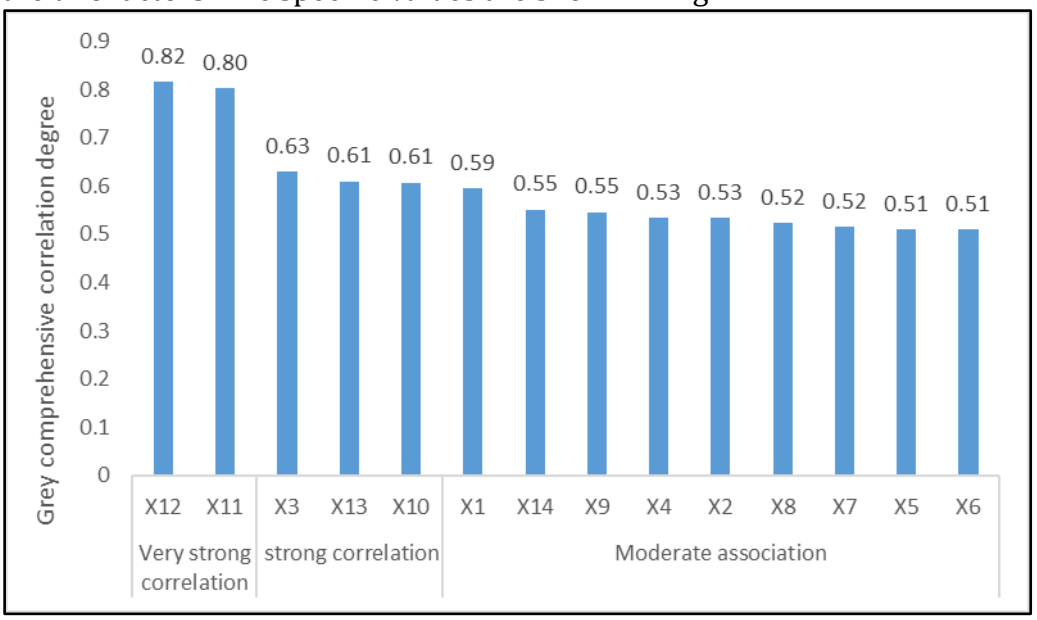

Fig.1 Grey correlation result graph

According to the grey correlation results, the correlation between the cold chain logistics market size (X_{12}), the registration volume of fresh e-commerce related enterprises (X_{11}), per capita consumption expenditure (X_3), express delivery business income (X_{13}), and the investment amount of fresh e-commerce industry (X_{10}) and the transaction scale of the fresh e-commerce industry reached more than 0.6, indicating that these five indicators are closely related to the transaction scale of the fresh e-commerce industry. Therefore, the above five indicators are selected as preregression subsets.

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(3) Multiple linear regression analysis

After gray correlation sorting, the scale of cold chain logistics market (X_{12}), the registration volume of fresh e-commerce related enterprises (X_{11}), per capita consumption expenditure (X_3), express delivery business income (X_{13}), and investment amount of fresh e-commerce industry (X_{10}) were preliminarily determined as the pre-regression subset of multiple linear regression analysis. Through scatter plot analysis, F test, T test, White test and autocorrelation test, the independent variables were finally determined as the registered volume of fresh e-commerce related enterprises (X_{11}) and the market size of cold chain logistics (X_{12}), and the relationship between the transaction scale of the fresh e-commerce industry and the main influencing factors (independent variables) was obtained by establishing a multiple linear regression model. $Y = -23303.35 - 516.3426\ln(X_{11}) + 3684.152\ln(X_{12})$

(4)GM(1,1,r) model prediction

In the process of data collection, the data of some indicators in 2022 has not been released, so when predicting the transaction scale of the fresh e-commerce industry in 2023, GM (1,1,r) models were established for the registration volume of fresh e-commerce related enterprises (X_{11}) and the scale of cold chain logistics market (X_{12}), and the forecast values for 2021 and 2022 were obtained. The specific values are shown in Table 3:

Table3 Predicted values of independent variables (2022-2023)

Year	related enterprise registrations / enterprises	Cold chain logistics market size /100 million yuan
2022	1925	7188.0
2023	1104	8975.3

According to the results of Table 3, substituting into the multiple linear regression model, it can be seen that the transaction scale of the fresh food e-commerce industry will reach 661.280 billion yuan in 2023.

4. Conclusion and suggestion

Based on the research of previous scholars, this paper selects 14 quantifiable indicators that affect the transaction scale of the fresh e-commerce industry, and predicts the transaction scale of the fresh e-commerce industry through gray correlation analysis, GM(1,1,r) model and multiple linear regression analysis. The following conclusions are drawn:

First, according to the MLR-GM (1,1,r) model, the transaction scale of the fresh e-commerce industry will reach 661.280 billion yuan in 2023, continuing to maintain the growth trend, but the growth rate has slowed down, and the profit margin of fresh e-commerce enterprises has decreased.

Second, the registration volume of fresh e-commerce related enterprises and the scale of the cold chain logistics market have a significant impact on the transaction scale of the fresh e-commerce industry. According to the prediction results of the GM(1,1,r) model, the growth rate of the cold chain logistics market is relatively stable, and the current upside is large. The number of fresh e-commerce related enterprises registered has increased year by year before 2020, but since 2021, its number has declined sharply, and it is still on a downward trend in a short period of time.

Third, fresh products have a short shelf life, are easily damaged, difficult to distribute, and difficult to make profits, so cold chain logistics plays a vital role in its development. From 2015 to 2021, the transaction scale of the fresh e-commerce industry increased by more than 8 times, while the scale of the cold chain logistics market only increased by 3 times, indicating that the current cold chain logistics technology is one of the reasons restricting the development of the fresh e-commerce industry.

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Although the fresh e-commerce industry has entered a bottleneck period and the growth rate has slowed down, with the continuous maturity of cold chain logistics technology, national economic development and consumer demand, fresh e-commerce still has great development potential. Based on this, this paper puts forward the following suggestions for fresh food e-commerce enterprises and relevant departments:

First, fresh food e-commerce companies should pay more attention to understanding consumers, understanding the market, and improving user retention. Fresh food e-commerce shows a trend of slowing growth rate, reduced profit margins and fierce competition, which is more conducive to preventing risks and promoting the long-term development of enterprises than expanding the scale of operation, building user portraits, and increasing user repurchase rates. For example, the use of big data technology, combined with the characteristics of consumer groups for customer positioning, so that not only can update and formulate corresponding products based on customer needs, but also timely promotional activities can be carried out to improve consumer purchase rate.

Second, enterprises should pay more attention to distribution efficiency in logistics distribution services and reduce their own distribution costs. The importance of cold chain logistics technology to fresh products is self-evident, but making full use of existing technical conditions and reasonably planning distribution routes can not only reduce distribution costs, but also better meet consumer requirements. For example, the establishment of fresh product storage points in urban residential areas.

Third, relevant government departments should optimize the policy development environment, implement various reform measures for fresh e-commerce, and enhance the confidence of fresh e-commerce enterprises. At present, China's fresh e-commerce has a large consumer group and advanced Internet technology, which provides an important foundation and driving force for the development of fresh e-commerce, although the development of fresh e-commerce is in a period of transition, still facing many problems and dilemmas, but with the in-depth development of modern information technology, the future of China's fresh e-commerce will open the situation, gradually enter the era of profit.

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