

Retraction

Retracted: Economic Decision-Making Algorithm for Cross-Border Industrial E-Commerce Material Purchase Quantity Based on Markov Chain

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This article has been retracted by Hindawi, as publisher, following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of systematic manipulation of the publication and peer-review process. We cannot, therefore, vouch for the reliability or integrity of this article.

Please note that this notice is intended solely to alert readers that the peer-review process of this article has been compromised.

Wiley and Hindawi regret that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

- [1] Y. Shen and Y. Ren, "Economic Decision-Making Algorithm for Cross-Border Industrial E-Commerce Material Purchase Quantity Based on Markov Chain," *Security and Communication Networks*, vol. 2021, Article ID 1439692, 9 pages, 2021.

Research Article

Economic Decision-Making Algorithm for Cross-Border Industrial E-Commerce Material Purchase Quantity Based on Markov Chain

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With the deepening of globalization, cross-border industrial e-commerce has increasingly become a mainstream means of trade exchanges, however, with the continuous increase in business volume. How to accurately estimate the procurement volume of cross-border materials is a significant issue, which plays a vital role in quantifying economic efficiency. To this end, this study proposes a financial decision-making algorithm for cross-border industrial e-commerce material procurement based on the Markov chain. The algorithm first preprocesses the original logistics data, including data cleaning, missing data filling, and noisy data removal, represents the data as structured panel data, finally builds a Markov chain model based on the panel data, and then makes predictions on the new data. We verified the effectiveness of the proposed model on a simulated dataset and an actual dataset.

1. Introduction

In recent years, my country's foreign trade has faced severe internal and external environments. From an external perspective, the global economic recovery is weak [1]. The E.U., the United States, Japan, and other developed countries have sluggish import demand, low commodity prices, geopolitical conflicts leading to regional turbulence, and proliferation of interregional trade protectionism, which have seriously hindered my country's international trade. According to CEPR, a British think tank, more than a quarter of global protectionist measures impact China's exports. From an internal point of view, my country's foreign trade industry is in a difficult stage of transformation. In the high-end field, my country's foreign trade industry is still unable to form intense competition with Western developed countries due to technical factors, and some production orders have returned from my country to developed countries [2, 3]. Although the low-end field has advantages in production scale, technology, and human

resources, these advantages are gradually offset by the increase in total costs such as human resources [4].

Some companies investing in China have shifted their production capacity to surrounding emerging economies. For example, Foxconn has gradually shifted its production base from China to India. In the complex and severe foreign trade environment, the traditional foreign trade sales model no longer meets the requirements of the times, forcing Chinese foreign trade companies, tiny and medium-sized foreign trade companies, to find new sales models, and cross-border e-commerce undoubtedly provides new options [5]. Since, the performance of third-party cross-border logistics directly affects consumers' or merchants' online shopping experience and future potential purchase opportunities and concerns the sales costs of domestic foreign trade merchants. To reduce costs and increase operating profits, cross-border e-commerce companies have begun to pay attention to the cross-border third-party logistics industry [6]. With the development of my country's traditional foreign trade industry, my country's domestic third-party

logistics industry has been improved to a certain extent and attracted by the vast potential of cross-border e-commerce development, some state-owned and private logistics service providers have set foot in the field of cross-border e-commerce logistics, but due to the single service function provided by most domestic logistics providers, the narrow range of transportation options, the limited global service network, and the low efficiency and quality of operations and other reasons, the logistics cost remains high. In the market environment of high-standard logistics demand and low-level service supply, most domestic third-party logistics companies have difficulty swallowing the huge cake of cross-border e-commerce and are forced to give up part of the market share to foreign logistics companies. Compared with domestic logistics companies, foreign logistics companies rely on advanced technology and management to maintain their advantages in market competition [7–9]. In the face of increasingly fierce market competition, what measures will the Chinese government and enterprises take to help domestic, cross-border third-party logistics companies improve their service levels and narrow the gap with foreign competitors?

Logistics is the core link of the entire e-commerce transaction and an important way for e-commerce to transform from virtual transactions to physical transactions [10]. It can even be regarded as an important factor restricting the development of cross-border e-commerce. However, it has significant security issues, including cargo security and data security. The current cross-border e-commerce logistics methods mainly include postal parcels, dedicated line logistics, international express delivery, overseas warehouses, and domestic express delivery. However, with the rapid development of cross-border e-commerce, problems such as high logistics costs, slow distribution speed, and low service levels have become problems that need to be resolved in developing e-commerce [11, 12].

Cross-border logistics is an essential part of modern logistics [13]. Its characteristics are shown in the following aspects. (1) Diversification of service functions and systematization of objectives: single logistics service function and single logistics link optimization can no longer meet the needs of modern logistics, so logistics is being carried out in operation; in addition to the coordination of transportation and warehousing links, the coordination of logistics and other links in the supply chain must also be considered not only to achieve the optimization of a single logistics link but also to pursue the overall optimization of logistics activities to ensure logistics demand optimization of the overall business objectives of the party. (2) Logistics operation standardization and service individualization: on the one hand, standardized operation procedures can simplify complex operations, facilitate cross-regional collaboration and communication, and facilitate operation process monitoring and evaluation of operation results. On the other hand, affected by the operating products, operating methods, capabilities, and traditional logistics services, logistics demanders also hope to obtain

customized, personalized services and value-added services based on their own operating products' characteristics and requirements such as market surveys. Services such as forecasting, purchasing and order processing, logistics consulting, logistics plan selection and planning, inventory control strategy recommendations, payment recovery, and settlement are to improve the supporting role of logistics services in decision-making. (3) Efficient and rapid response capabilities based on advanced logistics systems. Quick response-ability: according to the explanation of speed economy proposed by Professor Chandler of Harvard University, it refers to the ability of enterprises to respond quickly to the sudden change of the competitive environment, and its importance is no less than the advantage of quality [14].

With the rapid development of Internet technology in recent years, e-commerce and e-procurement based on multimedia and network technology emerge at the right moment and continue to develop, making the Internet a new battlefield of international competition. Security and communication network security is the lifeline of electronic commerce and electronic procurement. The key problem that hinders the wide application of electronic commerce and electronic procurement is information security.

To solve the problem of low efficiency in the existing cross-border industrial e-commerce logistics, this study proposes a Markov chain-based cross-border industrial e-commerce material purchase economic decision algorithm. The algorithm first preprocesses the original logistics data, including data cleaning, data missing filling, and noisy data removal, represents the data as structured panel data, finally builds a Markov chain model based on the panel data, and then makes predictions on the new data.

The research contributions of the thesis include the following:

- (1) Accurately estimating the procurement volume of cross-border materials is a critical issue, which plays a vital role in quantifying economic efficiency. To this end, this study proposes a financial decision-making algorithm for cross-border industrial e-commerce material procurement based on the Markov chain.
- (2) The algorithm first preprocesses the original logistics data, including data cleaning, data missing filling, and noisy data removal, represents the data as structured panel data, finally builds a Markov chain model based on the panel data, and then makes predictions on the new data
- (3) We verified the effectiveness of the proposed model on a simulated dataset and an actual dataset

The remainder of this study is organized as follows. Section 2 introduces the transaction process of cross-border e-commerce. Section 3 discusses the gray theory model. Section 4 discusses Markov model. Section 5 discusses experiment and analysis. Section 6 presents the conclusions of the study.

2. The Transaction Process of Cross-Border E-Commerce

Cross-border e-commerce transaction process [15] is where manufacturers display products through cross-border e-commerce platforms or self-operated platforms. After the transaction is completed, payment is made through the payment platform provided by the e-commerce platform. The e-commerce platform selects logistics providers for domestic transportation, customs declaration and commodity inspection, international transportation, destination country customs declaration, commodity inspection, and overseas distribution. According to the above transaction process, it can be seen that cross-border e-commerce transaction participants mainly include domestic buyers and sellers of different customs, cross-border transaction platforms, banks or financial institutions, businesses and commodity inspection, and other management functions responsible for logistics-related carriers and agents people wait.

2.1. Cross-Border Logistics and Main Types. International logistics under cross-border e-commerce belongs to third-party logistics and is part of the logistics field. It refers to the adequate flow of goods and information between different countries and the process of planning, implementation, and control management [16]. Its scope includes the movement of commodities among different countries, such as the transportation and trade of import and export commodities and the express service of international mail. Its essence is to use international logistics networks, facilities, and technologies to realize the flow and exchange of goods internationally following international practices and the principle of the international division of labor and cooperation to promote the development of regional economy and the optimal allocation of world resources; its goal is through the best way and route, with the lowest cost and the least risk; the goods will be transported from the seller in the exporting country to the demand side in the importing country promptly with quality and quantity. The core elements include packaging, transportation, warehousing, loading and unloading, customs clearance, and information exchange throughout international logistics activities.

2.2. Main Types of Cross-Border Logistics. Cross-border logistics is divided into cross-border export logistics and cross-border import logistics according to the different flow of cross-border transaction commodities. After the transaction is concluded for cross-border logistics imports, overseas e-commerce service platforms or sellers choose cross-border third-party logistics companies to handle customs clearance procedures. Domestic third-party logistics companies take customs clearance procedures and complete distribution tasks [17].

2.3. Characteristics of Cross-Border Logistics. Cross-border logistics is an essential part of modern logistics. Its characteristics are shown in the following aspects. (1)

Diversification of service functions and systematization of objectives: single logistics service function and single logistics link optimization can no longer meet the needs of modern logistics, so logistics is being carried out. In operation, in addition to the coordination of transportation and warehousing links, the coordination of logistics and other links in the supply chain must also be considered not only to achieve the optimization of a single logistics link but also to pursue the overall optimization of logistics activities to ensure logistics demand optimization of the overall business objectives of the party. (2) Logistics operation standardization and service individualization: on the one hand, standardized operation procedures can simplify complex operations, facilitate cross-regional collaboration and communication, and also facilitate operation process monitoring and evaluation of operation results. On the other hand, affected by the operating products, operating methods, and their capabilities, traditional logistics services and logistics demanders also hope to obtain customized personalized services and value-added services based on their own operating products' characteristics and requirements such as market surveys. Services such as forecasting, purchasing and order processing, logistics consulting, logistics plan selection and planning, inventory control strategy recommendations, payment recovery, and settlement are to improve the supporting role of logistics services in decision-making. (3) Efficient and rapid response capabilities based on advanced logistics systems. Quick response ability: according to the explanation of speed economy proposed by Professor Chandler of Harvard University, it refers to the ability of enterprises to respond quickly in the sudden change of the competitive environment, and its importance is no less than the advantage of quality.

When the logistics process involves packaging, loading and unloading, transportation, warehousing, distribution, and other links, it may cause all or part of the chain to stop, which directly affects logistics efficiency or causes huge losses. With the expansion of market space and product life, the cycle is shortened. In order to achieve the dual purpose of expanding market share and reducing costs, enterprises not only need to establish a complete global production, supply, and marketing management system but also need to improve their ability in timely supply and reduce inventory to reduce costs. Therefore, logistics management has become an important part of management. (4) The logistics technology is advanced. The extensive application of advanced logistics technology in all aspects of international logistics operations improves the efficiency of each operation link and ensures the realization of the entire business goal. For example, according to the instructions of the e-commerce service platform, logistics providers organize pick-up, warehousing, packaging, customs declaration, international transportation, and overseas distribution following the transportation plan. In the entire logistics chain, the participating parties effectively use the electronic data interchange system (EDI) to realize the instant exchange of information and resource sharing. The participating parties can understand the flow of goods and the next operation promptly, avoiding information. The lag

caused the delay of the operation link, thus ensuring the smoothness of the entire logistics chain. In cross-border e-commerce transactions, logistics companies play a role as a bridge, using their rich logistics management technology and operational experience to facilitate the smooth completion of the transaction. (5) Logistics system informatization and service network globalization. On the one hand, because the scope of cross-border transactions is on a global scale, the wider the coverage of the logistics service network, the more conducive for merchants to store and allocate products according to market changes to be more satisfying the logistics needs of the business. On the other hand, the advanced logistics network can not only achieve the consistency of logistics activities between logistics outlets and the optimal total inventory level and inventory distribution of the entire logistics network, rapid transportation and distribution, and adapt to business needs but also through the logistics information system, strengthen the coordination and cooperation of supply and sales links in the process of organizing logistics and the control of the logistics process.

3. Gray Theory Model

The gray theory model makes predictions on undetermined related data and displays the prediction models related to time changes [18]. The gray model is usually denoted as the G.M. (n, h) model, and the gray G.M. $(1, 1)$ model is the first-order differential equation of the G.M. (n, h) model (n is the number of differential equations, and h is the number of variables). By comparing the traditional linear regression prediction model, the gray G.M. $(1, 1)$ model has the characteristics of less data required and high model accuracy. When using the gray model to predict the data, the quasismoothness test is first required [19] to determine whether the data meet the smoothness test conditions. The test formula is as follows:

$$p(k) = \frac{x^{(0)}(k)}{x^{(1)}(k)} = \frac{x^{(0)}(k)}{x^{(1)}(k-1)}, \quad k = 2, 3, \dots, n. \quad (1)$$

The number satisfies the smoothness inspection strip.

- (1) $p(k+1)/p(k) < 1, k = 2, 3, \dots, n$
- (2) $p(k) \in [0, \theta], k = 3, \dots, n$
- (3) $\theta < 0.5$

The steps for establishing the gray model are as follows:

- (1) Let $x(0) \geq 0$, which corresponds to the original sequence of time series:

$$X^{(0)}(k) = \{x^{(0)}(1), x^{(0)}(2), \dots, x^{(0)}(n)\}, x^{(0)}(k) \geq 0, k = 1, 2, \dots, n. \quad (2)$$

- (2) Weaken the randomness of the data, and at the same time, perform accumulation processing to generate a series:

$$X^{(1)} = \sum_{i=1}^k x^{(0)}(i), \quad (3)$$

$$X^{(1)} = \{x^{(1)}(1), x^{(1)}(2), \dots, x^{(1)}(n)\}.$$

- (3) $x^{(1)}$ is treated as a mean value:

$$Z^{(1)}(k) = \frac{1}{2}(x^{(1)}(k) + x^{(1)}(k-1)), \quad k \geq 2. \quad (4)$$

It is next to the mean $Z^{(1)}\{z^{(1)}(2), z^{(1)}(3), \dots, z^{(1)}(n)\}$; $z^{(1)}(k)$ is the whitening background value.

- (4) Establish a differential equation for it:

$$\frac{dX^{(1)}}{dt} + aX^{(1)} = \mu. \quad (5)$$

Calculated by the least square method,

$$\hat{a} = \begin{pmatrix} a \\ \mu \end{pmatrix} = (B^T B)^{-1} B^T Y, \quad (6)$$

$$k = \begin{pmatrix} -Z^{(1)}(2) & 1 \\ -Z^{(1)}(3) & 1 \\ \vdots & \vdots \\ -Z^{(1)}(n) & 1 \end{pmatrix}, \quad y = \begin{pmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ \vdots \\ x^{(0)}(n) \end{pmatrix}.$$

- (5) Find the response equation

$$x_1^{(1)}(k+1) = \left(x^{(0)}(1) - \frac{\mu}{a}\right)e^{-ak}, \quad k = 1, 2, \dots, n-1. \quad (7)$$

- (6) Restore by accumulative subtraction

$$\hat{x}^{(0)}(k) = \hat{x}^{(1)}(k) - \hat{x}^{(1)}(k-1). \quad (8)$$

When $k = 1$,

$$\hat{x}^{(0)}(0) = \hat{x}^{(1)}(1) = x^{(0)}(1). \quad (9)$$

When $k \neq 1$,

$$\hat{x}^{(0)}(k) = (1 - e^a) \left(x^{(0)}(1) - \frac{\mu}{a}\right) e^{-u(k-1)}, \quad 2 \leq k \leq n. \quad (10)$$

By checking the accuracy of the G.M. (1, 1) model, comparing the posterior difference ratio and the probability of small error, the accuracy of the model can be controlled within a certain range.

- (1) The square of the mean square error of $x(0)$:

$$S_1^2 = \frac{1}{n-1} \sum_{k=1}^n ((x^{(0)}(k) - \bar{x}^{(0)})^2. \quad (11)$$

- (2) The square of the residual variance:

$$S_2^2 = \frac{1}{n-1} \sum_{k=1}^n (\varepsilon^{(0)}(k) - \bar{\varepsilon})^2, \quad (12)$$

$\bar{\varepsilon}$ is the residual average.

- (3) The posterior difference ratio:

$$C = \sqrt{\frac{S_2^2}{S_1^2}}. \quad (13)$$

- (4) Probability of small error:

$$P = P\{|\varepsilon^{(0)}(i) - \varepsilon| < 0.6745S_1\}. \quad (14)$$

- (5) Relative error:

$$P_{(k)} = \frac{x^{(0)}(k) - \hat{x}^{(0)}(k)}{x^{(0)}(k)}. \quad (15)$$

Comparing the calculated values of the posterior difference ratio and the probability of small error in Table 1, the accuracy range of the model can be calculated. Accuracy corresponds to relative error, accuracy = $(1 - \text{relative error}) \times 100\%$.

4. Markov Model

The Markov model was proposed by the Russian mathematician Markov in 1906. Its definition is as follows: suppose $X(n)$, $n = 1, 2, \dots$ is composed of two random sequence composition, the space of states S is finite, and for any positive integer m , n , if $i, j, i_k \in S (k = 1, 2, \dots, n-1)$ has $P\{X_{n+m} = j | X_n = i, X_{n-1} = i_{n-1}, \dots, X_1 = i_1\} = P\{X_{n+m} = j | X_n = i\}$, then called $\{\varepsilon_n, n = 1, 2, \dots\}$ is a Markov chain (Markov chain for short).

From the definition, it can be seen that the Markov transfer process is only related to the previous data connected and has nothing to do with other data in the past. The Markov model is based on the data predicted by the gray G.M. (1, 1) model. The state transition matrix is divided according to the calculated relative value, and the optimal state is found from the step of the state transition matrix to estimate the future change trend. Markov decision process is shown in Figure 1.

4.1. State Division. The relative value is calculated using the original and gray forecast data and is divided into m intervals according to the relative value [20], and each interval represents the current state. Since too many intervals will cause data complexity and less divisions will not allow accurate data prediction, so the interval is generally divided into 3-4, using $S_i \in [l_i, b_i]$ means $i = 1, 2, 3, \dots, n$, where l_i and b_i are the upper and lower limits of the interval [21].

Calculation of state transition probability p_{ij} :

$$p_{ij}^k = \frac{n_{ij}^k}{n_i}, \quad (16)$$

where k represents the number of steps of state transition, p_{ij} represents the probability of state S_i after k steps to reach S_j , n_i represents the number of S_i , $n_{(ij)}(k)$ means that $S_{(i)}$ has transferred k to get the number of $S_{(j)}$, and the transfer process is due to the last year's data. It is not clear enough, so cancel the data at the end to participate in the calculation.

4.2. Constructing the State Transition Matrix. The state matrix composed of transition probability after the transition is

$$E^{(k)} = \begin{bmatrix} p_{11}^k & p_{12}^k & \cdots & p_{1r}^k \\ p_{21}^k & p_{22}^k & \cdots & p_{2r}^k \\ \vdots & \vdots & \vdots & \vdots \\ p_{r1}^k & p_{r2}^k & \cdots & p_{rr}^k \end{bmatrix}. \quad (17)$$

Two conditions must be met during the state transition process:

- (1) For everything $i, j \in E$, $0 \leq p_{(ij)} \leq 1$
- (2) For everything $i \in E$, $\sum_{j \in E} p_{(ij)}(m) = 1$

This work studies the situation of $k = 1$, that is, the state matrix after one step transition is

$$E^{(1)} = \begin{bmatrix} p_{11}^1 & p_{12}^1 & \cdots & p_{1r}^1 \\ p_{21}^1 & p_{22}^1 & \cdots & p_{2r}^1 \\ \vdots & \vdots & \vdots & \vdots \\ p_{r1}^1 & p_{r2}^1 & \cdots & p_{rr}^1 \end{bmatrix}. \quad (18)$$

4.3. Determine the Optimal Value of Markov Chain. The maximum value of the column vector sum in the state list composed of the row vectors corresponding to the matrix $E(k)$ is the optimal transition state, combined with the state division, so the final optimized prediction value is

$$y^{(0)}(i+1) = \frac{1}{2} (l_i + b_i) \hat{x}^{(0)}(i+1), \quad (19)$$

where $l_{(i)}$ is the lower limit, $b_{(i)}$ is the upper limit, $\hat{x}^{(0)}(i+1)$ is the predicted value of the gray model, and $y^{(1)}(i+1)$ is the final value optimized by the gray Markov model.

TABLE 1: G.M. (1, 1) model accuracy comparison standard.

Prediction accuracy level	Relative error	Probability of small error	Mean square error ratio
Good	0.01	≥ 0.95	≤ 0.35
Qualified	0.05	(0.8, 0.95)	(0.35, 0.50)
General	0.10	(0.7, 0.8)	(0.50, 0.65)
Unqualified	0.20	≤ 0.7	≥ 0.65

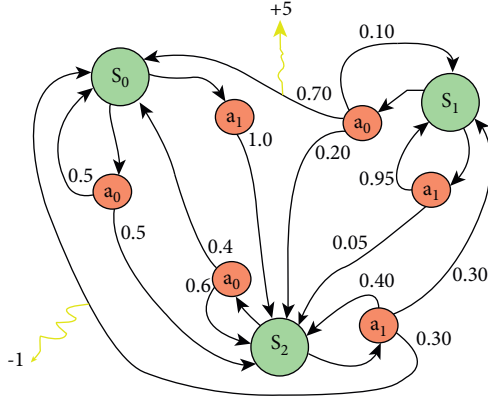


FIGURE 1: Markov decision process.

5. Empirical Analysis

Due to the availability of the original data, the available data were screened, and the total consumption of cold chain products per capita of urban households in the “China e-commerce Report 2019” and the total urban population corresponding to each year were selected, and they were compared. Multiply the total consumption of cold chain products by the urban population as given in Tables 2 and 3.

$P_k = \{1.1381, 0.5136, 0.3377, 0.2632, 0.1953, 0.1688, 0.1507, 0.1359\}$, $p(k+1)/p(k) = \{0.4513, 0.6575, 0.7794, 0.7420, 0.8463, 0.928, 0.9018\}$.

According to the calculation results, when $k > 3$, $p(k) < 0.5$, for all values satisfying the condition $p(k+1)/p(k)$, the test result conforms to gray. The G.M. (1, 1) model requires conditions, so the selection of data meets the conditions that the gray model must meet. The above data can be used to predict the cold chain demand of urban residents in Jiangsu Province.

5.1. Gray Markov Model for Optimization. According to Table 3, the data of the end year of 2019 is discarded, and the range of the relative value interval from 2011 to 2018 is (0.9479, 1.0374), and the state is divided into three ranges (0.9479, 0.9779), (0.9779, 1.0078), and (1.0078, 1.0374); the years falling in each interval are denoted as the state transitions in turn. Status list of each year is given in Table 4.

From Table 4 and formula (13), it can be seen that the state of the predicted value in 2011 is S2, which falls in the range of state division (0.9779, 1.0078), $y^0(2011) = 1/2 \times (0.9779 + 1.0078) \times 1027872.12 = 1020522.83$; the predicted values of the remaining years are given in Table 5 in turn.

It can be seen from the table that the average relative error predicted by the gray G.M. (1, 1) model is 0.0238, the

model accuracy is 97.62%, and the average error is 0.0139 after the Markov chain is optimized. The accuracy of the model is 98.61%. The optimized result of Markov chain is significantly better than the predicted value of the gray G.M. (1, 1) model. The comparison chart of the model is shown in Figure 2.

It can be seen from Figure 2 that the original data fluctuate linearly, showing a steady-state growth trend. We use MATLAB to conduct data analysis and the gray G.M. (1, 1) model to predict future data that show this trend. After using Markov chain optimization, the error rates in 2015 and 2017 are only 0.45% and 0.98%, and the data fair values are close to the actual values. After optimizing the data in 2019, the following state transition matrix can be obtained from Table 5:

$$\begin{aligned}
 R^1 &= \begin{bmatrix} 0.5 & 0 & 0.5 \\ 0 & 0.333 & 0.667 \\ 0.333 & 0.333 & 0.333 \end{bmatrix}, \\
 R^2 &= \begin{bmatrix} 0.4167 & 0.1667 & 0.4166 \\ 0.2223 & 0.3333 & 0.4444 \\ 0.2778 & 0.2222 & 0.5 \end{bmatrix}, \\
 R^3 &= \begin{bmatrix} 0.3472 & 0.1944 & 0.4584 \\ 0.2592 & 0.2592 & 0.4816 \\ 0.3054 & 0.2410 & 0.4536 \end{bmatrix}, \\
 R^4 &= \begin{bmatrix} 0.3264 & 0.2176 & 0.4600 \\ 0.2902 & 0.2469 & 0.4629 \\ 0.3039 & 0.2315 & 0.4646 \end{bmatrix}, \\
 R^5 &= \begin{bmatrix} 0.3145 & 0.2448 & 0.4607 \\ 0.2991 & 0.2373 & 0.4636 \\ 0.3068 & 0.2320 & 0.4612 \end{bmatrix}, \\
 R^6 &= \begin{bmatrix} 0.3106 & 0.2286 & 0.4608 \\ 0.3041 & 0.2336 & 0.4623 \\ 0.3072 & 0.2310 & 0.4618 \end{bmatrix}, \\
 R^7 &= \begin{bmatrix} 0.3089 & 0.2299 & 0.4612 \\ 0.3062 & 0.2322 & 0.4616 \\ 0.3075 & 0.2310 & 0.4615 \end{bmatrix}, \\
 R^8 &= \begin{bmatrix} 0.3081 & 0.2304 & 0.4615 \\ 0.3069 & 0.2313 & 0.4619 \\ 0.3074 & 0.2308 & 0.4618 \end{bmatrix}.
 \end{aligned} \tag{20}$$

TABLE 2: Per capita consumption of cold chain products of urban residents in Jiangsu Province (unit: kg).

Years	2011	2012	2013	2014	2015	2016	2017	2018	2019
Fresh vegetables	116.57	121.55	115.34	107.4	109.9	95.9	97.2	99.6	101.3
Pork	20.43	21.86	21.19	20.4	21	20.5	20.5	20.1	20.5
Fish and shrimp	16.82	16.8	16.13	17.4	19.3	19.1	19.5	20	20.1
Fresh eggs	10.66	10.75	11.82	9.7	9.8	9.5	10.3	10.6	10.9
Fresh milk	19.5	20.16	19.03	20.41	20.9	20.9	19.2	18.6	18.1
Fruits	52.72	54.44	47.32	49.8	49.2	45.6	47	49.5	51.5
Total	236.7	245.56	230.83	225.11	230.1	211.5	213.7	218.4	222.4

TABLE 3: Total consumption of cold chain products by urban residents in Jiangsu Province.

Years	Population/10,000	Total demand per capita/kg	Total demand/kt
2011	4342.51	236.7	1027872.12
2012	4767.63	245.56	1169785.69
2013	4889.36	230.83	1128610.97
2014	4990.09	225.11	1123319.16
2015	5090.01	230.1	1171211.3
2016	5190.76	211.5	1097845.74
2017	5305.83	213.7	1133855.87
2018	5416.65	218.4	1182996.36
2019	5520.95	222.4	1227859.28

TABLE 4: Status list of each year.

Years	2011	2012	2013	2014	2015	2016	2017	2018
State	S2	S3	S2	S2	S3	S1	S1	S3

TABLE 5: 2011–2018 model accuracy comparison.

Value year	Actual value (kt)	Gray G.M. (1, 1) model		Markov optimization	
		Predicted value (kt)	Relative error	Predicted value (kt)	Relative error
2011	1027872.12	1027872.12	0.0000	1020522.83	0.0071
2012	1169785.69	1127537.58	0.0361	1153019.93	0.0143
2013	1128610.97	1135117.09	0.0125	1127001.01	0.0014
2014	1123319.16	1142747.55	0.0173	1134576.91	0.0100
2015	1171211.30	1150429.30	0.0177	1176429.01	0.0045
2016	1097845.74	1158162.70	0.0549	1151944.86	0.0491
2017	1133855.87	1165948.07	0.0251	1122691.40	0.0098
2018	1182999.36	1173785.78	0.0376	1200313.34	0.0146
Mean	—	—	0.0238	—	0.0139

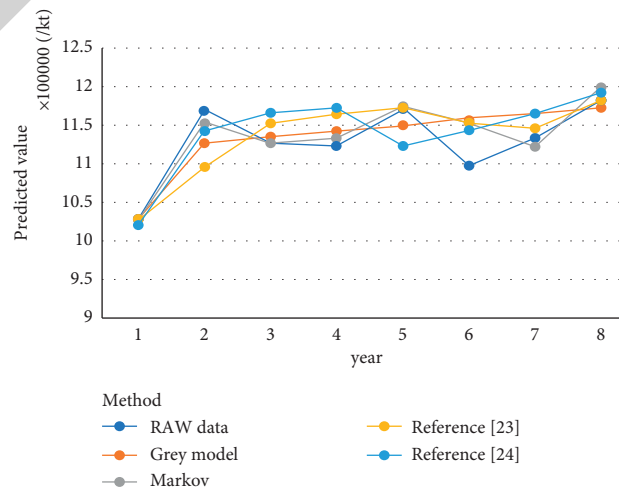


FIGURE 2: Original data, gray G.M. (1, 1) model prediction data, and Markov model prediction data line graph.

TABLE 6: Data state prediction.

Starting year	State	Starting steps	State		
			S1	S2	S3
2018	S3	1	0.3333	0.3333	0.3333
2017	S1	2	0.4167	0.1667	0.4166
2016	S1	3	0.3472	0.1944	0.4584
2015	S3	4	0.3039	0.2315	0.4646
2014	S2	5	0.2991	0.2373	0.4636
2013	S2	6	0.3041	0.2336	0.4623
2012	S3	7	0.3075	0.231	0.4615
2011	S2	8	0.3069	0.2313	0.4619
All			1.7002	1.1682	2.1375

According to the initial state, find the row vector corresponding to each state transition matrix and calculate the sum of each transition step number column vector, as given in Table 6:

After calculation, it can be seen from Table 6 that the sum of the column vectors of state S_3 is $2.1375 > 1.7002 > 1.1682$, so it can be predicted that the demand for cold chain products of urban residents in Jiangsu Province in 2019 is in state S_3 , that is, between the interval (1.0079, 1.0374), the predicted value $y = 0.5 \times (1.0374 + 1.0079) \times 11.8168 = 1208441.142 \text{ kt}$ can be calculated from formula (13). The relative error is 0.0158. Since the relative error of the gray model predicted value is 0.0376, it can be inferred from the list that the future predicted value gradually tends to state S_3 and gradually tends to a steady growth state.

6. Conclusion

This study uses the G.M. (1, 1) model to predict the demand for agricultural cold chain logistics in Jiangsu Province in the next five years, which embodies the idea of optimization. It uses the Markov chain to predict the gray G.M. (1, 1) model. The value is optimized, the two are combined, the prediction results show advantages, and through the fluctuation of data prediction, three suggestions are put forward for promoting the development of agricultural cold chain logistics. Due to the lack of original data in 2020 and a large amount of data calculations, there are still some data deviations in the use of Markov chains for data optimization, and the selection of the number of data in the process of Markov optimization cannot be accurate control. In the future work, we need to build a simple, practical, and easy to popularize model. In all aspects of the environmental conditions are relatively stable or change little, in a short period of time, these conclusions will still have some significance. However, the initial vector and transition matrix should be adjusted according to the actual situation in order to conform to the law of change and improve the reliability of prediction.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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References

- [1] M. Buheji, K. D. C. Cunha, G. Beka et al., "The extent of COVID-19 pandemic socio-economic impact on global poverty. A global integrative multidisciplinary review," *American Journal of Economics*, vol. 10, no. 4, pp. 213–224, 2020.
- [2] B. Prideaux, M. Thompson, and A. Pabel, "Lessons from COVID-19 can prepare global tourism for the economic transformation needed to combat climate change," *Tourism Geographies*, vol. 22, no. 3, pp. 667–678, 2020.
- [3] G. Mostafa and M. Mahmood, "Eurasian Economic Union: e," *Journal of Eurasian Studies*, vol. 9, no. 2, pp. 163–172, 2018.
- [4] E. J. Hackett, J. N. Parker, N. Vermeulen et al., "The social and epistemic organization of scientific work," *The handbook of science and technology studies*, vol. 4, pp. 733–764, 2017.
- [5] T. Pan, "Study on the impact of new crown epidemic situation on China's foreign trade enterprises and the countermeasures," in *Proceedings of the 2020 international conference on big data, artificial intelligence and Internet of things engineering (ICBAIE)*, pp. 388–392, IEEE, Fuzhou, China, June 2020.
- [6] A. Jazairy, J. Lenhardt, and R. V. Haartman, "Improving logistics performance in cross-border 3PL relationships," *International Journal of Logistics Research and Applications*, vol. 20, no. 5, pp. 491–513, 2017.
- [7] H. C. Pham, T. T. Nguyen, S. McDonald, and N. Q. K. Tran, "Information sharing in logistics firms: an exploratory study of the Vietnamese logistics sector," *The Asian Journal of Shipping and Logistics*, vol. 35, no. 2, pp. 87–95, 2019.
- [8] K. M. Park and O. Meglio, "Playing a double game? Pursuing innovation through ambidexterity in an international acquisition program from the Arabian Gulf Region," *R & D Management*, vol. 49, no. 1, pp. 115–135, 2019.
- [9] A. Ancarani and C. D. Mauro, "Reshoring and industry 4.0: how often do they go together?" *IEEE Engineering Management Review*, vol. 46, no. 2, pp. 87–96, 2018.
- [10] X. Zhang, "Investigation of e-commerce in China in a geographical perspective," *Growth and Change*, vol. 50, no. 3, pp. 1062–1084, 2019.
- [11] S. Ren, T. M. Choi, K. M. Lee, and L. Lin, "Intelligent service capacity allocation for cross-border-E-commerce related third-party-forwarding logistics operations: a deep learning approach," *Transportation Research Part E: Logistics and Transportation Review*, vol. 134, Article ID 101834, 2020.
- [12] Z. Liu and Z. Li, "A blockchain-based framework of cross-border e-commerce supply chain," *International Journal of Information Management*, vol. 52, Article ID 102059, 2020.
- [13] M. Giuffrida, R. Mangiaracina, A. Perego, and T. Angela, "Cross-border B2C e-commerce to Greater China and the role of logistics: a literature review," *International Journal of Physical Distribution & Logistics Management*, vol. 47, no. 6, 2017.

- [14] R. R. John, "Elaborations, Revisions, D: Alfred D. Chandler, Jr.'s, The visible hand after twenty years," *Business History Review*, vol. 71, pp. 151–200, 1997.
- [15] A. Asosheh, H. N. Shahidi, and H. Khodkari, "A model of a localized cross-border e-commerce," *iBusiness*, vol. 4, no. 2, 2012.
- [16] Y. Wang, F. Jia, T. Schoenherr, Y. Gong, and L. Chen, "Cross-border e-commerce firms as supply chain integrators: the management of three flows," *Industrial Marketing Management*, vol. 89, pp. 72–88, 2020.
- [17] Z. L. Jiao, "Modes and development characteristics of china's cross-border e-commerce logistics," *Contemporary Logistics in China*, Springer, Berlin, Heidelberg, pp. 211–232, 2016.
- [18] C. C. Hsu and C. Y. Chen, "Applications of improved grey prediction model for power demand forecasting," *Energy Conversion and Management*, vol. 44, no. 14, pp. 2241–2249, 2003.
- [19] S. J. Feng, Y. D. Ma, Z. L. Song, and J. Ying, "Forecasting the energy consumption of China by the grey prediction model," *Energy Sources, Part B: Economics, Planning and Policy*, vol. 7, no. 4, pp. 376–389, 2012.
- [20] X. Fang, X. Li, T. Yu, Z. Guo, and T. Ma, "Grey markov model prediction method for regular pedestrian movement trend," in *Proceedings of 2018 Chinese Intelligent Systems Conference*, Springer, vol. 528, pp. 575–584, Wenzhou, China, 2018.
- [21] C. C. Glüer, G. Blake, Y. Lu, B. A. Blunt¹, M. Jergas¹, and H. K. Genant¹, "Accurate assessment of precision errors: h," *Osteoporosis International*, vol. 5, no. 4, pp. 262–270, 1995.