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Research on Pricing Strategy of Overseas Warehousing Products under Markov Chain

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Abstract

Overseas warehouses are digital and intelligent storage facilities established by overseas companies. Overseas warehouses are not only a place for storing goods, but also an important bridge connecting production and sales, online and offline.The optimal selling price of an enterprise's products is neither the highest price nor the lowest price, but the price when the difference between sales revenue and sales cost reaches the maximum, that is, the price when the enterprise obtains the maximum profit.For the pricing problem of a single product, through mathematical model derivation, we can determine that at the optimal price, the marginal revenue of the product equals the marginal cost. At the optimal price, the price elasticity of the product is the inverse of the ratio of price to profit. Enterprises can first estimate the price elasticity of the product through random price experiments, classify the products based on this feature, and then make price decisions separately through the pricing engine. Actual test results show that after enterprises adopt the optimal price given by the Markov chain pricing model, sales, gross profit, and total transaction amount have all increased significantly.

Keywords

Markov chain; optimal price; product profit; overseas warehouse; pricing strategy

Introduction

Warehouses are a key node connecting buyers and sellers in modern logistics. Placing this node overseas is not only conducive to the expansion of overseas markets, but also reduces logistics costs. Goods exported from a country are stored in the country's warehouses by sea, freight, and air transport [1]. Overseas buyers place orders online to purchase the items they need, and sellers only need to operate online and promptly notify foreign warehouses to sort and pack the goods, and transport them from the country's warehouse to other regions or countries, which improves the logistics response time. At the same time, combined with the local logistics characteristics of foreign warehouses, it can ensure that the goods reach the end buyers safely, accurately, promptly, and at low cost [2].

By storing goods in overseas warehouses closer to end customers in advance, companies can significantly reduce the delivery time of goods, allowing products to be delivered to customers more quickly. This fast-response delivery model can not only improve customer satisfaction but also enhance customers' trust and loyalty to the brand [3]. In the fiercely competitive cross-border e-commerce market, fast delivery is often a key factor in attracting and retaining customers.

Table 1. Basic fee list for overseas warehouse products

Item	CostContent	Description
1	Product cost	The product cost is controlled by the seller.
2	Product profit	Product profits are controlled by the seller.
3	Freight	The merchant shall bear the costs of delivering the products to the overseas warehouse by sea or air, including the customs clearance and delivery fees of the package, etc.
4	Delivery failure rate cost	If the order fails to be delivered, storage fees will be incurred.
5	Return rate cost	If an order is returned, the warehousing processing fees and storage fees incurred are considered return rate costs (the average return rate for electronic products on the Amazon platform is 7%. When actually calculating, the seller can make corresponding adjustments based on the actual return rate).
6	E-commerce platform commission	The e-commerce platform commission is calculated only based on the actual sales price of the goods.
7	VAT	This fee must be paid when the product is clearing customs.
8	Overseas warehouse fees	Storage fees and delivery fees
Note: Overseas warehouse operating costs are not included here.		

Overseas warehouses can significantly reduce the international logistics costs of cross-border e-commerce and improve logistics efficiency [4]. The first leg of overseas warehouses is mostly transported by container shipping, which has more scale advantages and greatly reduces the logistics costs per unit of goods [5].

1. Inventory management and operating expenses

As part of the supply chain, overseas warehouses can perform centralized and automated inventory management, order processing, and distribution operations, greatly improving the efficiency and flexibility of the supply chain [6].

Overseas warehouses can break through these limitations and reduce the logistics and storage costs of large products. In addition, high-quality overseas warehouse services can keep the damage rate and lost item rate at a very low level, providing a strong guarantee for merchants to sell high-value goods. When shopping, local customers in the target market generally give priority to merchants who can ship from the local area. Using overseas warehouses, the local delivery advantage can greatly increase product exposure and sales[7].

In order to calculate the optimal price of a product, the concepts of marginal revenue, marginal cost and marginal profit must be introduced. Marginal revenue refers to the change in total revenue caused by an increase or decrease in business volume by a measurable unit. Marginal cost refers to the change in total cost caused by an increase or decrease in business volume by a measurable unit. Marginal revenue minus marginal cost is marginal profit [8].

There is an important relationship between marginal revenue and marginal cost, that is, when marginal revenue equals marginal cost and marginal profit equals zero, the total profit of the enterprise reaches the maximum. At this time, the sales price and sales quantity are the optimal price and optimal sales volume of the product.Inventory management is a vital part of modern business operations [9]. Its efficiency and accuracy directly affect product sales and corporate profits.

The average inventory of overseas warehouses refers to the average inventory volume over a period of time. We can calculate and analyze the average inventory level to promptly detect problems of excessive or low inventory to reduce storage costs and inventory risks.We calculate the total inventory at each time point in a period of time, add them up and divide them by the length of the period to get the average inventory. Enterprises can effectively control the average inventory level and reduce inventory costs and risks.The average inventory level of the company's best-selling products is 500 pieces. Through the timely adjustment of the inventory level through the inventory management module of Good Business, the average level has been successfully reduced to 400 pieces, effectively reducing storage costs and ensuring inventory security [10].

According to the ABC analysis method, we divide the goods into three levels: A, B, and C. Different management strategies are adopted for inventory items of different levels to achieve the best inventory management effect. The weights of all goods are calculated according to indicators such as product value and frequency of use. The inventory items are sorted according to the weights and divided into three levels: A, B, and C according to a certain proportion. This effectively manages inventory items, reduces capital turnover costs, and improves product sales efficiency [11].Enterprises can classify inventory items through ABC analysis blocks, optimize the management and sales of inventory items, reduce storage costs, and improve capital turnover.

Safety stock is a reserved amount of inventory to ensure inventory safety. It can deal with unexpected events, ensure inventory safety, and avoid problems such as supply chain disruptions and product sell-outs. Companies calculate the amount of safety stock to be retained based on historical sales data and inventory demand, etc. This can avoid inventory shortages and supply chain disruptions, improve customer satisfaction, and product sales efficiency. Safety stock needs to be adjusted flexibly and cannot be fixed. Enterprises use the safety stock module to manage inventory [12]. When product sales fluctuate greatly, the safety stock reserve is guaranteed to avoid problems such as product sell-outs.

Cycle inventory is a strategy of ordering and storing in a certain cycle to balance inventory demand and supply. Cycle inventory strategy allows enterprises to order and adjust inventory regularly to achieve the optimal inventory balance and avoid excessive or insufficient inventory. Enterprises need to determine a cycle and order, and store according to inventory demand. Balance inventory demand and supply, reduce inventory costs and risks. It effectively controls inventory, reduces costs and financial pressure, and improves supply chain efficiency.The cycle of periodic inventory needs to be determined according to the actual situation. Enterprises determine the inventory control cycle through the periodic inventory module, making the inventory more stable, reducing capital pressure, and improving capital turnover [13].

SLOB inventory refers to the management strategy for expired and slow-moving inventory. Enterprises need to adopt scientific management strategies to clean up these inventories in a timely manner to reduce costs and risks. Enterprises can analyze the usage of inventory items and remove and deal with expired and slow-moving inventory in a timely manner.Enterprises can remove invalid inventory and reduce costs and risks. They can optimize inventory management efficiency and reduce costs and financial pressure. SLOB inventory needs to be handled flexibly and the processing time cannot be delayed. Enterprises can use the SLOB inventory module to timely discover and handle expired and unsalable inventory, reduce costs and risks, and improve inventory management efficiency [14].

VMI inventory, or vendor managed inventory, is an inventory management strategy based on supplier inventory. By adopting the VMI inventory management strategy, enterprises can transfer inventory pressure to suppliers and effectively control inventory and costs. Enterprises establish contact with suppliers to determine the supplier managed inventory, and adjust the order quantity according to demand.Enterprises can quickly adjust inventory strategies to maximize the coordination of inventory and supply chain. VMI inventory requires a good supplier relationship. Enterprises use the VMI inventory module of Good Business to establish a stable relationship with suppliers, successfully achieve a certain coordination of inventory and supply chain, and reduce inventory costs and risks [15].

2. Markov chain pricing model

According to the above cost structure and analysis of its service costs, it can be seen that the first-leg transportation cost and tariff cost account for a large proportion, followed by overseas delivery costs. Therefore, the focus of warehousing cost management of cross-border e-commerce enterprises should be on first-leg transportation cost, tariff cost and overseas delivery cost. For example,

1. Basic product information

Product weight: 12kg.

Product size: 67x27x27 (about 0.05 cubic meters). Product purchase price: 140 US dollars.

2. Cost calculation

Assume that 100 bicycles are shipped by sea to the logistics company's US warehouse; customs duty rate: 4%; sea freight: 140 US dollars/cubic meter.

(1) First-leg transportation cost (including customs duty cost). Total sea freight: 700 US dollars. Total customs duty: 557 US dollars. Total customs clearance fee: 5 US dollars. Total: 1258 US dollars.

The first-leg transportation cost per bicycle: 13 US dollars.

(2) Warehousing service fee (including order processing fee, the cost of one bicycle, assuming an average storage of 30 days, calculated according to the published price). Warehousing volume charge: 0.42 US dollars. Warehousing value charge: 0.42 yuan. Order processing fee: 3.8 yuan. Total: 4.6 US dollars.

(3) Local delivery fee [United Parcel Service (UPS) shipping cost per unit]. Cost of shipping to Zone 2 in the United States: $13.22.

(3) Rationalization plan for overseas warehousing costs of enterprises

Flexibly use multiple transportation methods. Enterprises can choose five transportation methods: express delivery, air transportation, sea freight LCL and full container, and land transportation.

Choose the ocean shipping route reasonably. Taking the China-Europe route as an example, the freight rates for shipping to basic ports and non-basic ports vary greatly, generally between US$100 and US$200. Therefore, choosing a suitable shipping company and providing shipping services to basic ports can help reduce shipping costs. If the delivery date is not urgent, full sea transportation can be used. However, in the overseas warehouse model, try not to use bulk cargo. It is more economical to ship by full container or by LCL with other cross-border e-commerce companies.

Carefully design the transport packaging. Before shipment, scientifically calculate the cargo packaging, refer to the volume of the container, and reasonably design the packaging form according to the cargo volume. If the company designs each carton to hold 20 pieces of cargo, there will not be enough space in a container. If the carton is designed to hold 25 to 35 pieces, and the size of the carton is designed according to the container size, the best packing plan can be obtained, so that the container with international standards can be filled, which greatly reduces the freight cost.

Return Disposal Fee: Disposal of returned goods of no value according to customer's instructions.

Table 2. Return disposal fee

Item	Price(Euro)	Unit
Disposal (within 2 kg)	0.5	pcs
Disposal (2 to 10 kg)	1	pcs
Disposal (10 to 20 kg)	2	pcs
Disposal (over 20 kg)	5	pcs
Note: If the product contains batteries, it will be destroyed as an electronic product and an additional fee will be charged.		

Considering the product problem, the company adopts the Markov chain (s, S) pricing strategy. The overseas warehouse checks the remaining quantity of a certain product every morning, set as x, then the product pricing is:

$$\begin{cases} 0, & if\ x \geq s, \\ S - x, & \text{if}\ x < s. \end{cases}$$

Assume that inventory and product sales do not require time, and the daily demand Yn is independent and identically distributed and $P\{Y_n = j\} = a_j, j = 0{,}1$,Now we want to find a Markov chain from the above problem.

Xn is the product price at the end of the nth day. Because we need to consider the situation where the sales price Yn+1 is greater than the maximum profit Xn, the product price at the end of the n+1th day is:

$$X_{n+1} = \begin{cases} \max(0, X_n - Y_{n+1}), & X_n \geq s, \\ \max(0, S - Y_{n+1}), & X_n < s. \end{cases}$$

For Xn=i≥s , it has:

$$X_{n+1} = \begin{cases} i - Y_{n+1}, & 0 \leq Y_{n+1} < i \\ 0, & Y_{n+1} \geq i, \end{cases}$$

So for 1≤j≤i,

$$\begin{aligned} p_{ij} &= P(X_{n+1} = j | X_n = i) \\ &= P(Y_{n+1} = i - j) = a_{i-j}, \end{aligned}$$

Among 0≤i-j＜i. But j=0 has

$$\begin{aligned} p_{i0} = &\ P(i - Y_{n+1} \leq 0) = P(Y_{n+1} \geq i) \\ = &\ 1 - \sum_{k=0}^{i-1} a_k = 1 - \sum_{j=1}^{i} p_{ij} . \end{aligned}$$

Among 0≤S-j＜s. But j=0 has

$$\begin{aligned} p_{i0} &= P(S - Y_{n+1} \leq 0) = P(Y_{n+1} \geq S) \\ &= 1 - \sum_{k=0}^{S-1} a_k = 1 - \sum_{j=1}^{S-1} p_{ij} . \end{aligned}$$

In conclusion,

$$p_{ij} = \begin{cases} a_{i-j}, & j = 1,2, \ldots, i, s \leq i \leq S \\ 1 - \sum_{k=0}^{i-1} a_k , & j = 0, s \leq i \leq S \\ a_{S-j}, & j = 1,2, \ldots, S, 0 \leq i < s \\ 1 - \sum_{k=0}^{S-1} a_k , & j = 0{,}0 \leq i < s. \end{cases}$$

3. Product dynamic bidding model

The engine uses historical data on price points and demand for a specific product and processes it through a dynamic pricing algorithm.

The demand function is built based on the identified dependencies.

Advanced mathematical methods are able to process dozens of pricing and non-pricing factors to arrive at the optimal price.

After applying the recommended price, the algorithm takes into account the latest repricing results and repeats the cycle.

The product bidding method is a dynamic bidding model where enterprises can update their bids in each running instance cycle instead of using a single bidding price from the beginning to the end. The dynamic bidding model uses a bidding decision sequence consisting of two bidding decisions to make bidding decisions for each running instance cycle.

We formalize the problem of solving the global optimal bidding decision as a restricted Markov decision process. Here, we define a six-tuple {O, X, A, P, M, D} to establish a linear programming equation system equivalent to the Markov model.O ={t| t = 1,2,...} represents the running instance cycles of the bidding decision sequence, that is, one bidding decision is generated per unit hour. X={x1,x2,...,xn} represents a finite state space, and the physical meaning here is the running instance state space arranged in time order. It should be noted that although we assume a discrete state space here, the continuous state space can still be converted into a discrete state space for solution. Here, we use (xi∈X) to represent the running instance state of the i-th running instance cycle after the computing task is submitted.

A represents the set of bidding decisions, where A={B,G}. Theoretically, there are 4·E possibilities for the running instance status in each running instance cycle. As mentioned above, E is defined as the number of different prices in the historical price data of the running instance to be bid. Since α, β∈{I,O}, there are 4 different combinations of (α, β) tuples, so there are 4·E possibilities for the running instance status in each running instance cycle.

The optimal price of a product can be determined according to the following formula:

$$F(S,0)=0;$$

$$F(0,i)=0, 1\le i\le L;$$

$$F(S,i)=F(S,i)=\sum_{S'=0}^{S} T(S,p_i,S')\times(F(S',i-1)+R(S,p_i,S')), 1\le i\le L;$$

$$P_i=arg\max_{r_{\min}\le\alpha\le r_{\max}}\{\sum_{S\prime=0}^{N} T(S,\alpha,S')\times(F(S',i-1)+R(S,\alpha,S'))\};$$

Among them, S is the current inventory, S' is the expected inventory, L is the remaining clearance time, α is the possible price of the product, P i is the optimal price of the product on the i-th day, P min is the minimum price of the product, and P max is the maximum price of the product.T(S,α,S') is the state transition probability from the current inventory state S to the expected inventory state S' when the execution price α is reached, and T(S,P i,S') is the state transition probability from the current inventory state S to the expected inventory state S' when the optimal price P i is reached，F(S,i) is the cumulative profit when the remaining liquidation time is i. The current inventory is S. F(S',i-1) is the expected cumulative profit when the remaining liquidation time is i-1 and the expected inventory is S'. R(S,α,S') is the expected maximum profit from the current inventory state S to the expected inventory state S' under the execution price α. R(S,P i,S') is the expected maximum profit from the current inventory state S to the expected inventory state S' under the execution of the optimal price P i. F(S,0) and F(0,i) are the initial values.

Assume the price matrix of the Markov chain is:

$$P=\begin{pmatrix}1-p & p\\ q & 1-q\end{pmatrix}, 0<p,q<1,$$

We consider $P^{(n)}$ when $n\to\infty$.

From $P^{(n)}=P^n$, we can see that we only need to calculate the limit of the n-fold product of P. Let

$$Q=\begin{pmatrix}1 & -p\\ 1 & q\end{pmatrix},\qquad D=\begin{pmatrix}1 & 0\\ 0 & 1-p-q\end{pmatrix}$$

Then,

$$Q^{-1}=\begin{pmatrix}\frac{q}{p+q} & \frac{p}{p+q}\\ \frac{1}{p+q} & \frac{1}{p+q}\end{pmatrix},$$

$$P=QDQ^{-1},$$

This is a similarity transformation of P, where D is a diagonal matrix, which simplifies the calculation of the matrix power:

$$\begin{aligned}P^n &= (QDQ^{-1})^n = Q\begin{pmatrix}1 & 0\\ 0 & 1-p-q\end{pmatrix}^n Q^{-1}\\ &=\begin{pmatrix}\frac{q+p(1-p-q)^n}{p+q} & \frac{p-p(1-p-q)^n}{p+q}\\ \frac{q-q(1-p-q)^n}{p+q} & \frac{p+q(1-p-q)^n}{p+q}\end{pmatrix}\end{aligned}$$

Due to |1-p-q|, the limit of P^n is:

$$\lim_{n\to\infty}P^n=\begin{pmatrix}\frac{q}{p+q} & \frac{p}{p+q}\\ \frac{q}{p+q} & \frac{p}{p+q}\end{pmatrix},$$

It can be seen that the n-step transition probability of this Markov chain has a stable limit, and the two rows of the matrix are the same, which means that no matter which state you start from initially, the price fixation probability distribution of the two states is fixed after a long enough time.

So far, we have completed the search for the globally optimal bidding method for the current computing task on the running instance to be bid, and achieved the lowest operating cost while meeting user requirements.

E-commerce platform pricing USD = (purchase cost + product profit + shipping fee + storage fee + delivery fee) * (1 + return rate) / (1-commission rate) * exchange rate

The core of dynamic pricing is to adjust the dynamic balance between market demand and supply through price levers. When market demand increases, appropriately raising prices can suppress excessive demand and avoid resource shortages; conversely, when the market supply is oversupplied, lowering prices can stimulate demand and promote sales. This flexible pricing mechanism helps companies optimize resource allocation and maximize profits.

It relies on big data and artificial intelligence technology. Through real-time analysis and mining of market data, companies can accurately grasp market changes, predict consumer behavior, and thus formulate scientific and reasonable pricing strategies. These data include but are not limited to market demand, competitor prices, consumer purchasing power, product costs, etc. It also emphasizes differentiated pricing and personalized marketing. Companies can formulate differentiated pricing strategies based on the needs, preferences, and payment capabilities of different consumers to achieve precision marketing. This pricing method can not only improve customer satisfaction but also enhance the market competitiveness of enterprises.

4. Conclusion

Enterprise products require a comprehensive inventory management and pricing solution, including the application of mathematical models and various inventory management strategies. This can help enterprises effectively reduce inventory costs and risks, and improve the efficiency of inventory management and product sales.

As an important part of cross-border e-commerce, the profit model and operation mechanism of overseas warehouses are crucial to the success of enterprises. Through in-depth analysis of the direct sales model and the service fee model, we can see that optimizing procurement and inventory management, formulating effective pricing strategies, controlling warehousing costs, optimizing the supply chain, providing high-quality services, investing in warehousing facilities and technologies, managing partnerships, and expanding the market are all key factors in the profitability of overseas warehouses. At the same time, cost control, risk management, and strong management capabilities and resources are also important guarantees to ensure the successful operation of overseas warehouses.

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