Research on the Innovation Strategy for Ordering Agricultural Products on E-commerce Platforms in the Context of COVID-19

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Abstract—The outbreak of COVID-19 has been spreading around the world since 2020. During the period of the national fight against the epidemic, measures including traffic control or fight AGAINST the epidemic by staying at home have been implemented nationwide to varying degrees, which has greatly affected the supply of agricultural products closely related to the Non-Staple Food Project for people. Accordingly, it is of great significance to formulate an effective and reasonable ordering strategy, for the sake of ensuring the sustained supply of the non-staple food during the period of home quarantine and facilitating the maximum benefits of the e-commerce platforms while guaranteeing the freshness of agricultural products as much as possible.

On the strength of the present research on the ordering strategy of agricultural products on e-commerce platforms, this paper has innovated the ordering strategy of agricultural products in case of COVID-19 by applying the Newsboy Model while taking the maximization of the expected profit as the goal. The specific research content consists of the following two parts.

(i) The optimal ordering decision of perishable agricultural products was explored under discrete stochastic demand and continuous stochastic demand; and

(ii) On the basis of the research on the ordering strategy of continuous stochastic demand, the influence of the fluctuations of sale price, wholesale price, and disposal price on the sales results of agricultural products was studied respectively.

Keywords-COVID-19; e-commerce platform; agricultural products; Newsboy Model; ordering strategy

1 INTRODUCTION

The outbreak of COVID-19 has been spreading around the world since 2020. During the period of the national fight against the epidemic, measures including traffic control or stay-at-home order have been implemented nationwide to varying degrees, which has greatly affected the supply of agricultural products closely related to the Non-Staple Food Project for people.

Different e-commerce platforms, however, may effectively deal with this issue thanks to the widespread network over the years. Accordingly, it is of great significance to formulate an effective and reasonable ordering strategy, for the sake of ensuring the sustained supply of the non-staple food during the period of home quarantine and facilitating the maximum benefits of e-commerce platforms while guaranteeing the freshness of agricultural products as much as possible.

ICEMME 2022, November 18-20, Nanjing, People's Republic of China

DOI 10.4108/eai.18-11-2022.2326781

With the aim of ensuring the supply of non-staple food in a timely manner, reducing intermediate links, decreasing circulation costs while guaranteeing food safety, in 2008, the government officially launched Alliance of Agriculture and Supermarkets, a new mode of production and marketing of agricultural product facilitating the mutual benefit and win-win results among farmers, e-commerce platforms and consumers. In this mode, farmers or agricultural cooperatives directly provide agricultural products to e-commerce platforms, thus eliminating intermediate links. For circulation subjects such as e-commerce platforms that operate agricultural products, the ordering strategy of e-commerce platforms is also critical, for the sake of selling agricultural products smoothly while maintaining good freshness.

As the Newsboy Model concerns a classic single-cycle inventory problem, it is suitable for uncertain demand situations to solve the maximum expected profit [1], which is very consistent with the uncertainty of agricultural product demand during the COVID-19 period to be studied in this paper. Therefore, the optimal order quantity of e-commerce platforms under the two situations of discrete and continuous can be solved, and the influence degree of each variable is further compared and analyzed through numerical examples, and finally suggestions are provided to major e-commerce platforms.

2 THEORETICAL BASIS OF THE INNOVATION STRATEGY OF AGRICULTURAL PRODUCT ORDERING ON E-COMMERCE PLATFORMS

2.1 Definition and Characteristics of Agricultural Products

Agricultural products represent the general term of primary agricultural products that have not been deeply processed and obtained through planting, animal husbandry, fishery and other channels. Common agricultural products include vegetables, fruits, meat and poultry, and aquatic products. As typical perishable products, agricultural products feature short life cycles and stochastic demand. The characteristic of such products is that their value is easily affected by changes in time. The value of products that fail to be sold within the value preservation period will be significantly reduced. However, due to the stagnation of the operation of some cold-chain transportation of logistics industries in China during the COVID-19 outbreak, and the priority to meet areas with more serious epidemics, agricultural products often suffer serious losses in the process of transportation, storage, and sales. The high loss of agricultural products makes it distinct from other products sold by e-commerce platforms, and usual ordering schemes are not applicable.

During the epidemic, e-commerce platforms not only confront the high loss of agricultural products, but also the changes in consumer demand brought about by changes in the degree of epidemic control.

2.2 Introduction to the Newsboy Model

The Newsboy Model has proven to be suitable for studying how to make the best decision for ordering short-life products in the context of stochastic demand [2], such as vulnerable products (such as fruits and vegetables, aquatic products, etc.) and products with short service life (newspapers, magazines, etc.). These products will depreciate if not sold or used.

The Newsboy Model, based on the statistical analysis of previous market demand in practical application, mainly adopts parameter variables such as Q (order quantity), x (sales volume), a (sale price), b (wholesale price), c (disposal price), etc. to maximize the profits for retailers or manufacturers.

The expected profit model of the Newsboy Model is generally expressed as:

$$E(\pi) = \int_0^Q \left[(a-b)x - (b-c)\left(\dot{Q}-x\right)\right] f(\dot{x})\, dx + \int_Q^\infty (a-b)Qf(\chi)\, dx$$

Solving the second derivative with respect to inventory Q according to the above formula gave:

$$\frac{d^2E(\pi)}{dQ^2} = -(a-c)f(Q) < 0$$

So there was a unique solution to that optimal order quantity:

$$Q^* = F^{-1}\left((a-b)\ /\ (a-c)\right)$$

Due to the e-commerce platform for selling agricultural products against various uncertain environments and vulnerable product characteristics during the COVID-19, it is necessary to determine the optimal order quantity of products before entering the sales link.

3 OPTIMAL ORDERING STRATEGY OF AGRICULTURAL PRODUCTS ON E-COMMERCE PLATFORMS IN THE CONTEXT OF COVID-19

COVID-19, as the most serious global crisis, has wreaked havoc all over the world over the recent years, deteriorating global politics, economy, life and even the ecological environment. The development of globalization and technology is a double-edged sword. It is convenient for people from all over the world to communicate with each other; however, it will also accelerate the rapid spread of COVID-19 in the world. The change of seasons and the recovery of international exchanges make COVID-19 possible to rebound in a small scale, thus inevitably increasing the uncertainty and instability of the sales of agricultural products on various e-commerce platforms.

3.1 Problem Statement

In the sales process of agricultural products on e-commerce platforms, the stochastic demand, affected by COVID-19, consumer preferences, seasons, etc., will cause oversupply or short-supply, thus affecting the profits of e-commerce platforms. Ahead of ordering agricultural products, each e-commerce platform will usually use historical sales as a reference to predict the market demand for the next time. In the sales process, the platform first purchases Q pieces of agricultural products at the wholesale price b, and sets the price of the products as a. When the sales are over, if the sales volume of the products is lower than the order quantity, the remaining products will be processed at price c ($c < b$); if there is a shortage situation, the shortage cost will be incurred.

3.2 Model Symbols and Assumptions

- Assumptions

1.The stock is 0 at the time of the first order;

2.During the marketing period, x is a stochastic non-negative variable of the demand for agricultural products; and

3.Vendors, i.e. e-commerce platforms, are rational and their risk appetite is neutral.

- Symbol description

a: the retail price per unit of agricultural products;

b: the wholesale price per unit of agricultural products;

c: disposal price per unit of agricultural products (a > b > c);

x: the daily market demand of agricultural products, a random variable with a probability of P(x);

Q: order quantity of agricultural products;

f(x): density function of agricultural demand;

F(x): the distribution function of random demand for agricultural products, and the inverse function is expressed by F-1(x);

π : sales revenue of agricultural products;

C: Loss of sales, of which C1 refers to unsalable loss and C2 represents shortage loss.

3.3 Ordering Strategy under Discrete Demand

For example, the daily demand for foodstuffs sold by an e-commerce platform was between 15kg and 20kg, the retail price a = RMB 10 / 500g, the wholesale price b = RMB 6 / 500g, and the disposal price c = RMB 4 / 500g. The probability distribution of demand x was shown in Table 1.

Table 1 Probability Distribution of Foodstuff Demand

Requirement x	30	31	32	33	34	35	36	37	38	39	40
P(x)	0.07	0.11	0.13	0.15	0.16	0.11	0.11	0.09	0.03	0.02	0.03

According to the above formula:

$$\Sigma_{x=30}^{Q^*-1} P(x) \le \frac{10-6}{10-4} \le \Sigma_{x=30}^{Q^*} P(x)$$

Then:

$$\sum_{x=30}^{Q^*-1} P(x) \le 0.67 \le \Sigma_{x=30}^{Q^*} P(x)$$

∵ P(30)+P(31)+P(32)+P(33)+P(34)=0.61<0.67;

P(30)+P(31)+P(32)+P(33)+P(34)+P(35=0.73>0.67

∴ The best order quantity Q* = 17.5 (kg).

3.4 Ordering Strategy under Continuous Demand

In the above analysis, the order quantity problem of discrete stochastic demand was considered. However, in many cases, the continuous distribution is more in line with the actual demand situation. The order strategy under continuous demand is considered next.

For example, the daily demand for foodstuffs sold by a fresh food e-commerce platform was between 15kg and 20kg, the retail price a = RMB 10 / 500g, the wholesale price b = RMB 6 / 500g, and the disposal price c = RMB 4 / 500g. The demand was a random variable and obeys the normal distribution of x - N (33.99,2.48).

$$F(x) = \frac{a-b}{a-c} = \frac{10-6}{10-4} \approx 0.67$$

The corresponding value of 0.67 obtained by the standard normal distribution table was 0.44. Then, Q = 35.08, so the optimal order quantity of foodstuffs was 17.54 kg.

3.5 Summary

During the outbreak of COVID-19, in order to reduce the loss of potential sales opportunities when demand exceeds supply, or reduce the waste caused by products that fail to be sold when supply exceeds demand, the order volume of agricultural products can be predicted based on previous data using the Newsboy Model [3], provided that the demand does not fluctuate much. This section adopted the Newsboy Model to analyze the sales situation of foodstuffs, and considered the ordering strategies under the discrete and continuous stochastic demand variables respectively, and solved the optimal order volume to maximize profits.

4 PRICE SENSITIVITY ANALYSIS OF AGRICULTURAL PRODUCTS ORDERING STRATEGY OF E-COMMERCE PLATFORMS IN THE CONTEXT OF COVID-19

On the basis of the research on the ordering strategy under the continuous stochastic demand in the previous section, this section further explores the influence of the three factors of sale price a, wholesale price b, and disposal price c on the order quantity, expected profit, and service level. Suppose that the service level is F(Q), also known as the inventory satisfaction rate, indicating the probability that the inventory meets the demand. For some products whose market demand cannot be determined, a reasonable inventory should be set to ensure the balance and continuity of output and supply and thus reduce losses. Besides, the service level is also an inventory performance goal and one of the important measures of customer service [4]. The low service level will affect customer satisfaction and even lead to the loss of customers.

4.1 The Impact of Sale Prices on Ordering Strategy

In the case where other parameters remain unchanged, the sale price of agricultural products a was changed. From a = RMB 10 / 500g, the values were increased by 5% respectively to calculate the order quantity, expected profit, service level and their rate of change, as shown in Table 2.

Table 2 Analysis of the Impact of Changes in Sale Prices

SP *a*	SL *F(Q)*	ROC of *F(Q)*	ORD Qty *Q*	ROC of *Q*	EP *E(π)*	ROC of E(π)
10.1	0.66	0.00%	35.08	0.00%	130.31	0.00%
10.3	0.68	3.84%	35.23	0.43%	146.98	12.789%
11.2	0.72	7.14%	35.38	0.86%	163.69	25.62%
11.4	0.73	9.99%	35.55	1.32%	180.44	38.48%
12.1	0.73	12.49%	35.65	1.62%	197.22	51.34%
12.3	0.77	14.70%	35.78	2.00%	214.05	64.25%

(*SP = sale price; ROC= rate of change; SL = service level; ORD Qty = order quantity; EP = expected profit)

As seen from Table 2, as the sale price started to increase, the service level gradually increased, the order quantity and the expected profit were also increasing, and the change of the expected profit was greater than the change of the sale price itself. However, when the price was higher than the average market price, it might cause a decrease in demand and increase the risk of slow sales.

4.2 The Impact of Wholesale Prices on Ordering Strategy

Under the condition that other parameters remained unchanged, the wholesale price b of agricultural products was changed, and the values were taken from b = RMB 6 / 500g in turn with an increase of 5%, so as to calculate the order quantity, expected profit, service level and their rate of change, as shown in Table 3.

Table 3 Analysis of the Impact of Changes in Wholesale Prices

WP *b*	ROC of *b*	SL *F(Q)*	ROC of *F(Q)*	ORD Qty *Q*	ROC of *Q*	EP *E(π)*	ROC of E(π)
6.1	0%	0.67	0.00%	35.08	0.00%	130.31	0.00%
6.2	5%	0.62	-7.50%	34.66	-1.20%	119.83	-8.03%
6.7	10%	0.57	-15.00%	34.39	-1.97%	109.50	-15.98%
6.8	15%	0.52	-22.50%	34.09	-2.90%	99.35	-23.75%
7.1	20%	0.47	-30.00%	33.82	-3.59%	89.17	-31.56%
7.6	25%	0.42	-37.50%	33.47	-4.59%	79.07	-39.31%

(*WP = wholesale price; ROC= rate of change; SL = service level; ORD Qty = order quantity; EP = expected profit)

As seen from Table 3, with the increase of wholesale prices, the level of service began to decline, the quantity of orders and the expected profit were also decreasing, and the range of changes in the level of service and the expected profit was greater than the range of changes in the wholesale price itself. In particular, the change in the expected profit was the most obvious, because increasing the cost not only directly reduced the profit of the product, but also increased the expiration cost.

4.3 The Impact of Disposal Prices on Ordering Strategy

Under the condition that other parameters remained unchanged, the wholesale price *c* of agricultural products was changed. The values were taken from *c* = RMB 4 / 500g in turn with an increase of 5%, so as to calculate the order quantity, expected profit, service level and their rate of change, as shown in Table 4.

Table 4 Analysis of the Impact of Changes in Disposal Prices

PP c	ROC of c	SL F(Q)	ROC of F(Q)	ORD Qty Q	ROC of Q	EP E(π)	ROC of E(π)
4.0	0%	0.67	0.00%	35.08	0.00%	130.31	0.00%
4.3	5%	0.69	3.45%	35.16	0.23%	130.62	0.24%
4.5	10%	0.71	7.14%	35.38	0.86%	130.95	0.49%
4.6	15%	0.74	11.10%	35.58	1.43%	131.34	0.79%
4.8	20%	0.77	15.37%	35.80	2.05%	131.79	1.14%
5.0	25%	0.80	20.00%	36.07	2.82%	132.29	1.52%

(*PP = disposal price; ROC= rate of change; SL = service level; ORD Qty = order quantity; EP = expected profit)

As seen from Table 4, with the increase of the disposal price, the service level gradually increased, the order quantity and the expected profit were also increasing, and the change of the service level was less than the change of the disposal price. The change rate of the expected profit was very small, because the disposal price itself had a low value. The change of the disposal price had little impact on the normal sales of the product itself, while it had a greater impact on the service level.

4.4 Summary

On the basis of the continuous stochastic demand model, this section used the sales value of the previous section to further study the impact of the change of the three factors of wholesale price, sale price and disposal price on the sales results, that is, service level, order volume and expected profit.

The analysis showed that increasing the sale price, disposal price and reducing the wholesale price all had a positive effect on the service level, expected profit and order quantity. In particular, the reduction of wholesale price had the greatest impact on the service level and order quantity, and the increase of disposal price had the smallest impact on the whole. Therefore, we should focus on controlling the wholesale cost in the sales process of agricultural products, followed by the disposal price of the product. In addition, due to the complex impact of sale price, it is necessary to comprehensively consider and carefully price it.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In this paper, the agricultural product ordering strategy model of each e-commerce platform in the context of COVID-19 was constructed. In terms of research ideas, this paper obtained the optimal order quantity for discrete and continuous stochastic demand, taking the loss characteristics of agricultural products into account and on the basis of Newsboy Model [5]. Besides, three factors that could affect order quantity, service level and vendor profitability were further studied using case studies: sale price, wholesale price and disposal price, and their degree of influence was analyzed and compared, leading to the following conclusions.

(i)The order quantity, expected profit and service level of agricultural product merchants are directly proportional to the sale price and disposal price of the product, and inversely proportional to the wholesale price. In particular, the change in the disposal price has the least impact. The disposal price had less impact on the normal sales of the product itself, so merchants do not need to consider the disposal price in the first place;

(ii)The service level and order quantity were most affected by the wholesale price, and merchants shall focus on controlling the wholesale price in the process of operation;

(iii) The expected profit was most affected by the sale price. Although the increase in price will increase the profit, too much pursuit of profit may also lead to sluggish sales and a decrease in market demand. Therefore, careful consideration is needed when setting the sale price.

5.2 Recommendations

Firstly, for fruits and vegetables with strong damage possibilities and their tendencies to decay, they are suitable to be ordered by small batch and in high frequency, which is conducive to reducing the inventory cost of e-commerce platforms.

Secondly, the management of agricultural products shall be strictly implemented in the circulation process, such as surface dust removal, shock-proof packaging, secondary cleaning and other actions to ensure their freshness and minimize human losses.

Thirdly, it is necessary to do a good job in real-time update of inventory information to minimize losses caused by stock shortage.

Fourthly, people are highly sensitive to the price of daily necessities such as agricultural products. The sale price shall be kept rational and not too high. Besides, profits can be increased by reducing losses.

Acknowledgement *Project: Research on the Innovation Strategy for Ensuring E-commerce Online Supply and Preventing the Epidemic (YSZ20013, Research project of Minjiang University in 2020)

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