Financial Engineering and Risk Management (2023)
Clausius Scientific Press, Canada

DOI: 10.23977/ferm.2023.061105
ISSN 2523-2576 Vol. 6 Num. 11

Income Analysis of Vegetable Commodities Based on Mathematical Programming

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Keywords: Price elasticity model, Goods revenue model, Newton iteration method

Abstract: The income of vegetable commodities is particularly important for supermarkets. Mastering the sales rules of vegetable commodities and meeting the needs of consumers is the key to the success of supermarkets. Based on the data in the attachment of Question C of the 2023 National Mathematical Modeling Competition for College Students, this paper establishes a price elasticity model to explore the sensitivity of the sales volume of different categories of vegetables to the sales price. Then the profit rate is regarded as the addition proportion, the unitary regression model is established, the corresponding fitting curve is drawn, and the relationship between the two is found to be inversely proportional. Further, based on the idea of mathematical planning, the goods income model is established, taking the income as the target equation and discount frequency as the discount probability, in order to calculate the weighted average price of each vegetable. At last, Newton's iterative method is used to calculate that the maximum commercial surplus income from July 1 to 7, 2023 is 11875.252 yuan.

1. Review of relevant research literature:

Which products are discounted, and when they are discounted, can lead to the most sales, which also has a big impact on the ultimate profit of the merchant. Fang Li [1] (2021) studied the types of food in colleges and universities and analyzed that the cost of vegetable food accounted for 13% of the total food expenditure of schools. Because vegetables have a higher price and a lower expenditure, it is particularly important for merchants and consumers to determine a reasonable price of vegetables. Wang Shanshan [2] (2013) pointed out the practical significance of the formation of vegetable prices through the investigation of marketing and agricultural prices, which is conducive to stabilizing vegetable prices and balancing the interests of all parties in the vegetable industry. Tong Qiang [3] (2022) pointed out that "small profit" does not necessarily lead to "more sales" of goods. For some daily products, the final profit of merchants when they sell at discount may be less than that when they do not sell at discount. Therefore, it is not recommended for merchants to sell these products at discount. The sale of luxury goods at a discount can promote the demand of customers, increase the sales volume and thus obtain greater profits. The purchase price of vegetables is not the same in every season. Huang Jinggui and Li Chunhong [4] (2019) used a spatial econometric model to study the influencing factors of vegetable prices and found that the seasonal variation characteristics of vegetables lead to fluctuations in vegetable prices, which will also affect the final profits of merchants. At the same time, the quantity of purchased vegetables also affects the final income of the merchant.

When the quantity of purchased vegetables far exceeds the sales volume, the goods need to be stored, but a certain amount of losses will inevitably occur. Feng Kunxuan [5] (2015) studied the optimal storage temperature of vegetables and the optimal placement spacing of stored vegetables.

2. Background of the problem:

The pricing and replenishment of vegetable commodities are particularly important for supermarkets. Mastering the sales rules of vegetable commodities and the relationship between vegetable categories and individual products is the key to the success of supermarkets. Among them, the most important thing for merchants is the profit margin of vegetable goods. At present, the ability of market merchants to price vegetable commodities, so this paper launches the research on the reasonable pricing of vegetable commodities. This paper will focus on the analysis of vegetable commodity pricing and price elasticity.

3. Analysis of vegetable commodity income and its factors:

3.1 The mechanism by which the rate of vegetable loss affects the income of vegetable commodities

A recent study by the Food and Nutrition Development Institute of the Ministry of Agriculture and Rural Areas found that the average loss and waste rate of vegetable food in China is 22.7% per year, weighted by quality, about 160 million tons, of which 120 million tons of food is lost in the production and circulation link. The main causes of food loss are uneven sowing in production, excessive and extensive, unrefined harvesting and incomplete cold chain in storage and transportation. There is a close relationship between vegetable consumption and vegetable income. It is particularly important to reduce vegetable products to the normal value of the loss rate of vegetable products, the key is that operators need to be able to pay attention to every link, from the management, transportation and other aspects. Vegetable and fruit supermarket operators should strictly control and manage the whole process of purchasing, warehousing and display and sales of vegetables and fruit products, effectively reduce the amount of vegetable loss to a minimum, and improve operating profits, in order to achieve the maximum realization of supermarket.

3.2 The mechanism of vegetable discount rate and pricing affecting the income of vegetable commodities

Discount rate is the interest that sales enterprises return to buyers, which is mainly divided into: commercial discount and cash discount. Commercial discount is the price that must be paid for a long-term relationship with the shopper. The discount is given to the shopper on the basis of the original purchase price. Cash discounts are preferential discounts given to customers. Ensuring the discount profit of supermarket and the preferential balance between customers can improve the return rate of goods. Pricing will have a certain impact on the income of vegetable commodities. Pricing will depend on the ease of transport, the distance of transport, the cost and production of vegetables in each region. First, in terms of transportation difficulty, the transportation of plains is higher than that of hills and mountains, and the pricing is relatively high. Second, the distance between the place of origin and the place of transportation will determine the transportation cost and raise the price. The third is relatively good when the production of a certain area is in a reasonable proportion to the demand, which is greater than the latter will reduce the cost, and the latter is greater than the former.

3.3 The mechanism of the effect of vegetable sales volume on vegetable commodity income

The yield of vegetable commodities depends on how many vegetables are sold. There is a positive correlation between sales volume and vegetable commodity income. First of all, the output of vegetables will indirectly determine the sales volume of vegetables. When the output is greater than the sales volume, the vegetables will be unsalable, which may bring negative economy. When the output is less than the sales volume, it will reach a state of short supply, reducing the income of the commodity. Therefore, the equilibrium state will promote the income of vegetable commodities. Secondly, the stability of vegetable supply channels will affect the sales volume of vegetables, and the stable supply of vegetables can bring a great sense of security to supermarkets and improve the yield of vegetables. Finally, the consumer is the key to sales, with some specific means to attract customers, increase sales is crucial to improve profitability.

4. Establishment and analysis of vegetable commodity income model:

4.1 Construction of vegetable price elasticity model.

This paper mainly analyzes the sensitivity of vegetable sales to vegetable pricing. Here, we choose the change value of commodity demand as the dependent variable, and the change value of commodity price and the change value of consumer income as the independent variable to explore the impact of vegetable pricing changes on vegetable sales in the market.

Based on the price elasticity model:

$$e = \frac{(Q_2 - Q_1)}{(Q_1 + Q_2)} \frac{(D_1 + D_2)}{(D_2 - D_1)} \tag{1}$$

$$f = \frac{(Q_2 - Q_1)}{(Q_1 + Q_2)} \frac{(I_1 + I_2)}{(I_2 - I_1)} \tag{2}$$

When the elasticity coefficient is greater than 1, it means that the price is elastic demand; when the elasticity coefficient is less than 1, it means that the price is inelastic demand; if the elasticity coefficient is equal to 1, it means that the market sales volume has a linear relationship with the price of vegetables, and the change of vegetable prices will not affect the change of vegetable sales volume.

The above analysis of the meaning of the two elastic coefficients, the following will be based on the two elastic coefficients to calculate the total sales of different categories of vegetables, as shown in the following form:

$$Q = f * A^{-e} \tag{3}$$

4.2 The establishment of goods income model

Now we need to analyze the daily replenishment strategy and pricing strategy for the coming week according to the relevant data. In this problem, we used the least square method to fit the regression model of cost-plus pricing and total vegetable sales volume to fit a curve with strong correlation. The following are the main forms of the model:

$$P * (1 - r) = Q \tag{4}$$

$$P = \frac{Q}{1 - r} \tag{5}$$

$$\frac{A-B}{A}=E_1 \tag{6}$$

$$A=B*(1+E_1) \tag{7}$$

Among them, A means the price, B means the cost price, E_1 means the profit rate, and P means the replenishment. In the above formula, we take the profit rate as the percentage of addition and determine the corresponding interval through curve fitting.

Through the analysis of the total sales volume and pricing of various vegetables by the above model, we can find the relationship between different types of vegetables and the market vegetable pricing. In order to obtain the maximum profit of the supermarket, we establish the goods income model. The goods income model is a benefit model, which needs correlation analysis of different indicators, and obtains the most suitable income formula for vegetables according to the selling cost and pricing. The model is shown as follows:

$$Max w_i=(Q[r_1+1+(r_{2}-r_1)i]-B*\beta(P-Q)) \tag{8}$$

$$w=\sum_{i=1}^{251} w_i \tag{9}$$

Where, w represents the total revenue, i represents the discount probability, ß represents the loss rate, α represents the discount rate, P represents the replenishment volume, r_1 and r_2 represents the profit rate before discount and profit rate after discount respectively. In this formula, we take into account the reasons why the seller discounts the goods when the vegetables are damaged and the quality is reduced. In this formula, we introduce the concept of discount probability. Since the frequency of events is equal to the probability of events when the data is large, we divide the number of discounts in the purchase record by the total number of samples to obtain the discount probability.

4.3 Newton's analysis of vegetable income

Newton iteration model is established to solve the problem of maximum yield of vegetables. Newton iteration is a method to find the optimal solution in the optimization problem through a large number of iterations, update the approximate solution, and its core is to approach the limit value of a function through the tangent line of a certain function at a certain point.

In this problem, we should first establish an equation, f(p) will be used as the total income w to convert the problem into the form of an equation. Then, we will select an initial value P_0 in the sample data, and carry out corresponding iterative operations according to Newton's iterative formula, and constantly judge the convergence until the result converges, and finally obtain an approximate solution P .

The model can be expressed as:

$$w_i=f_{(P_{ij})}=f_{(P_n)}+f^{'}(P_n)+\frac{f^{''}_{(p_n)}}{2!}(P-P_n)^2+\ldots \tag{10}$$

$$P_{n+1}=P_n-\frac{f_{(P_n)}}{f^{'}_{(p_n)}}(n=1,2,3....) \tag{11}$$

w_i represents the revenue of each item, P_{ij} represents the revenue of i item on day j .

5. Analysis and solution of vegetable income examples:

In order to better explore the relationship between the total sales volume of each vegetable category and the cost plus pricing, we established a regression model and carried out a fitting analysis of the data:

$$SSE = \sum_{i=1}^{n} (w_i - \hat{w})^2 \tag{12}$$

$$SSR = \sum_{i=1}^{n} (\hat{w}_i - \bar{w})^2 \tag{13}$$

$$SST = SSE + SSR \tag{14}$$

$$R^2 = 1 - \frac{SSE}{SST} \tag{15}$$

SSE is the total sum of squares, which refers to the error between the predicted value and the original sample value. SSR is the regression sum of squares, which represents the error between the predicted value and the original sample value. Known w_i as the revenue per item, w is the total revenue. To solve the equation $f(x)=a*x^b+c$, it is calculated that $a=7.2291*10^{-13}$, b=-43.09, c=47.49, where the confidence interval of a is ($-4.85*10^{-11}$, $4.9*10^{-11}$), the confidence interval of b is (-128.8,42.64), and the confidence interval of c is (-33.49,128.5).

According to the establishment of the above model, we have analyzed the relationship between the sales volume of different categories of vegetables and the cost plus pricing. Now we need to analyze the daily replenishment strategy and pricing strategy of the coming week according to the relevant data such as the total daily replenishment amount of different categories in the past two years. In this problem, we used the least square method to fit the regression model of cost-plus pricing and total vegetable sales volume to fit the correlation curve .The regression curve is as follows:

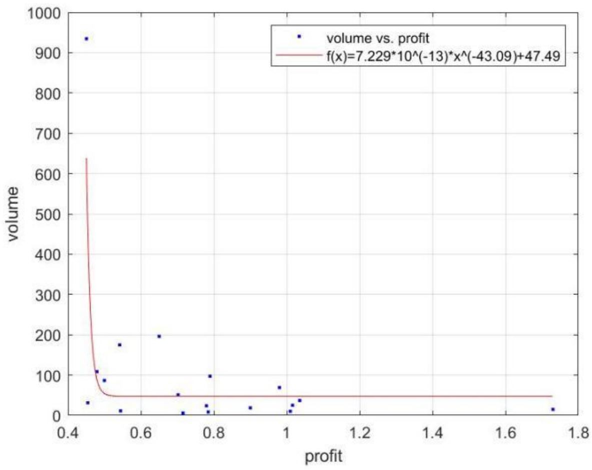

Figure 1: Relationship between total sales volume and markup ratio

As shown in Figure 1, we can see that the sales volume is inversely proportional to the markup ratio. The larger the markup ratio, the smaller the sales volume. Before 0.5, the markup ratio has a great impact on the sales volume, and after 0.5, the sales volume gradually flattens out, and the sales volume basically remains unchanged.

According to formula (13): $SSE=3.235*10^5$, the goodness of fit is obtained by using least square method R^2=0.5862. The reliability of goodness of fit can reach 95% through calculation, and the fitting curve is more accurate.

In summary, we take a profit of 0.45 as the optimal profit margin and price it accordingly.

The goods revenue model established by the above:

$$Maxw_i = (Q_A[r_1+1+(r_2-r_1)i]-B*\beta(P-Q)) \tag{16}$$

By differentiating the function and finding stagnation point, we can get the replenishment quantity and the maximum profit when the profit reaches the maximum value.

Taking 2023 mathematical modeling competition data as an example, using the total sales of different kinds of vegetables, we need to take the total inventory of each single product of the existing data from July 1 to July 7 as the X-axis, and use Newton iteration method to find the total revenue.

We can use a three-way chart of aggregate maximum returns for the four weeks leading up to July 1, 2023:

Table 1: Three-line chart of the relationship between time and revenue

time / index	6.3-6.9	6.10-6.16	6.17-6.23	6.24-6.30	7.1-7.7
earnings	9875.135	9969.235	10068.239	9674.961	10390.434

Through Table 1, the formula minimizes the cost and maximizes the benefit, and predicts the overall maximum benefit of 11,875.252 yuan from July 1 to July 7, 2023.

6. Conclusions

Through the processing and screening of big data, this paper uses the price elasticity model to explore the impact of vegetable pricing changes on the market vegetable sales. At the same time, based on the idea of mathematical planning, this paper puts forward the goods income model. This model has a good generalization ability, which can better characterize the problem in order to obtain the appropriate purchase quantity, thus increasing the profit of merchants and reducing the loss caused by the purchase quantity far exceeding the sales volume.

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