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The Pricing and Quantity Strategy of Reusable and Disposable Packaging

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Abstract: With the development of e-commerce, logistics has become a crucial component of agricultural product e-commerce. The rapid expansion of the logistics industry has led to an increasing demand for packaging, resulting in severe environmental issues caused by disposable packaging. Consequently, many agricultural product manufacturers have begun to adopt recyclable and reusable packaging for express delivery. This paper examines a profit-oriented supply chain model involving a packaging manufacturer and a courier company. The courier company offers both disposable conventional packaging and reusable green packaging. We investigate the profit relationship between the courier company and the packaging manufacturer under different proportions of conventional and green packaging. Specifically, we determine the optimal proportion that maximizes the profits of both the courier company and the packaging manufacturer. The findings of this study provide valuable insights for e-commerce businesses in selecting appropriate packaging types, encouraging more manufacturers to adopt recyclable packaging at an optimal proportion.

Keywords: Disposable, Reusable, Package.

1. Introduction

With the vigorous advancement of rural revitalization, the agricultural and rural economies have achieved remarkable progress. Agricultural products constitute a vital component of the rural economy. Under the concept of green development, the issue of agricultural product packaging has drawn increasing attention. Recyclable and eco-friendly packaging for agricultural products is not only crucial for ensuring product quality but also plays a significant role in promoting the sustainable development of agricultural products and protecting the ecological environment. Some agricultural product packaging requires large volume, impact resistance, and even insulation, such as foam boxes and other specialized packaging solutions.

At the beginning of 2023, the State Post Bureau of China proposed the implementation of the "9218" initiative. By the end of the year, this initiative aimed to ensure that 90% of e-commerce parcels would no longer require secondary packaging, thereby advancing efforts to mitigate excessive packaging and plastic pollution. Additionally, the initiative sought to facilitate the use of 1 billion recyclable express packages and the reuse of 800 million corrugated cardboard boxes in good condition. The entire postal and logistics industry was guided by the principles of "prohibition, restriction, reduction, circulation, and degradation" to promote direct delivery of original e-commerce packaging, facilitate the recycling and reuse of paper packaging, and steadily improve the standardization, reduction, recyclability, and biodegradability of express packaging.

In light of these developments, this study examines a supply chain model involving a packaging manufacturer and a courier company that utilizes both disposable and recyclable packaging. Given the objective of maximizing the profits of both the courier company and the packaging manufacturer, the study focuses on determining optimal pricing and batch decisions for packaging.

An analytical model is established to evaluate the supply chain based on the proportion of the two packaging types. The packaging manufacturer produces both recyclable and disposable packaging, generating revenue from packaging fees, with wholesale pricing as a key decision variable. The courier company provides logistics services for these packaging types, earning revenue from logistics service fees, which serve as its decision variable. The end users of the packaging are merchants and retailers. The courier company regulates the proportion of these two packaging types, while both the packaging manufacturer and the courier company optimize their pricing strategies to maximize profits. The primary research objectives of this study are as follows: How should the packaging manufacturer price the two types of packaging? How should the courier company regulate the usage proportion of packaging and adjust logistics fees to maximize profit? How does the adoption of recyclable packaging influence the decision-making of both the packaging manufacturer and the courier company? By analyzing these factors under profit-maximization conditions, this study aims to assist the market in making packaging decisions that are not only highly profitable but also environmentally sustainable.

2. Literature References

This study focuses on the pricing and batch decision-making of recyclable packaging manufacturers and courier companies, the regulation of the proportion of the two types of packaging by courier companies, and the interaction between reusable recyclable packaging and disposable packaging. Therefore, a review of relevant literature is conducted to support the research problem and the development of the mathematical model.

Existing literature primarily focuses on the management of packaging or product returns within supply chains, encompassing interactions such as new product manufacturing (or procurement), recycling, remanufacturing, and reuse. Schaefer [1] examines two types of recyclable

items: leased items and repairable spare parts. The objective is to minimize the total expected costs per unit time, including ordering, holding, repair, and shortage costs. A discrete-time Markov chain is used to determine the steady-state probabilities for the number of items in the system. The total cost function is developed under both instantaneous and deterministic resupply times, contributing to research on product recycling. Koh et al. [2] discuss a joint model where fixed demand is met through a combination of recycled and newly purchased products. The model assumes that a fixed proportion of used products is collected from customers and subsequently recycled for reuse. Recycled products are treated as new, and the study determines the economic order quantity for newly purchased products and the optimal inventory level for recyclable items to initiate the recycling process. Numerical models are proposed to analyze the system based on parameter relationships, followed by a solution process to identify optimal control parameters, along with numerical examples illustrating the model. Teunter [3] investigates an inventory system with product recovery capabilities, assuming that recycled materials are of equivalent quality to new ones and satisfy the same demand. Demand and return rates are deterministic. Relevant costs include ordering recovery batches, ordering production batches, holding inventory for recoverable items, and holding inventory for new or recovered materials. The study derives simple formulas to determine the optimal batch sizes for production, procurement of new items, and recovery of returned products, applicable under both finite and infinite production and recovery rates. Ilgin and Gupta [4] review the evolution of product recovery over the past decade and explore emerging research areas during this period. After providing background information, the study systematically categorizes over 540 published references into four major areas: environmentally conscious product design, reverse and closed-loop supply chains, remanufacturing, and disassembly. The paper summarizes the evolution of product recovery over the past decade and outlines future research directions. Geissdoerfer et al. [5] discuss the sustainability performance of circular business models and circular supply chains at the organizational level. The study proposes a framework integrating circular business models and circular supply chain management to achieve sustainable development. Coelho et al. [6] review trends in reusable packaging and relevant literature, providing an overview of the current international landscape concerning reusable packaging. Meherishi, Narayana, and Ranjani [7] consider a two-stage, profit-oriented supply chain that supplies products to price-sensitive consumers using disposable primary packaging, disposable protective packaging, and reusable secondary packaging. Special emphasis is placed on the return of last-mile packaging. The study develops an analytical model to examine the joint lot-sizing and pricing decisions for products and their secondary packaging. Model results indicate that in price-sensitive markets, the ordered quantity of products and the volume of packaging used and wasted in the supply chain depend significantly on retail pricing in the channel. Additionally, the study highlights the potential for encouraging last-mile return and reuse of secondary packaging by reducing reverse channel parameters and improving the speed of returned packaging collection. Accorsi, Baruffaldi, and Manzini [8] propose a strategic mixed-integer linear programming model to design a closed-loop system from the perspective of packaging manufacturers serving the food supply chain. The study specifically considers the lifespan of containers, i.e., the number of cycles a package can be reused before being recycled, incorporating this constraint into the proposed closed-loop network design model. Accorsi et al. [9] examine a single-cycle make-to-order system and find that under an exogenous recycling rate, waste reuse can complement conventional orders for new materials to reduce risk. Additionally, when the unit cost of emergency orders is high and increases, the total expected cost for manufacturers decreases. Lu et al. [10] explore two deposit-refund systems for recycling and reuse, concluding that the cost-benefit ratio of a recycling-and-reuse scheme is significantly higher than that of a recycling-only scheme. Gavrilescu, Seto, and Teodosiu [11] investigate post-recycling packaging management and propose future research directions to explore under which conditions the environmental impact of packaging waste management can offset the environmental impact associated with material production. They also examine how source reduction measures can influence the environmental impact of packaging waste management systems while maintaining high socio-economic indicators.

3. Model

3.1. Basic Model

We consider a model involving a packaging manufacturer and a courier company, where the courier company offers two types of packaging: disposable conventional packaging and reusable green packaging. The packaging manufacturer supplies these packaging materials to the courier company, which is responsible for logistics services. Upon receiving the packaging, the courier company packs the required products for retailers or merchants and delivers them accordingly, generating revenue from logistics service fees. Once the retailers or merchants receive the goods, they pay the courier company for the logistics services. For disposable packaging, it is discarded immediately after unpacking. In contrast, for recyclable packaging, after receiving the goods and paying the logistics fee, retailers or merchants return the unpacked recyclable packaging to the courier company for collection and reuse. Additionally, retailers and merchants can receive a refund from the courier company for returning the recyclable packaging. The courier company then transfers the collected packaging back to the packaging manufacturer, where it undergoes processing to be reused.

We denote the selling prices of recyclable and disposable packaging set by the packaging manufacturer as w_r and w_d respectively. The logistics service fees for shipments using recyclable and disposable packaging are represented by p_r and p_d .The manufacturing costs for recyclable and disposable packaging incurred by the packaging manufacturer are denoted as c_r and c_d. Let r represent the proportion of recyclable packaging used by the courier company, and let q denote the total number of packaging units in the market. The number of orders using recyclable packaging is thus rq. Assuming each recyclable package can be reused n times, the required number of recyclable packages to be purchased is $\frac{rq}{n}$, while the number of disposable packaging units required is $(1-r)q$. Additionally, let R represent the return cost per recyclable package. Based on these parameters, we can formulate the profit functions for the packaging manufacturer, denoted as π_M, and for the courier company, denoted as π_E.

$$\pi_M = (w_r - c_r)\frac{rq}{n} - c_m + (w_d - c_d)(1-r). \quad (1)$$

$$\pi_E = (p_r - w_r)\frac{rq}{n} - Rrq + (p_d - w_d)(1-r)q. \quad (2)$$

The maintenance cost associated with the reuse of recyclable packaging, including the repair and cleaning expenses incurred by the manufacturer, is denoted as c_m. The proportion of recyclable packaging used,r can be expressed as: $r = e^{-(p_r - p_d)}$ where $p_r > p_d$.

3.2. Logistics Costs for Courier Company

To maximize the profit of the courier company, we need to take the partial derivatives of the logistics profit with respect to p_r and p_d, that is, $\frac{\partial \pi_E}{\partial p_r} = 0$ and $\frac{\partial \pi_E}{\partial p_d} = 0$ By solving these equations, we determine the optimal pricing of logistics costs for recyclable packaging p_r and disposable packaging p_d under profit maximization conditions.

$$e^{-(p_r - p_d)}q\left(\frac{1}{n} + \frac{w_r}{n} + R + p_d - w_d - \frac{p_r}{n}\right) = 0. \quad (3)$$

$$e^{-(p_r - p_d)}q\left(\frac{p_r}{n} - \frac{w_r}{n} - R - p_d + w_d - 1\right) + q = 0. \quad (4)$$

We can get

$$p_r = \frac{nw_d - 1 - w_r - nR + n\ln\left(1 - \frac{1}{n} - w_d\right)}{n-1}. \quad (5)$$

$$p_d = \frac{nw_d - 1 - w_r - nR + \ln\left(1 - \frac{1}{n} - w_d\right)}{n-1}. \quad (6)$$

$$r = e^{-(p_r - p_d)} = \frac{n}{n - 1 - nw_d}. \quad (7)$$

3.3. Pricing For Packaging Manufacturer

From the above analysis, we have derived the pricing of logistics costs for the two types of packaging under the profit maximization condition of the courier company, as well as the proportion of recyclable packaging in the total packaging volume. Substituting these results into the profit function of the packaging manufacturer, we can obtain the corresponding outcome.

$$\pi_M = (w_r - c_r)\frac{q}{n - 1 - nw_d} - c_m + (w_d - c_d)\frac{-1 - nw_d}{n - 1 - w_d}q. \quad (8)$$

Since c_m is related to w_r, we define $c_m = \delta w_r q$, where δ is a coefficient associated with the packaging manufacturer. Taking the partial derivatives of the manufacturer's profit function π_M with respect to w_r and w_d, we obtain $\frac{\partial \pi_M}{\partial w_r} = 0$ and $\frac{\partial \pi_M}{\partial w_d} = 0$.By solving these equations, we determine the optimal pricing of logistics costs for recyclable packaging w_r and disposable packaging w_d under profit maximization conditions.

$$w_d = \frac{n - 1 - \frac{1}{\delta}}{n}. \quad (9)$$

4. Conclusion

With the rapid development of the e-commerce industry, the generation of packaging waste from agricultural products has gradually become a significant environmental concern. The choice between recyclable and disposable packaging has naturally become a focal point for retailers and merchants. While the cost of recyclable packaging is generally higher than that of disposable packaging, it can be reused multiple times through recycling and processing.

This paper investigates a profit-oriented supply chain model, with its innovation lying in the consideration of the proportion of recyclable packaging in the total packaging volume. A model involving a packaging manufacturer and a courier company is constructed, analyzing the pricing strategy of the packaging manufacturer, the logistics service pricing strategy of the courier company, and the optimal proportion of recyclable packaging that maximizes the courier company's profit.

This paper characterizes the purchasing behavior of retailers and merchants regarding recyclable and disposable packaging, thereby deriving the demand for both types of packaging from retailers. A model is established to describe the purchasing behavior of packaging manufacturers and courier companies, as well as the logistics services between courier companies and retailers. Under the profit maximization conditions of both the courier company and the packaging manufacturer, the optimal pricing strategies for logistics costs associated with recyclable and disposable packaging, as well as the optimal pricing strategies of the packaging manufacturer for both types of packaging, are determined. Furthermore, based on the optimal logistics pricing and the optimal pricing strategies of the packaging manufacturer, this paper explores how the courier company should set the proportion of recyclable packaging in the total packaging volume.

The main innovation of this study lies in the development and analysis of a model that, for the first time, incorporates the proportion of recyclable packaging in total packaging volume. The study derives the pricing strategies of both packaging manufacturers and courier companies. First, it provides guidance on pricing strategies for both packaging manufacturers and courier companies, assisting them in achieving profit maximization. Additionally, it offers insights for courier companies in selecting packaging types, highlighting the advantages of recyclable packaging and thereby discouraging the excessive use of disposable packaging. This contributes to reducing the overproduction of packaging waste, promoting more sustainable logistics practices.

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