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Self-Built or KOL-Operated? Short-Video Marketing Channel Choice for By-Product Sales

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Abstract

With the rapid development of the short video industry, an increasing number of manufacturers are leveraging short video channels to promote their by-products. In the context of by-product synergy (BPS), this paper investigates how a manufacturer should choose between two short video marketing channels for by-product sales: a self-built channel and a KOL-operated channel. By developing game-theoretic models, we analyze the optimal decisions regarding the quantity of the main product and by-product, short video creation effort, and traffic investment under different channel structures, and explore the effects of key factors such as spillover effect, commission rate, and signing fee on the manufacturer's channel preference and profitability. The results indicate that the manufacturer prefers a self-built channel when the spillover effect is low, whereas the KOL-operated channel becomes more favorable when the spillover effect is high and the manufacturer's self-building cost coefficient is high. The effect of the commission rate on channel preference depends on the spillover effect: a higher commission rate favors the self-built channel when the spillover effect is low, whereas a moderate commission rate favors the KOL-operated channel when the spillover effect is high. In the extended scenario where waste is not fully utilized, the waste disposal cost and traffic investment cost-sharing mechanism further influence the manufacturer's channel choice. This study provides theoretical foundations and managerial insights for manufacturers' by-product marketing strategies in the era of short video marketing, thereby filling a research gap in the literature on by-product synergy and marketing channel selection.

Keywords

By-Product Synergy, Short Video Marketing, Spillover Effect, Channel Selection

1. Introduction

Although production processes have improved, industrial production still causes severe environmental pollution and resource scarcity. Manufacturers not only consume large quantities of natural resources but also generate substantial waste. To address these challenges, some manufacturers have adopted by-product synergy (BPS)—a coproduction technology in which waste from one production process is repurposed as raw material for another [1]. Vivid examples span across industries: Forust transforms residual wood chips into timber products via 3D printing and rice bran is processed into rice bran oil. As public awareness of environmental protection increases, some consumers are willing to pay a premium or accept certain quality trade-offs for environmentally friendly products. For example, PwC's 2024 Voice of the Consumer Survey reported that more than 80% of consumers worldwide are willing to pay an average premium of 9.7% for sustainably produced or sourced goods, including products made from recycled or environmentally friendly materials. This provides a market foundation for manufacturers to produce by-products from waste. However, the successful commercialization of by-products relies heavily on effective marketing strategies. Unlike conventional products, by-products derived from waste often leave consumers with an "inferior" perception, making market promotion more challenging.

Manufacturers employ a variety of marketing approaches to promote by-products. For example, Brazil's Mosaic Company uses B2B direct sales to sell magnetite by-products to other firms, trading approximately 1 million tons annually. New Zealand's Rescued Company adopts storytelling marketing, processing expired bread into baking mixes and selling them back to the same supermarket in a closed-loop model. China's Donghua Jinlong posted glycine production videos on TikTok, amassing over 4.4 million views in its first month. Among various by-product marketing methods, compared to B2B direct sales, storytelling marketing and other marketing methods, short video marketing has changed the way people consume and disseminate information. First, it features a low entry barrier, allowing any enterprise to register and publish content for free [2]. Second, it enables fast dissemination. YouTube Shorts averaged 200 billion daily views worldwide in 2025, whereas customer reach through B2B direct sales typically takes months or even years of relationship building. Third, it offers a massive user base. Statista predicts that by 2026, over 60% of U.S. adults' daily screen time will be spent watching video content, providing unprecedented traffic for by-product promotion. Meanwhile, according to CNNIC, the number of short video users in China exceeded one billion by December 2025, accounting for 95.4% of Internet users. Finally, it enables precise targeting. Platform algorithms push videos to potential consumers based on their interests, whereas storytelling marketing's audience reach is relatively passive [3]. These advantages indicate that short video platforms are emerging as a new channel for promoting by-products. Based on this, this paper focuses on short video marketing and explores its mechanism in facilitating the commercialization of by-products.

In practice, manufacturers have two main options for short video marketing. They can build their own channel using internal resources, or collaborate with Key Opinion Leaders (KOLs) who handle content creation and promotion. Self-built channels give manufacturers full control but often involve higher operational costs due to limited expertise, while KOL-operated channels leverage professional creators with large followings to boost demand more cost-effectively [4] [5]. However, KOL collaboration entails cooperation costs and potential interest conflicts. Thus, channel choice is a critical strategic decision. Regardless of the channel, high-quality content is essential. Yet, creating such content demands greater creative effort [6], and KOLs typically possess stronger capabilities and fan bases in this regard [7]. Moreover, short video content featuring by-products can do more than just promote the by-products themselves—it may also enhance consumer perception of the manufacturer's overall brand value. For instance, Stanley's TikTok video showcasing a fire-surviving tumbler generated over 83 million views and led to a 275% annual sales increase across its full product line, including products not featured in the video. Beyond content creation, promotion to a wider audience is also crucial. For instance, TikTok offers a "DOU+" service that pushes videos to potential consumers, but access requires traffic purchase. Hence, platform traffic significantly influences marketing effectiveness, making short video marketing closely tied to both content creation and traffic investment [8].

Inspired by the above observations and discussions, this paper investigates the manufacturer's channel selection in short video marketing of by-products, particularly in the context of a single manufacturer adopting a by-product synergy strategy. It examines issues such as product quantity decisions, short video creation effort decisions, traffic investment decisions, robustness in general scenarios, and the incentive effect of traffic cost-sharing ratio under different channels. This paper attempts to address the following research questions: 1) When the manufacturer conducts short-video marketing for by-products, which channel should the manufacturer choose: build her own channel or adopt a KOL-operated channel? 2) What are the optimal levels of main-product output, short video creation effort and traffic investment under different channel modes? 3) What key factors would affect the manufacturer's short video channel preference and optimal decisions? 4) When considering the general scenario, whether the results of the base model are robust and how the waste disposal cost affects the manufacturer's profit?

To address the above problems, we employ game theory and numerical examples [9]. This paper considers a by-product short video marketing supply chain consisting of a manufacturer and a Key Opinion Leader (KOL), where the manufacturer can sell the by-product either by establishing its own short video channel (Model M) or by adopting a KOL-operated channel (Model R). Through model solving and comparative analysis, we identify the manufacturer's channel preference and further examine the impacts of key factors on the manufacturer's profit via numerical analysis. Finally, we extend the analysis to consider a general scenario and a case where the manufacturer shares the traffic cost. This study draws

several main conclusions. The spillover effect and the manufacturer's cost coefficient for short video marketing significantly affect the optimal quantities of the main product and by-product. The lower the self-built channel cost coefficient or the KOL commission rate, the higher the manufacturer's creation effort and traffic investment relative to those under the KOL-operated channel. Regarding channel preference, the manufacturer prefers to establish her own channel when the spillover effect is low, and tends to outsource short-video marketing to a KOL when the spillover effect is high and the signing fee is low. The commission rate affects channel preference non-monotonically, depending on the spillover effect: a higher commission rate favors self-building under a low spillover effect, while a moderate commission rate favors the KOL-operated channel under a high spillover effect. A low self-built channel cost coefficient, low spillover effect, and high KOL commission rate increase the probability of choosing the self-built channel. When waste is not fully utilized, the manufacturer prefers the KOL-operated channel when the waste disposal cost is high and the KOL's signing fee is low. Furthermore, under the KOL-operated channel, a traffic cost-sharing mechanism can enhance the manufacturer's profit when the KOL commission rate is moderate and the cost-sharing ratio is low.

This paper has the following contributions. Firstly, there is little research on the emerging sales mode of short video marketing. Our research focuses on the manufacturer's by-product short video marketing channel choice in the context of the popularity of short videos, and aims to put forward some valuable managerial insights to help manufacturers decide whether and how to operate an appropriate short-video marketing channel. Secondly, we concentrate on figuring out the optimal main product quantity, short video creation effort, and traffic investment under various short video marketing channels, which would assist manufacturers and KOLs in developing channel operational strategies. Finally, this investigation also extends to consider the impact of waste disposal cost and traffic cost-sharing ratio on the manufacturer's channel strategy choices, which makes our findings and management insights more applicable.

The remainder of this paper is organized as follows. In Section 2, we review the relevant prior studies. We describe the research problem and assumptions in Section 3. Section 4 constructs different channel operation models and analyzes their equilibrium solutions, and further examines the effects of some key parameters through numerical simulations. In Section 5, we extend the main model to investigate the impact of waste disposal cost and traffic investment cost-sharing on the manufacturer's channel selection. Finally, we conclude this paper and discuss future research directions in Section 6.

2. Literature Review

Several recent streams of studies are related to this work. The first stream focuses on short video marketing, including channel strategies and traffic investment. The second stream investigates the optimal operational decisions under by-product

synergy.

2.1. Short Video Marketing and Operations

In recent years, with the rapid development of various social e-commerce platforms, short videos have gradually become an important marketing tool for enterprises, attracting extensive attention from academia. Short video marketing is an emerging form of digital marketing that differs from traditional marketing in its use of short-form video content disseminated through social network platforms. Unlike traditional marketing, which focuses primarily on information arrival rate and repeated exposure to cultivate brand awareness, short video marketing emphasizes the integration of audiovisual elements, rapid capture of social hotspots, and the ability to shorten the conversion time from brand awareness to purchase action. Numerous scholars have investigated the effectiveness of short video marketing and user engagement and behavior. For example, Tafesse and Dayan found that excessively high content sharing frequency by video creators diminishes user engagement [10]. Moreover, Houshiarian *et al.* found that well-designed content on Instagram attracts customers' attention and facilitates their purchase decisions, thereby improving business profitability [11]. Existing research has examined the differential effects of personal branding stereotypes on user engagement in the context of short video marketing [12]. Existing literature has found that audiovisual features of short video advertisements significantly influence consumer likes and comments, with daytime posting yielding better engagement [13].

Currently, relatively few scholars have employed analytical models to study short video marketing. For example, prior research has investigated a video platform's optimal joint decisions on pricing and advertising in the presence of derivative videos [14]. In addition, Hu *et al.* investigated a video platform's optimal incentive mechanisms for creators and found that content-volume-based and view-volume-based schemes produce equivalent equilibrium outcomes [15]. Current short video marketing overemphasizes audiovisual impact and influencer effects, while neglecting deep-level content creation, with most attention focused on enhancing communication adaptability. Additional studies have suggested that the personalization and entertainment value of short video content should be enhanced to increase user satisfaction and dependence [16].

This study examines traffic investment in the context of short video promotion on platforms, with a particular focus on how optimizing user attention can effectively convert traffic investment into demand. The extant literature on traffic investment is relatively scarce. Other work has investigated how merchants can achieve targeted advertising when consumers allocate their attention across different advertising windows [17].

Research on short video marketing is still in its early stages, with most studies focusing on empirical analysis of user engagement and content characteristics. Some studies have constructed mathematical models to explore platform pricing

and advertising strategies. However, few studies have focused on the joint optimization of main product quantity, short video creation effort, and traffic investment, particularly in the context of by-product sales. Therefore, the primary objective of this study is to pioneer research on short video marketing channel strategies for manufacturers adopting by-product synergy.

2.2. By-Product Synergy

In the industrial ecology literature, by-product synergy (BPS) is also referred to as industrial symbiosis. Some studies focus on the environmental impact of firm production, and scholars in the field of sustainable development have investigated the production and operational decisions of firms engaged in by-product synergy. Some studies adopt a single-firm perspective. For example, Lee explored how manufacturing firms can convert waste generated during production into valuable by-products and developed a deterministic optimization model to analyze optimal production strategies [18]. Existing findings indicated that the optimal output decisions of by-product synergy firms from the perspective of external policy influences [19]. Furthermore, prior research has found that environmental regulation and market competition positively drive industrial symbiosis, and the centralized model yields the highest profit [20].

Beyond production-level output decisions, the pricing decisions of by-products and waste between firms under by-product synergy have also become a research focus. Relevant work has analyzed the impact of by-product transaction prices on firms' collaborative production decisions [21]. Other work has investigated the optimal waste transfer prices when downstream manufacturers face capacity constraints under by-product synergy strategies [22].

The above studies focus on the optimal production and pricing decisions of firms engaged in by-product synergy, as well as the setting of waste transfer prices. Different from these studies, some scholars have examined the market sales of green products in firm supply chains from the perspective of marketing efforts. Findings from existing studies have investigated the impact of marketing effort levels and greenness levels on the selection of supply chain contracts for green products [23].

Most of the existing literature on by-product synergy (BPS) focuses on production decisions, pricing, and platform marketing efforts in manufacturing or retail contexts. Building on this, this paper adopts short video marketing channels established by different entities into the framework of main and by-product sales. It considers the manufacturer's main product quantity, by-product short video content creation effort, and traffic investment as key decision variables, and explores the comparison between self-built and KOL outsourcing channels, as well as the spillover effect of by-product short video content on the main product.

2.3. Research Gaps

We summarize the differences between our research and the related literature in **Table 1** to highlight the research gaps and our contributions.

Overall, our research is related to the above studies but differs in three aspects. First, while previous studies on short video marketing have primarily focused on user engagement, content characteristics, and platform-level advertising strategies from the merchant's perspective, our research adopts the creator's perspective and combines creation effort with traffic investment as joint decision variables within the optimization framework. Second, unlike existing studies on by-product synergy that concentrate on production decisions, waste transfer pricing, and capacity investment in traditional manufacturing contexts, our research selects short video marketing among various by-product sales channels and integrates production decisions with marketing decisions. Third, while prior literature has examined supply chain structures such as integration versus decentralization or advertising window selection, our research considers both self-built and KOL-outsourced short video channels for by-product promotion, analyzes the manufacturer's channel preference, and further captures the content spillover effect of by-product short video content on main product demand.

Table 1. Differences between this paper and the most related papers.

Study	Short video	By-product synergy	Creation effort	Traffic investment	Channel preference
Value of by-product synergy: A supply chain perspective [22]		√			
Keep scrolling: An investigation of short video users' continuous watching behavior [16]	√				√
Video platforms' advertising and pricing decisions in the presence of derivative videos [14]	√		√		
How to achieve targeted advertising with the e-commerce platform's membership system? [17]				√	
Implementation of industrial symbiosis under environmental tax policy [19]		√			
Effect of personal branding stereotypes on user engagement on short-video platforms [12]	√		√		√
Contracting green product supply chains considering marketing efforts in the circular economy era [23]			√		
Content creators' participation in the creator economy: Examining the effect of creators' content sharing frequency on user engagement behavior on digital platforms [10]	√		√	√	
Green Supply Chain Formation Through By-Product Synergies [21]		√			
This paper	√	√	√	√	√

3. Model Setting

3.1. Problem Description

In this paper, we consider the scenario where a manufacturer adopts a by-product synergy (BPS) strategy. As shown in **Figure 1**, for each unit of the main product A produced by the manufacturer, a certain amount of waste is generated concomitantly, with t denoting the waste generation ratio. The manufacturer produces

the main product A for sale in market 1 and also realizes the resource utilization of the waste generated during its production process to produce the by-product B for sale in market 2. We assume that the market scale of market 1 is α and that of market 2 is $k\alpha$, where the parameter $k > 0$ represents the ratio of the market demand scale of market 2 to that of market 1. There we let the quantity of the main product A be q_a and the quantity of the by-product B be q_b. We make an idealized assumption that all waste from the production process is recycled for resource utilization, which leads to the quantity constraint $q_b = tq_a$, with $t \in (0,1)$. This implies that the market performance of the by-product B will inversely constrain the production decision-making of the main product A. This setting is applicable to typical by-product industries such as chemical engineering, energy, and joint production. To improve the practical relevance of the analysis, we later relax this assumption and consider incomplete waste utilization in Section 5.

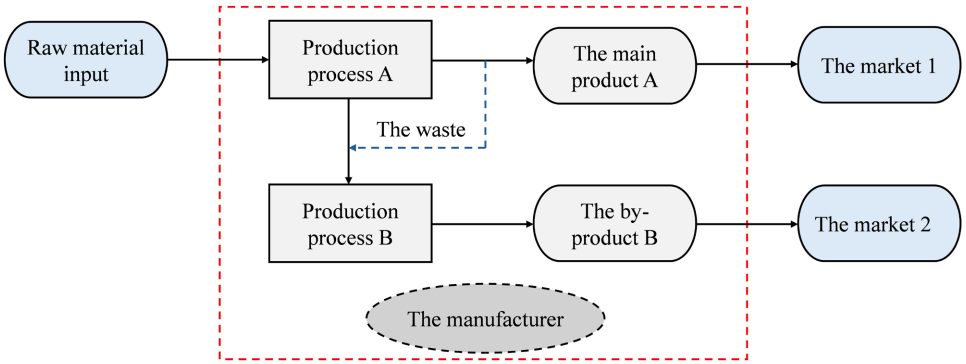


Figure 1. Schematic diagram of manufacturer's main and by-product production.

We explore a scenario where a manufacturer produces both the main product A and by-product B, while this study focuses solely on the short-video sales of by-product B. The manufacturer has two options: establishing its own short video channel (Model M) or adopting a KOL-operated channel (Model R). In Model M, the manufacturer creates and publishes short videos independently and purchases traffic from the platform to increase the playback volume of short videos, thereby enhancing product sales. In Model R, the manufacturer adopts a KOL who takes charge of short-video content creation and traffic investment, and the manufacturer needs to pay the KOL a signing fee h as well as a commission rate β on each unit of by-product B sold [24] [25]. In Model R, β and h are exogenous contract terms, as they are typically set by platforms and top KOLs, with manufacturers as price takers. The model thus has no prior stage for choosing β and h; we only conduct comparative statics on them. Unless stated otherwise, contract-design recommendations are confined to the manufacturer's channel-choice decision. Without loss of generality, we normalize the production and sales costs of both the main product and the by-product to zero [26].

Compared with self-built channels, KOL-operated channels possess greater market influence due to their established follower base, and they generally incur lower content creation costs because of their professional expertise in content produc-

tion and promotion. When the manufacturer outsources short video marketing to a KOL to sell the by-product B, let the parameter n denote the KOL's influence since KOL has a certain fan base and influence [27]. In the context of short video sales for the by-product B, the content creation of such short videos elaborates on the inherent attributes, including the brand correlation, production homology, and environmental value alignment between the main product A and the by-product B, which boosts consumers' purchase incentives for the main product A. Thus, the sales of the manufacturer's main product A can partially benefit from the content creation effort v devoted to the short videos of the by-product B, generating an additional demand increment of θv from the short-video sales of the by-product B, wherein the decision variable v is the short video creation effort and θ represents the spillover effect of the short video sales of the by-product B on the main product A [28] [29].

Based on the previous studies, it is assumed that the cost of creating a short video by the manufacturer or KOL is a quadratic function form relevant to the creation effort [30]. Both the manufacturer and KOL would spend the cost $\frac{\mu_i v^2}{2}$ to market products through the short video platform, wherein $\mu_i \left(i = B, L\right)$ is the creation effort cost coefficient of the manufacturer or KOL. Considering the specialization of the KOL in the field of short video creation, it can be assumed that $u_B > u_L$. A higher level of creation effort from the manufacturer or the KOL leads to a greater demand for the by-product B. Namely, it can increase the product demand by v. In addition, the manufacturer or the KOL can purchase traffic for short videos from the platform to increase payback, which in turn drives higher sales of the by-product B. We assume e be the short video publisher's traffic investment. Considering that traffic investment is characterized by diminishing marginal effects, we assume that the impact of traffic investment in incremental consumer demand is $\sqrt{e}$.

The notations used throughout this paper and their explanations are shown in **Table 2**. In particular, we use superscripts M and R to denote Model M and Model R respectively, and subscripts B and L to denote manufacturer and KOL respectively. We present the framework of the two channels in **Figure 2** and the corresponding sequence of events in **Figure 3**.

Table 2. Summary of notation.

Notation	Explanations
α	The potential market 1 size
β	The KOL's commission rate
k	The market demand scale ratio of Market 2 to 1
h	The signing fee for KOL
t	Waste generation ratio
m	Unit waste disposal cost
θ	The spillover effect of the short video sales of the by-product B on the main product A

Continued

n	The KOL's influence
q_b^j	The quantity of the by-product B in Model j ($j = M, R$)
μ_i	The creation effort cost coefficient of the manufacturer/KOL
π_i^j	The profit of the subject i ($i = B, L$) under Model j ($j = M, R$)
p_a^j	The retail price of the product A in scenario j ($j = M, R$)
p_b^j	The retail price of the by-product B in scenario j ($j = M, R$)
Decision variable	
q_a^j	The quantity of the product A in Model j ($j = M, R$)
v^j	The short video traffic investment in Model j ($j = M, R$)
e^j	The short video creation effort in Model j ($j = M, R$)

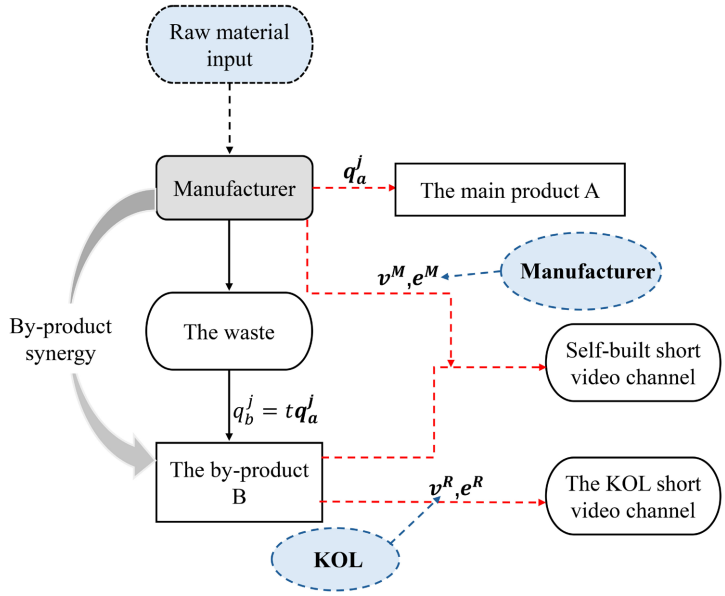


Figure 2. The channel structures for the manufacturer.

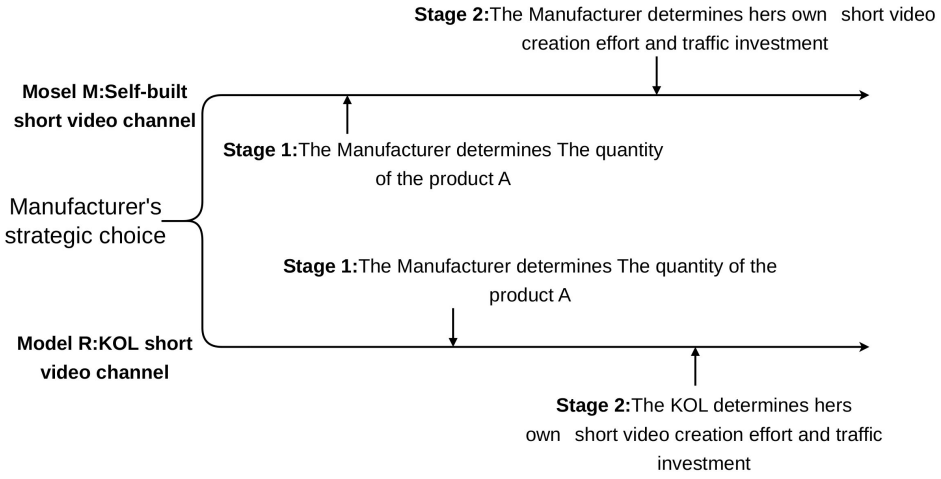


Figure 3. The sequence of events.

3.2. The Inverse Demand Functions

Following the work of Zhou *et al.* (2020), we assume that the market prices of the manufacturer's main product and by-product have a linear functional relationship with their demands, which are expressed as $\alpha - q_a$ and $k\alpha - q_b$ [22]. In Model M, the inverse demand functions for the manufacturer's main product A and by-product B can be given as follows:

$$p_a^M = \alpha - q_a^M + \theta v^M, \tag{1}$$

$$p_b^M = k\alpha - q_b^M + v^M + \sqrt{e^M}. \tag{2}$$

Furthermore, following the research of Feng *et al.* (2020), we assume that the introduction of KOL can expand the potential demand to $k(1+n)\alpha - q_b$ [27]. Thus, in Model R, the inverse demand functions for the manufacturer's main product A and by-product B are respectively given by:

$$p_a^R = \alpha - q_a^R + \theta v^R, \tag{3}$$

$$p_b^R = k(1+n)\alpha - q_b^R + v^R + \sqrt{e^R}. \tag{4}$$

3.3. Model M: Self-Built Short Video Channel

When the manufacturer establishes her own short video channel, she is independently responsible for short video creation effort and traffic investment. The manufacturer first determines the quantity of the main product A q_a^M and then decides the creation effort v^M and traffic investment e^M for by-product short videos. The goal of the manufacturer is to maximize her own profit, so the optimization problem of Model M is given as follows:

$$\begin{cases} \text{Max } \pi_B^M\left(q_a^M, v^M, e^M\right) = p_a^M q_a^M + p_b^M q_b^M - \dfrac{1}{2}\mu_B\left(v^M\right)^2 - e^M, \\ \text{s.t. } q_b^M = t q_a^M. \end{cases} \tag{5}$$

By solving the above model, when $4\mu_b + 3\mu_B t^2 - 2(\theta + t)^2 > 0$, the following Lemma 1 can be obtained.

Lemma 1. Under Model M, the optimal quantity of the product A is:

$$q_a^{M*} = \frac{2\mu_B\alpha(1+tk)}{4\mu_B + 3\mu_B t^2 - 2(\theta+t)^2},$$

the optimal short video creation effort and traffic investment are:

$$v^{M*} = \frac{2\alpha(1+tk)(\theta+t)}{4\mu_B + 3\mu_B t^2 - 2(\theta+t)^2},$$

$$e^{M*} = \frac{t^2}{4}\left(\frac{2\mu_B\alpha(1+tk)}{4\mu_B + 3\mu_B t^2 - 2(\theta+t)^2}\right)^2.$$

Substituting the equilibrium solutions of the decision variables into the calculation, the optimal profit of the manufacturer is obtained as

$$\pi_B^{M*} = \frac{\mu_b\alpha^2(1+tk)^2}{4\mu_b + 3\mu_b t^2 - 2(\theta+t)^2}.$$

A sensitivity analysis of the key parameters in Model M reveals a monotonic relationship between each parameter and the optimal decisions. As the spillover effect θ increases, the optimal quantity of the main product A q_a^{M*}, short video creation effort v^{M*} and traffic investment e^{M*} all increase. A higher θ enables short videos to not only drive by-product sales but also convey the manufacturer's environmental philosophy and enhance brand consistency. By shaping a green corporate image, high-quality short videos boost demand for the by-product and generate brand premium for the main product, prompting the manufacturer to expand main product output and increase marketing investment. As for the creation cost, when the cost coefficient of creation effort is relatively high, the magnitude of the decision variables decreases. As studied by the work of Ye *et al.*, higher creation costs reduce the motivation of short video creators [31]. Consequently, the manufacturer cuts creation and traffic investment to control costs. Under the constraint of full waste utilization, lower by-product sales and higher marketing costs force the manufacturer to reduce main product output, thereby lowering waste and by-product volumes to balance costs and operational risks.

In reality, according to a 2020 report by the Fu Kang Municipal People's Government, Xinjiang Wuxin Copper Industry mainly produces cathode copper with sulfuric acid as its by-product. During the COVID-19 pandemic in 2020, the delayed resumption of production of downstream sulfuric acid-consuming enterprises led to overstock and critical storage of sulfuric acid. The enterprise's person in charge stated that the poor sales of sulfuric acid, the by-product, in turn, forced the shutdown of the core production system for cathode copper.

3.4. Model R: KOL Short Video Channel

When a manufacturer adopts a KOL-operated channel for by-product sales, the KOL is responsible for short video creation and traffic investment work. The manufacturer first determines the quantity of the main product A q_a^R and then KOL decides the creation effort v^R and traffic investment e^R for by-product short videos. The KOL makes decisions with the goal of maximizing his own profit, so the optimization problem of Model V can be formulated as follows:

$$\begin{cases} \text{Max } \pi_B^R\left(q_a^R\right) = p_a^R q_a^R + \left(1-\beta\right) p_b^R q_b^R - h, \\ \text{Max } \pi_L^R\left(v^R, e^R\right) = \beta p_b^R q_b^R + h - \dfrac{1}{2}\mu_L\left(v^R\right)^2 - e^R, \\ \text{s.t. } q_b^R = t q_a^R. \end{cases} \tag{6}$$

The KOL accepts the collaboration only if its resulting profit is no less than his outside option z, *i.e.*, the participation constraint $\pi_L^R\left(v^R, e^R\right) = \beta p_b^R q_b^R + h - \frac{1}{2}\mu_L\left(v^R\right)^2 - e^R \geq z$ must hold. Without loss of generality, we normalize the KOL's outside option to zero, *i.e.*, $z = 0$. Our analysis focuses on the parameter region where this constraint is satisfied; otherwise, the KOL-operated channel is infeasible, and the manufacturer can only choose the

self-built channel. Following the prior research, we have $\mu_L = 1$ [32]. By solving the above model, when $2-2\beta\theta t+(1-\beta)(2-3\beta)t^2>0$, the following Lemma 2 can be obtained.

Lemma 2. Under Model R, the optimal quantity of the product A is:

$$q_a^{R^*}=\frac{\alpha\left(1+(1-\beta)(1+n)tk\right)}{2-2\beta\theta t+(1-\beta)(2-3\beta)t^2},$$

the optimal short video creation effort and traffic investment are:

$$v^{R^*}=\frac{\beta t\alpha\left(1+(1-\beta)(1+n)tk\right)}{2-2\beta\theta t+(1-\beta)(2-3\beta)t^2},$$

$$e^{R^*}=\frac{\beta^2t^2}{4}\left(\frac{\alpha\left(1+(1-\beta)(1+n)tk\right)}{2-2\beta\theta t+(1-\beta)(2-3\beta)t^2}\right)^2.$$

Substituting the equilibrium solutions of the decision variables into the calculation, the optimal profit of the manufacturer is obtained as

$$\pi_B^{R^*}=\frac{\alpha^2\left(1+(1-\beta)(1+b)tk\right)^2}{2\left(2-2\beta\theta t+(1-\beta)(2-3\beta)t^2\right)}-h.$$

In Model R, the spillover effect θ of by-product short video sales on the main product A has a similar trend of influence on the optimal decision variables as in Model M. The differences lie in that we set $\mu_L = 1$, and with the manufacturer adopting a KOL, the KOL's influence n also has a positive impact on the optimal decision variables ($\frac{\partial q_a^{R^*}}{\partial n}>0$; $\frac{\partial v^{R^*}}{\partial n}>0$; $\frac{\partial e^{R^*}}{\partial n}>0$). As demonstrated by Niu *et al.* (2023), a KOL's influence directly expands market potential through network externality and mitigates consumer distrust, which in turn positively affects optimal decisions such as sales quantity and brand profitability—consistent with the positive impact of n in our Model R [28]. On one hand, the KOL's influence directly expands the potential market of by-product B, boosting its sales. On the other hand, as a professional content creator, a more influential KOL receives stronger market feedback from the same effort and traffic investment, incentivizing proactive input for higher commission returns. Furthermore, the demand for main product A increases due to the spillover effect, which prompts the manufacturer to expand its quantity, leading to a synchronous rise in by-product sales.

4. Results Analysis

In this subsection, we first analyze the impact of parameter β on optimal decisions in Model R to obtain Propositions 1 - 2. Secondly, we compare the decision variables between Model M and Model R to obtain Propositions 3 - 5. Thirdly, we compare the manufacturer's profits under the two models to guide channel selection, leading to Proposition 6. Finally, numerical examples are used to examine the effects of the commission rate and spillover effect.

To make the feasible parameter region explicit, we impose the following regu-

larity conditions throughout the analysis. For Model M, we require $4\mu_b + 3\mu_B t^2 - 2(\theta + t)^2 > 0$; for Model R, we require $2 - 2\beta\theta t + (1-\beta)(2-3\beta)t^2 > 0$; and for the extension, the corresponding conditions in Lemmas 3 - 4 together with the nonnegative disposal volume $tq_a^* - q_b^* \geq 0$. These conditions guarantee a positive interior solution, so that all equilibrium quantities, efforts, prices, and (where applicable) disposal volumes are nonnegative. Throughout the analysis, we restrict attention to the parameter region where these conditions hold, and all numerical examples are constructed within this region.

4.1. Sensitivity Analysis in Model R

In Section 3, sensitivity analysis of other parameters has been conducted separately for two different models. In this subsection, we further focus on examining the impact of the commission rate β on the optimal decision variables in Model R.

Proposition 1. In Model R, the results of the sensitivity analysis of β with respect to the decision variable q_a^{R*} are that:

(1) If $\theta < \theta_0^*$, $\dfrac{\partial q_a^{R*}}{\partial \beta} < 0$;

(2) When $\theta_0^* < \theta < \theta_1^*$: if $0 < \beta < \beta^*$, $\dfrac{\partial q_a^{R*}}{\partial \beta} > 0$, if $\beta^* < \beta < 1$, $\dfrac{\partial q_a^{R*}}{\partial \beta} < 0$;

(3) If $\theta > \theta_1^*$, $\dfrac{\partial q_a^{R*}}{\partial \beta} > 0$,

wherein $\theta_0^* = \dfrac{C(1+t^2)}{t(1+C)} - \dfrac{5}{2}t$, $\theta_1^* = \dfrac{t^2 + 2C}{2t(1+C)}$,

$\beta^* = \dfrac{1+C}{C} - \dfrac{\sqrt{3\left[(3+t)t^2 - 2C(1+C)\theta t + 2C^2\right]}}{3Ct}$ and $C = (1+n)tk$.

Proposition 1(1)(3) reveals how the spillover effect shapes the manufacturer's response to commission incentives. When the spillover effect is weak, the KOL's short video content generates little benefit for the main product, and the manufacturer cannot bear the dual costs of short video investment and KOL's commissions, leading her to reduce main product output. When the spillover effect is strong, the KOL's short video content effectively conveys brand value. A higher commission rate incentivizes the KOL to increase creation effort and traffic investment. Although commission costs rise, the manufacturer benefits from the brand premium for the main product and the higher direct demand for the by-product, making her willing to increase the quantity of the main product and use commission incentives.

Proposition 1(2) shows that when the spillover effect is moderate, unlike Proposition 1(1) and 1(3). There exists a commission threshold β^*, only when the commission rate is below the threshold does a moderate increase in the commission rate have a positive incentive effect on the KOL and raise the main product

demand through by-product short video content. This is because when the commission rate is higher, the KOL captures too much of the by-product revenue, and the brand premium from the main product may not be sufficient to offset the commission cost.

This proposition can be intuitively illustrated in Figure 4. It reminds the Manufacturer that when collaborating with a KOL, she should consider the interaction between the spillover effect and commission costs, and flexibly adjust product quantity to avoid excessive waste disposal costs and inventory risks. This is logically consistent with the Xinjiang Wuxin Copper Industry case mentioned earlier: The market performance of the by-product will inversely affect the main product's entity.

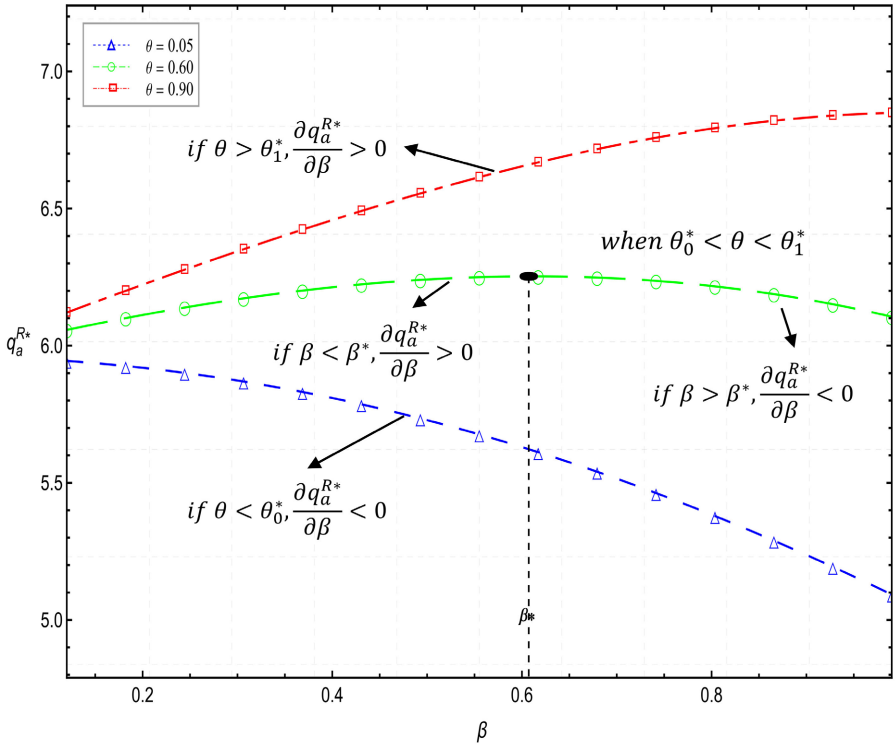


Figure 4. Effect of KOL's commission rate.

Proposition 2. In Model R, the partial derivatives of the KOL's short video creation effort v^{R*} and traffic investment e^{R*} with respect to the commission rate β exhibit an identical sign variation pattern. When $tk(1+n) > 1-\frac{t^2}{2}$, there exists a threshold $\theta_{v1}^* = \frac{2tk(1+n)+t^2-2}{2t^2k(1+n)}$, such that the partial derivatives of the KOL's by-product short video creation effort and traffic investment with respect to the commission rate satisfy this condition:

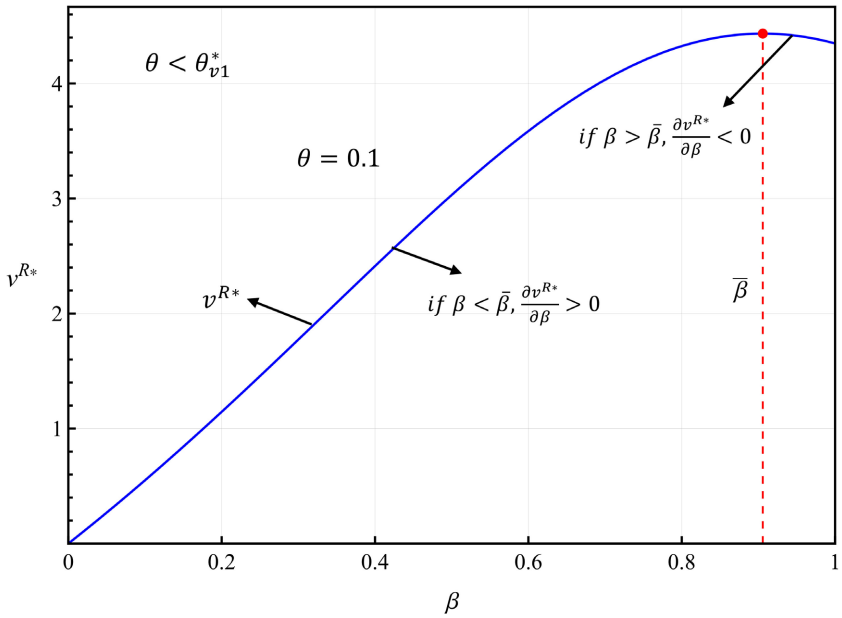
(1) When $\theta < \theta_{v1}^*$: if $\beta < \bar{\beta}$, $\frac{\partial v^{R*}}{\partial \beta} > 0$, $\frac{\partial e^{R*}}{\partial \beta} > 0$, if $\beta > \bar{\beta}$, $\frac{\partial v^{R*}}{\partial \beta} < 0$,

$\frac{\partial e^{R*}}{\partial \beta} < 0$;

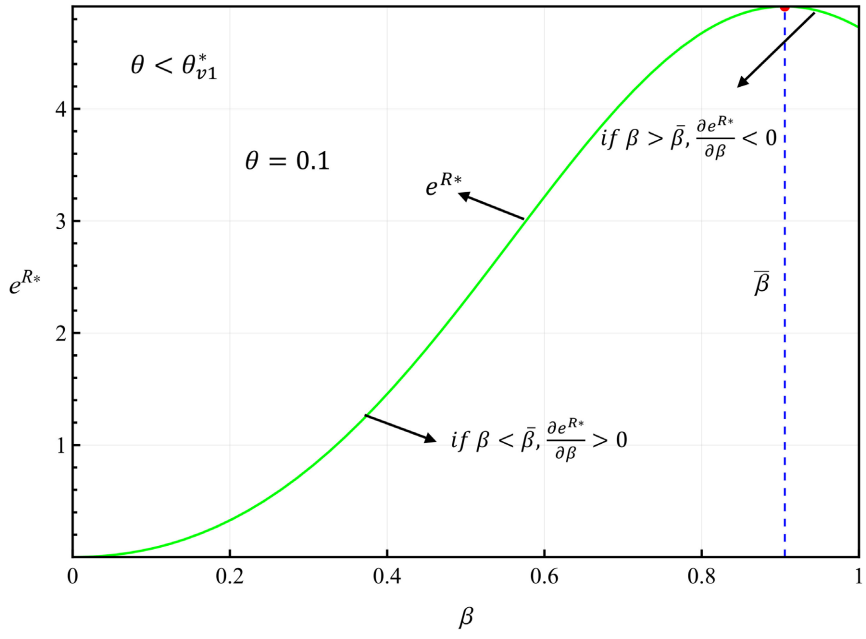
(2) When $\theta > \theta_{v1}^{*}$: $\frac{\partial v^{R*}}{\partial \beta} > 0$, $\frac{\partial e^{R*}}{\partial \beta} > 0$,

wherein $\bar{\beta} = \frac{4C\left(1+t^2\right) - \sqrt{8\left(1+t^2\right)\left[2C^2 + t^2\left(C+3\right) - 2C\left(1+c\right)\theta t\right]}}{2\left[2C\theta t + t^2\left(2C-3\right)\right]}$.

In Model R, the impact of the commission rate on the KOL's short video creation effort and traffic investment is moderated by the spillover effect. When the spillover effect is relatively small, the KOL's creation effort and traffic investment initially increase with the commission rate but begin to decrease once a certain threshold is exceeded, as illustrated in Figure 5. When the spillover effect is large, the commission rate exerts a consistently positive influence on the KOL, leading to a sustained increase in creation effort and traffic investment as the commission rate rises. This is because, when the spillover effect is substantial, the manufacturer's brand value (for the main product) derives significant benefits from short video sales. Consequently, even a high commission rate is acceptable to the manufacturer, as the additional benefits generated by the spillover effect can offset the associated commission costs. In contrast, when the spillover effect is small, the manufacturer's gain from the spillover is limited. Under a low commission rate, the KOL still has an incentive to increase effort and traffic investment; however, an excessively high commission rate erodes the manufacturer's profit, leading to a reduction in the KOL's effort and traffic. Referring to the findings of Song *et al.* (2024), in the context of platform competition with a spillover effect, the commission rate influences effort through the combined forces of a cooperation effect and a negative inhibition effect [33].



(a)



(b)

Figure 5. Effect of KOL's commission rate ($\theta < \theta^*_{v1}$). (a) The optimal short video creation effort; (b) The optimal short video traffic investment.

4.2. Comparison Analysis

Proposition 3. Comparing the manufacturer's quantity of the main product A between Model M and Model R, we have:

(1) When $\theta < \theta_2^*$, then $q_a^{M*} > q_a^{R*}$;

(2) When $\theta > \theta_2^*$: if $1 < \mu_B < \mu_B^*$, then $q_a^{M*} > q_a^{R*}$, if $\mu_B > \mu_B^*$, then $q_a^{M*} < q_a^{R*}$,

wherein $\theta_2^* = \dfrac{F(\beta)}{4\beta t(1+tk)}$,

$F(\beta) = \left[2(1-\beta)(2-3\beta)-3\right]t^2 + \left[4-4(1-\beta)(1+n)\right]tk + (1-\beta)(1-6\beta-3n)t^3k$,

$K = -4\beta\theta t(1+tk) + F(\beta)$, $\mu_B^* = \dfrac{-2\left[1+(1-\beta)(1+n)tk\right](\theta+t)^2}{K}$.

According to Proposition 3(1), when the spillover effect is low, short videos only promote the by-product and cannot effectively drive demand for the main product. In this case, the main product quantity under the Model M is higher than that under the Model R. For example, the "ice-pulling vinegar" short video of Shanxi Aged Vinegar showcases the manual vinegar-making process, where the spillover effect is limited. Niu Ziqun, the inheritor, used a self-built channel to publish the content, avoiding the signing fees and commission costs of a KOL. Proposition 3(2) shows that when the spillover effect is high, short videos can convey brand value through in-depth content and increase consumers' willingness to purchase the main product. However, only low costs enable the manufacturer to invest in high-quality content. If the self-built channel is underdeveloped, leveraging the KOL's fan base and professional advantages can more effectively

convert the spillover effect into value. This reminds manufacturers to pay attention to the cost of the self-built channel, as it directly affects the optimal product quantity under Model M and Model R. The changes in Proposition 3 can be observed in Figure 6.

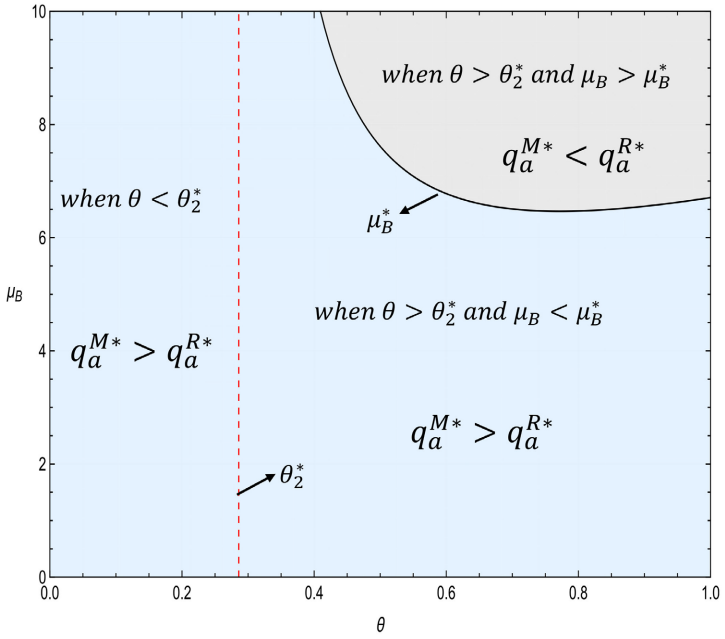


Figure 6. Manufacturer's quantity of the product A comparison between Models M and R.

Proposition 4. The relationship between the short video creation effort under Model M and Model R is summarized as follows:

(1) When $\mu_B < \mu_B^{0*}$, then $v^{M*} > v^{R*}$;

(2) When $\mu_B > \mu_B^{0*}$: if $\beta < \hat{\beta}$, then $v^{M*} > v^{R*}$, if $\beta > \hat{\beta}$, then $v^{M*} < v^{R*}$,

wherein

$$\hat{\beta} = \frac{2(1+tk)(\theta+t)(2\theta t+5t^2)+t(1+C)D_M - \sqrt{\left[2(1+tk)(\theta+t)(2\theta t+5t^2)+t(1+C)D_M\right]^2 - 4PR}}{2P},$$

$$\mu_B^{0*} = \frac{4(1+tk)(\theta+t)(1-\theta t)+2t(\theta+t)^2}{t(4+3t^2)}, \quad D_M = 4\mu_B + 3\mu_B t^2 - 2(\theta+t)^2.$$

Proposition 4(1) shows that when the manufacturer's creation effort cost coefficient is low, the KOL's optimal creation effort level is lower than that of the manufacturer's. Conversely, if the manufacturer's creation effort cost coefficient is high, the KOL will only exert greater creation effort when offered a higher commission rate, as a higher commission rate brings greater benefits, motivating the KOL to invest more effort to secure such returns. This suggests that the manufacturer should rationally weigh internal resources and external cooperation decisions. Instead of blindly following the trend of outsourcing by-product sales to the KOL, she should first assess her own short video content creation cost coefficient and capabilities, then determine whether to collaborate with a KOL and set a reason-

able commission incentive mechanism.

Proposition 5. The ratio of traffic investments satisfies $\frac{e^{M*}}{e^{R*}} = \frac{1}{\beta^2}\left(\frac{A_M}{A_R}\right)^2$, where $A_M = \frac{2\mu_B\alpha(1+tk)}{4\mu_B + 3\mu_B t^2 - 2(\theta+t)^2}$, $A_R = \frac{\alpha(1+(1-\beta)(1+n)tk)}{2-2\beta\theta t+(1-\beta)(2-3\beta)t^2}$. Therefore, $e^{M*} > e^{R*}$ if and only if $\beta < A_M/A_R$. Since $\frac{A_M}{A_R} > 0$ under the regularity conditions in Section 4, there exists a threshold $\beta_5 = A_M/A_R \in (0,1)$ such that $e^{M*} > e^{R*}$ for all $\beta < \beta_5$.

Proposition 5 demonstrates that, for all $\beta < \beta_5$, the self-built channel entails higher traffic investment than the KOL-operated channel. This suggests that from a long-term perspective, particularly regarding the autonomy and scale of traffic investment, relying on a KOL may not be a wise choice for the manufacturer. For instance, after establishing its own Douyin account, Huaxizi can autonomously invest millions of yuan monthly in platform traffic. However, ordinary KOLs, constrained by their commission earnings, cannot afford traffic investments of such magnitude. Consequently, dependence on the KOL-operated channel subjects the manufacturer's traffic investment to commission incentives, thereby hindering long-term and stable traffic expansion.

Proposition 6. Compare the profits of the Manufacturer in Model M and Model R, we have:

(1) When $\theta < \theta_3^*$, then $\pi_B^{R*} < \pi_B^{M*}$;

(2) When $\theta > \theta_3^*$: if $\mu_B < \mu_B^{1*}$, then, $\pi_B^{R*} < \pi_B^{M*}$, if $\mu_B > \mu_B^{1*}$ and $h < h_0$, then $\pi_B^{R*} > \pi_B^{M*}$, if $\mu_B > \mu_B^{1*}$ and $h > h_0$, then $\pi_B^{R*} < \pi_B^{M*}$,

wherein $\theta_3^* = \frac{4+(1-\beta)(4-6\beta)t^2 - \frac{(4+3t^2)(1+(1-\beta)(1+n)tk)^2}{(1+tk)^2}}{4\beta t}$,

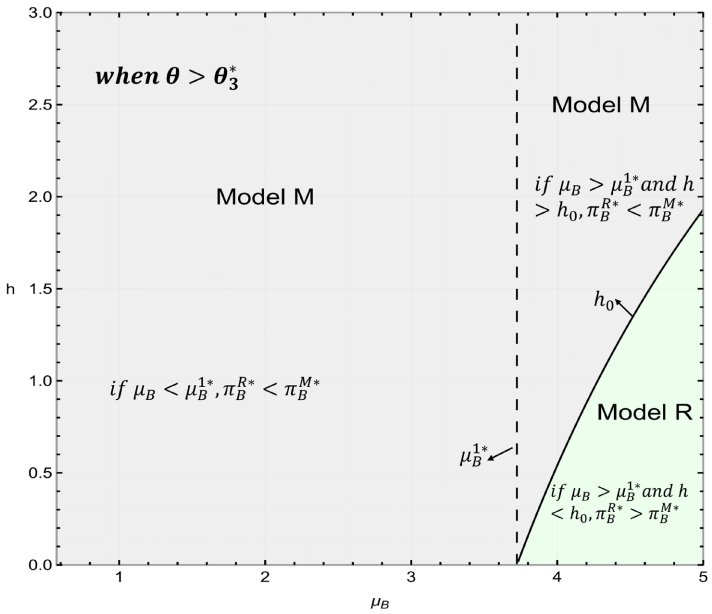
$\mu_B^{1*} = \frac{2(\theta+t)^2(1+(1-\beta)(1+n)tk)^2}{(4+3t^2)(1+(1-\beta)(1+n)tk)^2 - (1+tk)^2 D_R}$,

$h_0 = \frac{\alpha^2(1+(1-\beta)(1+n)tk)^2 D_M - \mu_b\alpha^2(1+tk)^2 D_R}{D_R D_M}$,

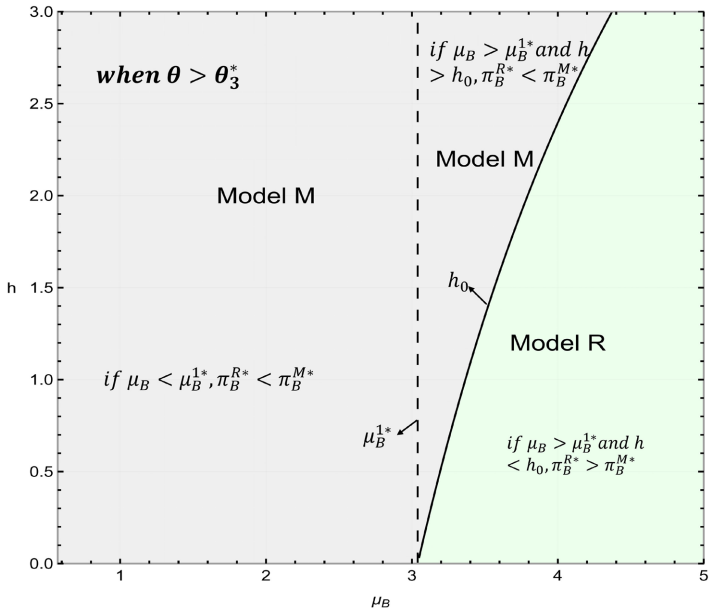
$D_R = 2(2-2\beta\theta t+(1-\beta)(2-3\beta)t^2)$.

According to Proposition 6(1), when the spillover effect is low, although the manufacturer bears higher short video creation costs under the self-built model, it does not need to pay KOL's commissions or signing fees and can retain all profits. Therefore, the self-built channel becomes the preferable choice. Proposition 6(2) shows that in situations where the spillover effect is relatively high, the manufacturer needs to evaluate the creation effort cost coefficient of the manufacturer. Only when the creation effort cost coefficient of the manufacturer is large and the KOL's signing fee is low, can the manufacturer achieve higher profits by adopting

the KOL. Furthermore, Ye *et al.* (2024) find that for top influencers, an excessively high fixed signing fee will erode the manufacturer's profit and lower the commission rate [31]. **Figure 7** illustrates the findings of Proposition 6(2). Therefore, when the spillover effect is high, the creation effort cost coefficient of the manufacturer becomes a crucial factor for manufacturers when deciding whether to establish their own short video channel or adopt a KOL-operated channel. The manufacturer's choice of Model R necessitates a lower signing fee.



(a)



(b)

Figure 7. Manufacturer's channel preference between Models M and R ($\theta > \theta_3^*$). (a) $\beta = 0.3$; (b) $\beta = 0.4$.

Furthermore, a comparison of Figure 7(a) and Figure 7(b) shows that the range of scenarios where the manufacturer adopts a KOL expands as the KOL's commission rate rises. This indicates that a moderate increase in the commission rate constitutes an effective incentive for the KOL rather than a profit erosion for the manufacturer when the spillover effect is high. According to Proposition 2, a higher commission rate will motivate the KOL to increase her short video creation effort and traffic investment and can be effectively converted into higher demand for the main product through the spillover effect. Although a moderate increase in the commission rate reduces the manufacturer's profit share per unit of by-product, while the growth in by-product sales and the main product demand driven by the spillover effect can offset the resulting commission costs. Consequently, such a moderate commission incentive can unlock greater profit potential for the manufacturer under the KOL-operated channel.

4.3. Key Factors on the Profits of the Manufacturer in Different Models

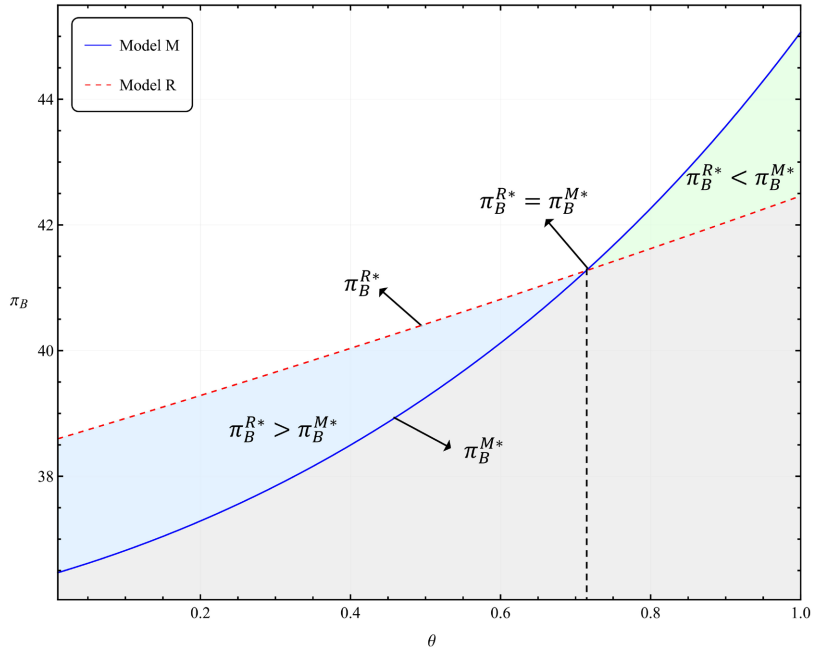
4.3.1. The Effect of Spillover of the By-Product B Short Video Sales on Product A

The impact of the spillover effect on the manufacturer's profit is illustrated in Figure 8. As shown in Figure 8(a) and Figure 8(b), under different commission rate settings, the manufacturer's profits in both Model M and Model R show an increasing trend with the increase in the spillover effect. When the commission rate is low ($\beta = 0.2$), the manufacturer achieves a higher profit in Model M when the spillover effect is substantial; by contrast, when the commission rate rises to 0.5, the manufacturer's profit in Model R becomes higher under a large spillover effect. This is because an increase in the spillover effect can expand the market demand for the manufacturer's main product, thereby bringing more profits to the manufacturer. Changes in the commission rate alter the comparison of the manufacturer's profit between Model R and Model M, leading the manufacturer to adjust its strategic choices. This variation indicates that the commission rate moderates the impact of the spillover effect on the profit difference of the manufacturer between the two models. Therefore, the manufacturer should select an appropriate short video channel based on the level of the commission rate and the magnitude of the spillover effect, with a low commission rate, establishing a self-built short video channel enables the manufacturer to gain higher profits under a high spillover effect; when the KOL's commission rate is appropriately raised, the manufacturer can achieve higher profits by leveraging the professional advantages of the KOL-operated channel and commission incentives under a relatively high spillover effect, making the introduction of the KOL short video channel a better choice.

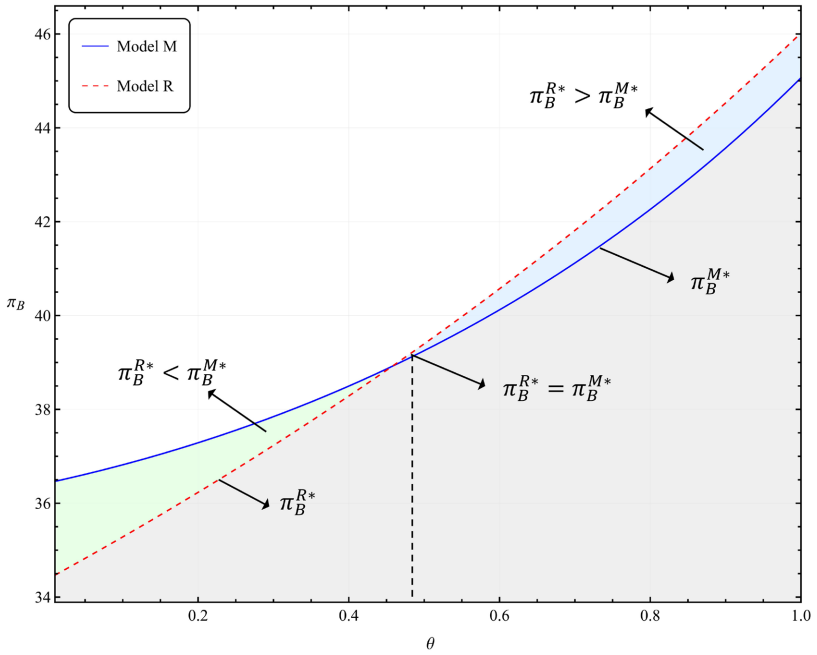
4.3.2. The Effect of the KOL's Commission Rate

Figure 8 displays how changes in the KOL's commission rate affect the manufacturer's profit. As observed in Figure 9(a), when the spillover effect is low

($\theta = 0.2$), it is not advisable for the manufacturer to set a high commission rate if it intends to adopt a KOL-operated channel for by-product sales. According to Figure 9(b), when the spillover effect is high ($\theta = 0.6$), the manufacturer's profit in Model R exhibits an inverted U-shaped curve with the increase in the commission rate, indicating the existence of an optimal commission range. A moderate

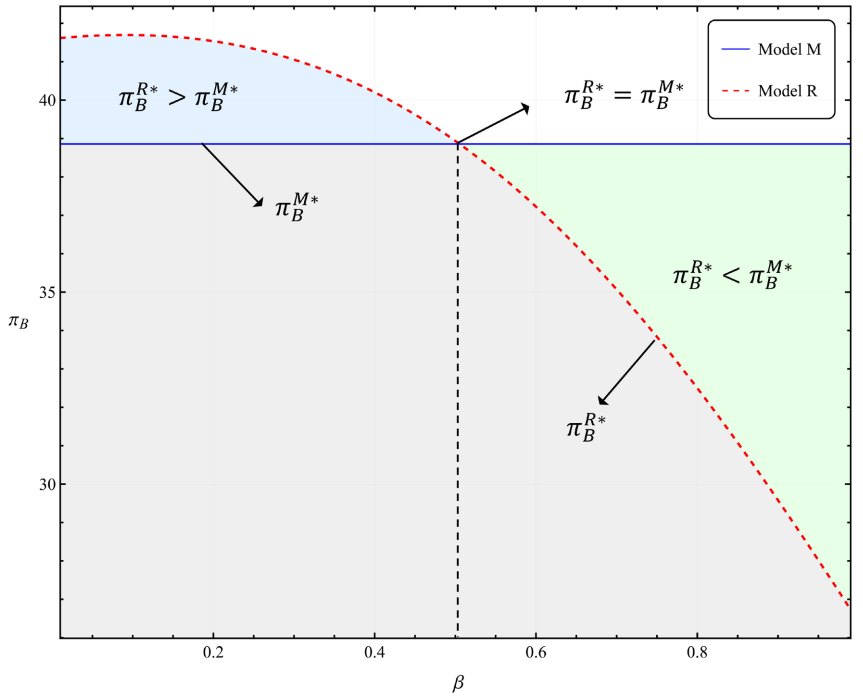


(a)

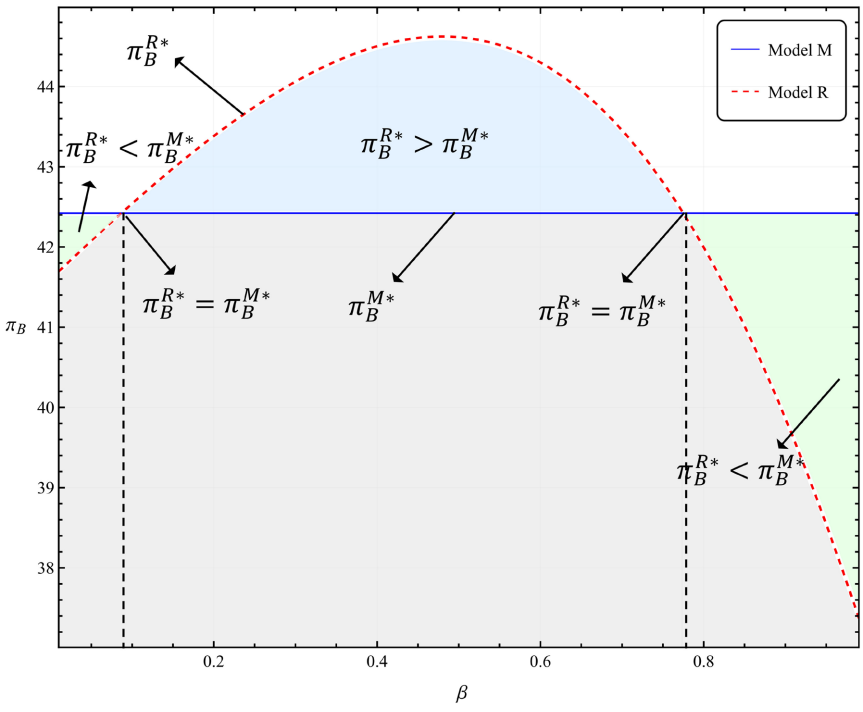


(b)

Figure 8. The effect of spillover effect on the manufacturer's profit. (a) $\beta = 0.2$; (b) $\beta = 0.5$.



(a)



(b)

Figure 9. The effect of KOL's commission rate on the manufacturer's profit. (a) $\theta = 0.2$; (b) $\theta = 0.6$.

commission rate can incentivize the KOL to raise the level of short video creation effort and increase traffic investment, in which case the manufacturer can achieve higher profits by adopting a KOL-operated channel. This section further elabo-

rates on the interaction between the spillover effect and the commission rate from the perspective of the commission rate itself, and clarifies how the manufacturer should design the KOL's commission rate under different spillover effects. This implies that the effect of the commission rate on the manufacturer's channel preference depends on the spillover effect: under a low spillover effect, a higher commission rate favors the self-built channel; under a high spillover effect, a moderate commission rate favors the KOL-operated channel.

5. Extension

5.1. Scenario Where Waste Is Not Fully Utilized

In the previous main models, we examined the scenario where all waste generated during the production of the main product A is recycled and utilized to manufacture by-product B. This assumption of full waste utilization leads to the quantity constraint $q_b = tq_a$. However, in real-world operations, technical and other constraints may prevent manufacturers from converting all waste into by-product B, thereby incurring disposal costs for a portion of the waste. Therefore, in this subsection we extend the model to a more general scenario where $q_b < tq_a$. We assume a unit waste disposal cost of m, such that the total waste disposal cost borne by the manufacturer is $m\left(tq_a - q_b\right)$.

5.1.1. Extension of Model M (Model MT)

Unlike Model M, in Model MT, the game sequence is changed: The manufacturer first determines the quantity of the main product A, and then sets the quantity of by-product B based on the actual waste utilization situation; subsequently, the manufacturer decides the short video creation effort and short video traffic investment for by-product B. The goal of the manufacturer is to maximize her own profit, so the optimization problem of Model MT is given as follows:

$$\begin{cases} \text{Max } \pi_B^{MT}\left(q_a^{MT}, q_b^{MT}, v^{MT}, e^{MT}\right) = p_a^{MT} q_a^{MT} + p_b^{MT} q_b^{MT} - \dfrac{1}{2}\mu_B\left(v^{MT}\right)^2 - e^{MT} - m\left(tq_a^{MT} - q_b^{MT}\right), \\ \text{s.t. } q_b^{MT} < tq_a^{MT}. \end{cases} \tag{7}$$

By solving the above model, when $\mu_B > \dfrac{3\theta^2+4}{6}$, $t > \dfrac{2\left[\theta\left(mt-\alpha\right)+\left(k\alpha+m\right)\left(\theta^2-2\mu_B\right)\right]}{\left(3\mu_B-2\right)\left(mt-\alpha\right)-2\theta\left(k\alpha+m\right)}$, the following Lemma 3 can be obtained.

The derivation process of Lemma 3 is similar to that of Lemma 1.

Lemma 3. Under Model MT, the optimal quantities of products A and B are:

$$q_a^{MT*} = \frac{\left(3\mu_B-2\right)\left(mt-\alpha\right)-2\theta\left(k\alpha+m\right)}{3\theta^2-6\mu_B+4},$$

$$q_b^{MT*} = \frac{2\left[\theta\left(mt-\alpha\right)+\left(k\alpha+m\right)\left(\theta^2-2\mu_B\right)\right]}{3\theta^2-6\mu_B+4},$$

the optimal short video creation effort and traffic investment are:

$$v^{MT*} = \frac{3\theta(mt-\alpha)-4(k\alpha+m)}{3\theta^2-6\mu_B+4},$$

$$e^{MT*} = \left(\frac{\theta(mt-\alpha)+(k\alpha+m)(\theta^2-2\mu_B)}{3\theta^2-6\mu_B+4}\right)^2.$$

Substituting the equilibrium solutions of the decision variables into the calculation, the optimal profit of the manufacturer is obtained as

$$\pi_B^{RT*} = \frac{2(\theta^2-2\mu_B)(k\alpha+m)^2-(3\mu_B-2)(\alpha-mt)^2-4\theta(k\alpha+m)(\alpha-mt)}{2(3\theta^2-6\mu_B+4)}.$$

5.1.2. Extension of Model R (Model RT)

Unlike Model R, in Model RT, the game sequence is changed: The manufacturer first determines the quantity of the main product A, then determines the quantity of by-product B according to the actual waste utilization situation; thereafter, the KOL decides the short video creation effort and traffic investment for by-product B. Both the manufacturer and the KOL make decisions with the goal of maximizing their own profits. The optimization problem of Model RT is given as follows:

$$\begin{cases} \text{Max } \pi_B^{RT}\left(q_a^{RT}, q_b^{RT}\right) = p_a^{RT}q_a^{RT} + (1-\beta)p_b^{RT}q_b^{RT} - h - m\left(tq_a^{RT} - q_b^{RT}\right), \\ \text{Max } \pi_L^{RT}\left(v^{RT}, e^{RT}\right) = \beta p_b^{RT}q_b^{RT} + h - \frac{1}{2}\mu_L\left(v^{RT}\right)^2 - e^{RT}, \\ \text{s.t. } q_b^{RT} < tq_a^{RT}. \end{cases} \tag{8}$$

Consistent with Model R, we have $\mu_L = 1$. By solving the above model, when $t > \frac{D_1\left[\theta\beta(\alpha-mt)+2(1-\beta)k(1+b)\alpha+2m\right]-(1-\beta)k(1+b)\alpha\theta^2\beta^2}{D_1\left[(\alpha-mt)D_1+m\theta\beta\right]}$, $0<\beta<\frac{2}{3}$, $2D_1-\theta^2\beta^2>0$. Where $D_1=(1-\beta)(2-3\beta)$, the following Lemma 4 can be obtained.

Lemma 4. Under Model RT, the optimal quantities of the products A and B are:

$$q_a^{RT*} = \frac{(\alpha-mt)D_1+m\theta\beta}{2D_1-\theta^2\beta^2},$$

$$q_b^{RT*} = \frac{D_1\left[\theta\beta(\alpha-mt)+2(1-\beta)k(1+n)\alpha+2m\right]-(1-\beta)k(1+n)\alpha\theta^2\beta^2}{D_1\left[2D_1-\theta^2\beta^2\right]},$$

the optimal short video creation effort and traffic investment are:

$$v^{RT*} = \frac{\beta D_1\left[\theta\beta(\alpha-mt)+2(1-\beta)k(1+n)\alpha+2m\right]-(1-\beta)k(1+n)\alpha\theta^2\beta^3}{D_1\left[2D_1-\theta^2\beta^2\right]},$$

$$e^{RT*} = \frac{\beta^2 D_1\left[\theta\beta(\alpha-mt)+2(1-\beta)k(1+n)\alpha+2m\right]-(1-\beta)k(1+n)\alpha\theta^2\beta^4}{4D_1\left[2D_1-\theta^2\beta^2\right]}.$$

Substituting the equilibrium solutions of the decision variables into the calculation, the optimal profit of the manufacturer is obtained as

$$\pi_B^{RT*} = \frac{\left[(\alpha - mt)D_1 + m\theta\beta\right]^2 + 2\left[2D_1 - \theta^2\beta^2\right]\left((1-\beta)k(1+b)\alpha + m\right)^2}{2D_1\left[2D_1 - \theta^2\beta^2\right]} - h.$$

5.1.3. Sensitivity Analysis of *m* and Profit Comparison Analysis

Lemma 5. The sensitivity analysis with respect to m results in $\frac{\partial q_b^{MT*}}{\partial m} > 0$, $\frac{\partial v^{MT*}}{\partial m} > 0$ and $\frac{\partial e^{MT*}}{\partial m} > 0$.

Lemma 5 shows that, in Model MT, an increase in the waste disposal cost m drives the manufacturer to increase by-product sales, short video creation effort, and traffic investment. This is intuitive: As disposing of waste becomes more expensive, the manufacturer has a stronger incentive to sell more by-products to reduce the amount of waste that must be disposed of. Consequently, she enhances her marketing efforts by investing more in short video creation and traffic to stimulate by-product demand.

Observation 1. Given the other model parameters, if m is low, the manufacturer prefers Model MT to Model RT; otherwise, the manufacturer prefers Model RT. The threshold of m at which the manufacturer switches from Model MT to Model RT depends on these parameters: a higher spillover effect θ lowers this threshold, making the KOL-operated channel more attractive at a lower disposal cost.

The results of Observation 1 are shown in **Figure 10**, where the black dashed line represents a profit difference of zero. We find that the manufacturer prefers to choose the KOL-operated channel when the unit waste disposal cost is high. This is because a portion of the waste is not utilized, forcing the manufacturer to bear the disposal cost. To mitigate the impact of this cost on profit, the manufacturer must sell as many by-products as possible, thereby increasing the demand for short video marketing. This finding is consistent with the relevant work, which shows that when online logistics costs are high, brands prefer AI livestream over KOL livestream, indicating that high operational costs shift preferences toward more cost-efficient channels [32]. In Model RT, the KOL determines the level of short video creation effort and traffic investment. Due to the KOL's higher creation efficiency and fan base, appropriate commission incentives drive the KOL to increase investment in pursuit of self-interest, leading to higher returns from by-product marketing. This explains why the manufacturer outsources short video sales of by-products to a KOL when waste disposal costs are high.

Proposition 7. Under the scenario where waste is not fully utilized, for the manufacturer: if $0 < h < h_1$, then $\pi_B^{RT*} > \pi_B^{MT*}$, if $h > h_1$, then $\pi_B^{RT*} < \pi_B^{MT*}$, wherein

$$h_1 = \frac{\left[(\alpha - mt)D_1 + m\theta\beta\right]^2 + 2\left[2D_1 - \theta^2\beta^2\right]\left((1-\beta)k(1+n)\alpha + m\right)^2}{2D_1\left[2D_1 - \theta^2\beta^2\right]} - \frac{2\left(\theta^2 - 2\mu_B\right)(k\alpha + m)^2 - (3\mu_B - 2)(\alpha - mt)^2 - 4\theta(k\alpha + m)(\alpha - mt)}{2\left(3\theta^2 - 6\mu_B + 4\right)},$$

$D_1 = (1-\beta)(2-3\beta)$.

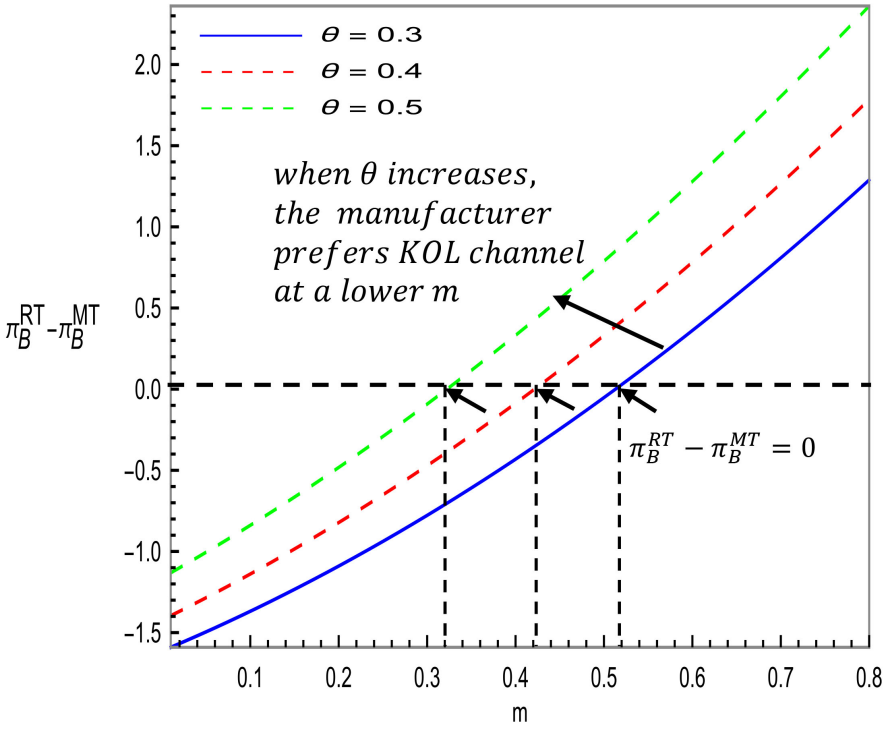
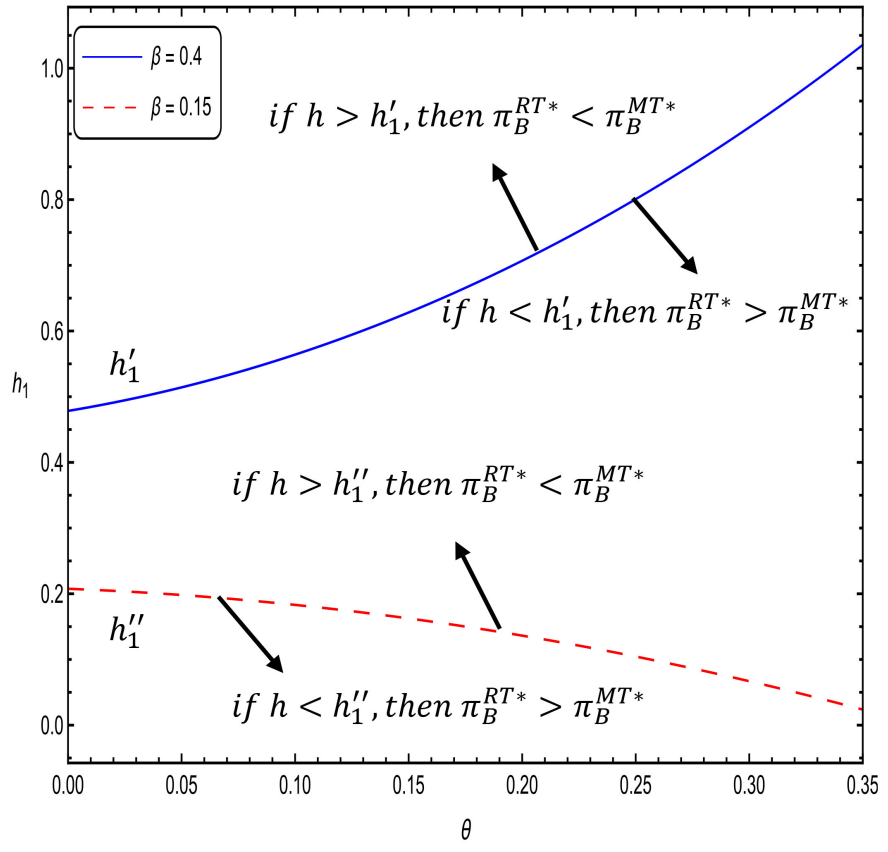
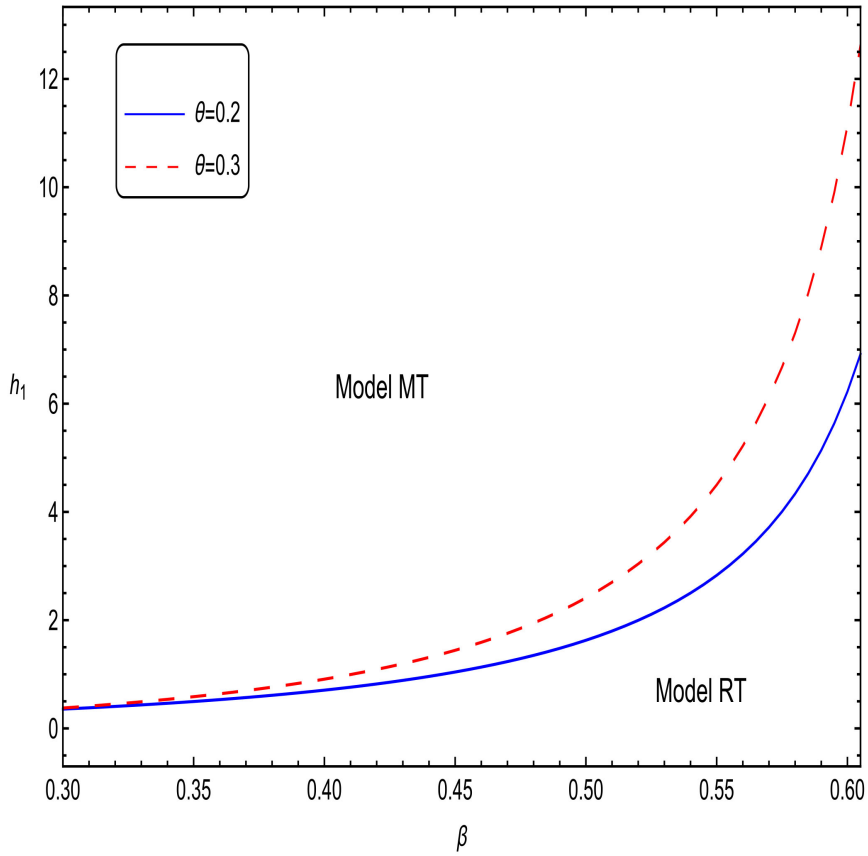


Figure 10. Comparison of the manufacturer's profits in Model RT and Model MT ($\beta = 0.4$, $h = 2$).



(a)



(b)

Figure 11. Manufacturer's profits comparison between Models MT and RT. (a) Effect of spillover effect; (b) Effect of KOL's commission rate.

Proposition 7 compares the manufacturer's optimal profits under the two short-video marketing channels in this extended scenario. When the KOL's signing fee is relatively low, the manufacturer achieves higher profits under Model RT than under Model MT. Conversely, when the KOL's signing fee is relatively high, the manufacturer's profit is higher under Model MT than under Model RT. This trend is consistent with that of Proposition 6. **Figure 11** illustrates the manufacturer's profitability from online consumers under varying spillover effects and KOL's commission rates. As shown in **Figure 11(b)**, the likelihood of the manufacturer achieving higher profits under Model RT increases with the KOL's commission rate. Notably, as shown in **Figure 11(a)**, when the commission rate is low, a stronger spillover effect raises the probability of higher profits under Model MT. Conversely, when the commission rate is set at an appropriately higher level, an increase in the spillover effect enhances the manufacturer's chance of obtaining higher profits under Model RT. For the manufacturer, Proposition 7 verifies the robustness of the main model. In this more realistic and general scenario, the manufacturer must consider the interactive effects of parameters such as the spillover effect and the KOL's commission rate, and select the optimal short video marketing channel to maximize its profits.

5.2. Traffic Investment Cost Sharing (Model RK)

In Model R, we examine the scenario that the short video creation and traffic investment are all done by the KOL after adopting the KOL short video channel. However, in practice, the manufacturer will encourage the KOL to invest more in traffic by sharing the cost. Hence, we further assume that the manufacturer agrees to share the KOL's short video traffic investment cost before the optimal decisions and the cost-sharing ratio of the manufacturer is γ. Then, the game sequence is consistent with that of Model R and the optimal decision-making problem of Model RK can be expressed as follows:

$$\begin{cases} \text{Max } \pi_B^{RK}\left(q_a^{RK}\right) = p_a^{RK} q_a^{RK} + (1-\beta) p_b^{RK} q_b^{RK} - h - \gamma e^{RK}, \\ \text{Max } \pi_L^{RK}\left(v^{RK}, e^{RK}\right) = \beta p_b^{RK} q_b^{RK} + h - \frac{1}{2}\mu_L\left(v^{RK}\right)^2 - (1-\gamma)e^{RK}, \\ \text{s.t. } q_b^{RK} = t q_a^{RK}. \end{cases} \tag{9}$$

Consistent with Model R, we assume $\mu_L = 1$. When $1-\theta\beta t + t^2\left((1-\beta)^2 - \frac{\beta(1-\beta)}{2(1-\gamma)} + \frac{\gamma\beta^2}{4(1-\gamma)^2}\right) > 0$, the optimal solutions are as follows:

$$q_a^{RK*} = \frac{\alpha\left(1+(1-\beta)(1+b)tk\right)}{2\left(1-\theta\beta t + t^2\left((1-\beta)^2 - \frac{\beta(1-\beta)}{2(1-\gamma)} + \frac{\gamma\beta^2}{4(1-\gamma)^2}\right)\right)},$$

$$v^{RK*} = \frac{\beta t\alpha\left(1+(1-\beta)(1+b)tk\right)}{2\left(1-\theta\beta t + t^2\left((1-\beta)^2 - \frac{\beta(1-\beta)}{2(1-\gamma)} + \frac{\gamma\beta^2}{4(1-\gamma)^2}\right)\right)},$$

$$e^{RK*} = \frac{\beta^2 t^2}{4(1-\gamma)^2}\left(\frac{\alpha\left(1+(1-\beta)(1+b)tk\right)}{2\left(1-\theta\beta t + t^2\left((1-\beta)^2 - \frac{\beta(1-\beta)}{2(1-\gamma)} + \frac{\gamma\beta^2}{4(1-\gamma)^2}\right)\right)}\right)^2,$$

$$\pi_B^{RK*} = \frac{\alpha^2\left(1+(1-\beta)(1+b)tk\right)^2}{4\left(1-\theta\beta t + t^2\left((1-\beta)^2 - \frac{\beta(1-\beta)}{2(1-\gamma)} + \frac{\gamma\beta^2}{4(1-\gamma)^2}\right)\right)} - h.$$

In order to investigate the effects of the traffic investment cost-sharing mechanism, and given that our primary objective is to analyze whether the manufacturer can achieve the desired sharing outcome by voluntarily bearing a portion of the KOL's traffic costs in the scenario where it adopts a KOL, we conduct a comparative analysis of the manufacturer's profits under Model R and Model RK, respectively, to obtain Proposition 8 as follows.

Proposition 8. Considering the traffic investment cost-sharing in the KOL

short video channel, we have: when $0<\beta<\frac{2}{3}$ and $\gamma<1-\frac{\beta}{2(1-\beta)}$, then $\pi_B^{RK*}>\pi_B^{R*}$, when $0<\beta<\frac{2}{3}$ and $\gamma>1-\frac{\beta}{2(1-\beta)}$, then $\pi_B^{RK*}<\pi_B^{R*}$ and when $\frac{2}{3}<\beta<1$, then there also has $\pi_B^{RK*}<\pi_B^{R*}$.

Proposition 8 shows that when the manufacturer sets a high commission rate for the KOL ($\frac{2}{3}<\beta<1$), regardless of the cost-sharing ratio the manufacturer is willing to share, its profit will decrease and be lower than that in Model R. This is because the manufacturer already bears commission costs when collaborating with a KOL for by-product marketing, with the KOL capturing the majority of the sales revenue from by-products. If the manufacturer shares the traffic investment cost in this case, she needs to pay double for bearing both high commissions and traffic costs, resulting in excessive profit dilution, and thus the manufacturer has no incentive to share the traffic cost.

When an appropriate commission rate is in place and the cost-sharing ratio of traffic investment is smaller, the manufacturer is more willing to share the traffic cost as she can obtain more profit. Under the cost-sharing contract, the combined effect of a reasonable commission incentive and the reduced cost burden on the KOL encourages the KOL to invest more money in traffic. As a result, market demand for the by-product becomes substantially greater than in the scenario without cost sharing. Moreover, more consumers learn about the environmental value of both the main and by-products through the by-product short video content, which in turn boosts market demand for the main product and significantly increases the manufacturer's revenue. Although the manufacturer's marketing costs rise to some extent, the additional revenue far outweighs the shared costs. When the cost-sharing ratio of traffic investment is relatively high, even though the KOL may continue to invest more money in traffic, the increased sales revenue is insufficient to offset the cost losses. As a result, the marketing cost paid by the manufacturer will become larger. At this time, the manufacturer will obtain a greater profit without cost-sharing, thus she has no incentive to share the traffic cost. Similarly, Song *et al.* (2024) find that under cost-sharing cooperation, platform profits increase only when the sharing ratio is low, consistent with Proposition 8 [33].

6. Conclusions

6.1. Main Research Findings

This paper investigates the operational decisions of a manufacturer that produces both main products and by-products, focusing on the short-video marketing channel for the by-products. Two primary game-theoretic models are established and analyzed. Specifically, Model M and Model R characterize the equilibrium solutions when the manufacturer establishes its own short-video marketing chan-

nel and when it adopts a KOL-operated short-video marketing channel, respectively. Furthermore, we compare the manufacturer's profits under different channels to assist in channel selection, and use numerical simulations to analyze the impact of key parameters on the manufacturer's profitability. In addition, in an extended model, we consider the effect of waste disposal costs on the manufacturer's profits under different channels, as well as the impact of the traffic cost-sharing ratio on the manufacturer's channel choice. Based on the above, we draw the following main conclusions.

First, the optimal main product output under different short-video marketing channels is primarily related to the level of spillover effect and the specific value of the manufacturer's short-video creation effort cost coefficient. When the spillover effect is low, or when the spillover effect is high but the manufacturer's short-video creation effort cost coefficient is low, the manufacturer sets a higher main product output on its own short-video channel, thereby obtaining more by-products, and vice versa. The optimal creation effort is mainly related to the KOL's commission rate and the manufacturer's short-video creation effort cost coefficient. When the manufacturer's short-video creation effort cost coefficient is large and the KOL's commission rate is high, the KOL's short-video creation effort is greater. In contrast, under other circumstances, the manufacturer's creation effort is higher. We find that within a reasonable economic range, the optimal traffic input of the manufacturer's self-built short-video channel is greater than that of the KOL short-video channel.

Second, the manufacturer should determine its marketing channel based on the spillover effect, the manufacturer's short-video creation effort cost coefficient, and the KOL's fixed fee. Specifically, when there is a high spillover effect and the manufacturer's short-video creation effort cost coefficient is low, the manufacturer should choose to establish its own short-video marketing channel. Alternatively, if the manufacturer's short-video creation effort cost coefficient is high and the KOL's fixed fee is low, the manufacturer may consider adopting a KOL-operated channel.

Finally, when the model incorporates waste disposal costs, the manufacturer prefers to adopt the KOL-operated short-video marketing channel when the waste disposal cost is high. Furthermore, when the manufacturer bears a portion of the traffic investment cost, it is willing to cooperate with the KOL and share part of the traffic investment cost only under appropriate KOL commission rates and relatively small cost-sharing ratios.

6.2. Managerial Insights

This study offers the following managerial insights for manufacturers producing both main products and by-products regarding channel selection and operational strategies in short-video marketing.

First, for manufacturers choosing to build their own short-video marketing channel, it is recommended that they pay close attention to the strength of the spillover

effect and their own short-video creation cost. By closely monitoring the spillover from by-product short-video content, manufacturers can reasonably control the production of main products and thereby enhance overall value through short-video marketing of by-products. The manufacturer's own short-video creation cost is closely related to optimal decisions. Within a reasonable range, the optimal levels of creation effort and traffic input in the manufacturer's self-built short-video channel are more significant than those in the KOL short-video channel. This implies that when building their own short-video channel, manufacturers need to invest more effort and financial resources to achieve satisfactory marketing outcomes.

Second, for manufacturers considering the introduction of a third-party KOL short-video marketing channel, it is advisable to leverage the KOL's cost advantage in short-video creation and commission incentives, rather than paying higher fixed fees. Such a strategy can reduce investment risk when the effectiveness of KOL marketing is uncertain. Under a high spillover effect, a moderate commission rate makes the KOL-operated channel more attractive, whereas an excessively high commission rate favors the self-built channel. Since the commission rate is exogenous in our model, the manufacturer's decision is confined to channel choice given the prevailing commission rate.

Third, when considering the impact of waste disposal costs, manufacturers should fully account for cost pressure in their channel decisions. Thus, we recommend that manufacturers pay close attention to waste disposal costs. When such costs are high, priority should be given to adopting the KOL-operated channel to alleviate cost pressure by increasing by-product sales. Furthermore, in the scenario of collaborating with a KOL, if the manufacturer shares part of the KOL's traffic investment cost, with an appropriate sharing ratio and commission incentive, the KOL will increase its optimal creation effort and traffic input. When the sharing ratio is low and the commission rate is moderate, the manufacturer benefits from such cost-sharing.

6.3. Limitation and Future Research

There may be three future research directions. On the one hand, this paper only considers a single manufacturer producing both main and by-products, without involving inter-manufacturer waste transactions. In practice, by-product synergy often involves cross-firm waste transfer and remanufacturing, introducing issues such as waste wholesale prices. Hence, future research could extend the model to incorporate cross-manufacturer transactions and examine how waste wholesale prices affect channel selection. On the other hand, this study does not treat the e-commerce platform as an independent decision-maker. In reality, platforms actively set commission rates and recommendation algorithms while pursuing profit maximization. Therefore, future research could consider the platform as a strategic player and analyze its interaction with the manufacturer's channel choice. Finally, this paper assumes a non-negative spillover effect of by-product short video

content on the main product. However, low-quality content may generate negative spillovers, damaging the main product's brand image. Thus, future research could allow the spillover effect to be bidirectional.

Author Contributions

Yunwei Shao was the sole principal contributor to this work and was responsible for all aspects of the study, including conceptualization, methodology, formal analysis, writing—original draft, and writing—review & editing. **Jiayi Li** assisted with investigation, specifically data collection and literature search.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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