

Research on Dual-Channel Supply Chain Based on Live Streaming E-commerce

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Abstract: This study investigates the dual-channel supply chain, focusing on the interaction between internet celebrity KOLs in live streaming e-commerce and traditional offline retailers, aiming to understand the dynamics and optimize the economic outcomes. A competitive model is established to analyze the dynamics between these channels. Using mathematical modeling and computational tools such as Mathematica and Matlab, optimal pricing strategies are derived to maximize economic benefits across the supply chain, fostering healthy competition and contributing to the growth of the digital economy.

Keywords: Dual-channel supply chain; Optimal pricing strategies; Live streaming e-commerce

1. Introduction

1.1. Research Background

With the continuous development of the internet, live-streaming e-commerce has gradually become an indispensable sales model.[1] According to statistics, the live-streaming e-commerce market in China reached 4.9 trillion yuan in transaction volume in 2023, with a year-on-year increase of 35.2%. Moreover, according to related predictions, the compound annual growth rate (CAGR) of live-streaming e-commerce in China from 2024 to 2026 is expected to be 18%. Live-streaming e-commerce is increasingly becoming a mainstream sales model.[2]

As an efficient real-time online marketing method, live-streaming e-commerce has strong entertainment and interactivity. Consumers can not only enjoy the services of traditional internet shopping but also actively interact with hosts through comments. Hosts can stimulate consumers' desire to purchase through certain means, while brand owners can capture their main audience groups, launch more products, and select "live-streaming influencers" more suitable for their audience. Therefore, with the vigorous development of live-streaming, the influencer effect has emerged. Some individuals with significant online influence, such as Qi Wei and Li Jiaqi, are known as internet celebrities or Key Opinion Leaders (KOLs).[3] This paper refers to these internet celebrities as KOLs who, with their large follower count, leverage the power of the internet and online platforms to seek more benefits for brand owners and drive e-commerce development.

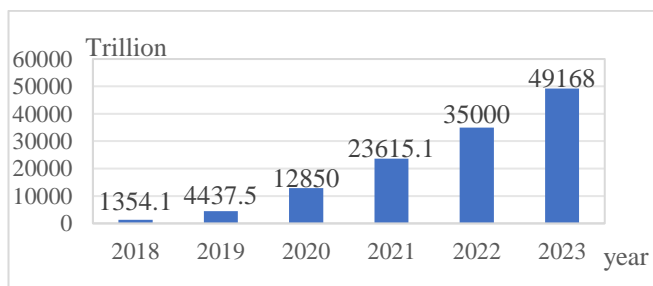


Figure 1. Live streaming e-commerce transaction volume

Figure (1) shows the live-streaming e-commerce transaction volume from 2018 to 2023, and it can be observed that the transaction volume has increased significantly. The reasons for this trend are not only the development of the internet and people's demand for goods but also national economic support for live-streaming e-commerce. To promote the development of the live-streaming e-commerce industry, China has issued several policies supporting, encouraging, and regulating the industry, such as the "Opinions on the Key Tasks of Promoting Rural Revitalization in 2022" released by the General Office of the CPC Central Committee and the General Office of the State Council in 2022, implementing the "Digital Business Revitalizing Agriculture" project and promoting the development of e-commerce in rural areas.[4] This promotes the standardized and healthy development of live-streaming e-commerce for agricultural and sideline products. With such a promising development prospect, issues such as reducing inventory, increasing profits, improving supply chain efficiency, and promoting brands have gradually become challenges that e-commerce needs to face in its next stage of development.[5]

1.2. Dual-channel Supply Chain Game Model Overview

Xiaoying Liang and others have demonstrated the existence of a four-party evolutionary game model involving anchors, merchants, platforms, and consumers in live-streaming e-commerce. Anchors' selection of high-quality products can drive merchants to excel in production, thereby attracting consumers and boosting merchants' profits. Consumers' strong awareness of rights protection and pursuit of high-quality products encourage anchors to select better products, constraining merchants and ensuring they receive high-quality goods. The platform's stringent punishment and selection of anchors and merchants can constraint both parties, leading to greater benefits. This game model significantly impacts the online channel of dual-channel supply chains. Dual-channel supply chains consist of online and offline channels, with online channels referring to e-commerce activities conducted over the internet, including direct online sales by manufacturers. Offline channels refer to product sales through physical stores. The impact of the four-party game on the online channel further affects the offline channel, such as

increased sales and product brand benefits.

For the common dual-channel supply chain structure, it can be divided into the following three types: (1) Direct dual-channel model: In this model, manufacturers sell products directly to consumers while maintaining traditional wholesale channels. (2) In this model, both manufacturers and retailers sell products through their own channels, but their sales networks overlap. (3) The hybrid dual-channel model combines the advantages of direct sales and traditional wholesale channels. Manufacturers not only sell products through their own channels but also through retailers. This article adopts the third type of channel.

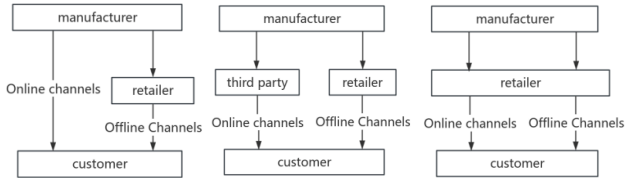


Figure 2. Dual channel supply chain structure

1.3. Related Literature Review and Research Motivation

After reading a large number of relevant materials and papers, it was found that most of the research on dual-channel sales and game models started from the consumer's perspective. For example, Cai Defa and others studied the game evolution model and concluded that unblocking the consumer channel and establishing a perfect regulatory system can greatly develop the e-commerce economy; Tian Lingyan focused on the interaction between consumers and fresh product merchants, pointing out the importance of consumers' online purchase intention; Zhang Jianyong emphasized the change of consumers from traditional online shopping to live streaming e-commerce platforms.

Nowadays, most of the relevant literature starts from the consumer's perspective. This paper starts from the leader, bases on the game model of dual-channel supply chain, considers the traffic characteristics of the anchor itself, and sets the anchor's marketing efforts, anchor traffic index, and influencer benefits as a parameter. At the same time, it considers the feedback effect of the anchor on the traditional sales channel, making it more practical. After considering various factors, strategies for manufacturers to seek higher profits and create higher value can eventually be obtained.

1.4. Research Objectives

In order to further consider the optimal decision of KOL anchors intervening in live streaming sales, this paper refers to the Stackelberg game method, integrates the platform influence into the anchor influence in the four-party game, and regards the manufacturer as the leader, and the traditional retailer and KOL anchor as followers. According to the Stackelberg game method, the optimal pricing strategies of manufacturers and retailers under the influence of live streaming sales are studied.

To clarify the above issues, the platform influence in the four-party game is integrated into the anchor influence, thereby simplifying the modeling difficulty. At the same time, the design considers the mutual influence among manufacturers, retailers, live streaming anchors, and consumers.

2. Model Assumptions and Symbol Descriptions

2.1. Symbol Descriptions

Table 1. parameter interpretation

Symbol	Description
ω	Manufacturer sells to retailer at wholesale price
P_i	Sales price across various channels
θ	Consumer preference for live streaming sales channel, where $0 < \theta < 1$
$1-\theta$	Consumer preference for traditional sales channel, where $0 < \theta < 1$
t	Promotional effect of live streaming events on live streaming channel
λ	Commission rate paid by manufacturer to influencer
f	Influencer's base level of increment to live streaming channel
$\frac{f^2}{2}$	Influencer's own cost of driving sales
u	Influencer's impact on traditional retail channel
e	Influencer's impact on live streaming retail channel
D_i	Sales demand for the channel over two weeks
π_i	Total profit of each party in the two models
i	$i=r, m, k$ represent retailer, manufacturer, and influencer KOL respectively

2.2. Basic Assumptions

To simplify calculations, it is assumed that the wholesale price set by the supplier is less than the sales price of each channel. The promotional effect of live streaming events on the live streaming channel is denoted by t and only has a positive impact on the live streaming channel. The influence of internet celebrities on traditional retail channels is denoted by u and is bidirectional; when u is greater than 1, it is a positive influence, and when u is less than 1, it is a negative influence.

2.3. Model Description

Based on the assumptions and the corresponding relationships of the dual-channel supply chain model, the traditional (offline) channel involves the supplier first wholesaling the product to the traditional retailer at a price, and then the retailer selling the product to consumers at a price. The online channel involves the manufacturer paying a commission percentage to internet celebrities (KOLs) for live streaming sales. The internet celebrities bring their own traffic base, and it is assumed that the gain level brought by the traffic base is f . The cost of the internet celebrities themselves for live streaming sales is $\frac{f^2}{2}$, the consumer group brought to the online channel is e , and the consumer group brought to the traditional channel is u .

Therefore, the demand functions for the dual channels are as follows:

$$D_r = 1 - \theta - P_r + (1 - u)f \quad (2.1)$$

$$D_m = \theta + ef - P_m + (1 + f)t \quad (2.2)$$

The profit functions for the retailer, manufacturer, and

influencer KOL are as follows:

$$\pi_r = (P_r - \omega)(1 - \theta - P_r + (1 - u)f) \quad (2.3)$$

$$\pi_m = \omega(1 - \theta - P_r + uf) + (1 - \lambda)P_m(\theta + ef - P_m + (1 + f)t) \quad (2.4)$$

$$\pi_k = \lambda(\theta + ef - P_m + (1 + f)t) - \frac{f^2}{2} \quad (2.5)$$

2.4. Problem Statement

Based on the assumptions and model, under the construction of this dual-channel supply chain, with certain parameters determined, we aim to find the optimal pricing strategy to seek more profits for the retailer, manufacturer, and internet celebrity KOL.

3. Dual-channel Pricing Decision with Internet Celebrity KOL Involvement

In the dual-channel model with the involvement of internet celebrity KOL, while keeping some parameters as known or fixed values, we adopt the reverse induction solution method. By using Matlab to first perform the second-order partial derivative on equation (2.3), we obtain the result $\frac{\partial^2 \pi_r}{\partial P_r^2} = -2 < 0$, indicating that (2.3) is a strictly concave function with respect to P_r . The relevant proof is in Appendix A.1. Then, we proceed with the first-order partial derivative to obtain the result $\frac{\partial \pi_r}{\partial P_r} = \omega - 2P_r - \theta - f(u - 1) + 1$, and by setting $\frac{\partial \pi_r}{\partial P_r} = 0$, we can derive the optimal equilibrium solution $P_r^* = \frac{\omega - \theta - f(u-1) + 1}{2}$. The programming code is detailed in Appendix B.1.

Substituting P_r^* into equation (2.4) and using Mathematica to calculate, we obtain the expression $\pi_m = p2(e f + o - p2 + t + f t)(1 - v) - 1/2 w(-1 + f + o - 3 f u + w)$. The programming code is detailed in Appendix B.2.

By taking the second-order derivative of π_m and using Mathematica, we can get the result $\frac{\partial^2 \pi_m}{\partial \omega^2} = -1$, $\frac{\partial^2 \pi_m}{\partial P_m^2} = -2 + 2\lambda$. The programming code is detailed in Appendix B.3.

Given the assumption that λ within the interval (0,1), it can be inferred that π_m is also strictly concave. The relevant proof is in Appendix A.2.

By substituting $\frac{\partial \pi_m}{\partial \omega} = 0$, $\frac{\partial \pi_m}{\partial P_m} = 0$ into equations, we can find $\omega^* = 1/2(1 - f - o + 3 f u)$, $P_m^* = 1/2(e f + o + t + f t)$, The programming code is detailed in Appendix B.4.

By using the obtained ω^* , P_r^* into equations (2.1), (2.2), (2.3), (2.4), and (2.5), we can determine the optimal demand quantity for the traditional channel D_r^* , the optimal demand quantity for the online live streaming channel D_m^* , the optimal profit for the retailer π_r^* , the optimal profit for the manufacturer π_m^* , and the optimal profit for the internet celebrity KOL π_k^* . The programming code is detailed in Appendix B.5. Expression as follows:

$$D_r^* = 1/4(1 - \theta + f(3 - 5u))$$

$$D_m^* = 1/2(e f + \theta + t + f t)$$

$$\pi_r^* = 1/16(-1 + \theta + f(-3 + 5u))^2$$

$$\pi_m^* = 1/8((-1 + f + \theta - 3 f u) - 2(e f + \theta + t + f t)(-1 + \lambda))$$

$$\pi_k^* = 1/2(-f^2 + f(e + t)\lambda + (\theta + t)\lambda)$$

By studying the relationship between the above values and related parameters, the following inferences can be drawn:

Inference 1: P_m^* , D_m^* , π_k^* are all increasing functions of θ .

Inference 2: ω^* , P_r^* , D_r^* , π_r^* are all decreasing functions of θ .

Inference 3: π_k^* , ω^* , P_r^* , D_r^* , π_r^* are all increasing functions of u .

Inference 4: P_m^* , D_m^* , π_k^* , π_m^* are all increasing functions of e .

Specific partial derivative values can be found in Appendix B.6.

Based on the above inference, it reveals a significant characteristic of the influencer KOL proxy broadcasting model: when the influencer KOL brings enhanced promotional effects to the live streaming channel, a series of chain reactions occur. Specifically, the wholesale price of the product, the pricing of the retail channel, the market demand of the retail channel, the pricing of the live streaming channel, and the market demand will all increase. At the same time, the profits of traditional retailers and brand manufacturers will also increase accordingly. However, in this process, the profit of the influencer KOL will decrease. This is mainly because when the influencer KOL's promotional effect is better, consumers can access more comprehensive product information, which enhances their trust in the product. This increase in trust may reduce the sensitivity of some consumers to price factors in their purchasing decisions, thus leading to a purchase. For traditional retail channels, this phenomenon may lead to a shift in market demand, thereby providing the retail channel with the opportunity to increase the selling price of the product.

4. Merits and Demerits Analysis

4.1. Merits

(1) Certain feasibility. This article establishes a relevant mathematical model based on the dual-channel model, introduces multiple parameters, effectively demonstrates the relationships among various parties, and provides specific calculation results, which are feasible and offer new benefits.

(2) Accurate and efficient results with programming assistance. This article uses Matlab and Mathematica for auxiliary calculations, making the calculation process concise and efficient while being persuasive.

(3) Conclusions are consistent with reality. The results of this article's model are in line with reality, indicating practical significance and providing genuinely guiding suggestions for the dual-channel supply model.

4.2. Demerits

(1) Lack of specific numerical analysis. This study currently lacks precise numerical simulations, which could further validate the proposed model in practical scenarios by offering real-world applicability.

(2) Overly complex programming. The programming in this article is poorly coherent, lacking a program that can calculate from start to finish.

5. Summary and Prospects

5.1. Summary

With the increasing popularity of live streaming shopping models and the rapid rise of internet celebrities and KOLs in the e-commerce field, brand manufacturers have begun to skillfully integrate and utilize live streaming, an emerging form. Based on traditional sales channels, they have

significantly enhanced the market exposure of products or services through live streaming platforms and the strong appeal of internet celebrities and KOLs, thereby successfully converting this into more substantial economic returns. Based on this phenomenon, this article explores pricing decisions among multiple parties and combines direct influencing factors. It mostly discusses manufacturers' decisions while ignoring the influence of other parties. Therefore, this article focuses on analyzing optimal pricing decisions among multiple participants in a dual-channel supply chain under the guidance of Stackelberg game theory. The conclusions of this study are as follows:

As consumers' preference for live streaming platforms increases and the brand exposure brought by live streaming channels significantly improves, the pricing strategy and market sales volume of retail channels face fierce competition from live streaming channels, experiencing significant reverse pressure. Meanwhile, the product pricing and market sales volume of live streaming platforms have received a positive boost. Internet celebrities and KOLs, with their strong influence, bring significant traffic spillover effects to both retail and live streaming channels, not only increasing the product pricing and market sales volume of both channels but also changing consumers' shopping habits and brand loyalty to some extent. Moreover, internet celebrities and KOLs further enhance the promotional effect of live streaming platforms through their personal charm and professional abilities. Although this approach has a positive impact on the product pricing and market sales volume of both channels in the short term, it may have an adverse effect on their personal income in the long run. Finally, with the commission ratio charged by internet celebrities and KOLs continuously rising, the profit margin of manufacturers has also been compressed accordingly, reflecting to some extent the new dynamics of profit distribution in the live streaming e-commerce ecosystem.

Therefore, we have the following management references:

For retailers: Pay attention to service quality and product quality and strive to participate in pricing to seek more benefits.

For manufacturers: Pay attention to the traffic value of

employing internet celebrities and consider their commission, keeping the pricing power in their own hands.

For internet celebrities and KOLs: Fully utilize their fan influence and merchandise level to make it a chip for negotiating their commission.

5.2. Prospects

As an emerging economic system, there are limitations in this study of live streaming e-commerce. In future research work, the following aspects can be extended and explored:

(1) The negative impact relationship between retailers and internet celebrities can be further refined.

(2) Consider the impact of local conditions and relevant policies on the research, such as economic level and policy support.

(3) Consider the losses caused by product oversupply and the negative impact of related negative reviews.

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