Impact of live commerce spillover effect on supply chain decisions

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Abstract

Purpose – With the booming of live commerce, sellers provide products through not only their traditional channels but also the anchors who show products by live broadcast, forming a live commerce supply chain. In fact, such selling mode generates two effects: the live broadcast service of the anchor affects the return rate of products sold live (live commerce effect) and related products of the manufacturer sold via its own channel (live commerce spillover effect). In this paper, the authors investigate the impacts of both live commerce and live commerce spillover effect on the price decisions as well as the anchor’s service effort.

Design/methodology/approach – The authors establish a live commerce supply chain model where the manufacturer sells related products directly and by the anchor with a wholesale price contract. The manufacturer decides the price of product sold directly based on the anchor’s broadcast effort since there exists the live commerce spillover effects. Backward induction is used to solve the Stackelberg game between the manufacturer and the anchor.

Findings – The results show that (1) the existence of the live commerce spillover effect brings more profit to the manufacturer while it reduces the anchor’s profit. Moreover, the total profit of the live commerce supply chain first decreases and then increases as the intensity of the live commerce spillover effect improves. (2) The pricing of products sold directly by the manufacturer and sold through the anchor is nonmonotonic with respect to the live commerce spillover effect. (3) The increase in return cost always leads to an increase in the profit of the anchor, whether it is borne by the anchor or by the consumer. (4) If the baseline return probability is high, the anchor should increase her effort, thus securing more profit. However, the spillover effect of live commerce and the horizontal differences between products will discourage the anchor from increasing the live streaming service level.

Originality/value – The study proposes the live commerce supply chain model where the anchor balances the cost and benefit of her live broadcast effort, which lowers the consumers expected return possibility. In addition the live commerce spillover effect is introduced, reducing the expected return rate for the related products without live broadcast (in the direct channel). With the inter-influence of live commerce, the price competition between the live anchor and the manufacturer becomes more complex. By solving the typical live commerce game model, managerial insights are given for the decision makers among the live commerce supply chain.

Keywords Game theory, Spillover effect, Live streaming, Live commerce supply chain

1. Introduction

Today, live commerce has been booming. In 2020, China’s e-commerce live commerce market, as a typical mode of live commerce, reached 961 billion yuan. Viya, the largest anchor in China, had two-hour live commerce with sales exceeding 267 million yuan [1]. Austin Li, the most popular and famous anchor, closed 1.03 million deals worth 200 million yuan in a four-hour live streaming show viewed by 22.95 million people on June 8, 2020 [2].
Live commerce refers to a new type of selling mode in which an anchor vividly and interactively displays products online, offers consults, answers questions, guides sales through some Internet platforms by live streaming (Hilvert-Bruce et al., 2018), and finally sells products to consumers. Mogujie and Taobao first launched live streaming e-commerce in 2016, indicating the start of live commerce. Due to the popularity of anchors, some manufacturers cooperate with anchors and have developed the live commerce supply chain, which has been pushing the boom in live commerce. For example, on November 24, 2020, Austin Li achieved 112-million-yuan sales through live commerce, which accounts for nearly 2/3 of Florasis total sales (185 million yuan) [3].

The live commerce supply chain is quite different from the traditional supply chain. In the traditional supply chain, manufacturers sell their products directly or through retailers. In the live commerce supply chain, manufacturers sell their products directly or by live commerce of anchors who are members of this supply chain. The anchor needs to determine the sales price of products, which depends on the level of the anchor’s live streaming service. Therefore, how to optimize decisions of live commerce supply chain to maximize its profit is a need for research to enhance our understanding of this supply chain.

More importantly, the live commerce supply chain generates two effects, the live commerce effect and the live commerce spillover effect. During live commerce, the anchor with live streaming, displays, demonstrates and realizes a real-time interaction with consumers and sells the products to them. Her efforts have facilitated consumer’s learning of information about whether the products match their taste. The consumer inspects and buys the products through live commerce of anchors. Therefore, if anchor’s efforts are more or less, the products’ return probability of consumers is lower or higher, which is the live commerce effect we called. Moreover, her efforts will also influence consumers’ willingness to buy the related products directly from the manufacturer, and their return probability, which is the live commerce spillover effect we called. In particular, as this live commerce spillover effect exists, supply chain decision-making is a challenging research problem.

Therefore, we explore the following questions:

1. What are the impacts of live commerce on supply chain decisions?
2. With the live commerce spillover effect, what are its implications for live commerce supply chain decisions?
3. How should the anchor decide the price of the product and service level of live streaming, and how should the manufacturer decide the price of the related product?

To address these questions, we construct a game-theoretic model where a manufacturer sells product A through the anchor with a wholesale price contract and sells related product B directly online. To focus on the impact of live commerce, we first obtain the equilibrium decisions for the manufacturer and anchor with/without the live commerce spillover effect. Then, we compare the decision-making and profits of the manufacturer and anchor under whether there exists the live commerce spillover effect to investigate the mechanism of the impact of the live commerce spillover effect on the decisions-making of the manufacturer and anchor. The obtained optimal decision strategies could provide insightful guidelines for the manufacturer and anchor to select the best pricing and information service level to achieve the goal of profit maximization.

The remainder of this paper is organized as follows. Section 2 provides a literature review. Section 3 formulates our models and obtains the optimal decisions of the manufacturer and the anchor. Section 4 discusses the impacts of live commerce and compares the equilibrium outcomes with and without live commerce spillover effects. Section 5 concludes our main findings.
2. Literature review
Our work is primarily related to two streams of research, namely, live streaming and research on the spillover effect and its impact on pricing strategy.

2.1 Live streaming
Some scholars have empirically analysed the impact of live streaming on consumers. Geng et al. (2020) showed that the interaction behaviors between marketers and consumers will significantly influence the e-commerce sales. Zhang et al. (2021) investigated the influence of information quality and interaction quality on swift guanxi and customers’ purchase intention in the context of live streaming platforms and confirmed the importance of swift guanxi in online market place. Wongkitrungrueng et al. (2020) studied the relationships among customers perceived value of live streaming, customer trust, and engagement. The results showed that live streaming plays an important role in increasing sales and loyalty. Sun et al. (2021) argued that live chat can increase online sales conversion by performing the functions of informing and persuading, and the strength of this positive effect depends on seller and product characteristics. Chen et al. (2020) used empirical research methods to explore the impact of e-commerce live streaming on consumer repurchase intentions. They concluded that perceived product quality, perceived interactivity and perceived professionalism have positive and indirect effects on consumer repurchase intentions, and this relationship is completely mediated by consumer satisfaction. Ding et al. (2020) introduced the e-commerce + live streaming mode and provided suggestions about how the e-commerce + live streaming mode should be conducted. However, all the above studies investigated live streaming. Unlike live streaming, live commerce is a new type of selling modes which an anchor sells products to consumers with live streaming, which is quite different research.

2.2 Research on the spillover effect and its impact on pricing strategy
The spillover effect in the supply chain is an important research topic in the literature. Through qualitative research and experimental research, Fei et al. (2010) found that the spillover effect contains both contagion and contrast effects and discussed the variables affecting the direction and intensity of the spillover effect. Song et al. (2018) demonstrated that knowledge spillover in supply chain network can improve the credit quality of small and medium-sized enterprises. Moreover, many scholars have discussed the impact of the spillover effect on pricing strategy. Considering the negative spillover effect of a retailer’s services on the electronic direct channel, Wang et al. (2014) investigated the pricing strategy of a dual-channel supply chain. Dongye et al. (2020) analysed the impact of the spillover effect of manufacturers’ R&D investment on the decisions of supply chain members.

The literature related to this paper includes two streams with respect to the spillover effect: the free-riding and the showrooming effect. Some scholars have discussed the phenomenon of free-riding. Shin (2007) argued that free riding is a necessary mechanism to prevent an aggressive response from another retailer and reduces the intensity of price competition. Moreover, Pu et al. (2016) examined the impact of consumer free-riding on sales effort and prices in a centralized and a decentralized dual-channel supply chain by using the two-stage optimization technique and the Stackelberg game. Li et al. (2016) studied the optimal pricing and sales effort decisions under a centralized and decentralized dual-channel supply chain consisting of a manufacturer, an e-tailer and a brick-and-mortar retailer with bidirectional free-riding and price competition. Pun et al. (2020) investigated the impact of customers’ free-riding behaviour on a manufacturer’s channel strategy.

Another stream of research focuses on the showrooming effect. Eriksson et al. (2013) showed that the cooperation between wholesaler and retailer and showroom decoration...
played an important role in the consumer sector. Bell et al. (2015) and Mehra et al. (2018) studied the impact of the showroming effect on the profits of brick and mortar (BM) stores, and Mehra et al. (2018) showed that showroming is detrimental to the profits of BM stores. Furthermore, by using quasi-experimental data on showroom openings by WarbyParker.com, Bell et al. (2018) examined the impact of showrooms on the two most basic retail objectives: demand generation and operational efficiency. Jing (2018) studied competition between a traditional retailer and an online retailer in the presence of showroming in a product market where consumers are open to uninformed purchases. Considering the impact of showroming, Kuksov and Liao (2018) analysed the strategic role of the manufacturer in the distribution channel. Li et al. (2019a) considered the effort strategies of no service, ex ante and ex-post service and investigated the influence of the showroming effect on firms’ pricing and service effort in a dual-channel supply chain. In conjunction with the online selling channel, Li et al. (2019b) explored the retailer’s deployment of physical showrooms, which mitigates consumer fit uncertainty, and discussed the impact of the showroom deployment strategy on product prices and information service provision.

The above studies provide potential directions for further research in the field of the spillover effect. However, unlike the above studies, our paper mainly focuses on that live commerce impacts not only products sold by an anchor from live commerce channel but also the related products sold by the manufacturer directly. The live commerce spillover effect is different from the free riding and the showroming effect.

3. Model

We develop a live commerce supply chain model where the manufacturer (M) sells product A through an anchor (H) with a wholesale price contract and sells product B directly online, as shown in Figure 1. Products B is related to product A; that is, they have similarities (the same material and processing technology) but are not exactly identical in many aspects, such as style and colour. Without loss of generality, we normalize the marginal production cost for each product to zero.

The overall valuation of an ideal product for the consumer is \( v \) (Nasser and Turcic, 2016; Sajeesh and Raju, 2010). Consumers have unit demand and are heterogeneous in their preferences for each product. The linear city model (Hotelling, 1990) is used to assume that the consumers are uniformly distributed over an interval \([0, 1]\); in addition, product A and B are located at 0 and 1, respectively. Let \( t \) be the unit mismatch cost; then, a consumer located at \( x \) suffers a mismatch cost \( tx \) from buying product A and a mismatch cost of \( t(1-x) \) from buying product B. The anchor displays product A by live streaming to provide consumers with more (or more perfect) information about whether product A matches consumers’ tastes.

The anchor makes efforts to introduce the detailed information, and in our model, the anchor’s cost of providing service for product A at the level of \( \lambda_{SA} \) (0 \( \leq \lambda_{SA} \leq 1 \)) can be denoted as \( f(\lambda_{SA}) \), where \( f(0) = 0 \), \( f'(\lambda_{SA}) > 0 \) and \( f''(\lambda_{SA}) > 0 \). Following Ofek et al. (2011), we assume that the live streaming service cost is quadratic in \( \lambda_{SA} \), i.e., \( f(\lambda_{SA}) = \frac{1}{2} h \lambda_{SA}^2 \), where \( h \) is a cost factor.

We rationally expect that the likelihood of a return is smaller if they learn more about the product before buying it. Similar to Ofek et al. (2011), we refer to the probability of a return by the consumer who only knows the product online (or does not watch the live streaming) as the
baseline return probability, i.e. \( q \). The information service provided by the anchor deploys interactive explanations that help consumers determine which product fits them best. Therefore, by watching live streaming, consumers benefit from the live commerce effect, i.e. buying product A after watching live streaming, with which the return probability of product A reduces to \( q_1 = (1 - \lambda_{SA})q \), where \( \lambda_{SA} \) is the level of live streaming service. On the other hand, consumers who are interested in the relative product are prone to watch the live streaming and obtain useful information about related product B sold through the manufacturer’s direct channel, which reduces the service differentiation among products and strengthens the competitive advantage of the manufacturer applying live commerce combined with an anchor. Therefore, consumers who purchase a related product B through the manufacturer’s direct channel certainly benefit from the live commerce spillover effect, i.e. watching the live streaming of product A before buying product B, with which the return probability reduces to \( q_2 = (1 - \mu \lambda_{SA})q \), where \( \mu \) is the similarity between product A and B, with a range of \( 0 < \mu < 1 \). Referring to Zhang et al. (2020), \( \mu \lambda_{SA} \) represents the value of common information that a consumer who buys product B can derive from the information service \( \lambda_{SA} \) provided by the anchor to product A. Thus, the term \( \mu \) implies the intensity of the live commerce spillover effect. In the event of a return, the manufacturer and the anchor incur a cost of \( g \) and the consumer incurs a cost of \( m \). Table 1 summarizes the basic notations.

The decision-making sequences of this paper are as follows. First, the anchor decides the live streaming service level \( \lambda_{SA} \) and the price \( p_A \) of product A. Second, the manufacturer decides the price \( p_B \) of product B in its direct channel. Finally, the consumer decides whether to buy product A or B.

Considering or disregarding the live commerce spillover effect, the decision model of supply chain pricing and the live streaming service level is constructed. When the live commerce spillover effect is not considered, it is expressed as Model N; when the live commerce spillover effect is considered, it is expressed as Model L. Symbol \( \Pi^j_i \) represents the profit of supply chain member \( j \) under model \( i \), where \( i \in \{N, L\} \); \( j \in \{M, H, T\} \), and the equilibrium decisions values are superscripted with “*”.

### 3.1 Without the live commerce spillover effect – Model N

In Model N, the live commerce spillover effect is not considered. The anchor’s service effort during live streaming is helpful for consumers to learn more about whether product A fits their tastes. In the event of a return, the consumer incurs a cost of \( m \). With the live commerce effect, the return probability of product A reduces to \( q_1 \), while the return probability of product B remains unchanged, i.e. \( q \). Therefore, in the scenario without live commerce

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Table 1. Summary of basic notations
spillover effect, the expected return cost to consumer is $q_1m$ for product A and $qm$ for product B. Thus, we formulate consumers’ expected utilities when purchasing products A and B as follows:

$$u_A = v - p_A - tx - q_1m \quad (1)$$

$$u_B = v - p_B - t(1-x) - qm \quad (2)$$

We denote the demands generated by product A and product B by $D^N_A$ and $D^N_B$, respectively. Then, the profit functions of the manufacturer and the anchor can be obtained as follows:

$$\Pi_M = D^N_A w_A + D^N_B (p_B - qg) \quad (3)$$

$$\Pi_H = D^N_A (p_A - w_A - qg) - \frac{h\lambda^2_{SA}}{2} \quad (4)$$

Through backward induction, we derive the optimal solutions as shown in Proposition 1.

**Proposition 1.** In the scenario without the live commerce spillover effect, the optimal live streaming service level, and the prices of product A and product B are as follows:

$$p^*_A = \frac{3t}{2} + w_A + gq - \frac{3tgt^2(g-m)(g+m)}{2q^2(8ht - (g + m)^2)} \quad (5)$$

$$\lambda^*_SA = \frac{3(g+m)tg^2}{8ht - (g + m)^2q^2} \quad (6)$$

$$p^*_B = 2t + w_A + gq - \frac{6ht^2}{8ht - (g + m)^2q^2} \quad (7)$$

Substituting the optimal decisions into the demand functions, we can obtain the equilibrium demands of product A and B:

$$D^*_A = \frac{3ht}{8ht - q^2(g + m)^2} \quad (8)$$

$$D^*_B = \frac{5ht - q^2(g + m)^2}{8ht - q^2(g + m)^2} \quad (9)$$

And, the equilibrium profits of the manufacturer and the anchor are:

$$\Pi^*_M = w_A + \frac{2t(5ht - q^2(g + m)^2)^2}{(8ht - q^2(g + m)^2)^2} \quad (10)$$

$$\Pi^*_H = \frac{9ht^2}{2(8ht - q^2(g + m)^2)} \quad (11)$$

$$\Pi^*_T = w_A + \frac{t}{2} \left(4 - \frac{3ht(28ht - 5q^2(g + m)^2)}{(8ht - q^2(g + m)^2)^2}\right) \quad (12)$$
3.2 With the live commerce spillover effect—Model L

In this subsection, the live commerce spillover effect is taken into account. In fact, such an effect exists in the live commerce supply chain. For instance, the manufacturer’s online shop webpage provides the anchor’s live streaming link; thus, consumers can switch to substitute products (e.g., product B) in the manufacturer’s online shop after watching the anchor’s explanation of product A. Consumers who watch the live streaming benefit from the anchor’s service through both the effect of live commerce and the live commerce spillover effect. As a result, the return probability of product A under the effect of live commerce reduces to $q_1$, and the return probability of product B under the spillover effect of live commerce reduces to $q_2$. Therefore, in the scenario with the live commerce spillover effect, the expected return cost to consumer is $q_1m$ for product A and $q_2m$ for product B. Thus, consumers’ expected utilities can be rewritten as follows:

$$u_A = v - p_A - tx - q_1m$$  \hspace{1cm} (13)
$$u_B = v - p_B - t(1-x) - q_2m$$  \hspace{1cm} (14)

We denote the demands generated by product A and product B by $D_A^L$ and $D_B^L$, respectively. Then, the profit functions of the manufacturer and the anchor can be obtained as follows:

$$\Pi_M = D_A^L w_A + D_B^L (p_B - qg)$$  \hspace{1cm} (15)
$$\Pi_H = D_A^L (p_A - w_A - q_1g) - \frac{h\lambda_{S\lambda}}{2}$$  \hspace{1cm} (16)

Through backward induction, we derive the optimal solutions as shown in Proposition 2.

**Proposition 2.** In the scenario with the live commerce spillover effect, the optimal live streaming service level and the prices of product A and product B are as follows:

$$p_A^L* = \frac{3t}{2} + w_A + gq - \frac{3q^2t(g + m)(1 - \mu)(g - m + (g + m)\mu)}{2(8ht - q^2(g + m)^2(1 - \mu)^2)}$$  \hspace{1cm} (17)
$$\lambda_{S\lambda}^L* = \frac{3gt(g + m)(1 - \mu)}{8ht - q^2(g + m)^2(1 - \mu)^2}$$  \hspace{1cm} (18)
$$p_B^L* = 2t + w_A + qg - \frac{3t(2ht + gg^2(g + m)(1 - \mu)\mu)}{8ht - q^2(g + m)^2(1 - \mu)^2}$$  \hspace{1cm} (19)

Substituting the optimal solutions into the demand functions, we can obtain the equilibrium demands of product A and B:

$$D_A^L* = \frac{3ht}{8ht - q^2(g + m)^2(1 - \mu)^2}$$  \hspace{1cm} (20)
$$D_B^L* = \frac{5ht - q^2(g + m)^2(1 - \mu)^2}{8ht - q^2(g + m)^2(1 - \mu)^2}$$  \hspace{1cm} (21)

And, the equilibrium profits of the manufacturer and the anchor are:

$$\Pi_M^L* = \frac{2t(5ht - q^2(g + m)^2(1 - \mu)^2)^2}{(8ht - q^2(g + m)^2(1 - \mu)^2)^2} + w_A$$  \hspace{1cm} (22)
4. Analysis

The live commerce spillover effect, which typically exists in the live commerce supply chain, plays a significant role in the decision-making of the manufacturer and the anchor. In this section, the impacts of the live commerce spillover effect, the return probability and the horizontal differences on the optimal solution as well as the equilibrium profits are analysed. Thus, we uncover the efficiency of live commerce with consideration of both the live commerce effect and the live commerce spillover effect. First, we examine the impact of the live commerce spillover effect on the optimal live streaming service level of the anchor in Proposition 3.

**Proposition 3.** With the live commerce spillover effect, the optimal live broadcast service level is decreasing in \( \mu \) (i.e. \( \frac{\partial \lambda^{L*}}{\partial \mu} < 0 \)), but increasing in \( q \) (i.e. \( \frac{\partial \lambda^{L*}}{\partial q} > 0 \)).

Proposition 3 shows that with the live commerce spillover effect, the impacts of the live commerce spillover effect on the live streaming service level are closely related to the parameters \((\mu, q)\), where \( \mu \) represents the intensity of the live commerce spillover effect, and \( q \) represents the baseline return probability. In particular, in the presence of the live commerce spillover effect, customers may purchase product B sold through the manufacturer’s direct channel after watching the anchor’s explanation of product A, resulting in a mitigation of the service difference between product A and product B. Therefore, the retailer is unwilling to provide a sufficiently high level of live streaming service to enhance the service difference between products. More specifically, the greater the intensity of the live commerce spillover effect, the lower the live streaming service level of the anchor will be. However, for the baseline return probability, an increase in the baseline return probability leads to a higher product return cost. When the anchor aims to maximize its profit, the equilibrium live streaming service level will decrease with the increase of the baseline return probability to reduce the cost of return.

Next, we conduct a sensitivity analysis to illustrate the impacts of the live commerce spillover effect on the optimal pricing decisions in Proposition 4.

**Proposition 4.** With the live commerce spillover effect, the optimal prices of product A (sold through the anchor) and product B (sold through the manufacturer’s direct channel) would be nonmonotonically affected by the spillover effect.

1. when \( 88htm - g(g + m)^2 q^2 > 0 \), if \( 0 < \mu < \mu_A \), the optimal price of product A is decreasing in \( \mu \) (i.e. \( \frac{\partial p^{L*}_A}{\partial \mu} < 0 \)).

2. when \( 4htm - 4htg + qg(q + m)^2 < 0 \), if \( \mu < \mu_B \), the optimal price of product B is decreasing in \( \mu \) (i.e. \( \frac{\partial p^{L*}_B}{\partial \mu} < 0 \)).
Note that the thresholds above follow:

\[
\mu_A = \frac{(g + m)(gq^2(g + m) - 4ht) + 2\sqrt{22}(2ht - g^2q^2)}{gq^2(g + m)^2},
\]

\[
\mu_B = \frac{2\sqrt{ht}(ht(3g - m)^2 - 2g^2q^2(g + m)^2) + gq^2(g + m)^2 - 2ht(3g - m)}{gq^2(g + m)^2}.
\]

Proposition 4 investigates the impacts of the live commerce spillover effect on optimal pricing decisions, which shows that the pricing of product A and B depends on the intensity of the live commerce spillover effect and the return cost borne by the manufacturer and the anchor. For the anchor, she needs to balance the trade-off between increasing the revenue of product A and reducing the service cost of live streaming. To be specific, the increase in the intensity of the live commerce spillover effect will prompt the anchor to cut the live streaming service level. Although it will reduce the cost of live streaming services, it will also hurt the demand for product A. Therefore, the price of product A is nonmonotonic in terms of the intensity of the live commerce spillover effect, as shown in Figure 2. More specifically, when the return cost borne by the anchor is low \((g < g_A)\), and if the intensity of the live commerce spillover effect is low \((\mu < \mu_A)\), the anchor will reduce the price of product A to attract consumers to buy it; otherwise, the anchor will increase the price of product A to compensate for the loss of its demand (see Figure 3a). However, when the return cost borne by the anchor is high, the optimal price of product A increases with the intensity of the spillover effect to make up for the return cost (see Figure 3b).

As for the manufacturer, from Figure 4, the price of product B is also nonmonotonic in terms of the intensity of the live commerce spillover effect. When the return cost borne by the manufacturer is low \((g < g_{B1})\) or high \((g > g_{B2})\), the manufacturer will inevitably increase the
price of product B (see Figure 5a). However, when the return cost is at the medium level ($g_{B1} < g < g_{B2}$), the low-intensity live commerce spillover effect will bring less increment to the demand for product B. Therefore, the manufacturer will reduce the price of product B to increase consumers’ willingness to buy it (see Figure 5b).

We continue to explore the sensitivity analysis of the manufacturer and the anchor’s equilibrium profits on the live commerce spillover effect and the return probability.

**Proposition 5.** With the live commerce spillover effect, the equilibrium profit of the manufacturer (the anchor) will always increase (decrease) in the spillover effect, but decrease (increase) in the return probability. However, the equilibrium profit of the supply chain would be nonmonotonically affected by the spillover effect and the return probability.
(1) The equilibrium profit of the manufacturer is increasing in $\mu$ (i.e. $\frac{\partial \Pi^*_m}{\partial \mu} > 0$), but decreasing in $q$ (i.e. $\frac{\partial \Pi^*_m}{\partial q} < 0$). The equilibrium profit of the anchor is decreasing in $\mu$ (i.e. $\frac{\partial \Pi^*_A}{\partial \mu} < 0$), but increasing in $q$ (i.e. $\frac{\partial \Pi^*_A}{\partial q} > 0$).

(2) When $0 < \mu < 1 - \frac{4ht}{\sqrt{5htq^2(g+m)^2}}$, the equilibrium profit of the live commerce supply chain is decreasing in $\mu$ (i.e. $\frac{\partial \Pi^*_L}{\partial \mu} < 0$); if $1 - \frac{4ht}{\sqrt{5htq^2(g+m)^2}} < \mu < 1$, the equilibrium profit of the live commerce supply chain is increasing in $\mu$ (i.e. $\frac{\partial \Pi^*_L}{\partial \mu} > 0$). Moreover, when $0 < q < \frac{4\sqrt{ht}}{\sqrt{5(g+m)^2(1-\mu)^2}}$, the equilibrium profit of the live commerce supply chain is increasing in $q$ (i.e. $\frac{\partial \Pi^*_L}{\partial q} > 0$); when $\frac{4\sqrt{ht}}{\sqrt{5(g+m)^2(1-\mu)^2}} < q < 1$, the equilibrium profit of the live commerce supply chain is increasing in $q$ (i.e. $\frac{\partial \Pi^*_L}{\partial q} > 0$).

Proposition 5 indicates that the profits of the manufacturer and the anchor are affected by the intensity of the live commerce spillover effect and the baseline return probability. When the live commerce spillover effect is considered, the live streaming service can partially serve consumers who buy product B sold via the manufacturer’s direct channel, which is beneficial to the manufacturer. In particular, as the intensity of the live commerce spillover effect increases, the return probability of product B decreases, which in turn brings more profit to the manufacturer. At the same time, the existence of the live commerce spillover effect homogenizes the services between product A and B, thereby weakening the advantages of the anchor brought by the difference of the live streaming service, which leads to a decline in the anchor’s profit. In addition, when $16ht - 5(g + m)^2q^2 < 0$, there exists a threshold of $\mu$ below (above) than $1 - \frac{4ht}{\sqrt{5htq^2(g+m)^2}}$, which decreases (increases) the total profit of the live commerce supply chain. This implies that as long as the intensity of the live commerce spillover effect is not too high, the improvement in the intensity of the live commerce spillover effect is beneficial to the live commerce supply chain. Otherwise, the total equilibrium profit of the live commerce supply chain will be lower.

Furthermore, the increase in the baseline probability of return leads to an increase in the demand for product A, but a decrease in the demand for product B. Because the benefit
from improving the demand for product A outweighs the increase in return cost, the equilibrium profit of the anchor increases as the baseline return probability increases. In terms of the manufacturer’s profit, the revenue from increasing demand for product A cannot compensate for the loss caused by the decrease in demand for product B and the increase in return cost, which results in a reduction in profit for the manufacturer. For the total profit of the live commerce supply chain, when \(16ht - 5(g + m)\left(1 - \mu^2\right) < 0\), if the baseline return probability is low, the expansion of the baseline return probability brings greater return cost to the live commerce supply chain, which leads to the decrease of the total profit of the live commerce supply chain. However, when the basic return probability is high, the benefit from improving demand for product A outweighs the cost of the loss caused by the increase in the baseline return probability. Therefore, the larger the baseline return probability is, the greater the total profit of the live commerce supply chain will be.

We define the aggregate return probability in the market as \(q_a = D_Aq_1 + D_Bq_2\), which implies the total return probability of products. As such, whether the live commerce spillover effect reduces the aggregate product return probability could be investigated.

**Proposition 6.** With the live commerce spillover effect, when \((g + m)^2 < \left(\frac{11 - \sqrt{105}}{q^2}\right)ht\), \(\frac{\partial q_a^*}{\partial \mu} > 0\), and there exists \(\mu_q \in [0, 1]\) such that \(\frac{\partial q_a^*}{\partial \mu} = 0\), when \(0 < \mu < \mu_q\), the aggregate return probability is decreasing in \(\mu\) (i.e. \(\frac{\partial q_a^*}{\partial \mu} < 0\)); when \(\mu_q < \mu < 1\), the aggregate return probability is increasing in \(\mu\) (i.e. \(\frac{\partial q_a^*}{\partial \mu} > 0\)). When \((g + m)^2 > \left(\frac{11 - \sqrt{105}}{q^2}\right)ht\), the aggregate return probability is increasing in \(\mu\) (i.e. \(\frac{\partial q_a^*}{\partial \mu} > 0\)).

The demand for product A and product B and their respective return probability jointly affect the aggregate return probability. As shown in Propositions 3 and 4, the existence of the live commerce spillover effect eases the service difference between product A and B, which makes the anchor unwilling to provide high-level live streaming service. As a result, the return probability of product A increases, but the demand decreases. The manufacturer can benefit from the live commerce spillover effect, which expands the demand for its direct-selling product B. The return probability of product B can either increase or decrease depending upon both the level of live streaming service and the intensity of the live commerce spillover effect. Therefore, the aggregate return probability is nonmonotonic with respect to the intensity of the live commerce spillover effect. Furthermore, according to Proposition 6, there exists a threshold for the total cost of return. This implies that the aggregate return probability will decrease as long as the total cost of return is less than the threshold, and the intensity of the live commerce spillover effect is low. Because the decrease in the demand for product A and the decline in the return probability of product B are dominant. Otherwise, when the live commerce spillover effect is high, the increase in the return probability of product A and the expansion of the demand for product B can drive the increase in the aggregate return probability. Moreover, when the total return cost is higher than the threshold, the increase in the intensity of the live commerce spillover effect will inevitably lead to an increase in the aggregate return probability.

The cost of mismatch reflects the horizontal differences between products, which refers to the difference in preferences among individuals. For instance, there are differences in the evaluations of the same characteristics by different people. Horizontal differences will cause price competition between products. Then, by analysing the influences of the parameter \(t\) on the equilibrium decision-making and profits of the manufacturer and anchor in Model L, we can obtain Proposition 7.
Proposition 7. (1) With the live commerce spillover effect, the equilibrium price of product A, price of product B, demand for product B and profit of the manufacturer are increasing in $t$ (i.e. $\frac{\partial p^*_A}{\partial t} > 0,$ $\frac{\partial p^*_B}{\partial t} > 0,$ $\frac{\partial D^*_B}{\partial t} > 0$ and $\frac{\partial \Pi^*_{LM}}{\partial t} > 0$), but the live streaming service level and the demand for product A are decreasing in $t$ (i.e. $\frac{\partial \lambda^*_L}{\partial t} < 0$ and $\frac{\partial D^*_A}{\partial t} < 0$).

(2) When $t > q^2 (g + m)^2 (1 - \mu)^2 \frac{4h}{4h},$ the equilibrium profit of the anchor is decreasing in $t$ (i.e. $\frac{\partial \Pi^*_H}{\partial t} < 0$); when $0 < t < q^2 (g + m)^2 (1 - \mu)^2 \frac{4h}{4h},$ the equilibrium profit of the anchor is increasing in $t$ (i.e. $\frac{\partial \Pi^*_H}{\partial t} > 0$) (see Figure 6).

Proposition 7 shows that with the increase in the mismatch cost, the horizontal differentiation between products becomes larger, leading to the weakening of the competition between product A and B. Therefore, both the anchor and the manufacturer will increase the prices of product A and product B, and the anchor will also lower the level of live streaming service. The increase in the price of product A and the decrease in the level of live streaming service will jointly cause a decline in the demand for product A, which in turn will increase the demand for product B sold through the manufacturer’s own channel. For the manufacturer, the raise in the price and demand for product B allows the manufacturer to gain more profit.

However, Proposition 7 also suggests that the profit of the anchor is affected not only by the cost of mismatch, but also by the intensity of the live commerce spillover effect. Specifically, when the intensity of the live commerce spillover effect is low, the increase in the price of product A cannot make up for the loss of its reduced demand, resulting in a decrease in the anchor’s profit. When the live commerce spillover effect is strong, the profit brought by the rise of the price of product A will be greater than the loss caused by the decline in its demand, which will improve the anchor’s profit. Therefore, when the intensity of the live commerce spillover effect is greater, the improvement in the mismatch cost is beneficial to both the manufacturer and the anchor.

Live streaming can provide a more convenient interactive way for consumer transactions, saving consumers’ time and energy. However, because consumers are unable to have a
complete understanding of the product before they receive it, the phenomenon of return still exists. Return will not only waste the time of consumers but also incur the cost of return. Next, in Propositions 8 and 9, we analyse the impact of the return cost borne by the manufacturer and the anchor and the return cost borne by the consumer on the profits of the manufacturer and the anchor separately.

**Proposition 8.** With the live commerce spillover effect, the equilibrium profit of the manufacturer is decreasing in \( g \) (i.e. \( \frac{\partial \Pi_L^*}{\partial g} < 0 \)), but the equilibrium profit of the anchor is increasing in \( g \) (i.e. \( \frac{\partial \Pi_H^*}{\partial g} > 0 \)).

It seems counterintuitive that the higher the return cost borne by the anchor is, the greater the profit of the anchor will be. However, from the analysis results, it can be found that when the return cost borne by the anchor is large, the anchor not only does not cut the live streaming service level to reduce the cost but also improves it. In this way, the demand for product A has increased. Although the cost of live streaming services is increased, the increase in demand brings more benefits, which in turn increases the profit of the anchor. However, the increase in demand for product A will inevitably damage the demand for product B, which is not conducive to the profit of the manufacturer.

**Proposition 9.** With the live commerce spillover effect, the equilibrium profit of the manufacturer is decreasing in \( m \) (i.e. \( \frac{\partial \Pi_L^*}{\partial m} < 0 \)), but the equilibrium profit of the anchor is increasing in \( m \) (i.e. \( \frac{\partial \Pi_H^*}{\partial m} > 0 \)).

When the return cost born by the consumer is large, the consumer will be more cautious when purchasing products. As shown in Proposition 9, in the face of the high cost of return borne by the consumer, the anchor would like to provide a higher level of live streaming service to alleviate the consumer’s concerns about the information uncertainty of product A, and adjust the price of product A according to the specific cost of return borne by the consumer, so as to increase the demand for product A. In the meantime, the way that the manufacturer can adapt is to lower the price of product B to attract consumers. Nevertheless, due to the high return cost borne by the consumer and the corresponding measures taken by the anchor, such as adjusting the price of product A and improving the level of the live streaming service, the consumer is more desirous to purchase product A than product B, which results in lower demand for product B. In the end, the rising demand for product A brings more profits to the anchor, but cannot make up for the loss caused by the decline in product B’s revenue, which leads to the profit of the manufacturer falling.

In summary, from the perspective of the anchor, she is motivated to increase the cost of the return, whether borne by herself or by the consumer, to maximize her profit.

Next, we examine the impact of the wholesale price of product A on the optimal pricing and profits of the manufacturer and the anchor with the live commerce spillover effect in Proposition 10.

**Proposition 10.** With the live commerce spillover effect, the equilibrium demands of product A and product B, the level of live streaming service and the profit of the anchor are independent of \( w_A \) (i.e. \( \frac{\partial D_A^*}{\partial w_A} = 0; \frac{\partial D_B^*}{\partial w_A} = 0; \frac{\partial \lambda^*}{\partial w_A} = 0 \) and \( \frac{\partial \Pi_H^*}{\partial w_A} = 0 \)), and the optimal prices of product A and product B, the equilibrium profit of the manufacturer and the total profit of the supply chain are increasing in \( w_A \) (i.e. \( \frac{\partial p_A^*}{\partial w_A} > 0; \frac{\partial p_B^*}{\partial w_A} > 0; \frac{\partial \Pi_M^*}{\partial w_A} > 0 \) and \( \frac{\partial \Pi_T^*}{\partial w_A} > 0 \)).
Proposition 10 shows that the pricing and profits of the manufacturer and the anchor are affected by the wholesale price of product A. As the wholesale price of product A increases, the anchor increases the price of product A to transfer some of the costs to the consumer and maintains the same level of live streaming service to keep the demand for product A constant. As both the premium and the demand for product A remain unchanged, the profit of the anchor remain unchanged. Moreover, due to the existence of the live commerce spillover effect, consumers who buy product B can obtain some of the common information from the live streaming service provided by the anchor for product A. Thus, the return probability of product B is reduced, leading to an increase in the price of product B. However, the increase in the price of product B and the reduction in the probability of return keep the demand for product A unchanged. The manufacturer is able to make greater profit due to the price improvement of product A. In short, the total profit of the live commerce supply chain also increases.

5. Concluding remarks

The rise of live commerce has generated live commerce supply chain. In the live commerce supply chain, manufacturers sell their products directly or by live commerce of anchors. During live commerce, the anchor with live streaming, displays, demonstrates and realizes a real-time interaction with consumers and sells the products to them. Her efforts can not only influence the return probability of products sold by live commerce of anchors through the live commerce effect but also influence the return probability of related products sold by the manufacturer’s online stores through the live commerce spillover effect.

In this paper, pricing and service level decisions in the live commerce supply chain are studied by constructing decision-making models with and without the live commerce spillover effect. The results show that the prices of products A and B are nonmonotonic with respect to the live commerce spillover effect. Specifically, when the live commerce spillover effect and the return cost are both small, the equilibrium price of the product sold via the manufacturer direct channel will be lower than that under the scenario without the live commerce spillover effect. Moreover, when the live commerce spillover effect is at a moderate level and the return cost is small, the equilibrium price of the product sold through the anchor will be lower than that under the scenario without the live commerce spillover effect.

The results further show that with the live commerce spillover effect, the live streaming service brings more profit for the manufacturer than without the live commerce spillover effect, while it reduces the anchor’s profit. Furthermore, the total profit of the live commerce supply chain first decreases and then increases as the intensity of the live commerce spillover effect improves. This conclusion indicates that the manufacturer could gain more profit when selling two related products directly and through the anchor, despite the lower live streaming service efforts of the anchor. Moreover, from the perspective of the live commerce supply chain, the manufacturer should choose products that are similar to those sold through its direct channel for the anchor to sell by live streaming.

Furthermore, when considering the live commerce spillover effect, the optimal prices of product A and product B, the profit of the manufacturer and the total profit of the supply chain increase with the wholesale price of product A, and the aggregate return probability can either increase or decrease depending upon the intensity of the live commerce spillover effect and total return cost. In addition, if the baseline return probability is high, the anchor should increase her effort, thus obtaining more profit, while higher horizontal differences between products or greater intensity of the live commerce spillover effect will discourage the anchors live commerce service level. It is of great interest to analyse the impacts of the return cost borne by the consumer and the anchor on the profit of the anchor. An increase in return
cost always leads to an increase in the profit of the anchor, whether it is borne by the anchor or by the consumer.

We have analysed the cooperation between manufacturers and anchors with wholesale price contracts. In practice, manufacturers and anchors may cooperate based on other contract mechanisms. Thus, future research can consider how contract mechanisms will affect manufacturers’ and anchors’ decisions and profits with the live commerce spillover effect.

Notes
2. https://ishare.ifeng.com/c/s/7xRHL9VRT9U

References


With the live commerce spillover effect, the equilibrium price of product A is 
\[ p_{A}^{E} = \frac{3g + \mu + w_A + qg}{2(b - q - q^2(1 - \mu))}. \]
Note that \( \frac{\partial p_{A}^{E}}{\partial \mu} = \frac{3g + \mu + w_A + qg - 3(g + m)q(1 - \mu) - 3(g + m)q(1 - \mu)g(1 - \mu)}{2(b - q - q^2(1 - \mu))^2} < 0 \) and \( \frac{\partial p_{A}^{E}}{\partial q} = \frac{3g + \mu + w_A + qg - 3(g + m)q(1 - \mu)g(1 - \mu) + 3g + \mu + w_A + qg - 3(g + m)q(1 - \mu)g(1 - \mu)g(1 - \mu)}{(b - q - q^2(1 - \mu))^2} > 0 \). Obviously, \( p_{A}^{E} \) is always decreasing in \( \mu \) but increasing in \( q \).
With the live commerce spillover effect, the aggregate return probability is \( q_L \), but increasing in \( \mu \). Moreover, we can obtain \( p_B^* \) first decreases and then increases. Furthermore, solving equation \( \frac{\partial \Pi_M^*}{\partial \mu} = 0 \), we have

\[
\mu_B^* = 2\sqrt{h(t\mu^2 + 9htg^2 - 6ghl - 2(g + m)^2q^2) + g(g + m)^2q^2 - 2h(3g - m)t}.
\]

Therefore, \( \frac{\partial \Pi_B^*}{\partial \mu} > 0 \) if \( \mu > (\mu_B^*) \).

Proof of proposition 6.

With the live commerce spillover effect, the aggregate return probability is \( q_L^* \), which makes the equation \( \frac{\partial \Pi_M^*}{\partial \mu} = 0 \). Hence, \( \frac{\partial \Pi_M^*}{\partial \mu} > (0) \) if \( \mu > (\mu_B^*) \). When \( 16ht - 5(g + m)^2q^2 < 0 \),\( \frac{\partial \Pi_M^*}{\partial \mu} > 0 \). Thus, as \( \mu \) increases, \( \Pi_M^* \) first decreases and then increases. Furthermore, we can obtain \( \mu = \mu_B^* \) which makes the equation \( \frac{\partial \Pi_M^*}{\partial \mu} = 0 \). Hence, \( \frac{\partial \Pi_M^*}{\partial \mu} > (0) \) if \( \mu > (\mu_B^*) \). When \( 16ht - 5(g + m)^2q^2 > 0 \),\( \frac{\partial \Pi_M^*}{\partial \mu} < 0 \). Thus, as \( \mu \) increases, \( \Pi_M^* \) first decreases and then increases. Furthermore, we can obtain \( q = q_M^* \) which makes the equation \( \frac{\partial \Pi_M^*}{\partial \mu} = 0 \). Hence, \( \frac{\partial \Pi_M^*}{\partial \mu} > (0) \) if \( q > (\mu_B^*)q_M^* \). When \( 16ht - 5(g + m)^2(1 - \mu)^2 > 0 \),\( \frac{\partial \Pi_M^*}{\partial \mu} < 0 \). Hence, \( \Pi_M^* \) is strictly decreasing in \( \mu \).
However, the equilibrium profit of the anchor is decreasing in $p_L$. Hence, $\lambda^*_A$ and $D^*_A$ are strictly decreasing in $t$.

(b) With the live commerce spillover effect, the equilibrium profit of the anchor is $\frac{3q}{2}(g + m)^2(1 - \mu)^3$ + $w_A$. Note that $\frac{\partial \Pi^*_A}{\partial t} = \frac{24q^2(g + m)^2(1 - \mu)^2}{(8ht - tq(g + m)^2(1 - \mu)^2)} < 0$. Obviously, $\Pi^*_A$ is always decreasing in $g$.

However, the equilibrium profit of the anchor is $\frac{3q}{2}(g + m)^2(1 - \mu)^3$. Note that $\frac{\partial \Pi^*_M}{\partial t} = \frac{24q^2(g + m)^2(1 - \mu)^2}{(8ht - tq(g + m)^2(1 - \mu)^2)} < 0$. Obviously, $\Pi^*_M$ is always decreasing in $m$.

(c) With the live commerce spillover effect, the equilibrium profit of the manufacturer is $\frac{24q^2(g + m)^2(1 - \mu)^3}{(8ht - tq(g + m)^2(1 - \mu)^2)} + w_A$. Note that $\frac{\partial \Pi^*_M}{\partial t} = \frac{24q^2(g + m)^2(1 - \mu)^2}{(8ht - tq(g + m)^2(1 - \mu)^2)} < 0$. Obviously, $\Pi^*_M$ is always decreasing in $m$.

Hence, $\Pi^*_A$, $\Pi^*_B$, $\lambda^*_A$ and $\Pi^*_M$ are independent in $w_A$, whereas, $p^*_A$, $p^*_B$, $\Pi^*_M$ and $\Pi^*_T$ are strictly increasing in $w_A$.

**Proof of proposition 10.**

With the live commerce spillover effect, take the first derivative with respect to $w_A$: $\frac{\partial \Pi^*_A}{\partial w_A} = 0$, $\frac{\partial p^*_A}{\partial w_A} = 0$, $\frac{\partial p^*_B}{\partial w_A} = 0$, $\frac{\partial \Pi^*_M}{\partial w_A} = 1 > 0$, $\frac{\partial \Pi^*_T}{\partial w_A} = 1 > 0$ and $\frac{\partial \Pi^*_M}{\partial w_A} = 1 > 0$.

Hence, $\Pi^*_A$, $\Pi^*_B$, $\lambda^*_A$ and $\Pi^*_M$ are independent in $w_A$, whereas, $p^*_A$, $p^*_B$, $\Pi^*_M$ and $\Pi^*_T$ are strictly increasing in $w_A$.

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