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The Dark Side of Regulatory Amplification in Live Streaming: Quality Provision, Influencer Selection and Consumer Surplus

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Article

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Posted Date: November 26th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11673584/v1

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Additional Declarations: No competing interests reported.

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Highlights

- Although live streaming increases regulatory intensity, it does not necessarily improve product quality.
- Stricter regulation and the live streaming channel do not necessarily improve consumer surplus.
- Higher commissions or stronger regulation may drive the seller to top influencers.
- A stronger awareness-enhancing effect may lead the seller to select lower-influence influencers.
- Seller strategies depend on penalty costs, pit fee levels, devaluation, and regulation.

Title:

The Dark Side of Regulatory Amplification in Live Streaming: Quality Provision, Influencer Selection and Consumer Surplus

Short Title / Running Head: Regulatory Amplification in Live Streaming

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Abstract

In e-commerce, product misrepresentation occurs frequently, causing consumers to become skeptical and ultimately lowering their willingness to purchase. Live streaming offers sellers an opportunity to enhance regulatory scrutiny through a distinct "regulatory amplification effect," driven by influencers' high visibility and real-time interaction. However, whether this effect improves sellers' operational decisions and consumer welfare remains unclear. To address this issue, this paper develops two analytical models to examine sellers' quality provision and channel strategies under live streaming. Our findings reveal that: (i) An increase in e-commerce regulatory intensity does not necessarily improve product quality; instead, the enhancement of consumer trust may translate into higher profits, thereby inducing a "free-riding effect" for low-quality sellers. Specifically, when the pit fee is low, a stronger regulatory amplification effect raises the probability that the seller provides low-quality products. (ii) Consumers also do not necessarily benefit from stricter e-commerce regulatory intensity, and opening a live streaming channel also harms consumer surplus when the regulatory amplification level is moderate. (iii) A higher regulatory amplification level of live streaming may reduce the seller's willingness to choose high-influence influencers but always incentivizes the seller to open the live streaming channel. This paper contributes by being the first to consider the regulatory amplification role of live streaming and reveals its non-monotonic impact on product quality and consumer surplus, challenging the conventional wisdom that stricter regulation universally benefits markets.

Keywords: live streaming; regulatory amplification effect; product authenticity; influencer selection; pricing

1 Introduction

1.1 Background and Motivation

Currently, the global e-commerce industry is experiencing rapid growth. Statistical data shows that global retail e-commerce sales are expected to reach USD 6.42 trillion in 2025 and are projected to further increase to USD 6.88 trillion in 2026 (Capital One Shopping, 2026). However, while the e-commerce market continues to expand, the regulation of product quality and safety still faces significant challenges. On the one hand, some platforms exhibit deficiencies in product quality review, allowing counterfeit and substandard products to enter the market. On the other hand, the virtual and cross-regional nature of online transactions increases the difficulty for consumers to safeguard

their rights (Sun and Liu, 2023), which causes unfair practices such as false advertising and the sale of inferior products to occur frequently. Taking the Chinese market as an example, in 2025, market regulatory authorities nationwide investigated and handled 44, 521 cases of product misrepresentation, with total fines and confiscations amounting to RMB 252 million (Xinhua News, 2026), indicating that the number of such product quality violations remains high. These unfair practices severely harm consumer rights and interests and also undermine consumer trust in the e-commerce market. Relevant surveys show that 56.31% of respondents have encountered misleading graphic or textual promotions, while 53.55% of respondents call for further strengthening the regulation of online trading platforms (Sichuan Provincial Consumer Council Secretariat, 2024).

The popularity of live streaming has grown significantly in recent years, offering a potential remedy for the regulatory deficiencies of traditional e-commerce. Unlike static images and text, live streaming provides richer product information through product trials, real-time interaction, functional demonstrations, and explicit commitments, which helps mitigate information asymmetry and enhance consumers' product understanding and willingness to pay. More importantly, live streaming generates a distinct "regulatory amplification effect." Because influencers—especially those with high influence—participate in the sales process, sellers often open live streaming channels and collaborate with them, which not only expands market demand but also significantly increases product exposure (Xinhua News, 2024). This heightened exposure raises the probability that low-quality products will be detected by consumers, platforms, or public scrutiny (Wang and Zhang, 2026). Moreover, as public figures, influencers face greater reputational risks: their misconduct is more likely to attract social attention and damage industry reputation, thereby placing pressure on platforms and sellers to implement stricter oversight. For instance, Xinba was fined RMB 900, 000 for selling counterfeit bird's nest products during a live stream (Jiang, 2021), and Crazy Little Brother Yang's affiliated company was fined RMB 68.95 million for false advertising related to "Hong Kong Meicheng mooncakes "(Fei et al., 2024). These cases illustrate that when an influencer's level of influence is high, the associated regulatory scrutiny and public pressure tend to be higher as well.

However, opening a live streaming channel is not without costs. Sellers must pay commission fees and pit fee levels, with higher-influence influencers commanding higher costs (e.g., commission rates range from 10% to 20% for established brands to 30% to 50% for lesser-known products) (Liu, 2024). Meanwhile, live streaming generates a "devaluation effect": consumers' willingness to pay is lower than in traditional channels, as early influencers like Li Jiaqi and Wei Ya embedded market perceptions of lower prices and frequent discounts. According to iiMedia Research, 58.8% of users are attracted to live streaming e-commerce by its price (iiMedia Research, 2023). Thus, live streaming presents a double-edged sword: on one hand, its regulatory amplification effect can enhance scrutiny and constrain seller misconduct; on the other hand, it introduces costs and a devaluation effect. Existing research focuses primarily on live streaming features, influencer characteristics, and shared

experiences in shaping consumer willingness to pay, or on comparing live streaming with other sales models. However, these studies pay limited attention to product quality issues and have yet to explore how the regulatory amplification effect shapes the interplay among influencer selection, product quality, and channel choice.

1.2 Research Questions and Major Findings

Based on the above analysis, this paper aims to investigate the following key questions: (i) What are the seller's optimal pricing and channel decisions under the regulatory amplification effect? Under what conditions will the seller open a live streaming channel instead of relying solely on traditional e-commerce? (ii) When does live streaming encourage quality improvement, and when does it induce low-quality behavior? (iii) How does the regulatory amplification effect shape the bidirectional interaction between channel choice, product quality, and consumer surplus?

To address these questions, this paper develops two standard analytical models and conducts a systematic study centered on the key research issues outlined above. First, the seller decides whether to open a live streaming channel. If the seller chooses to open a live streaming channel, they further determine the optimal influence of influencers, and then determine pricing. Subsequently, consumers make purchasing decisions based on channel information, prices, and expected product quality. Finally, the seller determines the actual quality of the products delivered (unobservable to consumers), choosing either high quality matching the influencer's presentation or low quality while bearing potential penalty costs. Within this framework, the paper focuses on analyzing the seller's optimal product quality choice, the influence of influencers, and their interaction mechanisms, while systematically examining how the regulatory amplification effect influences the seller's channel selection, pricing, and product quality. The main findings of this paper are summarized as follows:

- (1) An increase in regulatory intensity does not necessarily raise the probability that the seller provides high-quality products. In the traditional channel, relying solely on stronger regulation may expand demand through improved consumer trust, thereby inducing a "free-riding effect" for low-quality products. In the live streaming channel, the regulatory amplification effect is significantly influenced by the pit fee level: when the pit fee level is low, higher regulatory amplification level of live streaming may instead encourage the seller's low-quality provision. Moreover, high pit fee level does not naturally equate to high quality, as illustrated by the Simba bird's nest incident, and only when the regulatory amplification level of live streaming increases within a high range will it encourage the seller to provide high-quality products. In addition, the live streaming channel incentivizes the seller to provide high-quality products when the regulatory amplification level of live streaming is either low or high. This incentive effect first increases and then decreases, as the devaluation level of live streaming increases. Accordingly, platforms should avoid the simple strategy of linearly strengthening regulation.

- (2) The increase in regulatory intensity does not necessarily benefit consumer surplus. Stricter regulation tends to raise product prices; if the price increase exceeds the improvement in consumer trust, consumer surplus will decline. Meanwhile, in the live streaming channel, sellers should not assume that a low-price strategy is universally applicable, but should fully recognize the dual moderating effect of regulatory intensity on the pricing mechanism. When the regulatory amplification level of live streaming is high, sellers can achieve product premiums through quality endorsement and trust construction to avoid low-price competition. When the regulatory amplification level of live streaming is moderate, however, sellers should guard against the dilemma of "high prices and low trust", and carefully balance pricing and trust-building to effectively protect consumer welfare. When the regulatory amplification level of live streaming is low, sellers may appropriately lower prices to expand market demand.

- (3) A higher regulatory amplification level in live streaming may reduce the seller's willingness to choose high-influence influencers but does not necessarily discourage the seller from opening a live streaming channel. Specifically, the seller's decision to open a live streaming channel depends jointly on potential penalty costs, the pit fee level, the devaluation level, and the regulatory amplification level. Therefore, sellers should avoid simplistic presumptions that "high penalty costs necessarily deter the opening" or "low live streaming devaluation necessarily promotes opening". When the pit fee level is high and the devaluation level of live streaming is high, sellers can strengthen consumer trust through a higher regulatory amplification level of live streaming to maximize profits. Conversely, when the regulatory amplification level of live streaming is low, sellers should carefully evaluate the value of opening and even consider giving up the live streaming channel.

1.3 Statement of Contributions and the Organization of the Paper

This study makes several important contributions to the live-streaming e-commerce literature. First, this study shows that live streaming enhances product exposure through influencers, thereby improving the identification of low-quality sellers and mitigating regulatory deficiencies in traditional e-commerce. This extends prior research by uncovering the governance function of live-streaming channels beyond their conventional sales and marketing role. Second, this study introduces the concept of the regulatory amplification effect of live streaming and develops a theoretical framework to examine how this channel-specific feature shapes sellers' quality provision, channel choice, influencer selection, and consumer welfare. This enriches the literature by uncovering a novel mechanism through which digital platforms affect strategic interactions among market participants. Finally, by revealing how live streaming reshapes the relationship between regulatory intensity and seller decisions, this study provides new theoretical insights into platform governance and offers practical implications for

the sustainable development of live-streaming e-commerce ecosystems.

The remainder of this paper is organized as follows: Section 2 reviews the relevant literature. Section 3 introduces the assumptions and modeling framework. Section 4 examines sellers' optimal pricing, product quality, and influencer selection under two scenarios. Section 5 analyzes the incentives for opening live streaming, including their effects on pricing and product quality. Finally, Section 6 concludes the paper.

2 Literature review

Recent studies have examined livestreaming commerce from multiple perspectives. For example, Wang et al. (2026) investigated how the interaction between information sharing and cooperation mode affects overall supply chain performance. Cheng and Shi (2026) examined the impact of carbon price, freshness effort, CER level, and streamer effort on optimal decisions and profits within agricultural LSEC supply chains. Furthermore, Liu et al. (2026a) demonstrated that livestreaming simultaneously enhances consumer awareness and induces product devaluation perceptions, thereby influencing firms' pricing, influencer selection, and insurance decisions.

Some studies focus on the key roles of live streaming features, influencer characteristics, and co-experience in shaping consumer purchase willingness (Ye and Ching, 2023; Xin et al., 2024; Wang et al., 2024a; Huang et al., 2024; Chen and Liu, 2024; Guo et al., 2024; Chen et al., 2025b; Ye et al., 2026; Liu et al., 2026a; Wu et al., 2025). For example, Huang et al. (2024) discovered that live streaming expands consumer awareness and resolves valuation uncertainty. Chen et al. (2025a) argued that live streaming, through the two independent pathways of eliminating information uncertainty and building relational trust, drives sales. Chen et al. (2025b) pointed out that live streaming possesses a real-time value enhancement effect, which can mitigate consumers' strategic purchase delay behavior.Ye et al. (2026) examined the impact of live streaming timing on the precision of consumer trust perceptions.

Other studies also explore the factors that influence the decision to open a live streaming channel (Liu et al., 2026b; Wang et al., 2024b; Lu et al., 2025; Du et al., 2023; Duan and Song, 2024; Li et al., 2025b; Lu et al., 2025; Song et al., 2026; Wang et al., 2025; Matsui, 2026). For example, Wang et al. (2024b) discovered that the strength of network externality effects and the level of commission fees influence manufacturers' optimal choice of live streaming modes. Li et al. (2025a) analyzed the impact of deliberate product shortages in live streaming sales on retailers' profits and consumer welfare. Song et al. (2026) studies the driving motivations of the "loss-leading drainage" strategy in live streaming scenarios. Wang et al. (2025) states that the key to introducing live streaming lies in accurately evaluating when to open it and formulating the corresponding pricing strategy.

There are some studies explore its impact on product quality and how different levels of product quality influence merchants' decisions to engage in live streaming. There is a bidirectional relationship

between live streaming and product quality (Zhang et al., 2025; Liu et al., 2022; Wang et al., 2024c; Niu et al., 2025; Chen et al., 2025c; Cai et al., 2026; Shi and Chen, 2026; Xu et al., 2026; Cheng et al., 2025). For example, Qiao et al. (2025) studied the decision-making of video game providers when introducing live streaming sales, particularly how to balance competition and cooperation. Xu et al. (2026)found that live streaming reviews and influencer content value jointly shape consumer quality perceptions. Cheng et al. (2025) analyzed when influencers should choose high-quality products and how influencer type (entertainment-oriented versus knowledge-oriented) influences this decision. Shi and Chen (2026) developed a tripartite evolutionary game model to examine the strategic interactions among streamers' deceptive advertising, merchants' non-compliant operations, and government regulation in live streaming e-commerce.

While these studies, along with our paper, examine the application conditions and impacts of live streaming channels, our study differs significantly from prior research in three key aspects. First, existing studies rarely link the live streaming model with false advertising or fraudulent practices in e-commerce; considering the influence of influencers on regulation, our paper is the first to formally characterize the regulatory amplification effect of live streaming. Second, prior research has primarily focused on the impact of live streaming on consumer purchasing behavior. Our paper examines whether and how its regulatory amplification effect influences sellers' product quality and pricing decisions, thereby affecting consumer surplus. Third, our paper systematically investigates the interaction mechanisms through which the regulatory amplification effect affects sellers' channel choice, influencer selection, and pricing.

3 Model settings

Consider a seller who sells a product to consumers through a traditional e-commerce channel at a unit price p, with production cost c. Since high-quality products typically incur higher production costs than low-quality ones, i.e., $c_H > c_L$, the seller has an incentive to misrepresent product quality by claiming high quality while delivering a low-quality product. For example, Xinhua News Agency reported that some influencers claimed their figs could treat cardiovascular and cerebrovascular diseases, whereas the actual products were essentially indistinguishable from ordinary figs (Zhang, 2024).

We assume a consumer's valuation of a product with quality q is given by vq, where $v \sim U[0,1]$. However, consumers frequently observe discrepancies between advertised and actual product quality, even when the seller claims that the product is of high quality. As a result, consumers face uncertainty regarding the product's true quality. Without loss of generality, we assume that consumers hold a prior belief that the product is of high quality ($q = q_H$) with probability α, and of low quality ($q = q_L$) with probability $1-\alpha$, where $q_H > q_L > 0$ and $\alpha \in [0,1]$. Here, α represents regulatory intensity, capturing both the effectiveness of enforcement and the probability that any misrepresentation is detected and

penalized. A higher α increases the seller's expected cost of cheating — specifically, we assume the potential penalty cost is αF — thereby making the seller's high-quality claim more credible in the eyes of consumers.

To increase market size and consumer trust, the seller can choose to collaborate with an influencer with influence s and promote the product through a live streaming channel. Specically, engaging an influencer helps improve product visibility and attract additional consumers from among their followers, thereby effectively increasing the total market size. We refer to these individuals as influencer-driven consumers, whose number is assumed to be proportional to the influencer's influence s and the consumer attention level n toward live streaming, resulting in a *demand-enhancing effect* quantified as ns. Meanwhile, some consumers are already aware of the product and would purchase it even without live streaming, provided their expected utility is positive. We refer to these consumers as product-driven consumers in traditional e-commerce channels and normalize their size to 1. Therefore, the total potential market size in live streaming is given by: $D = 1 + ns$. Menawhile, influencers can introduce product details via live streaming, helping consumers gain a better understanding of the product. Specifically, they guide consumers through the entire transaction process and answer any questions they may have about the product (Liu et al., 2024). Hence, we assume that influencers generate an *awareness-enhancing effect* of m on consumer utility by increasing product knowledge, where m captures the extent to which consumer trust in the influencer's presentation enhances confidence in the product. To better align with the actual situation, our paper assumes that $m < c_H$, meaning the awareness-enhancing effect of live streaming is smaller than the unit production cost of high-quality products. [1]

Notably, live streaming also has the following three negative impacts to consumers.

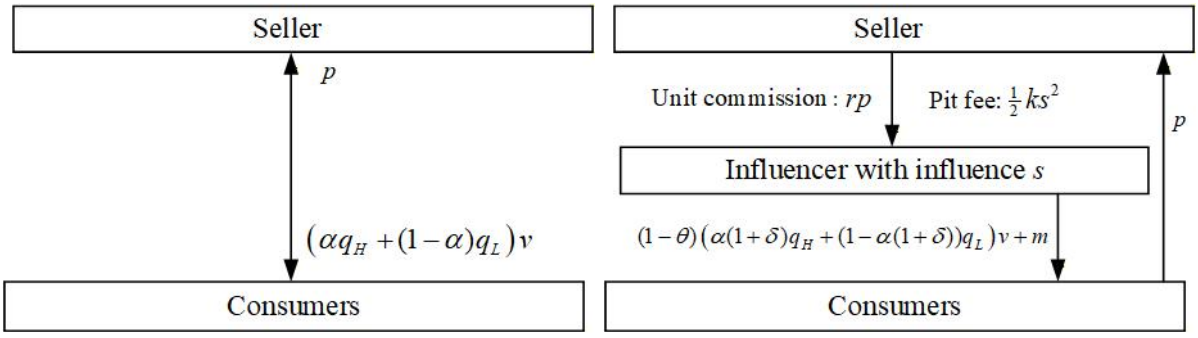
First, live streaming is not free, as sellers may incur the costs of both commission fees and pit fee levels. Typically, the commission ranges from 15% to 30% of the product price, while the pit fee level varies widely depending on the influencer's popularity and follower base, ranging from several thousand to several hundred thousand RMB. For example, according to iResearch, influencer Xiaolu Li typically charges a pit fee level of RMB 100, 000, whereas another influencer, Luo Yonghao, charges between RMB 600, 000 and 1.2 million in pit fee levels, plus a commission, for promoting each brand (He, 2020). Thus, when the seller opens a live streaming channel, we follow Huang et al. (2024) and assume a commission rate of r, meaning that the influencer charges rp for each product sold. Meanwhile, since a higher-influence influencer requires a higher pit fee level (though not proportionally), we assume that the marginal decline increases with the influencer's influence, specifically modeled as $ks^2/2$, this assumption is common in previous studies(Gill and Prowse, 2012; Liu et al., 2024).

[1] This is because, in practice, the informational value provided by influencers — such as product demonstration or usage tips — typically constitutes only a modest supplement to the product's intrinsic quality, rather than a substitute for costly quality improvements. If m exceeded c_H, sellers would have an incentive to rely on influencer promotion to compensate for low quality, undermining the credibility of high-quality claims. Thus, restricting $m < c_H$ preserves the economic significance of production costs and ensures that quality differentiation remains meaningful in equilibrium.

Second, owing to the strong persuasiveness and credibility endorsement of influencers, product information conveyed through live streaming is more easily perceived and verified by consumers. Consequently, inappropriate influencer behavior or product quality issues are more likely to be detected and tend to trigger more severe negative public opinion(China News Network, 2026), drawing heightened regulatory attention to the live streaming channel. To capture this difference, we introduce the regulatory amplification level of live streaming, denoted by δ. Specifically, the regulatory intensity in the live streaming channel is amplified from the baseline regulatory intensity α in the traditional channel to $(1+\delta)\alpha$. We refer to $\delta\alpha$ as the *regulatory amplification effect* of live streaming. Accordingly, in the live streaming channel, the probability that consumers perceive the product to be of high quality is amplified from α to $(1+\delta)\alpha$ and the potential penalty cost in the live streaming channel is $(1+\delta)\alpha F$. To avoid redundant boundary discussions, we assume $\delta \in \left[0, \frac{1-\alpha}{\alpha}\right]$, which has been verified not to affect the main findings.

Third, consumers in live streaming channels tend to exhibit lower willingness to pay compared with those in traditional channels when facing the same price. This is partly because early-stage live streaming commerce relied heavily on deep discounts, making consumers more price-sensitive in this environment(Fang, 2023). For instance, a survey by Forbes showed that 60.1% of respondents cited cost-effectiveness as the reason for choosing live streaming, and 53.9% mentioned favorable pricing (Forbes China, 2020). Thus, we assume that consumer valuation is discounted in live streaming channels. Specifically, valuation is reduced from v to $(1-\theta)v$, where $\theta \in (0,1)$ denotes the devaluation level of live streaming. Similar to Liu et al. (2026a), we refer to θv as the devaluation effect of live streaming.

Thus, based on the seller's decisions regarding live streaming two strategies can be identified. The corresponding model settings are summarized in Fig. 1. For simplicity, the following abbreviations represent different scenarios: N(L) denotes the seller not opening live streaming and delivering a low-quality product; N(H) denotes the seller not opening live streaming and delivering a high-quality product; Y(L) denotes the seller opening live streaming and delivering a low-quality product; and Y(H) denotes the seller opening live streaming and delivering a high-quality product.



(a) Without live streaming (b) With live streaming

Fig. 1. Seller Strategies for Live Streaming.

Specifically, the consumer utility and surplus are given as follows, respectively, and the corresponding market demand and seller profit are shown in Fig. 2.

- When the seller does not open a live streaming channel (Strategy N), the consumer utility is $U^N = (\alpha q_H + (1-\alpha) q_L) v - p$ and consumer surplus is

$$CS^N = \int_{\frac{p}{(\alpha q_H + (1-\alpha) q_L)}}^{1} \big(\alpha q_H + (1-\alpha) q_L\big) v - p dv.$$

- When the seller opens a live streaming channel (Strategy Y), the consumer utility is $U^Y = (\alpha(1+\delta) q_H + (1-\alpha(1+\delta)) q_L) v(1-\theta) - p + m$ and consumer surplus is

$$CS^Y = (1+ns) \int_{\frac{p-m}{(\alpha(1+\delta) q_H + (1-\alpha(1+\delta)) q_L)(1-\theta)}}^{1} \big((\alpha(1+\delta) q_H + (1-\alpha(1+\delta)) q_L) v(1-\theta) - p + m dv.$$

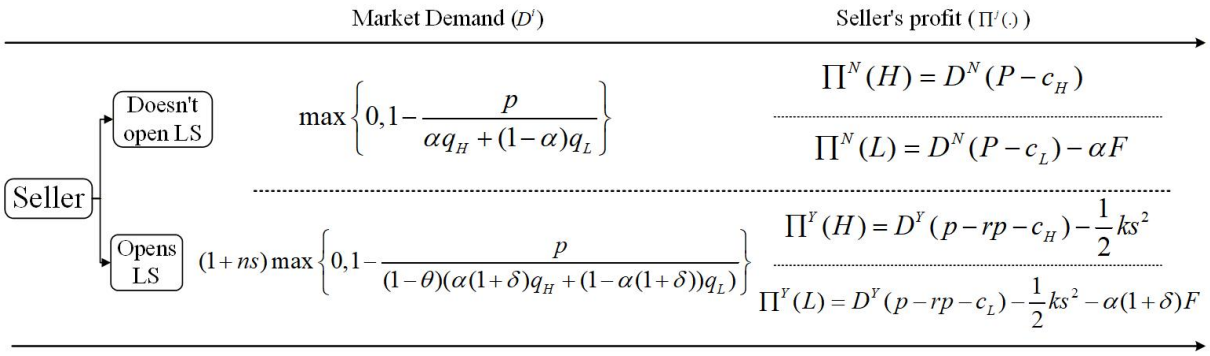


Fig. 2. Consumer utility.

The main sequence of the events is summarized as follows and can be visualized in Fig. 3 and all the notation is summarized in Table 1. Specifically, in Stage I, the seller decides whether to open a live streaming channel . In Stage II, the seller sets the product price and selects an appropriate influencer (if live streaming is adopted). In Stage III, consumers decide whether to purchase the product. In

Stage IV, the seller chooses to deliver a high- or low-quality product to the consumers who made purchases, while consumers can not observe this behavior.

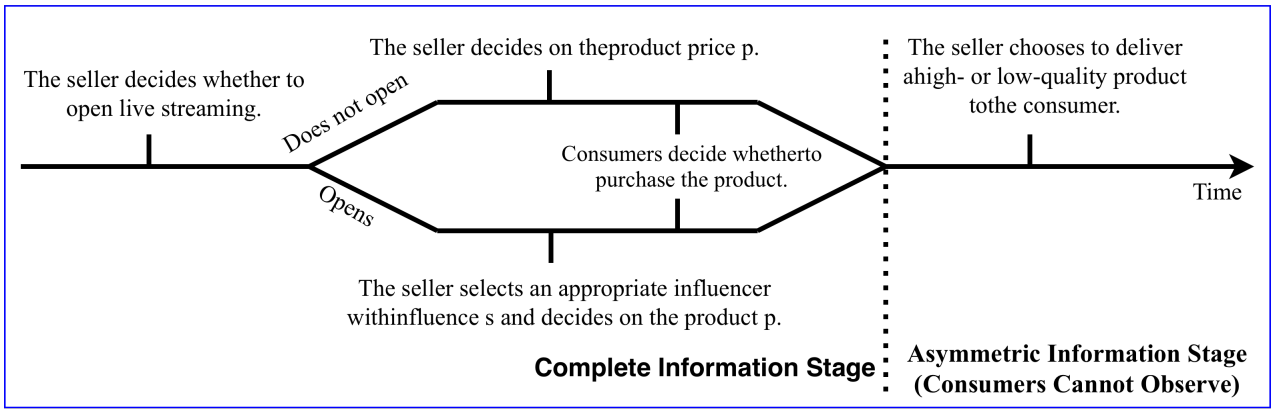


Fig. 3. Sequence of events.

Table 1: Notations.

Symbol	Definition
Notation related to decisions	
$D(.)$	Market demand under different scenarios.
s	Influence of influecners, reflecting their ability to convert exposure into actual sales.
p	Product price.
q_i	Quality of i-type product, where $i \in \{L, H\}$.
General notations	
r	Commission rate charged by the influencer on each sale made via live streaming; $r \in [0, 1]$.
k	Pit fee level, a coefficient in the cost of hiring an influencer, specifically modeled as $ks^2/2$.
θ	Devaluation level of live streaming; $\theta \in [0, 1]$.
m	awareness-enhancing effect, where $m \geq 0$.
n	Consumers' attention to live streaming, where $n > 0$.
v	A consumer's baseline valuation of the product, drawn from a uniform distribution over $[0, 1]$, i.e., $v \sim U(0, 1)$.
c_i	Unit cost of i-type product, where $i \in \{L, H\}$.
F	The potential penalty cost when the seller delivers low-quality products to consumers, where $F \geq 0$.
F^N/F^Y	Penalty cost threshold for high-quality provision under the traditional channel / live streaming channel.
α	The regulatory intensity of the e-commerce environment, where $\alpha \in [0, 1]$.
δ	Regulatory amplification level of live streaming, where $\delta \in [0, \frac{1-\alpha}{\alpha}]$.
Π^j	Seller's profits under two scenarios, where $j \in \{N, Y\}$.
CS^j	Consumer surplus under two scenarios, where $j \in \{N, Y\}$.
N/Y	The seller does not open/opens a live streaming channel.

4 Model anaysis

We first examine the seller's pricing and optimal product quality in the traditional channel. Subsequently, we extend the model to the live streaming channel to analyze the seller's decisions regarding influencer selection, pricing, and product quality. Finally, we further investigate how these decisions are influenced by the opening of a live streaming channel, as well as the conditions under which sellers choose to open live streaming channels and when opening live streaming channels encourages sellers to provide high-quality products. Without loss of generality, we assume $q_H = 1$ and $q_L = 0$ in the subsequent analysis to simplify the expressions without affecting the main findings.

4.1 Without live streaming

Based on Fig. 2, when the seller chooses the traditional channel (Strategy N), the seller's profits are denoted by $\Pi^N(H,p)$ and $\Pi^N(L,p)$ when providing high-quality and low-quality products, respectively.

$$\begin{aligned} \Pi^N(H,p) &= \left(1-\frac{p}{\alpha}\right)(p-c_H), \\ \Pi^N(L,p) &= \left(1-\frac{p}{\alpha}\right)(p-c_L) - \alpha F. \end{aligned} \tag{1}$$

Next, by maximizing the seller's profit with respect to the price p in Eq.(1), the optimal product price p^N is derived and presented in Lemma 1.

Lemma 1. *In strategy N, the optimal pricing p^N and consumer surplus CS^N are $p^N = \frac{\alpha}{2} + \frac{c_H}{2}$, $CS^N = \frac{(-\alpha+c_H)^2}{8\alpha}$. Meanwhile, when the potential penalty cost is high, the seller tends to provide a high-quality product, i.e., if $F < F^N$, then $q^N = q_L$ and $\Pi^N(L,p^N) > \Pi^N(H,p^N)$; otherwise, $q^N = q_H$ and $\Pi^N(L,p^N) \leq \Pi^N(H,p^N)$.*

Lemma 1 indicates that when potential penalty costs are low, the seller is more inclined to provide low-quality products. This is because when potential penalty costs are low, the losses associated with product quality violations are also low, and the seller is therefore willing to provide low-quality products, adopting a strategy that trades quality for cost advantages. When potential penalty costs are high, the losses associated with product quality violations are also high, and the seller is therefore willing to provide high-quality products.

Corollary 1. *As e-commerce regulatory intensity increases,*

- *the seller prefers to set a higher price, i.e., $\partial p^N/\partial\alpha > 0$ always holds.*
- *consumer surplus first decrease and then increases, i.e., if $\alpha < c_H$ then $\partial CS^N/\partial\alpha < 0$; otherwise, $\partial CS^N/\partial\alpha \geq 0$.*

Corollary 1 indicates that as e-commerce regulatory intensity increases, the seller tends to raise product prices, while consumer surplus is first decreasing and then increasing. This is because

strongere-commerce regulatory intensity enhances consumers' trust in product quality, thereby increasing their willingness to pay and enabling the seller to benefit from higher prices. Moreover, when e-commerce regulatory intensity increases within a low range, its effect on enhancing consumer trust is limited. Hence, the impact of price increases on consumer surplus dominates, leading to a decline in consumer surplus. However, when e-commerce regulatory intensity increases within a high range, the improvement in consumer trust and willingness to pay outweighs the effects of higher prices, resulting in an increase in consumer surplus.

These findings suggest that the seller should adopt a phased response strategy when determining optimal pricing decisions to adapt to the evolving regulatory environment. When e-commerce regulatory intensity is low, the seller should focus on improving product quality and strengthening information transparency to proactively build consumer trust. When the e-commerce regulatory intensity is high and with an established foundation of consumer trust, the seller can moderately increase prices while maintaining product quality, thereby maximizing profits.

Corollary 2. *As the regulatory intensity of e-commerce increases, the seller's profits first decrease and then increase, i.e., if* $\alpha < \alpha^i$ *then* $\partial\Pi^N(i)/\partial\alpha < 0$; *otherwise,* $\partial\Pi^N(i)/\partial\alpha \geq 0$, *where* $i \in (H, L)$.

Intuitively, as e-commerce regulatory intensity increases, the profit of the seller providing high-quality products should rise, while the profit from providing low-quality products should decline. However, corollary 2 indicates that this does not always hold. As e-commerce regulatory intensity increases, regardless of whether the seller chooses to provide high-quality or low-quality products, the seller's profit first decreases and then increases. This is because, as e-commerce regulatory intensity increases, it raises potential penalty costs and enhances consumer trust. The increase in consumer trust leads to higher willingness to pay and enables the seller to charge higher prices.

Hence, when the seller chooses to provide high-quality products, the seller's profit is jointly affected by the increase in consumer trust and the demand suppression with higher prices. When e-commerce regulatory intensity increases within a low range, the increase in consumer trust is limited, while the effect of higher prices on demand dominates, leading the seller's profit to decrease. When e-commerce regulatory intensity increases within a high range, the increase in consumer trust outweighs the effect of higher prices on demand, thereby leading the seller's profit to increase.

While when the seller chooses to provide low-quality products, the seller's profit is jointly affected by the increase in potential penalty costs and the increase in consumer trust. When e-commerce regulatory intensity increases within a low range, the increase in consumer trust is low, while the increase in potential penalty costs dominates, leading the seller's profit to decrease. When e-commerce regulatory intensity increases within a high range, the resulting increase in consumer trust begins to dominate, ultimately leading to an increase in the seller's profit.

This suggests that higher e-commerce regulatory intensity not only serves a constraining function

but also enhances overall consumer trust in the market through a signaling effect, thereby increasing willingness to pay and expanding demand, which ultimately benefits the seller. However, such trust exhibits externalities, as sellers providing low-quality products may also benefit from it, leading to a "free-rider" effect. Therefore, platform or government regulation should strengthen oversight and simultaneously introduce mechanisms that improve differentiation and identifiability. For example, information disclosure, quality certification, credit evaluation, and differentiated penalties can facilitate the efficient allocation of trust across sellers, promoting a high-quality, high-price equilibrium while disciplining low-quality products.

Corollary 3. *The seller's optimal product quality is determined by the potential penalty cost, while the penalty cost threshold first increases and then decreases as the e-commerce regulatory intensity increases, i.e., if* $\alpha < 2c_H$*, then* $\partial F^N/\partial\alpha > 0$*; otherwise,* $\partial F^N/\partial\alpha \leq 0$*.*

Corollary 3 indicates that as e-commerce regulatory intensity increases, the penalty cost threshold for high-quality provision under the traditional channel first increases and then decreases; that is, the probability that the seller chooses to provide high-quality products first decreases and then increases. This is because, as e-commerce regulatory intensity increases, it raises potential penalty costs and enhances consumer trust, both of which affect the seller's optimal product quality. When e-commerce regulatory intensity is low, the increase in consumer trust dominates the impact of potential penalty costs, and the seller is willing to provide low-quality products. While when e-commerce regulatory intensity is high, the increase in consumer trust becomes limited, and potential penalty costs increase substantially. Consequently, the seller is willing to provide high-quality products.

Therefore, relying solely on increasing potential penalty costs or strengthening regulation alone is unlikely to consistently guide the seller toward providing high-quality products across all stages. When e-commerce regulatory intensity is low, even higher potential penalty costs may have a limited constraining effect due to the cost advantage of low-quality products. Hence, it is necessary to enhance market transparency and consumer trust to reduce the relative profits of the low-quality strategy. As e-commerce regulatory intensity increases, the combination of demand expansion and strengthened enforcement improves the relative profits of high-quality products, making the constraining effect of the penalty cost threshold mechanism more effective. Thus, at higher e-commerce regulatory intensity, regulators should focus on establishing a stable and predictable penalty system to consolidate the market incentive structure, rather than relying solely on continuously increasing penalty intensity.

4.2 With live streaming

The seller also can collaborate with an influencer with influence s in a live streaming channel, which can generate additional demand from the influencer's followers from 1 to $1 + ns$, and can generate an awareness-enhancing effect of m on consumer utility. However, this strategy incurs additional

costs: the seller must pay a commission fee of rp, pit fees of $\frac{ks^2}{2}$, and a higher potential penalty cost of $\alpha(1+\delta)F$. Meanwhile, live streaming may also lead to a product devaluation effect, as early promotional provides can lower consumers' willingness to pay from v to $(1-\theta)v$. Therefore, based on Fig. 2, when the seller opens a live streaming channel (Strategy Y), consumers' utility is given by $U = \alpha(1+\delta)v(1-\theta) - p + m$, and the seller's profits are denoted by $\Pi^Y(H,p)$ and $\Pi^Y(L,p)$ when providing high-quality and low-quality products, respectively.

$$\begin{aligned}\Pi^Y(H,p) &= (ns+1)\left(1-\frac{p-m}{(1-\theta)\,\alpha\,(1+\delta)}\right)(-rp-c_H+p)-\frac{k\,s^2}{2},\\ \Pi^Y(L,p) &= (ns+1)\left(1-\frac{p-m}{(1-\theta)\,\alpha\,(1+\delta)}\right)(-rp-c_L+p)-\frac{k\,s^2}{2}-\alpha\,(1+\delta)\,F.\end{aligned} \tag{2}$$

By maximizing the seller's profit over p and s in Eq.(2), we have Lemma 2.

Lemma 2. *In strategy Y, the seller's optimal product price p^Y, influence s^Y, consumer surplus CS^Y and quality level q^Y are*

$$\begin{aligned}p^Y &= \frac{-(-1+\theta)(1+\delta)(r-1)\alpha + mr - m - c_H}{2r-2},\\ s^Y &= \frac{\left(-(-1+\theta)(1+\delta)(r-1)\alpha + mr - m + c_H\right)^2 n}{4(-1+\theta)(1+\delta)(r-1)\alpha k},\\ CS^Y &= -\frac{(ns+1)\left(-(-1+\theta)(1+\delta)(r-1)\alpha + mr - m + c_H\right)^2}{8\alpha(-1+\theta)(1+\delta)(r-1)^2}.\end{aligned} \tag{3}$$

Similarly, when the potential penalty cost is high, the seller tends to provide a high-quality product, i.e., if $F < F^Y$, then $q^Y = q_L$ and $\Pi^Y = \Pi^Y(L,p^Y)$; otherwise, $q^Y = q_H$ and $\Pi^Y = \Pi^Y(H,p^Y)$, where $\partial p^Y/\partial\delta > 0$, $\partial p^Y/\partial r > 0$, $\partial p^Y/\partial m > 0$, $\partial p^Y/\partial\theta < 0$ always hold.

Similar to traditional channel, the seller tends to set higher product prices when the regulatory amplification level of live streaming is high. Moreover, we find the seller also tends to set a higher price when both the commission rate and the awareness-enhancing effect are high, and the product devaluation level of live streaming is low. This is because a higher commission rate will increase costs for the seller to collaborate with influencers, prompting the seller to raise prices to maintain profitability. Meanwhile, a stronger awareness-enhancing effect reflects the ability of live streaming to increase consumers' willingness to pay, which enables the seller to set higher prices. Conversely, a higher product devaluation level is often caused by frequent early promotional discounts that lower consumers' willingness to pay in live streaming, which forces the seller to reduce prices to maintain demand. Thus, the seller's optimal pricing strategy must carefully balance these opposing forces to maximize profit.

Proposition 1. *The penalty cost threshold for high-quality product provision under the live streaming channel depends on both pit fee level and regulatory amplification level of live streaming.*

- *(i)When the pit fee level is low, the probability of the seller providing high-quality products decreases with the regulatory amplification level of live streaming increase, i.e., if* $k < a_0$ *then* $\partial F^Y/\partial\delta > 0$.

- *(ii)When the pit fee level is high, the probability of the seller providing high-quality products first decreases and then increases with the regulatory amplification level of live streaming increase, i.e., if* $k \geq a_0$*, then* $\partial F^Y/\partial\delta > 0$ *when* $\delta < d_2$*, and* $\partial F^Y/\partial\delta \leq 0$ *otherwise.*

Intuitively, as the regulatory amplification level of live streaming increases, the probability of the seller to provide high-quality products will increase. However, Proposition 1 indicates that the increase in the regulatory amplification level of live streaming may instead encourage the seller to provide low-quality products, depending on both the pit fee level and the regulatory amplification level of live streaming.

Specifically, when the pit fee level is low, Proposition 1(i) indicates that a stronger regulatory amplification level decreases the probability that the seller provides high-quality products. This is because a lower pit fee level significantly reduces the entry cost into the live streaming channel. As a result, stronger regulation enhances consumer trust but also generates a "low-cost, high-trust" environment. Facing weak cost constraints, the seller may exploit this increased trust premium by providing low-quality products. Even with higher potential penalty costs, low cost pressure may still incentivize the seller to sacrifice quality for higher profits.

Proposition 1 (ii) indicates that when the pit fee level is high, the seller's willingness to provide high-quality products first decreases and then increases. This is because a higher pit fee level significantly increases the seller's cost of live streaming. Consequently, only when the regulatory amplification level is low, and the consumer trust enhanced by regulation dominates the potential penalty cost, this incentivizes the seller to provide low-quality products. When the regulatory amplification level is high, the increase in the potential penalty cost outweighs the consumer trust enhanced, and the seller becomes more inclined to provide high-quality products. This suggests that higher channel fees can serve as a complement to regulation, incentivizing sellers to supply higher-quality products. As an external sunk cost for entering the live streaming channel, a higher pit fee level strengthens the seller's cost constraints and leads to more cautious quality decisions.

Overall, Proposition 1 suggests that strengthening regulation in live streaming does not necessarily lead to improvements in product quality. This helps explain why "failure" incidents may still occur in high-profile live streaming channels, such as the "Xinba Bird's Nest Incident". A high pit fee level does not inherently guarantee high quality, while under low pit fee levels, stronger regulation may instead encourage opportunistic behavior. Therefore, governments or platforms should not rely on a single dimension of regulatory strengthening but should implement differentiated governance based on the level of pit fees. When pit fees are low, where live streaming entry costs are low, stronger

regulation may induce low-quality behavior; thus, governments or platforms should focus on raising entry thresholds and introducing quality deposits to curb such incentives. When pit fees are high, where cost constraints are stronger, governments or platforms can coordinate regulation and cost mechanisms jointly, and should adopt measures such as information disclosure, credit-based penalties, and third-party inspections to reinforce quality constraints.

Proposition 2. *The increase in the commission rate or the regulatory amplification level of live streaming may encourage the seller to choose higher-influence influencers, whereas the increase in awareness-enhancing effect may lead the seller to choose lower-influence ones.*

- *(i)As the commission rate increases, the optimal influence s first decreases and then increases, i.e., if* $r \in (0, r^{Y(s)})$*, then* $\partial s^Y/\partial r < 0$*; otherwise, we have* $\partial s^Y/\partial r \geq 0$*.*
- *(ii) As the awareness-enhancing effect increases, the optimal influence s first decrease and then increase, i.e., if* $m \in (0, m^{Y(s)})$*, then* $\partial s^Y/\partial m < 0$*; otherwise,* $\partial s^Y/\partial m \geq 0$*.*
- *(iii) As the regulatory amplification level of live streaming increases, the optimal influence s first decreases and then increases, i.e., if* $\delta \in (0, \delta^{Y(s)})$*, then* $\partial s^Y/\partial \delta < 0$*; otherwise,* $\partial s^Y/\partial \delta \geq 0$*.*

Three insights stem from Proposition 2. First, intuitively, a higher commission rate encourages the seller to choose a low-influence influencer. However, Proposition 2(i) indicates that this result holds only when the commission rate increases within a low range. This is because collaborating with high-influence influencers can expand the market size, but it also requires higher pit fee levels and commissions. Meanwhile, an increase in the commission rate not only raises the product price and suppresses consumers' willingness to pay, but also increases the seller's live streaming costs. Consequently, when the commission rate increases within a low range, the reduction in collaboration costs from choosing low-influence influencers dominates the demand-enhancing brought by higher-influence influencers. Therefore, the seller prefers low-influence influencers. In contrast, when the commission rate increases within a high range, the product price has already risen significantly and consumers' willingness to pay declines substantially. Therefore, the seller is more willing to collaborate with a higher-influence influencer to increase demand.

Second, intuitively, a stronger awareness-enhancing effect makes live streaming a more cost-effective marketing tool, thereby encouraging the seller to choose more influential influencers. However, Proposition 2 (ii) indicates that when the awareness-enhancing effect increases within a low range, the seller instead prefers low-influence influencers. This is because a higher awareness-enhancing effect improves consumers' willingness to pay and enables the seller to charge higher prices, but higher prices will suppress consumers' willingness to pay. Consequently, when the awareness-enhancing effect increases within a low range, the impact of higher prices on consumers' willingness to pay is limited, and the cost savings from choosing low-influence influencers dominate, leading the seller to choose

a low-influence influencer. When the awareness-enhancing effect increases within a high range, the impact of higher prices on consumers' willingness to pay is significantly amplified, and the seller should choose high-influence influencers to expand market demand.

Third, Proposition 2 (iii) indicates that the impact of the regulatory amplification level of live streaming on the seller's willingness to choose high-influence influencers can be either positive or negative. Specifically, when the regulatory amplification level increases within a low range, it leads the seller to choose low-influence influencers; however, when it increases to a high level, the seller prefers high-influence influencers. The reason is as follows: the enhancement of consumer trust induced by stronger regulatory amplification level allows the seller to charge higher prices and obtain higher marginal profits. When the regulatory amplification level increases within a low range, the additional profits obtained by expanding the market size are lower than the collaborative costs associated with high-influence influencers, encouraging the seller to collaborate with low-influence influencers. When the regulatory amplification level increases within a high range, the increase in marginal profits begins to dominate. Consequently, the seller should collaborate with high-influence influencers to expand market size.

Corollary 4. *Consumer surplus is influenced by both the pit fee level and the regulatory amplification level of live streaming.*

- *(i) As the pit fee level increases, consumer surplus decreases, i.e.,* $\partial CS^Y/\partial k < 0$.
- *(ii) As the regulatory amplification level of live streaming increases, consumer surplus first decreases and then increases, i.e., if* $\delta \in (0, B_1)$*, then* $\partial CS^Y/\partial \delta < 0$*; otherwise,* $\partial CS^Y/\partial \delta \geq 0$.

Corollary 4 shows that consumer surplus decreases as the pit fee level increases, and first decreases and then increases as the regulatory amplification level of live streaming increases. Specifically, Corollary 4 (i) indicates that an increase in the pit fee level reduces consumer surplus. This is because the pit fee level affects consumer surplus indirectly through its impact on the seller's choice of influencer. As the pit fee level increases, the seller, constrained by costs, becomes more inclined to cooperate with low-influence influencers. The resulting decline in influencer influence weakens the trust endorsement and consumption experience that consumers obtain in live streaming channel, thereby reducing their willingness to pay and leading to a decrease in consumer surplus. This suggests that the welfare loss of the pit fee level is not only reflected in cost constraints on the seller, but also in the distortion of matching efficiency in the influencer market, which indirectly reduces consumers' utility and willingness to pay. Therefore, the design of the pit fee level mechanism should take into account both supply-side and demand-side effects.

Corollary 4 (ii) indicates that an increase in the regulatory amplification level of live streaming first reduces and then increases consumer surplus. This is because when the regulatory amplification level increases within a low range, the increase in product prices outweighs the improvement in willingness

to pay driven by enhanced consumer trust, leading to a decline in consumer surplus. However, when the regulatory amplification level increases within a high range, the increase in willingness to pay begins to dominate, thereby leading to an increase in consumer surplus. This suggests that the seller should dynamically monitor changes in the regulatory amplification level of live streaming. When the regulatory amplification level is low, the seller should place greater emphasis on price management and consumer trust building. In contrast, at higher levels, the seller can leverage the trust dividend to optimize pricing strategies, thereby achieving a win–win outcome in both consumer surplus and profit.

5 Impacts of live streaming on seller's decisions

In this section, we examine the impact of live streaming adoption on the seller's pricing and optimal product quality, as well as on consumer surplus, and analyze the seller's decision to adopt live streaming.

Proposition 3. *Live streaming may lead to a higher product price when the regulatory amplification level of live streaming is high, i.e., if* $\delta > \delta^p$*, then* $p^Y > p^N$*; otherwise,* $p^Y \leq p^N$*.*

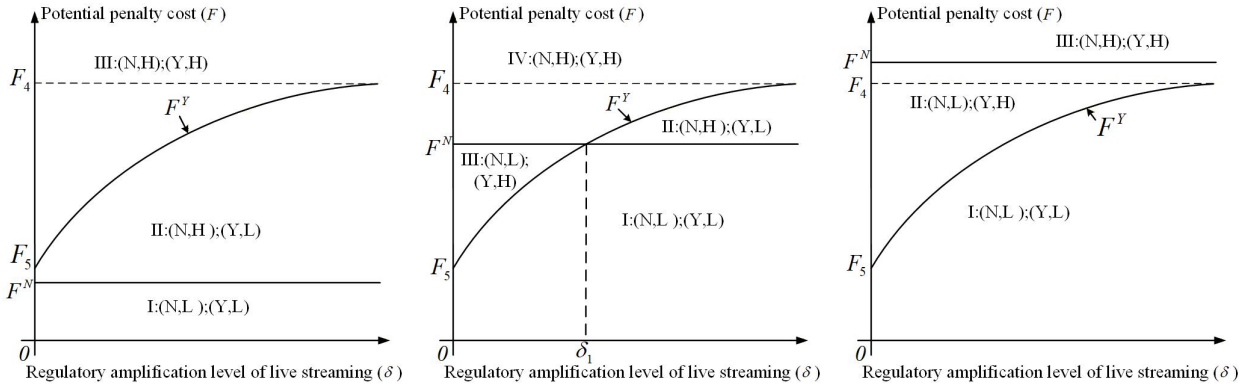
Intuitively, prices in the live streaming channel tend to be lower. Proposition 3, however, shows that this holds only when the regulatory amplification level of live streaming is low. This is because when the regulatory amplification level is low, the difference in regulatory intensity between the two channels is small. However, due to the presence of a devaluation level of live streaming channel, consumers' willingness to pay in live streaming channel is lower. Consequently, the seller tends to reduce product prices to stimulate market demand in the live streaming channel. When the regulatory amplification level is high, the e-commerce regulatory intensity in the live streaming channel is much stronger than that in the traditional channel. Hence, the live streaming channel significantly enhances consumers' trust in product quality and raises their expectations of product quality. Therefore, the seller in the live streaming channel can benefit from setting higher product prices.

This finding suggests important implications for the seller's pricing decisions in the live streaming channel. The seller should not assume that a low-price strategy is always appropriate in the live streaming channel, but should fully recognize the dual impact of e-commerce regulatory intensity on the pricing mechanism. When the regulatory amplification level is high, the seller can achieve a price premium through quality endorsement and trust building, rather than relying on low-price competition. When the regulatory amplification level is low, the seller should focus on the erosion of consumers' willingness to pay caused by the devaluation effect and formulate more attractive pricing strategies accordingly.

Proposition 4. *When the regulatory amplification level of live streaming is high or low, opening a live streaming channel promotes high-quality provision; otherwise, it reduces it; i.e., if* $\delta \in (\delta_1(k,\theta), \delta_2(k,\theta))$*, we have* $F^Y > F^N$*; otherwise,* $F^N \leq F^Y$ *holds.*

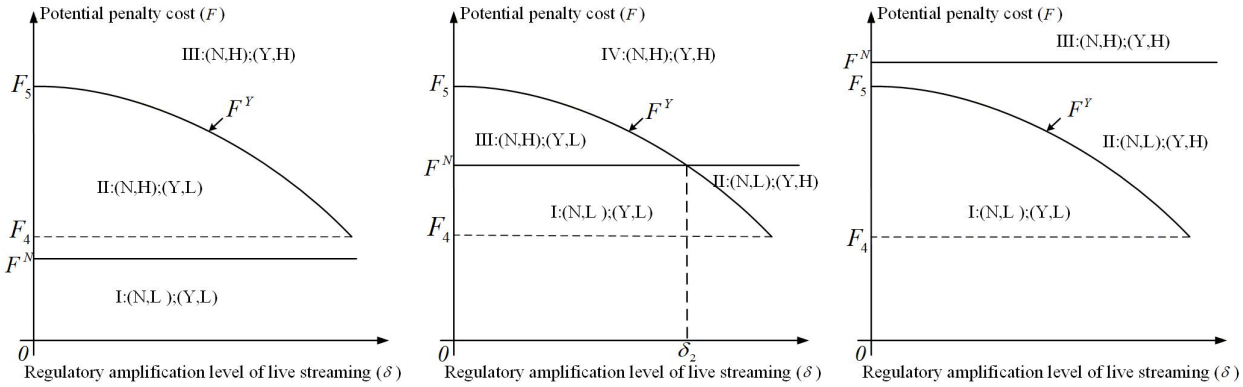
Reasonably, when potential penalty costs are high (low), the seller is always inclined to provide high-quality (low-quality) products, regardless of whether it is a traditional or live-streaming channel. Therefore, Proposition 4 shows that, only when the regulatory amplification level of live streaming is moderate, opening a live streaming channel may reduce the seller's willingness to provide high-quality products. Recall that Proposition 1 shows that as the regulatory amplification level increases, the probability that the seller provides high-quality products in the live streaming channel first decreases and then increases. That is, when the regulatory amplification level is moderate, the probability that the seller provides low-quality products in the live streaming channel is highest and may even exceed that in the traditional channel.

Overall, Proposition 4 indicates that the impact of opening a live streaming channel on product quality is non-monotonic. This largely depends on the potential penalty costs and the regulatory amplification level of live streaming. Although opening a live streaming channel increases e-commerce regulatory intensity, it may in some cases encourage sellers to reduce product quality, thereby highlighting the importance of appropriately calibrating regulatory mechanisms, as illustrated in Fig 4, 5, and 6. We next provide a detailed analysis.



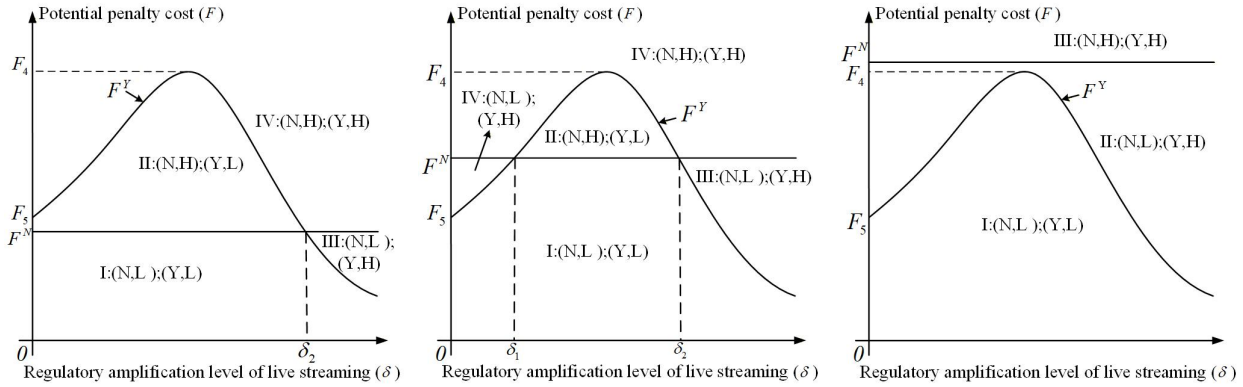
(a) $F_N < F_5$ (b) $F_5 < F_N < F_4$ (c) $F_N > F_4$

Fig. 4. Seller decisions for product quality when $k < a_0$, or $k \geq a_0$ with $\theta \geq \theta_1$.



(a) $F_N < F_4$ (b) $F_4 < F_N < F_5$ (c) $F_N > F_5$

Fig. 5. Seller decisions for product quality when $k \geq a_0$, $\theta < \theta_0$.



(a) $F_N < F_5$ (b) $F_5 < F_N < F_4$ (c) $F_N > F_4$

Fig. 6. Seller decisions for product quality when $k \geq a_0$, $\theta_0 < \theta < \theta_1$.

Fig. 4 indicates that when the pit fee level is low, as the regulatory amplification level of live streaming increases, the probability that the seller provides high-quality products in the live streaming channel decreases. Specifically, according to the penalty cost threshold for high-quality provision under the traditional channel, three cases can be distinguished. First, when the penalty cost threshold is low (Fig.4 (a)), opening a live streaming channel always encourages the seller to provide low-quality products (i.e., it always holds that $F_Y > F_N$). Second, when the penalty cost threshold is moderate (Fig.4 (b)), contrary to intuition, only when the regulatory amplification level is low does opening a live streaming channel encourage the seller to provide high-quality products (i.e., $F_Y < F_N$). Third, when the penalty cost threshold is high (Fig.4 (c)), opening a live streaming channel always encourages the seller to provide high-quality products (i.e., it always holds that $F_Y < F_N$).

The underlying mechanism is as follows. An increase in the regulatory amplification level of live streaming enhances consumer trust, thereby enabling the seller to raise product prices, which in turn increases the marginal profits from providing low-quality products. When the pit fee level is low, live streaming becomes a cost-effective tool, and the awareness-enhancing effect further increases product

prices. Consequently, the marginal profit from low-quality products may exceed potential penalty costs, creating incentives for the seller to provide low-quality products. When the pit fee level is high, live streaming not only becomes more costly but also amplifies potential penalty costs, which weakens the seller's incentive to provide low-quality products. Therefore, only when the devaluation level of live streaming is also high (i.e., $\theta > \theta_1$) do the above results continue to hold. Because the higher devaluation level of live streaming further reduces consumers' willingness to pay, it prompts the seller to reconsider increasing marginal profits through low-quality products, thereby sustaining the previously described results.

These findings suggest that the seller should avoid assuming that "low pit fee levels are always beneficial" or that "stronger regulation always improves quality" when formulating live streaming strategies. Specifically, when the penalty cost threshold in the traditional channel is either low or high, the impact of the live streaming channel on quality choice is clearer (deteriorating or improving, respectively). However, when the penalty cost threshold in the traditional channel is moderate, low pit fee level and an strong regulatory amplification level may instead induce the seller to provide low-quality products. Therefore, platforms should implement differentiated regulation linked to pit fee level. Under high pit fee level and a high devaluation level of live streaming, platforms should introduce additional mechanisms such as quality deposits or after-sales compensation to offset the marginal profits from low-quality products and guide the live streaming channel toward quality improvement rather than adverse selection.

Next, we further analyze the case where the pit fee level is high and the devaluation effect of live streaming is low ($k > a_0$, $\theta < \theta_1$), as illustrated in Fig.5 and 6. When the devaluation level of live streaming is either low or moderate, we obtain the following two findings.

Fig.5 indicates that when the pit fee level is high and the devaluation level of live streaming is low, an increase in the regulatory amplification level of live streaming raises the probability that the seller provides high-quality products in the live streaming channel (i.e., F_Y decreases with δ). This is because a low devaluation level leads to higher consumer willingness to pay. When the regulatory amplification level is high, consumer trust is further enhanced, while potential penalty costs increase significantly, eliminating the seller's incentive to bear such risks and encouraging the seller to provide high-quality products. Similarly, based on the penalty cost threshold for high-quality provision under the traditional channel, three cases can be identified.

First, when the penalty cost threshold is low (Fig.5 (a)), opening a live streaming channel doesn't encourage the seller to provide high-quality products(i.e., it always holds that $F_Y > F_N$). Second, when the penalty cost threshold is moderate (Fig.5 (b)), only when the regulatory amplification level of live streaming is sufficiently high does opening a live streaming channel encourage the seller to provide high-quality products (i.e., $F_Y < F_N$). Third, when the penalty cost threshold is high (Fig.5 (c)), opening a live streaming channel always encourages the seller to provide high-quality products

(i.e., it always holds that $F_Y < F_N$).

Fig.5 suggests that when the pit fee level is high and the devaluation level of live streaming is low, regulators should fully utilize the quality-enhancing role of the regulatory amplification effect by appropriately strengthening regulation (e.g., stricter inspections and clearer penalty rules) to encourage high-quality provision. Notably, the effectiveness of this strategy depends on the quality baseline in the traditional channel. When the penalty cost threshold for high-quality provision under the traditional channel is low, opening a live streaming channel may worsen quality choices; regulators can take measures such as increasing commissions to reduce the seller's incentive to enter live streaming. When the penalty cost threshold is moderate, regulators should implement a stronger amplification level in live streaming to differentiate the channel and promote quality improvement. When the penalty cost threshold is high, live streaming naturally supports quality improvement and can be promoted with less concern.

Fig.6 indicates that when the pit fee level is high and the devaluation level of live streaming is moderate, as the regulatory amplification level of live streaming increases, the probability that the seller provides high-quality products first decreases and then increases (i.e., F_Y first increases and then decreases with δ). This is because a moderate devaluation level corresponds to a moderate level of consumer willingness to pay, and the seller's advantage in the live streaming channel is limited. Hence, when the regulatory amplification level increases within a low range, the enhanced consumer trust outweighs the potential penalty costs, and the seller is willing to provide low-quality products. When the regulatory amplification level increases within a high range, potential penalty costs begin to dominate, leading the seller to provide high-quality products. That is, when the regulatory amplification level is either low or high, the seller has stronger incentives to provide high-quality products. Similarly, according to the penalty cost threshold for high-quality provision under the traditional channel, three cases can be distinguished.

First, when the penalty cost threshold is low (Fig.6(a)), only when the regulatory amplification level is high does opening a live streaming channel encourage the seller to provide high-quality products. This is because a low penalty cost threshold means that the seller has a higher willingness to provide high-quality products in the traditional channel. Hence, only when the regulatory amplification level is high will seller' willingness to provide high-quality products in the live streaming channel exceed that in the traditional channel.

Second, when the penalty cost threshold is moderate (Fig.6(b)), only when the regulatory amplification level is low or high does opening a live streaming channel encourage the seller to provide high-quality products. This is because when the penalty cost threshold is moderate, quality constraints are moderate and the seller's willingness to provide high-quality products in the traditional channel is also moderate. Recall that as the regulatory amplification level increases, the probability that the seller provides high-quality products in the live streaming channel first decreases and then

increases. Hence, when the regulatory amplification level is low or high, the seller's willingness to provide high-quality products in the live streaming channel is higher than that in the traditional channel.

Third, when the penalty cost threshold is high (Fig.6(c)), the probability that the seller provides low-quality products is high in the traditional channel. Meanwhile, the regulatory amplification level of live streaming deters the seller from providing low-quality products in the live streaming channel, and therefore, opening a live streaming channel always encourages the seller to provide high-quality products.

This suggests that, when pit fee levels are high and the devaluation level is moderate, platforms should recognize that the relationship between the regulatory amplification level and quality choice is non-linear. Both low and high levels of the regulatory amplification level can encourage the seller to provide high-quality products, while a moderate regulatory amplification level may induce low-quality provision. Therefore, platforms should avoid a simple linear strengthening of regulation. When the regulatory intensity is low, they should enhance trust and provide traffic support to improve the expected profit from high-quality provision; when the regulatory intensity is high, they should rely on strict penalty mechanisms to lower the expected marginal profits from the provision of low-quality products, thereby inducing the seller to choose high-quality products.

Proposition 4.1. *As the devaluation level of live streaming increases, the probability of opening a live streaming channel to promote sellers' provision of high-quality products first increases and then decreases (see Figs. 4, 5, and 6 for comparison).*

Proposition 4.1 shows that when the devaluation level of live streaming increases within a low range, the probability that opening a live streaming channel encourages the seller to provide high-quality products increases. However, when the devaluation level increases within a high range, this probability decreases. Specifically, from Fig.5 to Fig.6, this probability gradually increases; from Fig.6 to Fig.4, this probability gradually decreases.

This is because when the devaluation level of live streaming is low ($\theta < \theta_0$, e.g., Fig.5), consumers' willingness to pay is high, and the seller's willingness to provide high-quality products increases as the regulatory amplification level increases. Hence, only when the regulatory amplification level is high does opening a live streaming channel encourage the seller to provide high-quality products (i.e., Region II in Fig. 5(b) and Region II in Fig.5(c)).

When the devaluation level of live streaming is moderate ($\theta_0 \leq \theta < \theta_1$, e.g., Fig.6), consumers' willingness to pay is moderate, and the seller needs to more carefully balance potential penalty costs and expected profits. When the regulatory amplification level is low, the resulting increase in consumer trust is limited, and the seller is less willing to provide high-quality products(i.e., Region IV in Fig.6(b) and Region II in Fig.6(c)). When the regulatory amplification level is high, the potential penalty costs

are high, and therefore the seller is more willing to provide high-quality products (i.e., Region III in Fig. 6(a) and Region III in Fig.6(b)). Thus, regardless of whether the regulatory amplification level is low or high, the seller has the willingness to provide high-quality products, thereby increasing the probability that the live streaming channel promotes high-quality provision.

When the devaluation level of live streaming is high ($\theta \geq \theta_1$, e.g., Fig.4), consumers' willingness to pay becomes low. As the regulatory amplification level increases, the seller becomes more willing to provide low-quality products. Only when the regulatory amplification level is low can the live streaming channel encourage the seller to provide high-quality products (i.e., Region III in Fig.4(b) and Region II in Fig.4(c)). Therefore, the probability that the live streaming channel promotes high-quality provision decreases.

Proposition 4.2. *As the penalty cost threshold for high-quality provision under the traditional channel increases, the probability that opening a live streaming channel encourages the seller to provide high-quality products increases (see Figs. 4, 5, and 6 (from (a) to (c)) for comparison, respectively).*

Proposition 4.2 shows that when the penalty cost threshold for providing high-quality products under the traditional channel is high, opening a live streaming channel is more likely to encourage the seller to provide high-quality products, as illustrated in Fig.4, 5, and 6 (from (a) to (c)). This is because, as the penalty cost threshold increases, the constraints on product quality become looser, and the seller's willingness to provide low-quality products increases in the traditional channel. Consequently, a higher penalty cost threshold increases the probability that opening a live streaming channel encourages the seller to provide high-quality products.

Proposition 5. *The seller's live streaming decisions and optimal product quality.*

- *(i) When* $F \in \left(0, \min\{F^Y, F^N\}\right]$*, the seller always provides a lower-quality product and is willing to open a live streaming channel only when the potential penalty costs are low, i.e., if* $F \in (0, F_1)$*, then* $\Pi^Y(L, p^Y) > \Pi^N(L, p^N)$*; otherwise, if* $F \in (F_1, \min\{F^Y, F^N\})$*, then* $\Pi^L(L, p^N) \leq \Pi^N(L, p^N)$*.*

- *(ii) When* $F \in (\min\{F^N, F^Y\}, F^Y)$*, the seller provides low-quality product in live streaming and provides high-quality product without live streaming, and is willing to open a live streaming channel only when the potential penalty costs are low, i.e., if* $F \in (\min\{F^N, F^Y\}, F_2)$*, then* $\Pi^Y(L, p^Y) > \Pi^N(L, p^N)$*; otherwise, if* $F \in (F_2, F^Y)$*, then* $\Pi^Y(L, p^Y) \leq \Pi^N(L, p^N)$*.*

- *(iii) When* $F \in (F^Y, \max\{F^Y, F^N\})$*, the seller provides high-quality product in live streaming and provides low-quality product without live streaming, and is willing to open a live streaming channel only when the potential penalty costs are high, i.e., if* $F \in (F_3, \max\{F^Y, F^N\})$*, then* $\Pi^Y(H, p^Y) > \Pi^N(L, p^N)$*; otherwise, if* $F \in (F^Y, F_3)$*, then* $\Pi^Y(H, p^Y) \leq \Pi^N(L, p^N)$*.*

- *(iv) When* $F \in \left[\max\{F^Y, F^N\}, \infty\right)$*, the seller always provides a high-quality product and is willing to open a live streaming channel only when the pit fee level is low, i.e., if* $k \in (0, k_4)$*, then* $\Pi^Y(H, p^Y) > \Pi^N(L, p^N)$*; otherwise, i.e., if* $k \in (k_4, \infty)$*, then* $\Pi^Y(H, p^Y) \leq \Pi^N(L, p^N)$*.*

Proposition 5, as illustrated in Fig.7, 8, and 9, indicates that the seller's channel selection strategy depends on potential penalty costs and the pit fee level.

First, when potential penalty costs are low, the equilibrium analysis predicts that quality shirking may arise in both the traditional and live-streaming channels, as shown in Regions I and II of Fig.7, Fig.8, and Fig.9. The live-streaming channel is observed only when potential penalty costs are sufficiently low (e.g., Region I). This result suggests that when expected penalties are insufficient to discipline seller behavior, the amplified regulatory exposure associated with live streaming does not provide adequate deterrence against opportunistic quality reduction.

Second, when potential penalty costs are moderate and the penalty threshold under the live-streaming channel exceeds that under the traditional channel (i.e., $F_Y > F_N$), the equilibrium outcome exhibits asymmetric quality provision: quality shirking may persist in the live-streaming channel, whereas high-quality provision is sustained in the traditional channel, as shown in Regions III and IV of Fig.7(a-b), Fig.8(a-b), and Fig.9(a-b). Under these conditions, live-streaming adoption occurs only when expected penalty costs remain sufficiently low. This finding highlights that stronger regulatory exposure in live streaming can partially curb opportunistic behavior, but only sufficiently stringent penalties can effectively induce consistent high-quality provision across channels.

Third, when potential penalty costs are moderate and the penalty threshold under the live-streaming channel is lower than that under the traditional channel (i.e., $F_N > F_Y$), the equilibrium outcome exhibits the opposite asymmetric pattern: high-quality provision is sustained in the live-streaming channel, whereas quality shirking may persist in the traditional channel, as shown in Regions V and VI of Fig.7(b), Regions III and IV of Fig.7(c), Region V of Fig.8(b), and Regions III and IV of Fig.8(c). Unlike the previous case, live-streaming adoption becomes more likely as potential penalty costs increase (e.g., Region V in Fig.7(b)). This result reflects the differential regulatory burden across channels: when the traditional channel is subject to stronger expected penalties, higher penalty costs reduce the attractiveness of low-quality equilibria in that channel and shift channel adoption toward live streaming. This finding further suggests that regulatory asymmetry can significantly influence both channel selection and quality provision.

Finally, when potential penalty costs are sufficiently high, the equilibrium consistently supports high-quality provision in both the traditional and live-streaming channels. Under this condition, live-streaming adoption depends primarily on the operational cost associated with the channel, such as the pit fee level, and occurs only when this cost remains sufficiently low (e.g., Region V in Fig.7(a)). This result indicates that sufficiently stringent penalties effectively eliminate low-quality equilibria, making channel selection mainly driven by operational efficiency rather than by opportunities for

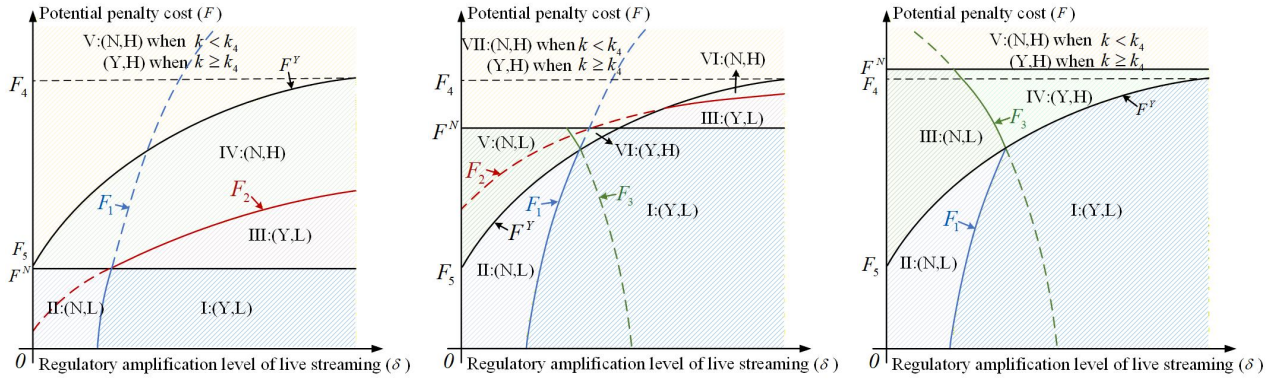
opportunistic quality reduction.

In addition to potential penalty costs and the pit fee level, the study further finds that the devaluation level of live streaming, the penalty cost threshold for high-quality provision under the traditional channel, and the regulatory amplification level of live streaming also influence the seller's decision to open the live streaming channel.

Specifically, first, the devaluation level of live streaming may counterintuitively encourage the seller to open a live streaming channel. That is, as the devaluation level increases within a moderate range (i.e., from Fig.9 to Fig.7), when the regulatory amplification level is high, the seller's willingness to open the live streaming channel increases (i.e., from Region III in Fig.9(a-b) to Region III in Fig.7(a-b)). This is because although a higher devaluation level reduces consumers' willingness to pay in the live streaming channel, a higher regulatory amplification level enhances the credibility of product quality and strengthens consumer trust. When the trust enhancement dominates the impact of reduced willingness to pay, the seller can still obtain stable profits from the live streaming channel. Therefore, even as the devaluation level increases, the seller maintains a strong incentive to open the live streaming channel under high regulatory intensity.

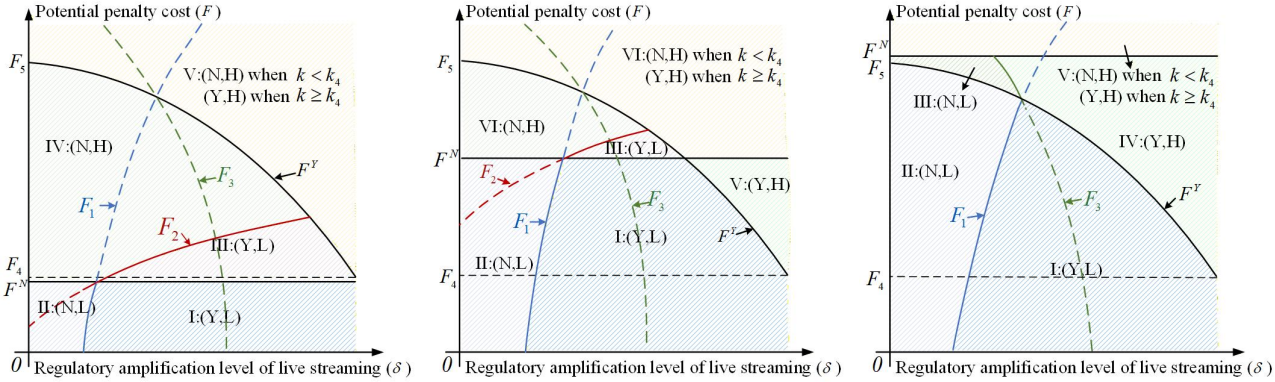
Second, as the penalty cost threshold for high-quality provision under the traditional channel increases, the seller's willingness to open the live streaming channel also increases, and the seller becomes more inclined to provide high-quality products. This is because a higher penalty cost threshold in the traditional channel makes the seller more likely to provide low-quality products. When the regulatory amplification level is high, it can effectively enhance consumers' willingness to pay, and the role of the live streaming channel in improving consumer trust is more significant than the impact of increased potential penalty costs. Consequently, the seller can obtain higher profits from the live streaming channel. In particular, when both penalty cost threshold under the traditional channel and the regulatory amplification level are high, their joint effect further encourages the seller to provide high-quality products in the live streaming channel (i.e., from Fig.7(a) to Fig.7(c)).

Finally, when the regulatory amplification level of live streaming is high, the probability that the seller opens the live streaming channel increases. This is because, although the regulatory amplification level entails stricter regulation and higher potential penalty costs, it also significantly enhances consumer trust. When the regulatory amplification level is low, the impact of potential penalty costs dominates the improvement in consumer trust, leading the seller to prefer the traditional channel. However, when the regulatory amplification level is high, the enhanced consumer trust outweighs the potential penalty costs, and the seller is therefore more inclined to open the live streaming channel.



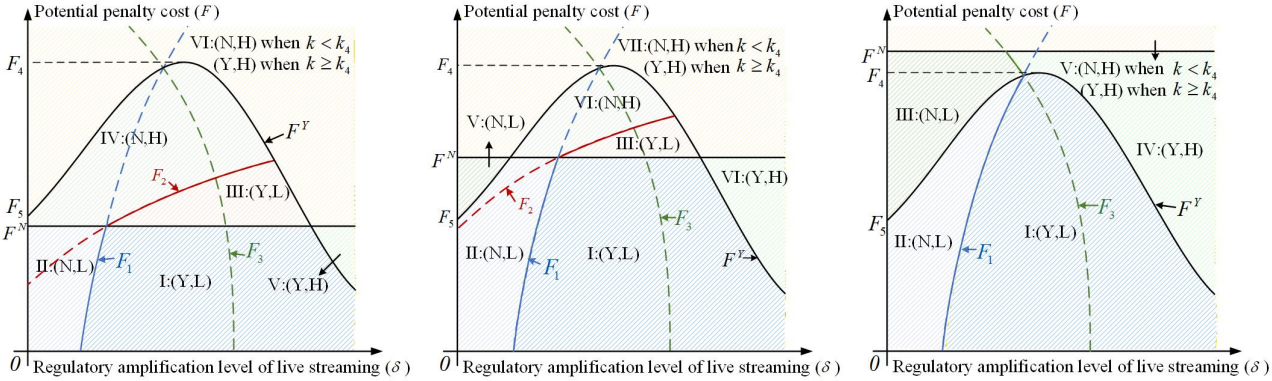
(a) $F_N < F_5$ (b) $F_5 < F_N < F_4$ (c) $F_N > F_4$

Fig. 7. Seller decisions for live streaming when $k < a_0$, or $k \geq a_0$ with $\theta > \theta_1$.



(a) $F_N < F_4$ (b) $F_4 < F_N < F_5$ (c) $F_N > F_5$

Fig. 8. Seller decisions for live streaming when $k \geq a_0$, $\theta < \theta_0$.



(a) $F_N < F_5$ (b) $F_5 < F_N < F_4$ (c) $F_N > F_4$

Fig. 9. Seller decisions for live streaming when $k \geq a_0$, $\theta_0 < \theta < \theta_1$.

Corollary 5. *Opening a live streaming channel makes consumers obtain a lower consumer surplus when the regulatory amplification level of live streaming is moderate, i.e., if* $\delta \in (\delta_3, \delta_4)$ *then* $CS^Y < CS^N$; *otherwise,* $CS^Y \geq CS^N$.

Corollary 5 indicates that when the regulatory amplification level of live streaming is either high or low, opening a live streaming channel can increase consumer surplus; however, when the regulatory amplification level of live streaming is moderate, opening a live streaming channel instead reduces consumer surplus. This is because when the regulatory amplification level is low, product prices in the live streaming channel are lower, which directly increases consumer surplus. When the regulatory amplification level is high, although product prices in the live streaming channel are higher than those in the traditional channel, stricter regulation significantly enhances consumers' trust in product quality. The resulting increase in willingness to pay outweighs the higher prices, thereby improving consumer surplus. In contrast, when the regulatory amplification level is moderate, product prices in the live streaming channel are relatively high, while the improvement in consumer trust is insufficient to offset the adverse effect of price increases, leading to a reduction in consumer surplus.

When deciding whether to open a live streaming channel, the seller should implement differentiated strategies based on the level of the regulatory amplification effect in the market. In particular, when the regulatory amplification level is moderate, the seller should be cautious of a "high-price, low-trust" situation and carefully balance pricing and consumer trust to avoid reducing consumer welfare.

6 Conclusions

6.1 Concluding remarks and answers to research questions

This paper identifies the regulatory amplification effect of live-streaming channels and demonstrates its role in mitigating regulatory deficiencies in traditional e-commerce. It advances the literature on product quality governance by examining how this effect influences sellers' quality provision, pricing, influencer selection, and consumer surplus. The analysis further characterizes the conditions that induce quality improvement and derives the equilibrium thresholds for sellers' channel adoption. The main findings are as follows:

First, intuitively, stronger e-commerce regulatory intensity should lead to a higher probability that the seller provides high-quality products. However, this relationship does not necessarily hold in either the traditional channel or the live streaming channel. In the traditional channel, regardless of whether the seller provides high-quality or low-quality products, profit first decreases and then increases as e-commerce regulatory intensity rises. In the live streaming channel, when the pit fee level is low, a stronger regulatory amplification effect enhances consumer trust but instead motivates the seller to provide low-quality products. When the pit fee level is high, the cost of the pit fee level can partially form a complementary constraint with regulation, and when the regulatory amplification level of live streaming is high, it encourages the seller to provide high-quality products. Meanwhile, when the regulatory amplification level of live streaming is either low or high, the live streaming channel can incentivize the seller to provide high-quality products; moreover, as the devaluation level

of live streaming increases, this incentive effect first strengthens and then weakens.

Second, an increase in e-commerce regulatory intensity may paradoxically reduce consumer surplus. In the traditional channel, stronger regulation leads the seller to set higher product prices; if the price increase dominates the improvement in consumer trust, consumer surplus may decline. Similarly, in the live streaming channel, an increase in the regulatory amplification level raises the seller's optimal pricing, which may even exceed prices in the traditional channel. Consumer surplus also first decreases and then increases as the regulatory amplification level rises. Moreover, when the regulatory amplification level is low, prices in the live streaming channel are lower; when the regulatory amplification level is high, consumers' willingness to pay is high. Therefore, consumer surplus in the live streaming channel exceeds that in the traditional channel within both low and high ranges of the regulatory amplification level. In addition, by affecting product pricing and consumers' willingness to pay, the regulatory amplification level causes the seller's optimal choice of influencer influence to first decrease and then increase.

Finally, we find a higher regulatory amplification level in live streaming may reduce the seller's willingness to choose high-influence influencers but does not necessarily discourage the seller from opening a live streaming channel. Specifically, when potential penalty costs are insufficient to discipline seller behavior, low-quality equilibria may arise, and live-streaming adoption depends critically on the relative regulatory burden across channels. When the live-streaming channel is associated with stronger expected penalties, live-streaming adoption emerges only under sufficiently low potential penalty costs, whereas when the traditional channel faces stronger expected penalties, live-streaming adoption becomes more likely as potential penalty costs increase. As potential penalty costs become sufficiently high, the equilibrium consistently supports high-quality provision across both channels, and channel adoption is then determined primarily by operational considerations, with the pit fee level becoming the key determinant of live-streaming entry. In addition, a stronger regulatory amplification effect can offset the adverse impact of product devaluation by enhancing consumer trust, thereby increasing the likelihood of live-streaming adoption. Furthermore, as the penalty threshold required to sustain high-quality provision in the traditional channel increases, the governance role of live streaming in promoting high-quality provision becomes more pronounced.

6.2 Managerial implications and discussion

This study investigates the impact of the regulatory amplification level of live streaming on sellers' product quality, providing important insights for platforms and regulators in addressing false advertising in e-commerce, formulating effective regulatory strategies, and optimizing sellers' channel selection and pricing decisions. The key managerial insights are as follows.

First, our findings show that stronger e-commerce regulatory intensity does not necessarily increase the likelihood that the seller provides high-quality products. In the traditional channel, relying solely

on stricter regulation may, through enhanced consumer trust and the resulting demand expansion, induce a "free-riding" effect associated with low-quality products. Therefore, platforms should adopt mechanisms such as information disclosure, quality certification, and differentiated penalties to allocate trust more precisely to high-quality sellers, thereby achieving incentive compatibility. In the live streaming channel, the effectiveness of regulation is significantly moderated by the level of the pit fee: when the pit fee level is low, stronger regulation may instead induce low-quality behavior by the seller; when the pit fee level is high, it does not inherently imply high quality (e.g., the Xinba bird's nest incident). Consequently, regulators should implement a tiered regulatory scheme linked to the pit fee level: When entry costs are low, the regulator should raise entry thresholds and impose quality deposits, whereas when entry costs are high, the regulator should strengthen credit constraints and ex post accountability. Moreover, both low and high levels of regulatory intensity can incentivize high-quality products, whereas moderate intensity may instead induce low-quality behavior. Hence, platforms should avoid adopting a simplistic strategy of linearly intensifying regulation. Instead, when regulatory intensity is low, the platform should place emphasis on trust enhancement and traffic support, while when regulatory intensity is high, the platform should employ strict penalty mechanisms to reduce the expected marginal profits of low-quality products, thereby effectively guiding the seller to provide high-quality products.

Second, an increase in e-commerce regulatory intensity may reduce consumer surplus when the price increase outweighs the improvement in consumer trust; consumer surplus declines accordingly. Therefore, the seller should adopt a phased pricing strategy. When regulatory intensity is low, the seller should focus on improving product quality and enhancing information transparency to proactively build consumer trust. When regulatory intensity is high and a solid trust foundation has been established, the seller can moderately increase prices to maximize profit. Meanwhile, in the live-streaming channel, the seller should not assume that a low-price strategy is always optimal. Instead, the seller should recognize the dual impact of regulatory intensity on pricing. Under strict regulatory environments, the seller can rely on quality endorsement and trust building to achieve price premiums and avoid excessive price competition. However, when the regulatory amplification level is moderate, the seller should be cautious of a "high-price, low-trust" scenario and carefully balance pricing and trust to safeguard consumer welfare.

Finally, the seller's decision to open the live streaming channel depends on the joint effects of potential penalty costs, pit fee levels, the devaluation effect, the penalty cost threshold, and the regulatory amplification effect. Therefore, the seller should avoid simplistic assumptions such as "higher penalty costs necessarily discourage the opening of live streaming" or "lower devaluation always benefits live streaming". When the pit fee level is high and the devaluation level is also high, the seller can rely on a strong regulatory amplification level to enhance consumer trust in the live streaming channel and achieve higher profits. Conversely, when regulatory intensity is low, the seller

should carefully evaluate or even refrain from opening the live streaming channel. Moreover, under moderate regulatory intensity, opening the live streaming channel may instead induce low-quality behavior. Hence, platforms should avoid linear regulatory enhancement strategies and instead combine trust-building mechanisms with traffic support, while relying on strict penalty systems to reduce the marginal profits of low-quality behavior, thereby guiding the seller toward optimal decisions in both channel selection and product quality provision.

6.3 Future studies

This paper systematically analyzes the seller's optimal live streaming and product quality strategies under different scenarios within a static framework. However, real-world market environments are more dynamic. Future research could incorporate dynamic factors such as reputation accumulation, product quality fluctuations, and expectations of regulatory changes to better capture seller decision-making. Additionally, while this paper focuses on the optimal behavior of a single seller, multiple sellers on the same platform often engage in strategic interactions in practice. Future studies could explore how competition among sellers influences their choices of live streaming and product quality strategies under varying regulatory intensities and technology adoption conditions.

References

Cai, S., Li, S., Xue, J., Han, X., 2026. Product bundling strategy and pricing for co-livestreaming rooms considering consumer subscription. Omega 138, 103379. doi:10.1016/j.omega.2025.103379.

Capital One Shopping, 2026. E-commerce statistics. https://capitaloneshopping.com/research/ecommerce-statistics/. (Accessed 31 may 2026).

Chen, C., Hu, Y., Lu, Y., Hong, Y., 2025a. Two streams to success: Unpacking the informational and relational roles of live streaming in online shopping. Production and Operations Management doi:10.1177/10591478251403725.

Chen, J., Liu, H., 2024. Modeling interaction behavior and preference decline for live stream recommendation. Decision Support Systems 179, 114146.

Chen, P., Xie, L., Dai, L., Song, Z., 2025b. How live-streaming commerce interacts with two-period pricing when selling to strategic customers. European Journal of Operational Research 327, 148–161. doi:10.1016/j.ejor.2025.05.042.

Chen, Q., Yan, X., Bian, Y., Han, X., 2025c. Live streaming channel and product assortment with both national and store brand products. Omega: The International Journal of Management Science 131. doi:10.1016/j.omega.2024.103212.

Cheng, H., Shi, L., 2026. Decisions and coordination of the agricultural product live streaming e-commerce supply chain, considering low-carbon efforts. Humanities and Social Sciences Communications 13, 1745. doi:10.1057/s41599-026-07789-6.

Cheng, S., Guo, Q., Anderson, C.K., 2025. When and should streamers choose high-quality products? Effects of streamer types. European Journal of Operational Research 327, 971–985. doi:10.1016/j.ejor.2025.05.057.

China News Network, 2026. Joint release of the livestream e-commerce industry development white paper by the development research center of the state administration for market regulation and other entities: Collaborative governance achieves notable results. https://dzswgf.mofcom.gov.cn/news/43/2026/2/1770703142379.html. (Accessed 31 May 2026).

Du, Z., Fan, Z.P., Sun, F., Liu, Y., 2023. Open the live streaming sales channel or not? analysis of strategic decision for a manufacturer. Annals of Operations Research doi:10.1007/s10479-023-05383-6.

Duan, Y., Song, J., 2024. The adoption of live streaming channel considering impulse buying and product returns. International Journal of Production Economics 274, 109295.

Fang, M., 2023. The dilemmas of livestreaming in china. https://www.warc.com/newsandopinion/opinion/the-dilemmas-of-livestreaming-in-china/en-gb/6454. (Accessed 31 May 2026).

Fei, Q., Luo, S., Zheng, S., 2024. "hong kong meisun mooncake" incident continues to escalate. https://news.cnr.cn/dj/20240918/t20240918_526908648.shtml. (Accessed 31 May 2026). Source: CNR (China National Radio).

Forbes China, 2020. China consumers association releases online survey report on livestream e-commerce shopping satisfaction. https://www.forbeschina.com/business/48042. (Accessed 31 May 2026).

Gill, D., Prowse, V., 2012. A structural analysis of disappointment aversion in a real effort competition. American Economic Review 102, 469–503. doi:10.1257/aer.102.1.469.

Guo, Y., Zhang, Y., Goh, K.Y., Peng, X., 2024. Can social technologies drive purchases in e-commerce live streaming? an empirical study of broadcasters' cognitive and affective social call-to-actions. Production and Operations Management , 10591478241276131.

He, J., 2020. Interview with the operator behind li xiaolu's livestream: We've caught the wind again on douyin. https://news.hexun.com/2020-04-25/201140259.html. (Accessed 31 May 2026).

Huang, L., Liu, B., Zhang, R., 2024. Channel strategies for competing retailers: Whether and when to introduce live stream? European Journal of Operational Research 312, 413–426. doi:10.1016/j.ejor.2023.06.017.

iiMedia Research, 2023. China live streaming e-commerce industry 2022-2023: Investment has spread across the entire industry chain, driving optimization across all segments. https://www.iimedia.cn/c1020/91650.html. (Accessed 31 May 2026).

Jiang, J., 2021. Final ruling on xinba's bird's nest incident: Bird's nest brand intentionally misled, ordered to pay 30.35 million yuan in compensation. https://www.jiemian.com/article/6370820.html. (Accessed 31 May 2026).

Li, K., Yao, S., Li, Y., Tang, F., Wang, Z., 2025a. Deliberate shortage in live-streaming commerce. Omega: The International Journal of Management Science 131. doi:10.1016/j.omega.2024.103201.

Li, Q., Zhu, S., Choi, T.M., Shen, B., 2025b. Maintaining E-commerce supply chain viability: Addressing supply risks with a strategic live-streaming channel. Omega 133, 103276. doi:10.1016/j.omega.2025.103276.

Liu, B., 2024. Is li jiaqi's 20% commission reasonable or not? https://awtmt.com/articles/3736972. (Accessed 31 May 2026).

Liu, S., Hua, G., Cheng, T.E., Choi, T.M., 2022. Optimal pricing and quality decisions in supply chains with consumers' anticipated regret and online celebrity retailers. IEEE Transactions on Engineering Management 71, 1115–1129.

Liu, X., Hu, H., Cheng, T., Zhou, Z., Liu, S.S., 2026a. Devaluation and awareness enhancement: The dual roles of live streaming and their impacts on return shipping insurance choice. European Journal of Operational Research , S0377221726001530doi:10.1016/j.ejor.2026.02.015.

Liu, X., Zhou, Z., Zhong, F., Hu, M., 2024. Resolving the information reliability issue in live streaming through blockchain adoption. Transportation Research Part E: Logistics and Transportation Review 189, 103652. doi:10.1016/j.tre.2024.103652.

Liu, Z., Guo, Q., Nie, JJ., Wu, L., 2026b. Manufacturer's channel strategy in live streaming commerce: Two business models. Managerial and Decision Economics 47, 541–553. doi:10.1002/mde.70055.

Lu, W., Ji, X., Wu, J., 2025. Retailer's information sharing and manufacturer's channel expansion in the live-streaming e-commerce era. European Journal of Operational Research 320, 527–543.

Matsui, K., 2026. Optimal pricing timing for an e-commerce platform selling a private label on its own marketplace. European Journal of Operational Research 331, 1005–1021. doi:10.1016/j.ejor.2025.10.001.

Niu, B., Chen, Y., Zhang, J., Chen, K., Jin, Y., 2025. Brands' livestream selling with influencers' converting fans into consumers. Omega: The International Journal of Management Science 131. doi:10.1016/j.omega.2024.103195.

Qiao, L., Tang, W., Hao, G., Xia, Y., Zhang, J., 2025. When and how to introduce live streaming for video game? Consumers' trade-off between buying and watching. Omega: The International Journal of Management Science 135. doi:10.1016/j.omega.2025.103306.

Shi, B., Chen, X., 2026. An evolution analysis of living streaming governance: Deceptive advertising and non-compliant operation. International Journal of Production Economics 293. doi:10.1016/j.ijpe.2026.109916.

Sichuan Provincial Consumer Council Secretariat, 2024. Survey report on the current state of online consumer right to know protection. http://scjgj.sc.gov.cn/scsjgj/c104529/2024/9/20/d2ff4348072c43ba9d8d99e15876e2cb.shtml. (Accessed 31 May 2026).

Song, J., He, Y., Duan, Y., 2026. Loss leader strategy in the live streaming considering cross-product and cross-channel spillover effects. International Journal of Production Economics 294. doi:10.1016/j.ijpe.2025.109803.

Sun, B., Liu, C., 2023. Problems and solutions in the quality and safety supervision of online shopping products. https://www.cqn.com.cn/zj/content/2023-04/21/content_8931194.htm. (Accessed 31 May 2026).

Wang, H., Li, G., Xie, X., Wu, S., 2024a. An empirical analysis of the impacts of live chat social interactions in live streaming commerce: A topic modeling approach. Electronic Commerce Research and Applications 65, 101397.

Wang, H., Zhu, A., Yu, L., Mu, D., 2026. Cooperation mode selection of competitive brands in the live streaming E-commerce supply chain with information sharing and traffic investment. Humanities and Social Sciences Communications 13, 654. doi:10.1057/s41599-026-07251-7.

Wang, J., Shi, Y., Shi, V., Venkatesh, V., 2024b. Should we keep the tradition or follow the trend? the optimal live-streaming e-commerce mode selection in a sustainable and circular supply chain under competition. Annals of Operations Research , 1–29.

Wang, L., Zhou, L., Chan, H.K., Fan, T., 2025. Impact of cost structure and cannibalisation on live streaming pricing strategies. International Journal of Production Economics 285. doi:10.1016/j.ijpe.2025.109619.

Wang, X., Han, X., Chen, Y., 2024c. Optimal manufacturer strategy for live-stream selling and product quality. Electronic Commerce Research and Applications 64, 101372.

Wang, Y., Zhang, J., 2026. A study on public opinion of legal violations in the live-streaming e-commerce industry. https://www.cpd.com.cn/n15737398/n26490099/1024/t_1154678.html. (Accessed 31 May 2026).

Wu, GK., Yang, WS., Hou, XR., Chen, MZ., 2025. Selection of live-streaming sales methods for the manufacturer and streamer: The role of the MCN institution. Managerial and Decision Economics 46, 2540–2561. doi:10.1002/mde.4480.

Xin, M., Liu, W., Jian, L., 2024. Live streaming product display or social interaction: How do they influence consumer intention and behavior? a heuristic-systematic perspective. Electronic Commerce Research and Applications 67, 101437.

Xinhua News, 2024. An in-depth analysis of live-streaming e-commerce. https://www.news.cn/tech/20240104/0d7fb92ee9dc49ba94f579d43666069c/c.html. (Accessed 31 May 2026).

Xinhua News, 2026. Samr releases ten typical cases of illegal advertisements. https://www.news.cn/fortune/20260131/b7a71709bc5f4ec2bf6dff05ce08486d/c.html. (Accessed 31 May 2026).

Xu, X., Chen, X., Choi, T.M., Cheng, T..C..E., 2026. Employee or influencer live streaming? A manufacturer's strategy for virtual character adoption considering live streaming reviews. International Journal of Production Economics 293. doi:10.1016/j.ijpe.2025.109882.

Ye, F., Zhang, S., Zhou, J., Li, Y., 2026. Live streaming strategies for agri-products: Logistics, timing, and initiator selection. Transportation Research Part E: Logistics and Transportation Review 210. doi:10.1016/j.tre.2026.104724.

Ye, M., Ching, T.C., 2023. Research and application flow-based live-streaming shopping towards compulsive buying. Annals of Operations Research , 1–29.

Zhang, S., 2024. When will false advertising in live-streaming e-commerce end? https://www.news.cn/legal/20240823/4837c03354fc41d39c84264a0ea12037/c.html. (Accessed 31 May 2026).

Zhang, Z., Chen, Z., Wan, M., Qiu, S., 2025. Choice of product quality in supply chain of live-streaming e-commerce under different power structures. Australian Journal of Management 50, 266–286.

Figure legends

Fig.1.: Seller Strategies for Live Streaming.
Fig.2.: Consumer utility.
Fig.3.: Sequence of events.
Fig.4.: Seller decisions for product quality when $k < a_0$, or $k \geq a_0$ with $\theta \geq \theta_1$.
Fig.5.: Seller decisions for product quality when $k \geq a_0$, $\theta < \theta_0$.
Fig.6.: Seller decisions for product quality when $k \geq a_0$, $\theta_0 < \theta < \theta_1$.
Fig.7.: Seller decisions for live streaming when $k < a_0$, or $k \geq a_0$ with $\theta > \theta_1$.
Fig.8.: Seller decisions for live streaming when $k \geq a_0$, $\theta < \theta_0$. **Fig.9.:** Seller decisions for live streaming when $k \geq a_0$, $\theta_0 < \theta < \theta_1$.

Data availability

No or not applicable. This manuscript does not report data generation or analysis.

A Proofs

Proof of Lemma 1

Proof. In a traditional channel, for a given product with price p, consumers utility is denoted by $U = (\alpha q_H + (1-\alpha)q_L)v - p$, and consumers will buy the product only when $(\alpha q_H + (1-\alpha)q_L)v - p \geq 0$. Therefore, the market demand can be represented as

$$D = \int_{\frac{p}{\alpha q_H + (1-\alpha)q_L}}^{1} 1 \mathrm{d}v = 1 - \frac{p}{\alpha}.$$

And the seller's profit for providing high and low quality products are

$$\Pi^N(H,p) = \left(1 - \frac{p}{\alpha}\right)(p - c_H), \Pi^N(L,p) = \left(1 - \frac{p}{\alpha}\right)(p - c_L) - \alpha F,$$

respectively. To obtain the optimal product price p, we first have

$$\frac{\partial \Pi^N(H,p)}{\partial p} = \frac{-2p + c_H + \alpha}{\alpha}, \frac{\partial^2 \Pi^N(H,p)}{\partial p^2} = -\frac{2}{\alpha} < 0.$$

Hence, the optimal $p^N = \frac{\alpha}{2} + \frac{c_H}{2}$, where p^N is unique and $p^N = \{p | \partial \Pi^N(H,p)/\partial p = 0\}$. By substituting p^N into the seller's profit function, we have

$$\Pi^N(H,p) = \frac{(-\alpha + c_H)^2}{4\alpha}, \Pi^N(L,p) = \frac{(-4F+1)\alpha^2 - 2\alpha c_L - c_H(c_H - 2c_L)}{4\alpha}.$$

And the consumer surplus is

$$CS^N = \int_{\frac{p^N}{\alpha + (1-\alpha)q_L}}^{1} ((\alpha + (1-\alpha)q_L)v - p^N) \mathrm{d}v = \frac{(-\alpha + c_H)^2}{8\alpha}.$$

□

Proof of corollary 1

Proof. As e-commerce regulatory intensity increases, the seller prefers to set a higher price and the consumer surplus first decrease and then increases, since $\partial p^N/\partial \alpha = \frac{1}{2} \geq 0$, and $\partial CS^N/\partial \alpha = \frac{\alpha^2 - c_H^2}{8\alpha^2} > 0$ if $\alpha > c_H$; otherwise, $\partial CS^N/\partial \alpha \leq 0$. □

Proof of corollary 2

Proof. When the seller provides high-quality products, we have $\partial \Pi^N(L,p^N)/\partial \alpha = \frac{\alpha^2 - c_H^2}{4\alpha^2} > 0$ when $\alpha > c_H$; otherwise, $\partial \Pi^N(L,p^N)/\partial \alpha \leq 0$. When the seller provides low-quality products, we have $\partial \Pi^N(L,p^N)/\partial \alpha = \frac{(-4F+1)\alpha^2 + c_H(c_H - 2c_L)}{4\alpha^2} > 0$ when $\alpha > \sqrt{\frac{c_H(2c_L - c_H)}{-4F+1}}$ or $\alpha < -\sqrt{\frac{c_H(2c_L - c_H)}{-4F+1}}$. Considering that $\alpha \in (0,1)$, we have $\partial \Pi^N(L,p^N)/\partial \alpha > 0$ when $\alpha > \sqrt{\frac{c_H(2c_L - c_H)}{-4F+1}}$; otherwise, $\partial \Pi^N(L,p^N)/\partial \alpha \leq 0$. □

Proof of corollary 3

Proof. We have $\Pi^N(H,p) - \Pi^N(L,p) = \frac{2\alpha^2 F + (-c_H + c_L)\alpha + c_H(c_H - c_L)}{2\alpha} > 0$ when $F > F^N$, where $F^N = -\frac{(-\alpha + c_H)(c_H - c_L)}{2\alpha^2}$ and $\partial F^N/\partial \alpha = -\frac{(c_H - c_L)(\alpha - 2c_H)}{2\alpha^3} > 0$ when $\alpha < 2c_H$; otherwise, $\partial F^N/\partial \alpha \leq 0$. □

Proof of Lemma 2

Proof. In live streaming channel, for a given product with price p, consumers utility is denoted by $U^Y = (\alpha(1+\delta)q_H + (1-\alpha(1+\delta))\,q_L)\,v\,(1-\theta) - p + m$, consumers will buy the product only when $U^Y \geq 0$. Therefore, the market demand can be represented as

$$D = (1+ns)\int_{\frac{p-m}{(1-\theta)(\alpha(1+\delta)q_H+(1-\alpha(1+\delta))q_L)}}^{1} 1\mathrm{d}v = (ns+1)\left(1-\frac{p-m}{(1-\theta)\,(1+\delta)\,\alpha}\right).$$

And the seller's profit for providing high and low quality products are

$$\Pi^Y(H,p) = (ns+1)\left(1-\frac{p-m}{(1-\theta)\,(1+\delta)\,\alpha}\right)(-rp-c_H+p) - \frac{k\,s^2}{2},$$

$$\Pi^Y(L,p) = (ns+1)\left(1-\frac{p-m}{(1-\theta)\,(1+\delta)\,\alpha}\right)(-rp-c_L+p) - \frac{k\,s^2}{2} - \alpha(1+\delta)F.$$

To obtain the optimal product price p, we first have

$$\frac{\partial\Pi^Y}{\partial p} = \frac{(ns+1)\,(-\,(1+\delta)\,(-1+\theta)\,(r-1)\,\alpha + (m-2p)\,r - m + 2p - c_H)}{(-1+\theta)\,(1+\delta)\,\alpha},$$

$$\frac{\partial^2\Pi^Y}{\partial p^2} = -\frac{2\,(ns+1)\,(-r+1)}{(1-\theta)\,\alpha\,(1+\delta)} < 0.$$

Hence, the optimal $p^Y = \frac{-(1+\delta)(-1+\theta)(r-1)\alpha+mr-m-c_H}{2r-2}$, where p^Y is unique and $p^Y = \{p|\partial\Pi^Y(H,p)/\partial p = 0\}$. By substituting p^Y into the seller's profit function, let $\Delta = (1+\delta)\,(-1+\theta)\,(r-1)\,\alpha$, we have

$$\Pi^Y(H,p) = \frac{(ns+1)\,\Delta^2 - 2\left(m\,(ns+1)\,r + k\,s^2 - n\,(m-c_H)\,s - m + c_H\right)\Delta + (mr+c_H-m)^2\,(ns+1)}{4\Delta}.$$

Next, to obtain the optimal influence s, we first have

$$\frac{\partial\Pi^Y(H,p)}{\partial s} = \frac{n\,\Delta^2 - 4\,(1+\delta)\,(-1+\theta)\left(\frac{(mr+c_H-m)n}{2}+ks\right)(r-1)\,\alpha + (mr+c_H-m)^2\,n}{4\Delta},$$

$$\frac{\partial^2\Pi^Y(H,p)}{\partial s^2} = -k < 0.$$

Hence, the optimal $s^Y = \frac{n(-(-1+\theta)(1+\delta)(r-1)\alpha+mr-m+c_H)^2}{4(-1+\theta)(1+\delta)(r-1)\alpha k}$, where s^Y is unique and $s^Y = \{s|\partial\Pi^Y(H,p)/\partial s = 0\}$. Meamwhile, it can be obtained that the consumer surplus is

$$\begin{aligned} CS^Y &= a\int_{\frac{p-m}{(1-\theta)(\alpha(1+\delta)q_H+(1-\alpha)(1+\delta)q_L)}}^{1} \big(\alpha(1+\delta)q_H + (1-\alpha(1+\delta))q_L\big)v(1-\theta) - p + m dv \\ &= -\frac{(ns+1)\,(-\,(-1+\theta)\,\alpha\,(1+\delta) + m - p)^2}{2\alpha\,(1+\delta)\,(-1+\theta)}. \end{aligned} \tag{4}$$

Similarly, when the penalty cost is high, the seller tends to provide a high-quality product, since $\partial(\Pi^Y(H,p) - \Pi^Y(L,p))/\partial F = \alpha(1+\delta) \geq 0$. We have $\Pi^Y(H,p) > \Pi^Y(L,p)$ when $F > F^Y$; otherwise, $\Pi^Y(H,p) \leq \Pi^Y(L,p)$. Where $F^Y = \{F|\Pi^Y(H,p) - \Pi^Y(L,p) = 0\} = \frac{(-A+B)\left(\frac{n^2A^2\alpha^2}{4}+\left(-\frac{B\,n^2}{2}+k\right)A+\frac{n^2B^2}{4}\right)(c_H-c_L)}{-2k\,\alpha^3(r-1)^2(1+\delta)^3(-1+\theta)^2}$, $A = (-1+\theta)\,(1+\delta)\,(r-1)\,\alpha$, $B = mr + c_H - m$. In addition, we have $\partial p^Y/\partial\delta = \frac{\alpha(1-\theta)}{2} \geq 0$, $\partial p^Y/\partial\alpha = -\frac{\theta}{2}+\frac{1}{2} \geq 0$, $\partial p^Y/\partial r = \frac{c_H}{2(r-1)^2} \geq 0$, $\partial p^Y/\partial m = \frac{1}{2} \geq 0$, $\partial p^Y/\partial\theta = -\frac{\alpha}{2} \leq 0$. □

Proof of Proposition 1

Proof. Let $a_0 = -\frac{3(-mr-c_H+m)n^2}{4}$, $a_1 = (-1+\theta)(r-1)$, we have

$$\frac{\partial F^Y}{\partial \delta} = -\frac{\alpha^2 {a_1}^2 (-a_0+k)\delta^2}{2} + (-a_0+k)(-a_1\alpha + mr + c_H - m) a_1 \alpha \delta + C,$$

where $C = -\frac{{a_1}^2(-a_0+k)\alpha^2}{2} + a_1(-a_0+k)(mr+c_H-m)\alpha + \frac{3n^2(mr+c_H-m)^3}{8}$.

Since $\partial F^Y/\partial\delta$ is a quadratic function in δ, when $k < a_0$, its leading coefficient is positive and its discriminant satisfies $\Delta = (c_H+(r-1)m)^2(r-1)^2(-1+\theta)^2\alpha^2(-a_0+k)k < 0$ (i.e., no real roots), hence $\partial F^Y/\partial\delta > 0$ holds. When $k > a_0$, its leading coefficient is negative and its discriminant satisfies $\Delta = (c_H+(r-1)m)^2(r-1)^2(-1+\theta)^2\alpha^2(-a_0+k)k > 0$, hence $\partial F^Y/\partial\delta > 0$ when $\delta \in (d_1, d_2)$, where $d_1 = \frac{-3(c_H+(r-1)m)((r-1)m-a_1\alpha+c_H)n^2+4k(r-1)m-4ka_1\alpha-4\sqrt{(c_H+(r-1)m)^2k(-a_0+k)}+4c_Hk}{4\alpha(r-1)(-a_0+k)(-1+\theta)}$, $d_2 = \frac{-3(c_H+(-1+r)m)((-1+r)m-a_1\alpha+c_H)n^2+4k(r-1)m-4ka_1\alpha+4\sqrt{(c_H+(r-1)m)^2k(-a_0+k)}+4c_Hk}{4\alpha(r-1)(-a_0+k)(-1+\theta)}$, and $\{d_1, d_2)\} = \{\delta | \frac{\partial F^Y}{\partial\delta} = 0\}$. Hence, as δ increases, F^Y first decreases, then increases, and finally decreases. Therefore, there are three solutions to $F_L = 0$. Specifically, $F^Y = 0$ when $\delta = D_1, D_2$, or D_3, respectively, where $D_1 > D_3 > D_2$, and

$$D_1 = \frac{-a_1\alpha + mr + c_H - m}{a_1\alpha},$$

$$D_2 = \frac{(-a_1\alpha+mr+c_H-m)n^2 - 2\sqrt{(((-r+1)m-c_H)n^2+k)k} - 2k}{n^2a_1},$$

$$D_3 = \frac{(-a_1\alpha+mr+c_H-m)n^2 + 2\sqrt{(((-r+1)m-c_H)n^2+k)k} - 2k}{n^2a_1\alpha}.$$

Next, we can verify that $D_3 < 0$ always holds. First, we have

$$\frac{\partial D_3}{\partial k} = -\frac{2a_3(r)}{\sqrt{(((-r+1)m-c_H)n^2+k)k}\, n^2(r-1)(-1+\theta)\alpha},$$

where

$$a_3(r) = -k + \frac{n^2(mr+c_H-m)}{2} + \sqrt{(((-r+1)m-c_H)n^2+k)k}$$

and

$$\frac{\partial a_3}{r} = \frac{mn^2\left(1 - \frac{k}{\sqrt{-k((c_H+(r-1)m)n^2-k)}}\right)}{2} < 0.$$

The inequality holds because $c_H + (r-1)m > 0$, which implies

$$\sqrt{-k((c_H+(r-1)m)n^2-k)} < k.$$

Meanwhile, we find that $a_3(a_4) = 0$, where $a_4 = \frac{m-c_H}{m} < 0$. This implies that $\frac{\partial D_3}{\partial k} > 0$ always holds. Thus, $D_3 < 0$ always holds for all k, since $\lim_{k\to\infty} D_3 < 0$ (we will provide the proof next).

Given the function

$$D_3(k) = C + \frac{2\sqrt{k^2+Ak} - 2k}{B},$$

where $B = n^2(r-1)(-1+\theta)\alpha > 0$, $A = ((-r+1)m - c_H)n^2 < 0$, and $C = \frac{-(-1+\theta)(r-1)\alpha+mr-m+c_H}{(r-1)(-1+\theta)\alpha}$ is a constant.

As $k \to +\infty$, we perform an asymptotic expansion of $\sqrt{k^2+Ak}$:

$$\begin{aligned}\sqrt{k^2+Ak} &= k\sqrt{1+\frac{A}{k}} \\ &= k\left[1+\frac{A}{2k}-\frac{A^2}{8k^2}+O\left(\frac{1}{k^3}\right)\right] \\ &= k+\frac{A}{2}-\frac{A^2}{8k}+O\left(\frac{1}{k^2}\right).\end{aligned}$$

Now compute $2\sqrt{k^2+Ak}-2k$:

$$\begin{aligned}2\sqrt{k^2+Ak}-2k &= 2\left(k+\frac{A}{2}-\frac{A^2}{8k}+O\left(\frac{1}{k^2}\right)\right)-2k \\ &= 2k+A-\frac{A^2}{4k}+O\left(\frac{1}{k^2}\right)-2k \\ &= A-\frac{A^2}{4k}+O\left(\frac{1}{k^2}\right).\end{aligned}$$

Therefore,

$$\frac{2\sqrt{k^2+Ak}-2k}{B} = \frac{A}{B}-\frac{A^2}{4Bk}+O\left(\frac{1}{k^2}\right).$$

Substituting into $D_3(k)$:

$$D_3(k) = C+\frac{A}{B}-\frac{A^2}{4Bk}+O\left(\frac{1}{k^2}\right).$$

As $k\to+\infty$, the terms $-\frac{A^2}{4Bk}$ and $O\left(\frac{1}{k^2}\right)$ tend to 0. Hence, we have

$$\lim_{k\to+\infty} D_3(k) = C+\frac{A}{B}\equiv -1.$$

Therefore, there is one feasible solution to $F_L=0$. Given that $\delta\in(0,\frac{1-\alpha}{\alpha})$, it follows that F_L decreases with δ when $d_2<0$; F_L first increases and then decreases when $0<d_2<\frac{1-\alpha}{\alpha}$; and F_L increases when $d_2>\frac{1-\alpha}{\alpha}$. First, let's compare the relationship between d_2 and 0. Since $d_2=\frac{-3(c_H+(-1+r)m)((-1+r)m-a_1\alpha+c_H)n^2+4k(r-1)m-4ka_1\alpha+4\sqrt{(c_H+(-1+r)m)^2k(-a_0+k)}+4c_Hk}{4\alpha(r-1)(-a_0+k)(-1+\theta)}$, where it holds that $4(r-1)(-a_0+k)(-1+\theta)\alpha>0$, we let $w_0=-3(c_H+(r-1)m)((r-1)m-a_1\alpha+c_H)n^2-4ka_1\alpha+4k(r-1)m+4\sqrt{(c_H+(r-1)m)^2k(-a_0+k)}+4c_Hk$. Since $\frac{\partial w_0}{\partial\theta}=-4(r-1)\alpha(-a_0+k)>0$, we have $w_0<0$ when $\theta<\theta_0$; otherwise, $w_0\geq 0$. It follows that $d_2<0$ when $\theta<\theta_0$; otherwise, $d_2\geq 0$, where $\theta_0=\{\theta|w_0=0\}=\frac{4\sqrt{(-a_0+k)(c_H+(r-1)m)^2k}+3Bn^2+4k(\alpha(r-1)+(r-1)m+c_H)}{4\alpha(-a_0+k)(r-1)}$ and $B=\left(-r^2\alpha+2(-c_H+\alpha)r+2c_H-\alpha\right)m+\left(-r^2+2r-1\right)m^2-c_Hr\alpha-c_H^2+c_H\alpha$. Secondly, since $d_2-\frac{1-\alpha}{\alpha}=\frac{-3(c_H+(r-1)m)((r-1)m+(1-\theta)r-1+c_H+\theta)n^2+4k((-1+\theta)r+c_H+\theta-1)+4\sqrt{(-a0+k)(c_H+(r-1)m)^2k}}{4(r-1)(-1+\theta)\alpha(-a0+k)}$, where $4(r-1)(\theta-1)\alpha(k-a_0)>0$, we let $w_1=-3(c_H+(r-1)m)((r-1)m+(1-\theta)r-1+c_H+\theta)n^2+4k((-1+\theta)r+c_H+\theta-1)+4\sqrt{(-a_0+k)(c_H+(r-1)m)^2k}$. Since $\frac{\partial w_1}{\partial\theta}=-4(r-1)(-a_0+k)>0$, we have $w_1<0$ if $\theta<\theta_1$; otherwise, $w_1\geq 0$. It follows that $d_2<\frac{1-\alpha}{\alpha}$ when $\theta<\theta_1$; otherwise, $d_2\geq\frac{1-\alpha}{\alpha}$. Furthermore, since $\theta_1-\theta_0=\frac{\left(2(c_H+(r-1)m)(-a_0+k)+2\sqrt{(-a_0+k)(c_H+(r-1)m)^2k}\right)(-1+\alpha)}{2(r-1)\alpha(-a_0+k)}>0$, we have $d_2<0$ when $\theta<\theta_0$; $0<d_2<\frac{1-\alpha}{\alpha}$ when $\theta_0<\theta<\theta_1$; $d_2>\frac{1-\alpha}{\alpha}$ when $\theta>\theta_1$.

□

Proof of Proposition 2

Proof. We have

$$\frac{\partial s^Y}{\partial r} = \frac{\left((1-\theta)(1+\delta)(r-1)\alpha + mr - m + c_H\right)\left((1-\theta)(1+\delta)(r-1)\alpha + mr - m - c_H\right)n}{4(-1+\theta)(1+\delta)(r-1)^2\alpha k} > 0$$

if $r > r^{Y(s)} = 1 - \frac{c_H}{(1-\theta)\alpha(1+\delta)+m}$; otherwise, $\partial s^Y/\partial r \leq 0$, since $4(-1+\theta)(1+\delta)(r-1)^2\alpha k < 0$ and $-(-1+\theta)(1+\delta)(r-1)\alpha + mr - m - c_H < 0$. Similarly, we have

$$\frac{\partial s^Y}{\partial m} = \frac{\left(-(-1+\theta)(1+\delta)(r-1)\alpha + mr - m + c_H\right)n}{2(-1+\theta)(1+\delta)\alpha k} > 0$$

when $m > m^{Y(s)} = \frac{c_H+(1-\theta)(1+\delta)(r-1)\alpha}{1-r}$; otherwise, $\partial s^Y/\partial m \leq 0$, since $2(-1+\theta)(1+\delta)\alpha k < 0$. Finally, we have

$$\frac{\partial s^Y}{\partial \delta} = \frac{\left((-1+\theta)(1+\delta)(r-1)\alpha + mr - m + c_H\right)\left(-(-1+\theta)(1+\delta)(r-1)\alpha + mr - m + c_H\right)n}{-4(-1+\theta)(1+\delta)^2(r-1)\alpha k} > 0$$

when $\delta > \delta^{Y(s)} = \frac{-(-1+\theta)(r-1)\alpha+mr-m+c_H}{(-1+\theta)(r-1)\alpha}$; otherwise, $\partial s^Y/\partial \delta \leq 0$, since $4(-1+\theta)(1+\delta)^2(r-1)\alpha k > 0$ and $(-1+\theta)(1+\delta)(r-1)\alpha + mr - m + c_H > 0$.

□

Proof of corollary 4

Proof. As pit fee levels increases, the consumer surplus decreases, since

$$\frac{\partial CS^Y}{\partial k} = \frac{\left(-(-1+\theta)(1+\delta)(r-1)\alpha + mr - m + c_H\right)^4 n^2}{32(-1+\theta)^2(1+\delta)^2(r-1)^3\alpha^2 k^2} < 0.$$

Let $b = (-1+\theta)(1+\delta)(r-1)\alpha$, we have

$$\frac{\partial CS^Y}{\partial \delta} = \frac{(mr+b+c_H-m)(mr-b+c_H-m)\left(\frac{n^2b^2}{2} + b\left((-mr-c_H+m)n^2+k\right) + \frac{n^2(mr+c_H-m)^2}{2}\right)}{8b^2k}.$$

Let $A = (mr+b+c_H-m)(mr-b+c_H-m)\left(\frac{n^2b^2}{2} + b\left((-mr-c_H+m)n^2+k\right) + \frac{n^2(mr+c_H-m)^2}{2}\right)$,

$$\frac{\partial A}{\partial \delta} = \left((mr+c_H-m)^2\left((m-mr-c_H)n^2+k\right) - 2n^2b^3 - 3b^2\left((m-mr-c_H)n^2+k\right)\right)\alpha(r-1)(\theta-1),$$

$$\frac{\partial^2 A}{\partial \delta^2} = -6b^3\left(\left((-1+\theta)(1+\delta)(r-1)\alpha - mr + m - c_H\right)n^2 + k\right).$$

Since $-6b^3 < 0$, we have $\partial^2 A/\partial\delta^2 > 0$ if $\left((\theta-1)(1+\delta)(r-1)\alpha - mr + m - c_H\right)n^2 + k < 0$. This condition is equivalent to $\delta < d_1 = \frac{(-(\theta-1)(r-1)\alpha+mr-m+c_H)n^2-k}{n^2(r-1)(\theta-1)\alpha}$. Otherwise, $\partial^2 A/\partial\delta^2 \leq 0$. Therefore, $\frac{\partial A}{\partial \delta}$ first increases and then decreases with δ rise, and A first decreases, then increases, and decreases again as δ increases. Specifically, $A = 0$ when $\delta = B_1$, B_2 or B_3 respectively, where $B_1 > B_2 > B_3$, and

$$B_1 = \frac{-(\theta-1)(r-1)\alpha + mr - m + c_H}{(\theta-1)(r-1)\alpha}$$

$$B_2 = \frac{\left(-(\theta-1)(r-1)\alpha + mr - m + c_H\right)n^2 + \sqrt{\left(\left(\left(-2r+2\right)m - 2c_H\right)n^2 + k\right)k} - k}{n^2(r-1)(\theta-1)\alpha}$$

$$B_3 = \frac{\left(-\left(\theta-1\right)\left(r-1\right)\alpha + mr - m + c_H\right)n^2 - \sqrt{\left(\left(\left(-2r+2\right)m - 2c_H\right)n^2 + k\right)k} - k}{n^2\left(r-1\right)\left(\theta-1\right)\alpha}.$$

Next, we can verify that $B_2 < 0$ always holds. Similar to the proof of $D_3 < 0$ in Proposition 1, first, we have

$$\frac{\partial B_2}{\partial k} = -\frac{b_2(r)}{\sqrt{\left(\left(\left(-2r+2\right)m - 2c_H\right)n^2 + k\right)k}\, n^2\left(r-1\right)\left(-1+\theta\right)\alpha},$$

where

$$b_2(r) = \sqrt{\left(\left(\left(-2r+2\right)m - 2c_H\right)n^2 + k\right)k} - \left(\left(1-r\right)m - c_H\right)n^2 - k$$

and

$$\frac{\partial b_2}{\partial r} = m\,n^2\left(1 - \frac{k}{\sqrt{\left(-2m\,n^2 r - 2c_H\,n^2 + 2m\,n^2 + k\right)k}}\right) < 0.$$

The inequality holds because $-2\left(c_H + \left(r-1\right)m\right)n^2 < 0$, which implies

$$\sqrt{\left(-2m\,n^2 r - 2c_H\,n^2 + 2m\,n^2 + k\right)k} < k.$$

Meanwhile, we find that $b_3(b_4) = 0$, where $b_4 = \frac{-c_H+m}{m} < 0$. This implies that $\frac{\partial B_2}{\partial k} > 0$ always holds. Thus, $B_2 < 0$ always holds for all k, since $\lim_{k\to\infty} B_2 < 0$ (we will provide the proof next). Given the function

$$B_2(k) = C + \frac{2\sqrt{k^2 + Dk} - 2k}{E},$$

where $D = \left(\left(2-2r\right)m - 2c_H\right)n^2 < 0$, $E = n^2\left(r-1\right)\left(\theta-1\right)\alpha > 0$, and $C = \frac{-(r-1)(-1+\theta)\alpha + mr - m + c_H}{(r-1)(-1+\theta)\alpha}$ is a constant.

As $k \to +\infty$, we perform an asymptotic expansion of $\sqrt{k^2+Dk}$:

$$\begin{aligned}\sqrt{k^2+Dk} &= k\sqrt{1+\frac{D}{k}} \\ &= k\left[1 + \frac{D}{2k} - \frac{D^2}{8k^2} + O\left(\frac{1}{k^3}\right)\right] \\ &= k + \frac{D}{2} - \frac{D^2}{8k} + O\left(\frac{1}{k^2}\right).\end{aligned}$$

Now compute $\sqrt{k^2+Dk} - k$:

$$\begin{aligned}\sqrt{k^2+Dk} - k &= k + \frac{D}{2} - \frac{D^2}{8k} + O\left(\frac{1}{k^2}\right) - k \\ &= \frac{D}{2} - \frac{D^2}{8k} + O\left(\frac{1}{k^2}\right).\end{aligned}$$

Therefore,

$$\frac{\sqrt{k^2+Dk} - k}{E} = \frac{D}{2E} - \frac{D^2}{8Ek} + O\left(\frac{1}{k^2}\right).$$

Substituting into $B_2(k)$:

$$B_2(k) = C + \frac{D}{2E} - \frac{D^2}{8Ek} + O\left(\frac{1}{k^2}\right).$$

As $k \to +\infty$, the terms $-\frac{D^2}{8Ek}$ and $O\left(\frac{1}{k^2}\right)$ tend to 0. Hence,

$$\lim_{k\to+\infty} B_2(k) = C + \frac{D}{2E} \equiv -1.$$

Therefore, we have $A > 0$ for $\delta \in (0, B_1)$ and $A \le 0$ for $\delta \in (B_1, \frac{1-\alpha}{\alpha})$, which implies $\frac{\partial CS^Y}{\partial \delta} < 0$ for

$\delta \in (0, B_1)$ and $\frac{\partial CS^Y}{\partial \delta} \geq 0$ for $\delta \in (B_1, \frac{1-\alpha}{\alpha})$. Consequently, CS^Y first decreases and then increases with δ. □

Proof of Proposition 3

Proof. We have $p^Y - p^N = \frac{(r-1)(-1+\theta)\alpha\delta}{2-2r} + \frac{-(r-1)\theta\alpha+(m-c_H)r-m}{2r-2} > 0$ when $\delta > \frac{(-\theta\alpha-c_H+m)r+\theta\alpha-m}{(r-1)(-1+\theta)\alpha}$; otherwise, $p^Y - p^N \leq 0$. □

Proof of Proposition 4

Proof. According to Proposition 1, F^Y first increases and then decreases with δ. We have $F^Y > F^N$ when $\delta \in (\delta_1, \delta_2)$, where δ_1 and δ_2 are the two solutions of $F^Y - F^N = 0$ with $\delta_1 < \delta_2$. Specifically, since $\delta \in (0, \frac{1-\alpha}{\alpha})$, F^Y is strictly increasing when either $k < a_0$, or $k > a_0$ with $\theta > \theta_1$, as illustrated in Fig.4; F^Y is strictly decreasing when $k > a_0$ with $\theta < \theta_0$, as shown in Fig.5; and F^Y first increases and then decreases when $k > a_0$ with $\theta_0 < \theta < \theta_1$, as depicted in Fig.6.

Next, to compare the relationship between F^N and F^Y, we define $F_4 = F^Y(\delta = d_2)$ when $k > a_0$ and $\theta_0 < \theta < \theta_1$; otherwise (i.e., when $k < a_0$ or $\theta \leq \theta_0$ or $\theta \geq \theta_1$), we define $F_4 = F^Y(\delta = \frac{1-\alpha}{\alpha})$. Meanwhile, we define $F_5 = F^Y(\delta = 0)$. Accordingly, if $F^N < \min(F_4, F_5)$ corresponds to Figs.4, 5, 6(a); if $\min(F_4, F_5) < F_N < \max(F_4, F_5)$ corresponds to Figs.4, 5, 6(b); and $F^N > \max(F_4, F_5)$ corresponds to Figs. 4, 5, 6(c). If $k > a_0$ and $\theta_0 < \theta < \theta_1$, $F_4 = F^Y(\delta = d2) = \frac{16(-1+\theta)(c_H-c_L)\left(-n^2(r-1)^2m^2+2(-1+r)\left(-c_H n^2+k\right)m-c_H^2n^2+2\sqrt{kA(c_H+(r-1)m)^2}+2c_Hk\right)\sqrt{kA(c_H+(-1+r)m)^2}\,A(r-1)}{\left(-3n^2(r-1)^2m^2+4\left(-\frac{3c_H n^2}{2}+k\right)(r-1)m-3c_H^2n^2+4\sqrt{kA(c_H+(r-1)m)^2}+4c_Hk\right)^3}$, where $A = \frac{(3(-r+1)m-c_H)n^2}{4} + k$; otherwise, $F_4 = F^Y(\delta = \frac{1-\alpha}{\alpha}) = -\frac{\left(\frac{(C+B)^2n^2}{4}+kC\right)(C+B)(c_H-c_L)}{2kC^2}$. $F_5 = F^Y(\delta = 0) = -\frac{(-C\alpha+B)\left(\frac{n^2C^2\alpha^2}{4}+\left(-\frac{Bn^2}{2}+k\right)C\alpha+\frac{n^2B^2}{4}\right)(c_H-c_L)}{2k\alpha^3C^2}$, where $B = mr + c_H - m$, $C = (-1+\theta)(r-1)$. □

Proof of Proposition 5

Proof. The seller's product quality and live streaming channel strategies depend on penalty costs, devaluation level of live streaming, and pit fee levels. Specifically, let $A = (-1+\theta)(1+\delta)(r-1)$, $B = mr + c_H - m$, $C = (-1+\theta)(r-1)$.

(i) If $F \in \left(0, \min\{F^Y, F^N\}\right]$, the seller always provides a lower-quality product. Since $\Pi^Y(L, p^Y) - \Pi^N(L, p^N) = -\alpha\delta F + \frac{(A\alpha-B)(A\alpha+(1-r)m+c_H-2c_L)\left(n^2A^2\alpha^2-2A\left(Bn^2-2k\right)\alpha+n^2B^2\right)}{16A^2\alpha^2k} - \frac{(B-A\alpha)^4n^2}{32kA^2\alpha^2} + \frac{(c_H-\alpha)(c_H-2c_L+\alpha)}{4\alpha}$, we have $\Pi^Y(L, p^Y) - \Pi^N(L, p^N) > 0$ if $F < F_1$; otherwise, $\Pi^Y(L, p^Y) - \Pi^N(L, p^N) \leq 0$ holds, where $F_1 = \{F | \Pi^Y(L, p^Y) - \Pi^N(L, p^N) = 0\}$.

(ii) If $F \in (\min\{F^Y, F^N\}, F^Y)$, the seller provides low-quality product in live streaming and provides high-quality product without live streaming. Since $\Pi^Y(L, p^Y) - \Pi^N(L, p^N) = -\alpha F - \frac{(-C\alpha+B)^4n^2}{32kC^2\alpha^2} - \frac{(\alpha-c_H)^2}{4\alpha} + \frac{(-C\alpha+mr-c_H+2c_L-m)\left(\frac{n^2C^2\alpha^2}{4}+H\left(-\frac{Bn^2}{2}+k\right)\alpha+\frac{n^2B^2}{4}\right)(-C\alpha+B)}{4H^2\alpha^2k}$, we have $\Pi^Y(L, p^Y) - \Pi^N(L, p^N) > 0$ if $F < F_2$; otherwise, $\Pi^Y(L, p^Y) - \Pi^N(L, p^N) \leq 0$ holds, where $F_2 = \{F | \Pi^Y(L, p^Y) - \Pi^N(L, p^N) = 0\}$.

(iii) If $F \in (F^Y, \max\{F^Y, F^N\}]$, the seller provides high-quality product in live streaming and provides low-quality product without live streaming. Since $\Pi^Y(H, p^Y) - \Pi^N(L, p^N) = \alpha F + \frac{-\alpha^2+2\alpha c_L+c_H(c_H-2c_L)}{4\alpha} + \frac{(-A\alpha+B)^2\left(\frac{n^2A^2\alpha^2}{8}+A\left(\frac{(-mr-c_H+m)n^2}{4}+k\right)\alpha+\frac{n^2B^2}{8}\right)}{4A^2\alpha^2k}$, we have $\Pi^Y(H, p^Y) - \Pi^N(L, p^N) > 0$ if $F > F_3$; otherwise, $\Pi^Y(H, p^Y) - \Pi^N(L, p^N) \leq 0$ holds, where $F_3 = \{F | \Pi^Y(H, p^Y) - \Pi^N(L, p^N) = 0\}$.

(iv) If $F \in \left(\max\{F^Y, F^N\}, \infty\right)$, the seller always provides high-quality products both with and without live streaming. Since $\Pi^Y(H, p^Y) - \Pi^N(L, p^N) = \frac{(-A\alpha+B)^2\left(\frac{n^2A^2\alpha^2}{8}+A\left(\frac{(-mr-c_H+m)n^2}{4}+k\right)\alpha+\frac{n^2B^2}{8}\right)}{4A^2\alpha^2k}$

and $\partial(\Pi^Y(H,p^Y)-\Pi^N(L,p^N))/\partial k = -\frac{(r(1-\theta+m)-m+c_H+\theta-1)^4 n^2}{32k^2(\theta-1)^2(r-1)^2} \leq 0$. Thus, we have $\Pi^Y(H,p^Y)-\Pi^N(L,p^N)>0$ if $k<k_4$; otherwise, $\Pi^Y(H,p^Y)-\Pi^N(L,p^N)\leq 0$, where k_4 is uniquely defined by the condition $k_4=\{k|\Pi^Y(H,p^Y)-\Pi^N(L,p^N)=0\}$. Specifically, as shown in Fig.7, 8, 9. □

Proof of Corollary 5

Proof. we have

$$CS^Y-CS^N=-\frac{(mr-\Delta+c_H-m)^2\left(\frac{n^2\Delta^2}{4}+\left(\frac{(-mr-c_H+m)n^2}{2}+k\right)\Delta+\frac{n^2(mr+c_H-m)^2}{4}\right)}{8(r-1)\Delta^2 k}-\frac{(-\alpha+c_H)^2}{8\alpha}$$

and $\frac{\partial(CS^Y-CS^N)}{\partial\delta}=\frac{(mr+b+c_H-m)(mr-b+c_H-m)\left(\frac{n^2b^2}{2}+b\left((m-mr-c_H)n^2+k\right)+\frac{n^2(mr+c_H-m)^2}{2}\right)}{8b^2k}$,
where $b=(-1+\theta)(1+\delta)(r-1)\alpha$. Thus, we have $\frac{\partial(CS^Y-CS^N)}{\partial\delta}=\frac{\partial CS^Y}{\partial\delta}$. Thus, we find $\frac{\partial(CS^Y-CS^N)}{\partial\delta}$ also first decreases and then increases. The proof follows the same procedure as that for $\frac{\partial CS^Y}{\partial\delta}$ in Proof of Corollary 4 and is omitted here for brevity. Therefore, we have $CS^Y<CS^N$ when $\delta\in(\delta_3,\delta_4)$; otherwise, $CS^Y\geq CS^N$, where $(\delta_3,\delta_4)=\{\delta|CS^Y-CS^N=0\}$. □