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Information disclosure strategies of live-streaming supply chains in the digi-economy era

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Abstract
Live e-commerce is one of the important forms of digital transformation of supply chain, which has become increasingly popular in recent years as a powerful tool for internet advertising, interaction, and merchandising. We propose two pricing models to examine the strategies of information disclosure and pricing within the live-streaming supply chain. One model revolves around the agency framework, wherein the manufacturer determines the price while the streamer decides the level of information disclosure. The other model pertains to a self-implementing framework, wherein the manufacturer determines both the level of information disclosure and the price. To evaluate the robustness of our findings, we extend our models to encompass three significant scenarios: (i) the platform involvement model, where a live-streaming support platform becomes part of the supply chain; (ii) the fixed price model, which externalizes the manufacturer's pricing decision; and (iii) the dual-channel operations model. Our analysis reveals that the cost associated with information disclosure impacts the streamer's profits in a nonlinear manner within the agency model. Interestingly, expanding the revenue-sharing parameter does not invariably favor the manufacturer. Moreover, we observe that none of the live-streaming sales models exhibits a clear advantage over the others. Additionally, we demonstrate that the platform's involvement limits the manufacturer's ability to utilize the agency model for live-streaming sales. In situations with fixed pricing, the manufacturer is advised to disclose more production information during live-streaming sales.

1 | INTRODUCTION

1.1 | Background and motivations

The digital transformation of the supply chain is an important trend in the manufacturing and retail industries. The rise of live streaming e-commerce provides new ideas for the digital transformation of the supply chain (Ma et al., 2023). Live-streaming business, which combines instantaneous shopping with entertainment, provides retailers, manufacturers, and digital platforms with an innovative channel (Bawack et al., 2023; Bender et al., 2022; Kang et al., 2021; Wu et al., 2023; Xie et al., 2022). It is estimated that live-streaming sales hold significant potential for enhancing business value. From 2017 to 2021, the live-streaming business is projected to grow at an annualized rate exceeding 280%, reaching an anticipated total of $171 billion.[1]

The information disclosure of products in live-streaming sales enables consumers to comprehend products more intuitively, thereby providing brands with competitive advantages (Liu et al., 2022; Wongkitrungrueng et al., 2020; Zhao et al., 2019). For instance, live-streaming sales offer consumers an exciting and immersive experience, fostering prolonged engagement in shopping. Moreover, they enhance the desirability and distinctiveness of a brand, attracting a larger online audience (Popescu & Crama, 2016). This approach has the potential to strengthen brand positioning among existing consumers and attract new shoppers, owing to its innovative information disclosure method.[1]

Nonetheless, the progression of the live-streaming business encounters substantial hurdles, particularly concerning product information disclosure. Brands encounter numerous challenges in this regard (Zhang et al., 2023). Primarily, some operators resort to excessive propaganda as a tactic to bolster competitiveness. Due to the inherent opacity of the Internet economy, consumers often struggle to ascertain the authentic quality of goods during live-streaming sales. A survey indicates that exaggerated advertising ranks among the most significant concerns consumers associate with information disclosure in live-streaming sales.[2] The Federal Trade Commission (FTC) of America's "Disclosures 101 for Social Media Influencers" serves as a reminder to streamers that they must disclose their connections with merchants when posting marketing content on social media to prevent misleading consumers into making uninformed purchasing decisions. Hence, brands' disclosure strategies play a crucial role in the success of live-streaming sales operations. There exists a trade-off in how to manage product information disclosure. Specifically, a minimal level of disclosure renders live-streaming sales meaningless, whereas excessive publicity hampers consumers' ability to discern authenticity, resulting in decreased consumer satisfaction and unsuccessful business outcomes.

Thus, analyzing information disclosure strategies in live-streaming sales is of significant importance. Firstly, retailers face a dilemma regarding information disclosure. Insufficient product information disclosure diminishes the significance of live-streaming sales, while excessive disclosure leads to exaggerated propaganda. Therefore, retailers must balance how to disclose product information effectively in live-streaming sales. Secondly, the importance of information disclosure lies in its ability to enhance consumers' awareness of products, enabling them to understand the characteristics and advantages of products more intuitively. Showcasing products through live streaming not only stimulates consumers' shopping interests but also shapes unique brand images and experiences, thus enhancing market competitiveness. Lastly, different business models entail different entities responsible for product information disclosure, resulting in varied strategies adopted by different entities. Consequently, inconsistencies in information asymmetry between sales entities and consumers across different business models affect product sales. Therefore, through in-depth exploration of the mechanisms and influencing factors of information disclosure in live-streaming sales, more scientific and effective disclosure strategies can be provided for retailers and industry stakeholders, promoting the healthy development and sustainable prosperity of the live-streaming sales industry.

Moreover, considering the pivotal concerns surrounding information disclosure in live-streaming sales, brands must deliberate on the sales method to adopt. Under the agency model, the streamer determines the information disclosure strategy, while under the self-implement model, the brand assumes this responsibility. For brands, self-implement entails a controlled disclosure strategy but incurs higher costs, whereas the agency model offers cost savings but may result in an uncontrollable disclosure strategy. Hence, resolving the dilemma of selecting the appropriate model for live-streaming sales is not straightforward.

Previous studies have underscored the significance of selecting live-streaming sales methods, as evidenced by works such as, Zhang, Chen, and Liu (2022), Pan et al. (2022), and Wang and Zhang (2022). Our study shares similarities with Hao and Yang (2022) in the research stream pertaining to live-streaming supply chain operations. Both studies investigate the selection of models for live-streaming sales. Hao and Yang (2022) proposed that the sales effort in live streaming follows a quadratic function, a premise akin to ours. However, they did not account for the impact of live sales on consumer utility. We argue that the cost of information disclosure, akin in some respects to the cost of live-streaming sales effort as suggested by Hao and Yang (2022), follows a quadratic function while enhancing consumer utility. Furthermore, some of these studies neglect to explore how the disclosure strategy influences brands' decisions regarding live-streaming sales models. For instance, Pan et al. (2022) concentrated on the streamer's commercial viability and the consumers' inconvenience cost associated with participating in live-streaming sales. Similarly, Wang and Zhang (2022) compared retailer strategies with and without live-streaming sales, overlooking the impact of disclosure strategies on brand preferences for sales models.

1.2 | Research questions and main findings

The practical evidence and theoretical insights discussed above motivate our investigation into the following research questions in this study:

i. How do brands make information disclosure and pricing decisions under various live-streaming sales models?
ii. What factors influence brands' selection between different live sales models, namely, the agency or the self-implement models?
iii. How does the response to the preceding question evolve when considering the involvement of live streaming platforms in the competitive landscape?
iv. When the product price is fixed, what strategies should brands employ to disclose product information in live-streaming sales, and how should they prioritize between live-streaming sales models?

In this paper, we construct models aimed at elucidating the information disclosure strategy in live-streaming sales, with the objective of tackling the aforementioned concerns. We depict a scenario where a brand (manufacturer) conducts live-streaming sales to sell products directly to consumers. The brand faces two options for executing live-streaming sales: the agency model and the self-implement model. Specifically, in the agency model, the manufacturer sets the product's pricing, while the streamer, acting as the intermediary, facilitates the sale to consumers and determines the information disclosure strategy. In the self-implement model, the manufacturer engages a streamer to host live-streaming sales on a social media platform. Here, the manufacturer not only determines the product's price but also dictates the level of information disclosure. We initially derive the optimal pricing and information disclosure decisions of the live-streaming supply chain under both the agency and self-implement models. Subsequently, we explore how the manufacturer adjusts pricing and information disclosure decisions in response to variations in model parameters. Finally, by comparing the optimal outcomes and the profitability of the manufacturer under these two models, we analyze the manufacturer's selection of live-streaming sales models. To validate the robustness of our initial findings, we explore two additional extended models: (i) the platform involvement model and (ii) the fixed price model, and (iii) the dual-channel operation model. In addition to confirming the robustness of the results, we also generate further management insights under these extended models.

In this paper, we unveil several intriguing discoveries. Firstly, under the agency model, the streamer's profit exhibits a non-linear response to the cost of disclosure. Initially, a decrease in profit is anticipated with rising costs. However, we demonstrate that with moderate cost factors, an increase in costs can paradoxically lead to enhanced streamer profits. If consumers are attentive to information disclosure, the manufacturer stands to gain a larger profit, albeit occasionally at the expense of the streamer incurring losses. Interestingly, we find that a higher revenue sharing parameter does not necessarily confer advantages to the manufacturer. Conversely, in the self-implementation model, the manufacturer can leverage consumers' sensitivity to information disclosure for their benefit.

Secondly, contrary to the self-implementation model, the agency model does not emerge as unequivocally superior. However, consumers stand to potentially gain more surplus from the agency model. Naturally, the manufacturer is inclined towards a self-implementation strategy if it receives a smaller revenue percentage from the streamer. Nevertheless, we find it intriguing that in such instances, both the price and the disclosed information volume are high. This suggests that the manufacturer can opt for a high-price strategy if it chooses the self-implement model for live-streaming sales.

We extend the basic models to three other settings to glean more insightful findings and validate the robustness of our results. Contrary to the results obtained under the basic models, we discover that consumers derive more surplus under the self-implement model with platform involvement. Additionally, the integration of the platform into the live-streaming supply chain constrains the manufacturer's ability to utilize the agency model. Consequently, the manufacturer is more inclined to opt for the self-implementation option in this case. Furthermore, in scenarios where the price is fixed, the self-implementation strategy outperforms the agency model, and the manufacturer should disclose additional production details in live-streaming sales. Notably, the self-implementation model results in a substantial consumer surplus when the price is fixed.

1.3 | Contribution statements and paper arrangements

In this study, we make three primary contributions. Firstly, we offer the first theoretical exploration, to the best of our knowledge, of how manufacturers disclose product information within various live-streaming sales models. Secondly, we present several counterintuitive findings. For instance, our results indicate that the streamer's cost for disclosing information exhibits a nonmonotonic impact on its profit under the agency model. Surprisingly, a higher cost has the potential to yield higher profits for the streamer. Furthermore, it is noteworthy to find that no single live-streaming sales model emerges as superior to all others. Thirdly, our theoretical findings enrich the existing literature on the operation of live-streaming sales. Some of our discoveries challenge conclusions drawn from prior research. For instance, while Hao and Yang (2022) posited that the agency model is not advisable for live-streaming supply chains, we demonstrate that although the agency model is not inherently superior, consumers can derive greater surplus from it.

The remainder of the study is structured as follows: To contextualize our work within existing literature and identify the gap in the research, we present a concise literature review in Section 2. Following this, we outline the research problem, develop preliminary models, and analyze them in Sections 3 and 4, respectively. In Section 5, we introduce additional models to further validate the robustness of our findings obtained from the preliminary models. Finally, we conclude the paper in Section 6, where we present managerial insights gleaned from our findings and offer recommendations for future research. In the appendix, we provide closed-form results of extended models and proof of all research findings.

2 | LITERATURE REVIEW

In the present era, with the continuous development and widespread adoption of internet technologies (Ma et al., 2023), live-streaming sales have emerged as a highly scrutinized domain within business operations (Liu et al., 2024; Xu et al., 2024). This part aims to provide a comprehensive review of three aspects: live-streaming sales operations, business models, and supply chain contracting and coordination, exploring their significance and impact in the commercial realm.

2.1 | Live-streaming sales operations

The retail sector has increasingly adopted the practice of selling products through live streaming sessions hosted by online celebrities (Wongkitrungrueng et al., 2020; Yu & Liu, 2023; Zhang et al., 2023;

Zhou et al., 2023). It is imperative for manufacturers or retailers to consider the adoption of live streaming as a sales channel (Liu et al., 2022; Lu et al., 2021; Zhang, Guo, & Wu, 2022). Zhang et al. (2022) investigated strategies for implementing live streaming sales and developed a supply chain model comprising a manufacturer, an online retail marketplace and platform, and a streamer. Their findings indicate that both the online retailer and the streamer can benefit from the implementation of live streaming as a sales channel. However, Wang and Zhang (2022) contend that the decision of whether a company initiates live-streaming sales and e-commerce hinges on consumers' inconvenience costs. Wang et al. (2022) investigated a multi-tier supply chain scenario where the manufacturer can distribute goods through an internet platform and a live-streaming e-commerce channel. They proposed that the manufacturer should select a streamer with a moderate number of followers and emphasized that an excessively high commission rate from the streamer is not viable. We challenge this conclusion by proposing a viable strategy to mitigate high commission rates.

Our research diverges from these studies by exploring whether the manufacturer should independently undertake live-streaming sales. We account for costs associated with live-streaming sales by incorporating the information disclosure costs of either the manufacturer or the streamer, instead of focusing solely on unit selling costs.

2.2 | Business models of live-streaming sales

Two distinct models of live-streaming sales exist: reselling and agency selling. Pan et al. (2022) introduced three essential parameters for modeling live-stream sales: the online influencer's (acting as the retailer) selling power, the added value attributed to live-streaming sales, and the inconvenience cost. This framework bears similarity to that of Wang and Zhang (2022). However, Pan et al. (2022) advocate for a single live-stream channel as preferable, contrary to the stance of Wang et al. (2022). Furthermore, Pan et al. (2022) revealed that a high streamer's selling capacity could potentially lead to a loss of profit, aligning with the findings of Wang et al. (2022) that a streamer with a large following might not necessarily benefit the manufacturer. Our study offers a distinct perspective by focusing on information disclosure rather than solely on the streamer's sales capability or inconvenience costs. While Ji et al. (2022) and Ji et al. (2023) concentrated on selecting the sales model for live-streaming sales, they primarily examined the price discount strategy. They proposed that the advent of live-streaming sales reduces the retailer's barriers to adopting the agency model. Our findings complement their research by asserting that a higher revenue sharing parameter prompts the manufacturer to adopt the agency model.

Both Yang et al. (2022) and Hao and Yang (2022) explored live-streaming sales formats within two distinct online retail modes: the marketplace and wholesale price modes. Hao and Yang (2022) specifically examined high and low pricing strategies, whereas Yang et al. (2022) focused on consumer returns stemming from influencer sales. The prevailing consensus suggests that the agency mode of online retail mitigates double marginalization and enhances the supply chain's members, including the online platform and the supplier, whereas the reselling mode fails to achieve these objectives. Interestingly, Hao and Yang (2022) showcased that the reselling mode is advantageous for both the platform and the supplier/manufacturer. Furthermore, both Yang et al. (2022) and Hao and Yang (2022) examined the hybrid mode of live-streaming sales. However, Yang et al. (2022) suggested that the hybrid model could yield higher profits for the manufacturer or retailer, excluding the streamer, in contrast to Hao and Yang's (2022) findings, which indicated that the hybrid model may be disadvantageous to the manufacturer or retailer but advantageous to the streamer.

Our study diverges from these two research endeavors by integrating the effect of live sales on consumer utility. We posit that live-streaming sales augment consumer utility, a notion supported by previous empirical investigations (Singh et al., 2018; Wongkitrungrueng et al., 2020). Additionally, while the aforementioned papers examined the sales model of reselling or agency with the retail platform addressing the issue, our focus lies on the manufacturer's independent decision to implement live-streaming sales.

2.3 | Live-streaming supply chain contracting and coordination

Another avenue of research in live-streaming sales operations focuses on supply chain contracting and coordination issues in live streaming. Liu and Liu (2021) investigated decision-making and cooperation within revenue-sharing agreements for live-streaming supply chains. They introduced a subsidy scheme aimed at incentivizing streamers to contribute additional efforts to increase internet traffic on the live streaming platform. Zhang and Wang (2023) devised an option contract for the supply chain involving online influencers, distinguishing their approach from that of Liu and Liu (2021) by considering the retailer's capital constraints. Meanwhile, introduced a bonus-driven mechanism to incentivize streamers to enhance performance. They argued that through meticulous design of remuneration schemes, live streaming platforms could eliminate underperforming streamers while attracting high-performing ones. Evaluating the value of collaborating with streamers (online celebrities), collaboration strategies, and pricing and stocking considerations, Liu and Wang (2023) concluded that if businesses are not overly confident in the success of their live-streaming sales, they should opt for a low-price strategy.

The studies discussed above provide a comprehensive examination of operational issues within the live-streaming supply chain. However, certain key aspects remain unexplored. For instance, the impact of platform commissions under various live-streaming sales models on pricing and disclosure decisions has not been adequately addressed. Our study contributes to filling this gap by demonstrating that platform commissions can constrain the manufacturer's options when considering the adoption of the agency model for live-streaming sales. Furthermore, we introduce a novel scenario where pricing is not a strategic operational decision but remains fixed, reflecting the firm's brand value. This real-world setting enriches the literature by incorporating fixed pricing considerations. Our findings suggest that when prices are fixed, the manufacturer should independently implement live-streaming sales.

2.4 | Summary of results comparison

Upon comparing our conclusions with those of most similar studies, several intriguing disparities and commonalities emerge.

Firstly, our analysis underscores the non-linear impact of information disclosure costs on the streamer's profits within the agency model, challenging conventional wisdom. In contrast, Hao and Yang (2022) and Wang et al. (2022) suggest a preference for resale by suppliers and advocate agency sale for platforms. This highlights differing perspectives on the optimal sales format. Secondly, we find that expanding the revenue-sharing parameter may not consistently benefit manufacturers. Zhang, Chen, and Liu (2022) assert that manufacturers' introduction of live streaming services consistently proves advantageous for e-commerce platform supply chains. This discrepancy underscores the complexity of revenue allocation dynamics in live-streaming sales. Thirdly, the involvement of platforms limits the manufacturer's ability to utilize the agency model, contrasting with Pan et al. (2022) and Liu and Wang (2023)'s discovery that a single live-stream channel can be optimal. This discrepancy suggests nuanced considerations regarding platform involvement and sales channel optimization.

Moreover, our observation of the non-monotonic relationship between the streamer's information disclosure cost and profit contradicts common intuition, while findings from Ji et al. (2023) and Wang and Zhang (2022) suggest that the incorporation of a live-streaming channel diminishes the barrier for retailers in choosing the agency selling format. These discrepancies underscore the multifaceted nature of information disclosure and its implications in live-streaming sales.

In conclusion, while our study sheds light on the nuanced dynamics of information disclosure and its impact on profitability within the agency model of live-streaming sales, it is evident that the field is rich with diverse perspectives and complexities that warrant further exploration.

3 | MODEL DEVELOPMENT

In this section, we formulate the operational dynamics of live-streaming sales supply chains, comprising a manufacturer and a live-streaming streamer. One of the sales models entails the manufacturer directly selling the product through self-implemented live-streaming sales at a price denoted as p^S. Under this mode of live-streaming sales, the manufacturer engages a streamer to conduct product sales and assumes the cost of disclosure. Another sales mode is agency sales, wherein the manufacturer and the streamer, known as the brand, establish a revenue-sharing arrangement. In this setup, the streamer is tasked with sales and disclosure responsibilities, while the manufacturer determines the price p^A. Under both sales modes, manufacturing costs and marketing costs are normalized to zero, allowing us to concentrate on the comparison of sales modes. Additionally, in the agency model, the manufacturer typically pays the streamer a fixed cost F, referred to as a pit fee in the live-streaming supply chain. Previous research has indicated that fixed costs minimally influence manufacturers' operational decisions (Liu et al., 2022). Consequently, we treat the manufacturer's fixed cost as a sunk cost and assume $F=0$ in this paper. Furthermore, to streamline our analysis of live-streaming sales, we initially restrict our consideration to a single livestream channel. We subsequently extend this assumption to encompass dual-channel operations, which better reflects real-world practices, to assess the robustness of the results in Section 5.3.

Consumers make unit purchases and aim to maximize their utility. Furthermore, all consumers perceive a uniform value v when purchasing the product, which is distributed between 0 and 1., i.e., $v \sim U[0,1]$ (Liu et al., 2023; Ma et al., 2022). A consumer is aware of their specific value, whereas the manufacturer and the streamer are only privy to the distribution of values among consumers. This assumption has been widely embraced in operations management research, as demonstrated by Ma et al. (2022) and Choi et al. (2020). The consumer's utility is $u=v-p+\alpha i$, where i is the information disclosure level, and α is the sensitivity coefficient of consumers to the information disclosure level. We posit that information disclosure leads to greater utility for the consumer. This is because consumers tend to perceive a higher value for a product when they have access to more information about it. This assumption aligns with earlier studies (Choi et al., 2020; Wang & Guo, 2023). Furthermore, information disclosure on social media also impacts consumers' purchase decisions (Choi, 2018) and fosters consumer trust (Singh et al., 2018; Wongkitrungrueng & Assarut, 2020), thereby enhancing consumers' utility. The consumer will make the purchase decision only when $u>0$, i.e., when $v>v_o=p-\alpha i$.

3.1 | Agency model

In this subsection, we delve into the agency model of live-streaming sales. In this model, the retail price is determined by the manufacturer, and the streamer, acting as the agency, conducts product sales to consumers. The sequence of events under this sales model unfolds as follows: Initially, the manufacturer and the streamer negotiate a revenue-sharing agreement whereby the streamer shares a portion of revenue $(1-s)$ with the manufacturer (Ha et al., 2022; Feng and Jin, 2022). The manufacturer determines the selling price, while the streamer decides the level of information disclosure. We adopt an exogenous revenue-sharing parameter, reflecting the observed reality where the streamer's percentage fee remains consistent across different manufacturers, and the streamer's commission on product sales remains fixed. This assumption is consistent with prior research (Hao & Tan, 2019; Xu et al., 2022).

According to the utility function, the demand for the product can be determined as follows:

$$D^A = \int_{v_0}^{1} (v - p + \alpha i) dv = 1 - p^A - \alpha i^A. \quad (1)$$

We assume a single consumer quantity in the model, consistent with prior studies (see Sun and Ji, 2022). Subsequently, the profits of the manufacturer and the streamer are expressed as follows:

$$\pi_M^A = p^A (1-s) D^A, \quad (2)$$

$$\pi_S^A = p^A s D^A - k {i^A}^2. \quad (3)$$

The manufacturer initially determines the price, followed by the streamer, acting as the retailer, deciding on the information disclosure level. By employing backward induction and solving the first-order conditions, we readily derive the optimal price of the product and the information disclosure level, as illustrated in the following.

Lemma 3.1. Under the agency model, the optimal price of the product is $p^{A^*} = \frac{k}{2k - a^2 s}$, the optimal information disclosure level is $i^{A^*} = \frac{as}{4k - 2a^2 s}$, and the optimal profits are $\pi_M^{A\,*} = \frac{k(1-s)}{4k - 2a^2 s}$ and $\pi_S^{A^*} = \frac{ks(4k - 3a^2 s)}{4(2k - a^2 s)^2}$, respectively.

See Appendix B for proof.

The aforementioned results illustrate the optimal operational strategies for the manufacturer and the streamer, aiming to maximize their respective profits. It is evident that their operational decisions are influenced by factors such as the revenue-sharing parameter, consumer sensitivity to information disclosure levels, and the cost associated with disclosing information.

For consumers, we calculate the consumer surplus. Following the approach of Luo and Choi (2022) and Siqin et al. (2022), we define consumer surplus as the difference between the maximum price that consumers are willing to pay and the actual price they pay. Therefore, the consumer surplus under the agency model can be expressed $CS^{A^*} = \int_{p^{A^*} - \alpha i^{A^*}}^{1} \left(v - p^{A^*} + \alpha i^{A^*}\right) dv = \frac{1}{8}$.

3.2 | Self-implement model

Here, we consider the scenario where the manufacturer implements live-streaming sales independently. In this model, the manufacturer engages a streamer to host live-streaming sales on a social media platform. The manufacturer determines not only the product's price but also the information disclosure level. The demand can be expressed as $D^S = 1 - p - \alpha i$. Similar to the agency model, we assume a single consumer quantity in the self-implement model. Then, the manufacturer's profit function can be expressed as follows:

$$\pi_M^S = p^S D^S - k {i^S}^2. \quad (5)$$

Solving the first-order conditions, we can easily derive the optimal retail price of the product, the information disclosure level, and the optimal profits for the manufacturer under the self-implement model, as follows:

Lemma 3.2. *Under the self-implement model, the optimal price is* $p^{S^*} = \frac{2k}{4k - a^2}$, *the optimal information disclosure level is* $i^{S^*} = \frac{a}{4k - a^2}$, *and the optimal manufacturer' profit is* $\pi_M^{S\,*} = \frac{k}{4k - a^2}$.

See Appendix B for proof.

The above results demonstrate the optimal operational strategies for the manufacturer under the self-implement model. For consumers, the consumer surplus under the self-implement model can be expressed as follows:

$$CS^{S^*} = \int_{p^{S^*} - \alpha i^{S^*}}^{1} \left(v - p^{S^*} + \alpha i^{S^*}\right) dv = \frac{2k^2}{(a^2 - 4k)^2}. \quad (6)$$

Up to this point, we have derived the operational decisions for the manufacturer and the streamer under the two sales models. Next, we will conduct sensitivity analysis and compare the results to gain deeper insights.

4 | ANALYSIS AND COMPARISON

Now, our focus shifts to the results under the agency sales and self-implement scenarios. Through a sensitivity analysis of key parameters (refer to Table 1), we aim to gain a deeper understanding of how the operational strategies of the manufacturer and the streamer are influenced by these parameters. Furthermore, by comparing the results, we seek to derive insights regarding the selection of the sales model.

4.1 | Sensitivity analysis

To enhance clarity, we summarize the sensitivity analysis results in Table 1. The outcomes are as follows:

Proposition 4.1. *In the context of the agency model, the cost associated with information disclosure for the streamer exhibits a non-monotonic effect on its profitability, whereas in the self-implement model, this effect follows a monotonic pattern. Specifically,*

i. Under the agency model,
   a. p^{A^*} and i^{A^*} decrease with k and increase with α and s;

TABLE 1 The results of sensitivity analysis under agency and self-implement models.

	Agency				Self		
	p^{A*}	i^{A*}	π_M^{A*}	π_R^{A*}	p^{S*}	i^{S*}	π_M^{S*}
$k\uparrow$	$\downarrow$	$\downarrow$	$\downarrow$	$\uparrow$ when $\underline{k}_2 < k < \bar{k}^2$ $\downarrow$ when $k > \bar{k}^2$	$\downarrow$	$\downarrow$	$\downarrow$
$\alpha\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$	$\downarrow$ when $\underline{k}_2 < k < \bar{k}^2$ $\uparrow$ when $k > \bar{k}^2$	$\uparrow$	$\uparrow$	$\uparrow$
$s\uparrow$	$\uparrow$	$\uparrow$	$\uparrow$ when $\underline{k}_1 < k < \bar{k}^1$ $\downarrow$ when $k > \bar{k}^1$	$\uparrow$ when $k > \bar{k}^3$ $\downarrow$ when $\underline{k}_2 < k < \bar{k}^3$	–	–	–

b. π_M^{A*} decreases with k and increases with α. However, the impact of s on π_M^{A*} is an inverse U shape;

c. The impacts of k and s on π_R^{A*} is an inverse U shape, and the impact of α on π_R^{A*} is a U shape.

ii. Under the self-implement model, p^{S*}, i^{S*}, and π_M^{S*} decrease with k and increase with α.

See Appendix B for proof.

From Proposition 4.1, we observe a nonmonotonic relationship between the streamer's information disclosure cost and its profit under the agency model, which contrary to common intuition. Conventional wisdom suggests that higher costs lead to lower profits. However, we demonstrate that for moderate values of k, an increase in k actually yield higher profits for the streamer. This is attributed to the streamer's adoption of a high-price strategy in response to the rising k, consequently boosting margin profits and total revenues. Here, k represents the cost incurred by the streamer to disclose product information, with higher values indicating a greater expenditure to inform consumers about the product. In scenarios with manageable costs, i.e., a moderate k value, increased disclosure costs stimulate demand and profits. However, it is important to note that a higher k are detrimental to the manufacturer. Hence, the manufacturer should assist the streamer in minimizing the cost of information disclosure.

Furthermore, in cases where consumers exhibit heightened sensitivity to information disclosure (i.e., a higher α), the manufacturer stands to gain higher profits, albeit at times to the detriment of the streamer. Specifically, when the streamer faces significant costs associated with information disclosure, increased consumer sensitivity can actually be advantageous for the streamer.

Interestingly, we reveal that an expanded value of s does not inherently favor the manufacturer. A heightened s signifies that the manufacturer can garner greater revenue from the streamer, consequently leading to diminished profits for the streamer. In such circumstances, the streamer lacks motivation to increase product sales as it does not yield proportionate benefits, particularly when information disclosure entails significant costs. Therefore, while an increased s results in higher prices, it is not advisable for the manufacturer to allocate more of the streamer's earnings.

Under the self-implement model, the manufacturer is responsible for directly disclosing information during live-streaming sales. Consequently, a higher k is undesirable. Furthermore, the manufacturer stands to gain from consumer responsiveness to information disclosure. This is attributed to the visual nature of live-streaming sales, which effectively inform consumers about products. Greater consumer interest in comprehensive product knowledge leads to a preference for purchasing products via live-streaming sales.

4.2 | Comparisons

In this subsection, we compare the optimal strategies and profits arising from the agency and self-implement models. The primary distinction between these models lies in the entity responsible for determining the level of information disclosure. Given that the information disclosure level directly impacts consumers' purchasing decisions, we delve into the variation in disclosure levels to ascertain whether the manufacturer or the streamer is better suited for disclosing information in the live-streaming supply chain. Our analysis has demonstrated that the manufacturer sets distinct prices under various sales models, prompting an exploration into the underlying reasons for this discrepancy. Through a comparison of the optimal outcomes, we aim to elucidate the rationale behind these differences:

Proposition 4.2. *In contrast to the self-implementation model, the agency model does not demonstrate unequivocal superiority. Specifically,*

i. $p^{A*} > p^{S*}$ when $s > \tilde{s}_1$; and

ii. $i^{A*} > i^{S*}$ when $s > \tilde{s}_2$; and

iii. $\pi_M^{A*} > \pi_M^{S*}$ when $s > \tilde{s}_3$; and

iv. $CS^{A*} > CS^{S*}$,

where $\tilde{s}_1 = \frac{1}{2}$, $\tilde{s}_2 = \frac{4k}{4k+a^2}$, and $\tilde{s}_3 = \frac{a^2}{3a^2-4k}$.

See Appendix B for proof.

Proposition 4.2 illustrates the manufacturer's selection between the live-streaming sales models. Contrary to the self-implementation model, the agency model does not exhibit absolute superiority, as depicted in Figure 1. However, consumers can attain greater surplus through the agency model. This is attributed to the streamer's role in product sales within the live-streaming context. Positioned closer to the market and consumers, and equipped with superior sales skills, the streamer is more inclined to deliver additional surplus to consumers under the agency model.

The outcomes outlined in Proposition 4.2 are logical, as evidenced by the manufacturer's inclination towards the self-implement model when the streamer shares fewer revenues. Notably, we discover that in such scenarios, both the price and the extent of information disclosure are elevated, suggesting that the manufacturer can adopt a high-price strategy within the self-implemented live-streaming sales model. Furthermore, it becomes apparent that the manufacturer should amplify the disclosure of product information. This stems from the acknowledgment that, in live-streaming sales, the manufacturer lags behind the streamer in sales proficiency. Consequently, the manufacturer must attract a sufficient consumer base by providing comprehensive information, thereby augmenting revenues.

Comparing the three key thresholds, we have $\tilde{s}_1-\tilde{s}_2=\frac{a^2-4k}{2(a^2+4k)}<0$, $\tilde{s}_1-\tilde{s}_3=\frac{a^2-4k}{2(3a^2-4k)}<0$, and $\tilde{s}_2-\tilde{s}_3=-\frac{(a^2-4k)^2}{(3a^2-4k)(a^2+4k)}<0$, meaning that $\tilde{s}_1<\tilde{s}_2<\tilde{s}_3$. Hence, we discern that the widest feasible range for selecting the agency model and implementing the high-pricing strategy exists. When s is moderate, i.e., $\tilde{s}_1<s<\tilde{s}_2$, the manufacturer can elevate prices within the agency model, albeit without achieving higher profits. This finding implies that if the manufacturer is unable to escalate prices, the agency model of live-streaming sales presents itself as a promising option.

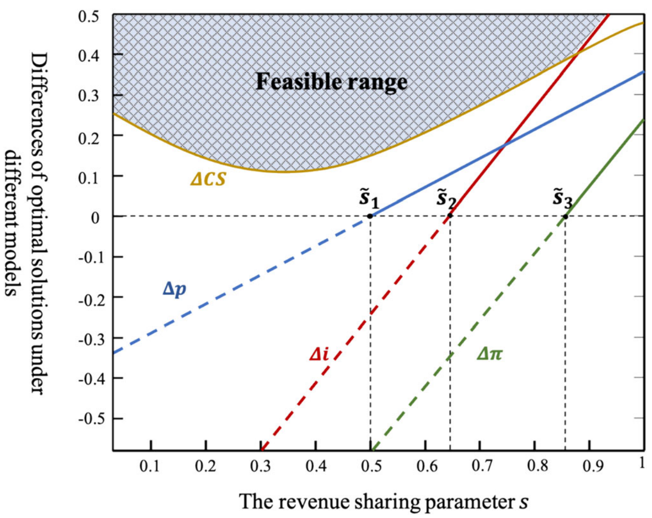

FIGURE 1 Illustration of the feasible range of the agency model.

5 | EXTENSIONS AND ROBUSTNESS CHECK

In this section, we delve into two alternative extensions. Firstly, we examine the live-streaming platform's involvement in supply chain operations under both the agency and self-implement models. Secondly, we assess the scenario where the product price remains fixed across both live-streaming sales models. The objective of this section is twofold: to scrutinize the robustness of our primary findings derived from the initial models and to generate supplementary management insights.

5.1 | Platform involvement

In practice, live-streaming sales are facilitated through social media platforms like TikTok. We now incorporate the presence of these platforms into our operations. The social media platform hosting live-streaming provides manufacturers or streamers with an online marketplace for product sales, along with essential technologies ensuring smooth viewing and purchasing experiences for consumers. Manufacturers or streamers must prepare for live-streaming sales, incurring additional operational expenses for each merchandise. Particularly under the agency model, the streamer earns a commission fee (i.e., s) but also bears the operational cost c (a unit service fee) charged by the live-streaming platform. Our subsequent analysis will delve into both live-streaming models separately. The main models and results of this extension are shown in Extension A in Appendix A.

Before proceeding to compare the optimal outcomes under the platform involvement model, we conduct a sensitivity analysis (presented in Table 2, and see Appendix B for proof). Our findings reveal that platform involvement does not significantly alter the results of the sensitivity analysis, thus affirming the conclusions drawn from the basic models.

TABLE 2 The results of sensitivity analysis under the platform involvement model.

	Agency				Self		
	p^{PA*}	i^{PA*}	π_M^{PA*}	π_R^{PA*}	p^{PS*}	i^{PS*}	π_M^{PS*}
$k\uparrow$	↓	↓	↓	↑ when $\underline{k}_4<k<\overline{k}^4$ ↓ when $k>\overline{k}^4$	↓	↓	↓
$a\uparrow$	↑	↑	↑	↓ when $k>\overline{k}^4$ ↑ when $\underline{k}_4<k<\overline{k}^4$	↑	↑	↑
$s\uparrow$	↑	↑	↑ when $\underline{k}_1<k<\overline{k}^1$ ↓ when $k>\overline{k}^1$	↑ when $k>\overline{k}^5$ ↓ when $k<\overline{k}^5$	–	–	–

Now, we compare the optimal solutions under the platform involvement model. We observe that the performance of the agency model remains inconclusive compared to the self-implement model, consistent with our findings from the preliminary models. Furthermore, we uncover additional intriguing insights within this extension, which are summarized in the subsequent results.

Proposition 5.1. *The platform's involvement restricts the scope within which the manufacturer can feasibly employ the agency model in live-streaming sales. Specifically,*

i. $p^{PA*} > p^{PS*}$ when $s > \tilde{s}_1^P$; and
ii. $i^{PA*} > i^{PS*}$ when $s > \tilde{s}_2^P$; and
iii. $\pi_M^{PA*} > \pi_M^{PS*}$ when $s > \tilde{s}_3^P$; and
iv. $CS^{PA*} < CS^{PS*}$; and
v. $c^{PA*} > c^{PS*}$,

where $\tilde{s}_1^P = \frac{a^2k-8k^2}{a^2(a^2-6k)} =$, $\tilde{s}_2^P = \frac{8(a^2k-2k^2)}{a^2(5a^2-12k)}$, and $\tilde{s}_2^P = \frac{-a^2+8k}{a^2+4k}$.

See Appendix B for proof.

Proposition 5.1 validates the robustness of several results obtained in the basic models. Intriguingly, we discover that consumers can attain greater surplus under the self-implement model when considering platform involvement, a deviation from the findings in the basic models, as illustrated in Figure 2. Under the agency model with platform involvement, the platform appropriates the streamer's profit, compelling the streamer to transfer the cost burden to consumers to avoid losses, consequently reducing consumer surplus. However, why do consumers experience higher surplus under the self-implement model with platform involvement? This phenomenon arises from the manufacturer's enhanced bargaining power relative to the streamer, rendering it less vulnerable to the platform's influence. Consequently, the manufacturer is inclined to offer consumers greater surplus.

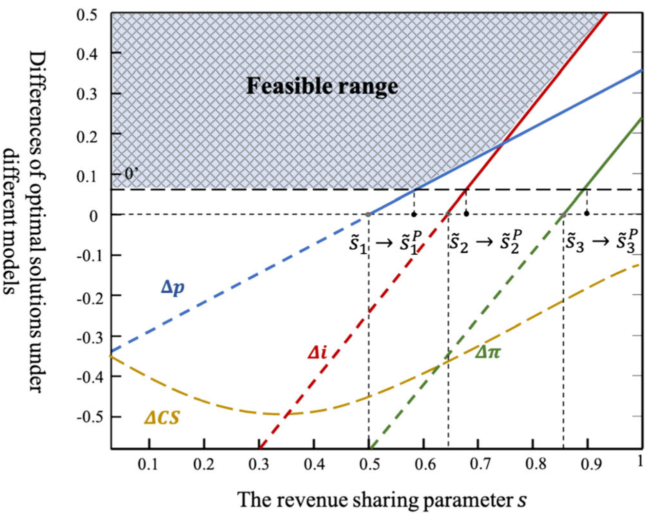

FIGURE 2 Illustration of the feasible range of the agency model under the platform involvement case.

Furthermore, we observe that $\tilde{s}_1^P > \tilde{s}_1$, $\tilde{s}_2^P > \tilde{s}_2$, and $\tilde{s}_3^P > \tilde{s}_3$, indicating that the platform constricts the feasible range for the manufacturer to adopt the agency model of live-streaming sales. This outcome suggests that if the manufacturer cannot secure a substantial revenue share, opting for the self-implement model is advisable. Additionally, there is a higher likelihood that the manufacturer will prefer the self-implement model when the platform is involved in the live-streaming supply chain. This trend stems from the inherent challenge for the streamer to compete effectively against the platform. The streamer essentially functions as a newcomer retailer within the market, whereas the platform possesses greater market power. Even prominent streamers are more inclined to negotiate with the manufacturer than with the platform, given the latter's control over traffic.

5.2 | Fixed price

Some manufacturers delegate the determination of product pricing to strategic decision-making levels, as noted by Choi and Ouyang (2021). This is particularly relevant for luxury goods in the fashion industry, where the retail price reflects the brand value of either the manufacturer or the retailer (Chiu et al., 2018). The main models and results of this extension are shown in Extension B in Appendix A.

Next, we conduct a sensitivity analysis of the optimal solution under the fixed price model (detailed results provided in Table 3, and see Appendix B for proof). Our analysis demonstrates that the influences of the information disclosure cost, revenue sharing factor, and consumer sensitivity to information on i^{FA*} remain consistent with those observed in the basic models. Additionally, we uncover that the fixed price dictates the impact of s on both the manufacturer's and the streamer's margins.

Here, we compare the optimal solutions under the fixed price model to affirm the robustness of the results obtained from the basic models. Interestingly, we encounter some outcomes that challenge our primary findings.

Proposition 5.2. *When the price is fixed, the self-implement model outperforms the agency model, i.e.,* $i^{FA*} < i^{FS*}$, $\pi_M^{FA*} < \pi_M^{FS*}$, *and* $CS^{FA*} < CS^{FS*}$.

TABLE 3 The results of sensitivity analysis under the fixed price model.

	Agency			Self	
	i^{FA*}	π_M^{FA*}	π_R^{FA*}	i^{FS*}	π_M^{FS*}
$k\uparrow$	↓	↓	↓	↓	↓
$a\uparrow$	↑	↑	↑	↑	↑
$s\uparrow$	↑	↑ when $0 < p < \overline{p}_1$ ↓ when $p > \overline{p}_1$	↑ when $0 < p < \overline{p}_2$ ↓ when $p > \overline{p}_2$	–	–

See Appendix B for proof.

The outcomes presented in Proposition 5.2 are intriguing. Under the scenario where the price is fixed, we observe that the self-implement model outperforms the agency model, as depicted in Figure 3. As previously discussed, a fixed price is typically associated with products boasting high brand value. In such instances, it is imperative for the manufacturer to exert full control over the sales channel. Consequently, the manufacturer is unlikely to opt for the streamer as the retailer to sell its products.

With a fixed price, it becomes imperative for the manufacturer to disclose more product information during live-streaming sales. This necessity arises from the fact that the fixed price lacks the capacity to influence demand or act as a quality reference, as it primarily represents the brand's reputation. Consequently, the manufacturer must enable consumers to access comprehensive product information through disclosures in live-streaming sales. Moreover, in the context of a fixed price, consumer surplus is augmented when the manufacturer opts for the self-implement model.

5.3 | Dual channel operations

In this subsection, we examine a more realistic scenario where the manufacturer operates via dual channels. This implies that the manufacturer not only establishes a live-streaming sales channel but also manages its own conventional online store on the online retail platform. The consumer's utility is $u_l = v - p_l + \alpha i$ under the live-streaming channel. The consumer's utility is $u_r = \beta v - p_r$ under the regular online channel. If $u_r \geq u_l$ and $u_r > 0$, consumers will purchase online; otherwise, if $u_l > u_r$, consumers will purchase in the live-streaming channel. As a result, we find the indifferent point $\tilde{v} = \frac{p_l - p_r - \alpha i}{1 - \beta}$, where consumers are indifferent in purchasing in each channel. The main models and results of this extension are shown in Extension C in Appendix A.

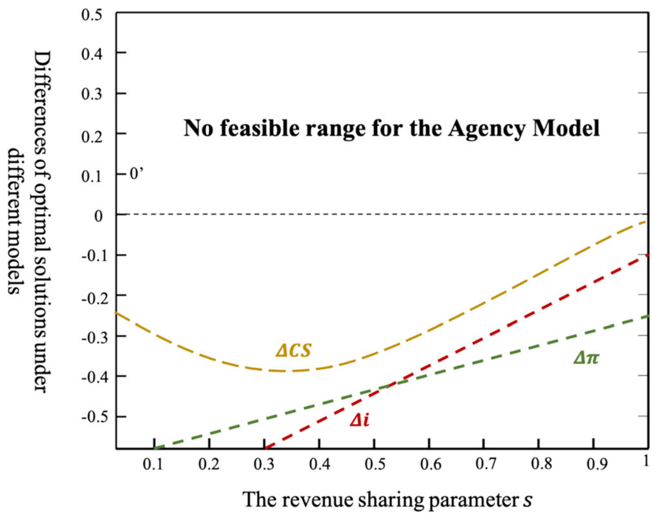

FIGURE 3 Illustration of the feasible range of the agency model under the fixed price case.

By comparing the outcomes presented in Lemmas C.1 and C.2, we identify scenarios where the agency model outperforms the self-implement model, as illustrated in Figures 4 and 5. These results substantiate the resilience of the findings derived from the basic models.

The manufacturer achieves a higher profit through the agency model compared to the self-implement model. This indicates that the manufacturer is motivated to delegate agents to undertake live marketing, thus saving costs and time, while sharing the sales revenue generated by the agents. From Figures 4 and 5, it is evident that as

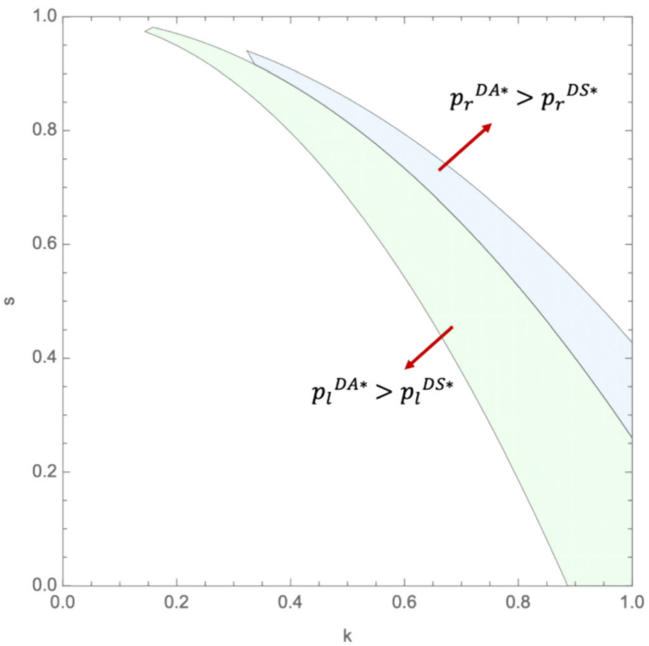

FIGURE 4 Results of comparing the optimal prices.

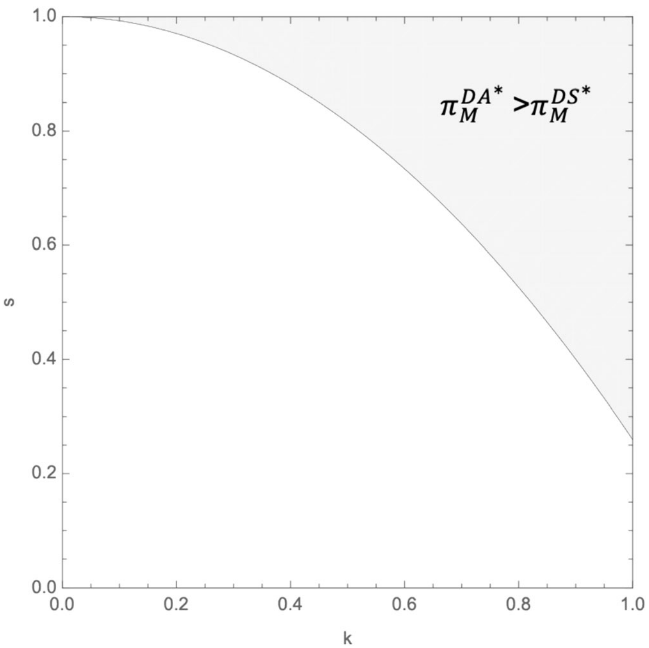

FIGURE 5 Results of comparing the optimal profit.

TABLE 4 Managerial insights remarks.

Research question	Conclusion and managerial insight
(i) How do brands determine disclosure and pricing decisions under different live-streaming sales models?	• Increases in the price reflect the heightened challenge associated with disclosing information. Adopting such a high-priced tactic enables the streamer to augment overall earnings by bolstering margin profits. • The manufacturer should assist the streamer in minimizing the cost of information disclosure. • If this cost for the streamer is substantial, then consumer sensitivity to it will prove advantageous for the streamer. • Although a higher revenue sharing parameter results in an elevated price, it would not be wise for the manufacturer to allocate a larger percentage of the streamer's revenues.
(ii) How do brands choose different live sales models, the Agency or the Self-implement models?	• In live-streaming sales, the streamer assumes responsibility for product sales under the agency model. It becomes imperative for the streamer to engage closely with consumers and enhance its sales capabilities. • Under the self-implement model, the manufacturer must be more forthcoming with product details. This necessity arises from the manufacturer's deficiency in sales expertise compared to the streamer, compelling them to disclose more information to attract an adequate customer base. • If the manufacturer cannot increase the price, the agency model of live-streaming sales can serve as an excellent alternative.
(iii) How does the answer to the above question change when considering the live-streaming platforms involved in the competition?	• When the platform is involved in the live-streaming supply chain, the streamer cannot pass operational costs onto consumers, leading to a reduction in consumer surplus. • The manufacturer possesses greater leverage and autonomy from the streaming service platform compared to the streamer. Consequently, the manufacturer can afford consumers a greater surplus. • The manufacturer should opt for the self-implementation strategy if it does not anticipate a substantial revenue share from the platform's involvement in the live-streaming supply chain.
(iv) If the price of the product is fixed, how should brands disclose the product in the live-streaming sales, and how should they choose the live-streaming sales model?	• When the price is fixed, the manufacturer must retain full control over the distribution channels, making the streamer an unsuitable choice as the retailer. • The manufacturer must furnish customers with ample information about the product during live-streaming sales. • By adopting live-streaming sales methods, the manufacturer can market premium and high-end products alongside standard ones.

the manufacturer's cost of disclosing product information increases, the blue area also expands, signifying an increasing advantage of the agency model. This is attributed to the higher quality of live sales resulting from the heightened cost of disclosing product information by the manufacturer, which facilitates easier consumer attraction and, consequently, enables the manufacturer to garner greater profits through revenue sharing.

These results can be attributed to several factors. Firstly, live-streaming sales involve key participants such as manufacturers, retailers, and agents, whose interactions are characterized by a combination of cooperation and competition, with each aiming to maximize their own profits and benefits. Secondly, the primary determinants influencing live-streaming sales are the cost of disclosing product information and the profit-sharing coefficient, which define the contractual relationship between the manufacturer and the retailer. Therefore, it is imperative for both the manufacturer and the retailer to judiciously determine the cost of disclosing product information and the profit-sharing coefficient based on product characteristics and market demand. This ensures a balance of interests and risks between the parties involved, incentivizes the retailer to select the most suitable live-streaming mode, and enhances the efficiency and effectiveness of product sales.

6 | CONCLUSIONS

6.1 | Conclusion remarks

Live-streaming sales represent an efficient advertising method wherein companies showcase and offer their products to consumers through real-time digital purchasing experiences. This approach provides brands with an excellent opportunity to bolster their connection with consumers, extend their reach through influencer collaborations, and potentially enhance revenues. However, brands encounter various challenges when implementing live-streaming sales. For instance, inadequate consumer satisfaction with product information disclosure in live-streaming sales poses hurdles for brands in gaining a competitive edge. Moreover, determining the appropriate live-streaming sales model presents a challenge for brands, as both the agency and self-implement models offer distinct advantages. Therefore, our research delves into both models of live-streaming sales, developing models to analyze product information strategies under each model and examining the brand's optimal solutions concerning pricing and model selection. Through this investigation, we uncover several intriguing findings and managerial insights:

In the basic setting, we discover that the cost of information disclosure in live-streaming sales does not always have a detrimental effect on the live-streaming supply chain. Particularly under the agency model, a moderate cost has the capacity to yield higher profits for the streamer. This phenomenon arises from the streamer's ability to capitalize on consumer sensitivity to information disclosure. Surprisingly, under the self-implement model, a more generous revenue-sharing clause does not guarantee profitability for the manufacturer. By contrasting the equilibrium outcomes of the models across various modes of live-streaming sales, we can determine whether and when implementing one of the live-streaming sales models is advantageous. Our findings suggest that the agency model is not inherently superior to the self-implement model. However, consumers tend to prefer the agency model because it allows them to attain more surplus compared to the self-implement model. Additionally, if the manufacturer opts for the self-implement model of live-streaming sales, it can set higher prices and maintain greater transparency regarding its products.

Our comprehensive analysis encompasses three extended scenarios: the platform involvement model, the fixed price model, and the dual-channel operations model. Comparing the results of these extensions with those derived from the main model, we observe that while platform participation reduces consumer surplus in both live-streaming sales models, this negative impact is more pronounced in the agency model. Moreover, the platform diminishes the manufacturer's opportunity to transition live-streaming sales to the agency model. In cases where the price is predetermined, such as in the fixed price model, the self-implement model outperforms the agency model. Additionally, the manufacturer should prioritize disclosing more product information in live-streaming sales to maximize effectiveness.

6.2 | Managerial insights

Certainly, our results offer valuable insights for the management of the live-streaming supply chain, benefiting both brands (manufacturers) and streamers. These findings provide guidance on optimal information disclosure strategies and sales models. Rooted in rigorous theoretical analysis, our research addresses practical challenges encountered in the operational management of live-streaming supply chains. As a summary, Table 4 outlines the management insights gleaned from this study, aiding stakeholders in navigating and optimizing their live-streaming sales strategies.

6.3 | Future research

Future research will explore the demand expansion or cannibalization effect of live-streaming sales. Currently, it remains unclear how live streaming impacts the demand for manufacturers or brands, particularly given the low consumer satisfaction often observed in practice. Furthermore, the existing literature seldom delves into omnichannel strategies, wherein brands simultaneously operate direct online sales channels, agency sales channels, and live-streaming sales channels. Lastly, investigating metaverse-based live-streaming sales strategies presents an intriguing avenue. Many brands are leveraging virtual streamers to market products, yet the impact of adopting virtual streamers on live-streaming supply chain operations remains unclear.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

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ENDNOTES

[1] [Access online] Available online: https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/its-showtime-how-live-commerce-is-transforming-the-shopping-experience. March 3, 2023.

[2] [Access online]: https://www.cca.org.cn/jmxf/detail/29533.html. March 3, 2023.

REFERENCES

Bawack, R. E., Bonhoure, E., Kamdjoug, J. R. K., & Giannakis, M. (2023). How social media live streams affect online buyers: A uses and gratifications perspective. *International Journal of Information Management*, *70*, 102621. https://doi.org/10.1016/j.ijinfomgt.2023.102621

Bender, M., Gal-Or, E., & Geylani, T. (2022). The emergence of streaming and its impact on pricing and product strategies of content providers. *Managerial and Decision Economics*, *43*(6), 2148–2171. https://doi.org/10.1002/mde.3515

Chiu, C. H., Choi, T. M., Dai, X., Shen, B., & Zheng, J. H. (2018). Optimal advertising budget allocation in luxury fashion markets with social influences: A mean-variance analysis. *Production and Operations Management*, *27*(8), 1611–1629. https://doi.org/10.1111/poms.12886

Choi, T. M. (2018). Incorporating social media observations and bounded rationality into fashion quick response supply chains in the big data era. *Transportation Research Part E: Logistics and Transportation Review*, *114*, 386–397. https://doi.org/10.1016/j.tre.2016.11.006

Choi, T. M., & Ouyang, X. (2021). Initial coin offerings for blockchain based product provenance authentication platforms. *International Journal of Production Economics*, *233*, 107995.

Choi, T. M., Feng, L., & Li, R. (2020). Information disclosure structure in supply chains with rental service platforms in the blockchain technology era. *International Journal of Production Economics*, *221*, 107473. https://doi.org/10.1016/j.ijpe.2019.08.008

Feng, L., & Jin, M. (2022). Platform vs. manufacturer: Who should implement innovation in e-commerce supply chains? *Transportation Research Part E: Logistics and Transportation Review*, *166*, 102858. https://doi.org/10.1016/j.tre.2022.102858

Ha, A. Y., Tong, S., & Wang, Y. (2022). Channel structures of online retail platforms. *Manufacturing & Service Operations Management*, *24*(3), 1547–1561. https://doi.org/10.1287/msom.2021.1011

Hao, C., & Yang, L. (2022). Resale or agency sale? Equilibrium analysis on the role of live-streaming selling. *European Journal of Operational Research*, *307*(3), 1117–1134. https://doi.org/10.1016/j.ejor.2022.09.021

Hao, L., & Tan, Y. (2019). Who wants consumers to be informed? Facilitating information disclosure in a distribution channel. *Information Systems Research*, *30*(1), 34–49. https://doi.org/10.1287/isre.2017.0770

Ji, G., Fu, T., Choi, T. M., Kumar, A., & Tan, K. H. (2022). Price and quality strategy in live-streaming e-commerce with consumers' social interaction and celebrity sales agents. *IEEE Transactions on Engineering Management*. Available online: https://doi.org/10.1109/TEM.2022.3227106

Ji, G., Fu, T., & Li, S. (2023). Optimal selling format considering price discount strategy in live-streaming commerce. *European Journal of Operational Research*. *309*, 529–544. Available online: https://doi.org/10.1016/j.ejor.2023.01.034

Kang, K., Lu, J., Guo, L., & Li, W. (2021). The dynamic effect of interactivity on customer engagement behavior through tie strength: Evidence from live streaming commerce platforms. *International Journal of Information Management*, *56*, 102251. https://doi.org/10.1016/j.ijinfomgt.2020.102251

Liu, B., & Wang, W. (2023). Live commerce retailing with online influencers: Two business models. *International Journal of Production Economics*, *255*, 108715. https://doi.org/10.1016/j.ijpe.2022.108715

Liu, H., & Liu, S. (2021). Optimal decisions and coordination of live-streaming selling under revenue-sharing contracts. *Managerial and Decision Economics*, *42*, 1022–1036. https://doi.org/10.1002/mde.3289

Liu, S., Hua, G., Cheng, T. C. 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. Available online: https://doi.org/10.1109/TEM.2022.3144482

Liu, S. S., Hua, G., Ma, B. J., & Cheng, T. C. E. (2023). Competition between green and non-green products in the blockchain era. *International Journal of Production Economics*, *264*, 108970.

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.

Lu, S., Yao, D., Chen, X., & Grewal, R. (2021). Do larger audiences generate greater revenues under pay what you want? Evidence from a live-streaming platform. *Marketing Science*, *40*(5), 964–984. https://doi.org/10.1287/mksc.2021.1292

Luo, S., & Choi, T. M. (2022). E-commerce supply chains with considerations of cyber-security: Should governments play a role? *Production and Operations Management*, *31*(5), 2107–2126. https://doi.org/10.1111/poms.13666

Ma, B. J., Kuo, Y. H., Jiang, Y., & Huang, G. Q. (2023). RubikCell: Toward robotic cellular warehousing systems for e-commerce logistics. *IEEE Transactions on Engineering Management*, *71*, 9270–9285. Available online: https://doi.org/10.1109/TEM.2023.3327069

Ma, B.J., Zhang, Y., Liu, S., Jiang, Y., He, Y., & Yan, K., (2022). Operational strategies for IoT-enabled brick-and-mortar retailers in a competitive market. *Computers & Industrial Engineering*, *173*, 180665. https://doi.org/10.1016/j.cie.2022.108665

Ma, B. J., Zhang, Y., Liu, S., Jiang, Y., He, Y., & Yan, K. (2022). Operational strategies for IoT-enabled Brick-and-Mortar retailers in a competitive market. *Computers & Industrial Engineering*, *173*, 108665.

Pan, R., Feng, J., & Zhao, Z. (2022). Fly with the wings of live-stream selling: Channel strategies with/without switching demand. *Production and Operations Management*, *31*, 3387–3399. https://doi.org/10.1111/poms.13784

Popescu, D. G., & Crama, P. (2016). Ad revenue optimization in live broadcasting. *Management Science*, *62*(4), 1145–1164. https://doi.org/10.1287/mnsc.2015.2185

Singh, A., Shukla, N., & Mishra, N. (2018). Social media data analytics to improve supply chain management in food industries. *Transportation Research Part E: Logistics and Transportation Review*, *114*, 398–415. https://doi.org/10.1016/j.tre.2017.05.008

Siqin, T., Choi, T. M., & Chung, S. H. (2022). Optimal E-tailing channel structure and service contracting in the platform era. *Transportation Research Part E: Logistics and Transportation Review*, *160*, 102614. https://doi.org/10.1016/j.tre.2022.102614

Sun, C., & Ji, Y. (2022). For better or for worse: Impacts of IoT technology in e-commerce channel. *Production and Operations Management*, *31*(3), 1353–1371. https://doi.org/10.1111/poms.13615

Wang, J., & Zhang, X. (2022). The value of influencer channel in an emerging live-streaming e-commerce model. *Journal of the Operational Research Society*, *74*(1), 112–124. https://doi.org/10.1080/01605682.2022.2027825

Wang, Q., Zhao, N., & Ji, X. (2022). Reselling or agency selling? The strategic role of live-streaming commerce in distribution contract selection. *Electronic Commerce Research*. Available online: https://doi.org/10.1007/s10660-022-09581-5

Wang, S., & Guo, X. (2023). Strategic cooperation of live-stream platform in e-commerce. *Managerial and Decision Economics*, *44*(7), 4201–4227. https://doi.org/10.1002/mde.3942

Wongkitrungrueng, A., & Assarut, N. (2020). The role of live-streaming in building consumer trust and engagement with social commerce sellers. *Journal of Business Research*, *117*, 543–556. https://doi.org/10.1016/j.jbusres.2018.08.032

Wongkitrungrueng, A., Dehouche, N., & Assarut, N. (2020). Live-streaming commerce from the sellers' perspective: Implications for online relationship marketing. *Journal of Marketing Management*, *36*(5–6), 488–518. https://doi.org/10.1080/0267257X.2020.1748895

Wu, G., Yang, W., Hou, X., & Tian, Y. (2023). Agri-food supply chain under live streaming and government subsidies: Strategy selection of subsidy recipients and sales agreements. *Computers & Industrial Engineering*, *185*, 109647. https://doi.org/10.1016/j.cie.2023.109647

Xie, C., Yu, J., Huang, S. S., & Zhang, J. (2022). Tourism e-commerce live-streaming: Identifying and testing a value-based marketing framework from the live streamer perspective. *Tourism Management*, *91*, 104513. https://doi.org/10.1016/j.tourman.2022.104513

Xu, X., Wang, Y., Cheng, T. C. E., & Choi, T. M. (2024). Should Live Broadcasting Platforms Adopt Artificial Intelligence? A Sales Effort Perspective. *European Journal of Operational Research*, *318*(3), 979-999.

Xu, X., Yan, L., & Choi, T. M. (2022). Platform operations with consumer returns windows: Reselling mode versus marketplace mode. *IEEE Transactions on Engineering Management*. Available online: https://doi.org/10.1109/TEM.2022.3201275

Yang, L., Zheng, C., & Hao, C. (2022). Optimal platform sales mode in live-streaming commerce supply chains. *Electronic Commerce Research*. Available online: https://doi.org/10.1007/s10660-022-09587-z

Yu, Y., & Liu, Y. (2023). Fly or fall with the wings of live streamers? Quality signaling and platform governance in live streaming commerce. *Managerial and Decision Economics*, *45*, 1547–1556. Available online: https://doi.org/10.1002/mde.4094

Zhang, T., Guo, X., & Wu, T. (2022). An analysis of cross-channel return processing with return-freight insurance for live-streaming platforms. *Computers & Industrial Engineering*, *174*, 108805. https://doi.org/10.1016/j.cie.2022.108805

Zhang, X., Chen, H., & Liu, Z. (2022). Operation strategy in an E-commerce platform supply chain: Whether and how to introduce live-streaming services? *International Transactions in Operational Research*, *31*, 1093–1121. Available online: https://doi.org/10.1111/itor.13186

Zhang, Z., Chen, Z., Wan, M., & Zhang, Z. (2023). Dynamic quality management of live streaming e-commerce supply chain considering streamer type. *Computers & Industrial Engineering*, *182*, 109357. https://doi.org/10.1016/j.cie.2023.109357

Zhang, Z., & Wang, H. (2023). Optimal contract design for live streaming platforms under dual asymmetric information considering corporate social responsibility. *Managerial and Decision Economics*. Available online: https://doi.org/10.1002/mde.4094

Zhao, K., Hu, Y., Hong, Y., & Westland, J. C. (2019). Understanding characteristics of popular streamers on live streaming platforms: Evidence from Twitch. tv. *Journal of the Association for Information Systems*, *22*(4), 1076–1098. https://doi.org/10.17705/1jais.00689

Zhou, N., Jia, K., & Song, H. (2023). Design of live broadcast service outsourcing contract considering risk aversion and financial constraints. *Managerial and Decision Economics*, *44*(2), 848–857. https://doi.org/10.1002/mde.3716

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APPENDIX A: EXTENDED MODELS

Extension A: Platform involvement

In this subsection, we follow the basic models to explore the scenario where the platform is involved under the agency and self-implement models.

A.1 | Agency model

Under the agency model with platform involvement, the live-streaming platform first determines the unit service charge, followed by the streamer deciding the information disclosure level, and finally, the manufacturer setting the price of the product. The streamer pays the unit service fee to the live-streaming platform, and the manufacturer and the streamer share the revenue through the revenue-sharing contract, mirroring the setup in the basic model. It is important to note that we assume the operational cost for the manufacturer is a sunk cost and normalize it to zero. The demand function under the agency model with platform involvement remains the same as that under the basic model. The profit functions are as follows:

$$\pi_M^{PA} = p^{PA}(1-s)D^{PA}, \tag{A1}$$

$$\pi_S^{PA} = \left(p^{PA} - c^{PA}\right)sD^{PA} - ki^{PA^2}, \tag{A2}$$

$$\pi_{LP}^{PA} = c^{PA}D^{PA}. \tag{A3}$$

Using backward induction and solving the first-order conditions, we derive the optimal solutions as follows:

Lemma A.1. Under the agency model with platform involvement, the optimal price of the product is $p^{PA^*} = \frac{k}{2(2k-a^2s)}$, the optimal information disclosure level is $i^{PA^*} = \frac{4k-3a^2s}{4a(2k-a^2s)}$, and the optimal unit service fee is $c^{PA^*} = \frac{k}{a^2s}$. The optimal profits are $\pi_M^{PA^*} = \frac{k(1-s)}{8(2k-a^2s)}$, $\pi_S^{PA^*} = \frac{k\left(8k-5a^2s\right)\left(4k-3a^2s\right)}{16a^2(2k-a^2s)^2}$, and $\pi_{LP}^{PA^*} = \frac{k}{4a^2s}$, respectively.

In Lemma A.1, we derive the optimal solutions in the live-streaming supply chain. We can also calculate the consumer surplus as follows:

$$CS^{PA^*} = \int_{p^{PA^*}-ai^{PA^*}}^{1} \left(v - p^{PA^*} + ai^{PA^*}\right)dv = \frac{1}{32}. \tag{10}$$

It is straightforward to know that $CS^{PA^*} < CS^{A^*}$, meaning that consumers will suffer from platform involvement. This is because the streamer passes on operating costs to consumers, leading to a decreased consumer surplus.

A.2 Self-implement model

Under the self-implement model, the live-streaming platform decides the unit service fee first, following that the manufacturer announces the price of the product. Then, we derive the profit functions as follows:

$$\pi_M^{PS} = \left(p^{PS} - c^{PS}\right)D^{PS} - ki^{PS^2}, \tag{A4}$$

$$\pi_{LP}^{PS} = c^{PS}D^{PS}. \tag{A5}$$

Similarly, we can derive the optimal solutions, as shown in the following results.

Lemma A.2. Under the self-implement model with platform implementation, the optimal price of the product is $p^{PS^*} = \frac{6k-a^2}{2(4k-a^2)}$, the optimal information disclosure level is $i^{PS^*} = \frac{a}{2(4k-a^2)}$, and the optimal unit service fee is $c^{PS^*} = \frac{1}{2}$. The optimal profits are $\pi_M^{PS^*} = \frac{k}{4(4k-a^2)}$ and $\pi_{LP}^{PS^*} = \frac{k}{2(4k-a^2)}$, respectively.

Lemma A.2 shows the optimal solutions for the live-streaming supply chain under the self-implement model with platform involvement. For the consumer surplus, we have

$$CS^{PS^*} = \int_{p^{PS^*}-ai^{PS^*}}^{1} \left(v - p^{PS^*} + ai^{PS^*}\right)dv = \frac{k^2}{2(a^2-4k)^2}. \tag{A6}$$

Meanwhile, it is easy to see that $CS^{PS^*} < CS^{S^*}$. Thus, we know that platform involvement decreases consumer surplus under both live-streaming sales models. Both the manufacturer and the streamer will pass on the extra costs to consumers. Although consumers can understand the products more clearly by participating in live-streaming sales, their surplus has decreased.

Extension B: Fixed price

In this subsection, we follow the basic models to explore the scenario where the price is predetermined and given exogenously under the agency and self-implement models.

B.1 Agency model

Under the agency model with a fixed price, only the streamer of the live-streaming platform determines the information disclosure level. Thus, the profit functions are as follows:

$$\pi_M^{FA} = p^{FA}(1-s)D^{FA}, \tag{B1}$$

$$\pi_S^{FA} = p^{FA}sD^{FA} - ki^{FA^2}. \tag{B2}$$

The sequence of events under the agency model with the fixed price is the same as our main models. Then, we can find the optimal outcomes using backward induction as follows:

Lemma B.1. Under the agency model with a fixed price, the optimal information disclosure level is $i^{FA^*} = \frac{aps}{2k}$. The optimal profits are $\pi_M^{FA^*} = \frac{p(1-s)\left(2k(1-p)+a^2ps\right)}{2k}$ and $\pi_S^{FA^*} = \frac{ps\left(4k(1-p)+a^2ps\right)}{4k}$, respectively.

Now, we focus on consumer surplus, and we have

$$CS^{FA^*} = \int_{p^{FA}-\alpha i^{FA^*}}^{1} \left(v - p^{FA} + \alpha i^{FA^*}\right) dv = \frac{\left(2k\left(1-p^{FA}\right) + a^2 ps\right)^2}{8k^2}. \quad \text{(B3)}$$

It is easy to find that $CS^{FA^*} < CS^{A^*}$ when $\frac{k}{2k-a^2 s} < p^{FA} < \frac{3k}{2k-a^2 s}$, meaning that the consumer will obtain less surplus when the fixed price is moderate. It is interesting to find that if the fixed piece is low, i.e., $p^{FA} < \frac{k}{2k-a^2 s}$, the consumers will have a higher surplus. This is because, under the fixed price model, the pricing decision is not an operational decision, while the price of the product represents the image or reputation of the brand, especially for high-end products. Consumers will obtain a better product at a lower price and therefore obtain more surplus. This result suggests that under live-streaming sales models, consumers can buy high-end products instead of just ordinary ones.

B.2 Self-implement model

Under the self-implement model with a fixed price, the manufacturer determines the information disclosure level. Then, we can know the profits for the manufacturer in Equation (B4).

$$\pi_M^{FS} = p^{FS} D^{FS} - k {i^{FS}}^2. \quad \text{(B4)}$$

Evidently, $\pi_M^{FS}\left(i^{FS}\right)$ is concave function regarding i^{FS}. Considering the first-order condition of Equation (B4), we can find the optimal information disclosure level. The results are shown in the following lemma.

Lemma B.2. *Under the self-implement model with a fixed price, the optimal information disclosure level is* $i^{FS^*} = \frac{ap}{2k}$; *the optimal profit is* $\pi_M^{FS^*} = \frac{p\left(2k(1-p)+a^2 p\right)}{4k}$.

For the consumer surplus, we have

$$CS^{FS^*} = \int_{p^{FS^*}-\alpha i^{FS^*}}^{1} \left(v - p^{FS^*} + \alpha i^{FS^*}\right) dv = \frac{\left(2k(1-p) + a^2 p\right)^2}{8k^2}. \quad \text{(B5)}$$

Comparing the result of consumer surplus under the basic model, we have $CS^{FS^*} < CS^{S^*}$ when $\frac{2k}{4k-a^2} < p^{FS} < \frac{2\left(6k^2-a^2 k\right)}{a^4-6a^2 k+8k^2}$, which is the same as the results of the agency model with a fixed price.

Extension C: Dual channel operations

C.1 Agency model

Under the agency model, the demands from the regular online and live-streaming channels are as follows, respectively.

$$D_r = \int_{\frac{p_r}{\beta}}^{\tilde{v}} (\beta v - p_r) dv, \quad \text{(C1)}$$

$$D_l = \int_{\tilde{v}}^{1} (v - p_l + \alpha i) dv. \quad \text{(C1)}$$

Then, the profits of the manufacturer and the streamer are as follows:

$$\pi_M^{DA} = p_r D_r + p_l (1-s) D_l, \quad \text{(C3)}$$

$$\pi_S^{DA} = p_l s D_l - k {i^A}^2. \quad \text{(C4)}$$

The manufacturer decides p_r and p_l simultaneously, and the streamer decides the information disclosure level. Using backward induction and solving the first-order conditions, we can easily derive the optimal prices of the product, and the information disclosure level, as shown in the following results.

Lemma C.1. Under the agency model with dual channel operations, the optimal prices of the product is ${p_l}^{DA*} = \frac{8k^2(1-s)(-1+\beta)^3}{s^2\left(a^2+2k(-1+\beta)\right)^2}$ and ${p_r}^{DA*} = \frac{2k(-1+s)\left(-a^2 s+2k(-2+s)(-1+\beta)\right)(-1+\beta)^2}{s^2\left(a^2+2k(-1+\beta)\right)^2}$, the optimal information disclosure level is $i^{DA^*} = \frac{4ak(-1+s)(-1+\beta)^2}{s\left(a^2+2k(-1+\beta)\right)^2}$, and the optimal profits are $\pi_M^{DA^*} = \frac{4k^2(-1+s)^2(-1+\beta)^3}{s^2\left(a^2+2k(-1+\beta)\right)^2}$ and $\pi_S^{DA^*} = \frac{8k^2(1-s)\left(a^4 s+4a^2 ks(-1+\beta)+4k^2(-1+\beta)^2\right)(-1+\beta)^3}{s^2\left(a^2+2k(-1+\beta)\right)^4}$, respectively.

C.2 Self-implement model

Under the self-implement model, we derive the demand and profit functions as follows:

$$D = p_r D_r + p_l D_l, \quad \text{(C5)}$$

$$\pi_M^{DA} = p_r D_r + p_l D_l - k {i^{DA}}^2. \quad \text{(C6)}$$

Under this model, the manufacturer first decides the information disclosure level, and the decides the price under each channel, respectively. Using backward induction and solving the first-order conditions, we can easily derive the optimal prices of the product, and the information disclosure level, as shown in the following results.

Lemma C.2. *Under the self-implement model with dual channel operations, the optimal prices of the product is* ${p_l}^{DS*} = \frac{\left(a^2+6k(-1+\beta)\right)(1-\beta)}{2a^2+9k(-1+\beta)}$ *and* ${p_r}^{DS*} = \frac{\left(a^2+3k(-1+\beta)\right)(1-\beta)}{2a^2+9k(-1+\beta)}$, *the optimal information disclosure level is* $i^{DS^*} = \frac{a(1-\beta)}{9k-2a^2-9k\beta}$, *and the optimal profit is* $\pi_M^{DS^*} = \frac{\left(a^2+5k(-1+\beta)\right)(-1+\beta)}{2a^2-9k(1-\beta)}$.

APPENDIX B: PROOF OF RESULTS

Proof of Lemma 3.1. Checking the second-order condition of $\pi_S^A\left(i^A\right)$ regarding i^A, it is easy to find that $\pi_S^A\left(i^A\right)$ is a strictly concave function of i^A for a given p^A, i.e., $\frac{\partial^2 \pi_S^A}{\partial {i^A}^2} = -2k < 0$. Differentiating $\pi_S^A\left(i^A\right)$ with respect to i^A once, we derive $i^A\left(p^A\right) = \frac{asp^A}{2k}$. Next, substituting $i^A\left(p^A\right)$ into $\pi_M^A\left(p^A\right)$ and checking the second-order condition of $\pi_M^A\left(p^A\right)$ regarding p^A, we derive $\frac{\partial^2 \pi_M^A}{\partial {p^A}^2} = \frac{(-1+s)\left(2k-a^2 s\right)}{k} < 0$ when $2k > a^2 s$, which indicates that

$\pi_M^A(p^A)$ is a strictly concave function of p^A. Then, differentiating $\pi_M^A(p^A)$ with respect to p^A once, we derive $p^{A*}=\frac{k}{2k-a^2s}$. Substituting p^{A*} into $i^A(p^A)$, we derive i^{A*}. Substituting p^{A*} and i^{A*} into the profit functions, we derive $\pi_M^{A*}=\frac{k(1-s)}{4k-2a^2s}$ and $\pi_S^{A*}=\frac{ks(4k-3a^2s)}{4(2k-a^2s)^2}$. ■

Proof of Lemma 3.2. The Hessian matrix π_M^S with respect to p^S and i^S is given as $H=\begin{vmatrix}-2 & a\\ a & -2k\end{vmatrix}=4k-a^2>0$ when $4k>a^2$. Thus, π_M^S is a strictly concave function, and its maximum value exists under the given condition. Considering the first-order conditions of π_M^S with respect to p^S and i^S, respectively, we have $\frac{\partial\pi_M^S}{\partial p^S}=1+ai-2p$ and $\frac{\partial\pi_M^S}{\partial i^S}=-2ik+ap$. Letting $\frac{\partial\pi_M^S}{\partial p^S}=0$ and $\frac{\partial\pi_M^S}{\partial i^S}=0$, we derive the sub equilibrium results $p^S(i^S)=\frac{1}{2}(1+ai^S)$ and $i^S(p^S)=\frac{ap^S}{2k}$. Combining $p^S(i^S)$ and $i^S(p^S)$, we derive the optimal results $p^{S*}=\frac{2k}{4k-a^2}$ and $i^{S*}=\frac{a}{4k-a^2}$. Substituting p^{S*} and i^{S*} into $\pi_M^S(p^S,i^S)$, we have $\pi_M^{S*}=\frac{k}{4k-a^2}$. ■

Proof of Proposition 4.1. We first define some key thresholds to simplify the expressions. Defining $\underline{k}_1=\frac{a^2}{4}$, $\underline{k}_2=\frac{a^2s}{2}$, $\overline{k}^1=\frac{a^2}{2}$, $\overline{k}^2=\frac{3a^2s}{2}$, $\overline{k}^3=a^2s$. ■

Under the agency model, we have (i) $\frac{\partial p^{A*}}{\partial k}=-\frac{a^2s}{(-2k+a^2s)^2}<0$, $\frac{\partial p^{A*}}{\partial a}=\frac{2aks}{(2k-a^2s)^2}>0$, and $\frac{\partial p^{A*}}{\partial s}=\frac{a^2k}{(2k-a^2s)^2}>0$; (ii) $\frac{\partial i^{A*}}{\partial k}=-\frac{4as}{(4k-2a^2s)^2}<0$, $\frac{\partial i^{A*}}{\partial a}=\frac{s(2k+a^2s)}{2(-2k+a^2s)^2}>0$, and $\frac{\partial i^{A*}}{\partial s}=\frac{ak}{(-2k+a^2s)^2}>0$; and (iii) $\frac{\partial\pi_M^{A*}}{\partial k}=\frac{a^2(s-1)s}{2(-2k+a^2s)^2}<0$, $\frac{\partial\pi_M^{A*}}{\partial a}=\frac{4ak(1-s)s}{(4k-2a^2s)^2}>0$, $\frac{\partial\pi_M^{A*}}{\partial s}=\frac{(a^2-2k)k}{2(-2k+a^2s)^2}>0$ when $\underline{k}_1<k<\overline{k}^1$, and $\frac{\partial\pi_M^{A*}}{\partial s}=\frac{(a^2-2k)k}{2(-2k+a^2s)^2}<0$ when $k>\overline{k}^1$. (iv) $\frac{\partial\pi_R^{A*}}{\partial k}=\frac{s^2(-2a^2k+3a^4s)}{4(2k-a^2s)^3}>0$ when $\underline{k}_2<k<\overline{k}^2$, $\frac{\partial\pi_R^{A*}}{\partial k}=\frac{s^2(-2a^2k+3a^4s)}{4(2k-a^2s)^3}<0$ when $k>\overline{k}^2$, $\frac{\partial\pi_R^{A*}}{\partial a}=-\frac{aks^2(-2k+3a^2s)}{2(2k-a^2s)^3}>0$ when $k>\overline{k}^2$, $\frac{\partial\pi_R^{A*}}{\partial a}=-\frac{aks^2(-2k+3a^2s)}{2(2k-a^2s)^3}<0$ when $\underline{k}_2<k<\overline{k}^2$, $\frac{\partial\pi_R^{A*}}{\partial s}=\frac{2k^2(k-a^2s)}{(2k-a^2s)^3}>0$ when $k>\overline{k}^3$, and $\frac{\partial\pi_R^{A*}}{\partial s}=\frac{2k^2(k-a^2s)}{(2k-a^2s)^3}<0$ when $\underline{k}_2<k<\overline{k}^3$.

Under the self-implement model, we have (i) $\frac{\partial p^{S*}}{\partial k}=-\frac{2a^2}{(a^2-4k)^2}<0$ and $\frac{\partial p^{S*}}{\partial a}=\frac{4ak}{(-a^2+4k)^2}>0$; (ii) $\frac{\partial i^{S*}}{\partial k}=-\frac{4a}{(-a^2+4k)^2}<0$, and $\frac{\partial i^{S*}}{\partial a}=\frac{a^2+4k}{(a^2-4k)^2}>0$; and (iii) $\frac{\partial\pi_M^{S*}}{\partial k}=-\frac{a^2}{(a^2-4k)^2}<0$, and $\frac{\partial\pi_M^{S*}}{\partial a}=\frac{2ak}{(-a^2+4k)^2}>0$. ■

Proof of Proposition 4.2. (i) According to the optimal prices under agency and self-implement models, we have $\Delta p=p^{A*}-p^{S*}=\frac{a^2k(-1+2s)}{(4k-a^2)(2k-a^2s)}>0$ when $s>\frac{1}{2}=\tilde{s}_1$; (ii) according to the optimal information disclosure levels under agency and self-implement models, we have $\Delta i=i^{A*}-i^{S*}=\frac{4ak(-1+s)+a^3s}{2(4k-a^2)(2k-a^2s)}>0$ when $s>\frac{4k}{4k+a^2}=\tilde{s}_2$; (iii) according to the optimal profits under agency and self-implement models, we have $\Delta\pi_M=\pi_M^{A*}-\pi_M^{S*}=\frac{k(a^2(3s-1)-4ks)}{2(4k-a^2)(2k-a^2s)}>0$ when $s>\frac{a^2}{3a^2-4k}=\tilde{s}_3$; and (vi) according to the optimal consumer surplus under agency and self-implement models, we have $\Delta CS=CS^{A*}-CS^{S*}=\frac{a^2(a^2-8k)}{8(a^2-4k)^2}$. Since $4k>a^2$, $\Delta CS<0$. ■

Proof of results shown in Table 2:

Under the agency model, we have:

(i) $\frac{\partial p^{PA*}}{\partial k}=-\frac{a^2s}{2(-2k+a^2s)^2}<0$, $\frac{\partial p^{PA*}}{\partial a}=\frac{4aks}{(4k-2a^2s)^2}>0$, $\frac{\partial p^{PA*}}{\partial s}=\frac{2a^2k}{(4k-2a^2s)^2}>0$.

(ii) $\frac{\partial i^{PA*}}{\partial k}=-\frac{as}{2(-2k+a^2s)^2}<0$, $\frac{\partial i^{PA*}}{\partial a}=\frac{8k^2-6a^2ks+3a^4s^2}{4(-2ak+a^3s)^2}>0$, $\frac{\partial i^{PA*}}{\partial s}=\frac{ak}{2(-2k+a^2s)^2}>0$.

(iii) $\frac{\partial\pi_M^{PA*}}{\partial k}=\frac{a^2(-1+s)s}{8(-2k+a^2s)^2}<0$, $\frac{\partial\pi_M^{PA*}}{\partial a}=-\frac{ak(-1+s)s}{4(-2k+a^2s)^2}>0$, $\frac{\partial\pi_M^{PA*}}{\partial s}=\frac{(a^2-2k)k}{8(-2k+a^2s)^2}>0$ when $\underline{k}_1<k<\overline{k}^1$, $\frac{\partial\pi_M^{PA*}}{\partial s}=\frac{(a^2-2k)k}{8(-2k+a^2s)^2}<0$ when $k>\overline{k}^1$.

(iv) $\frac{\partial\pi_R^{PA*}}{\partial k}=\frac{64k^3-96a^2k^2s+58a^4ks^2-15a^6s^3}{16a^2(-2k+a^2s)^3}>0$ when $\underline{k}_4<k<\overline{k}^4$; $\frac{\partial\pi_R^{PA*}}{\partial k}=\frac{64k^3-96a^2k^2s+58a^4ks^2-15a^6s^3}{16a^2(-2k+a^2s)^3}<0$ when $k>\overline{k}^4$; $\frac{\partial\pi_R^{PA*}}{\partial a}=\frac{k(-64k^3+96a^2k^2s-58a^4ks^2+15a^6s^3)}{8(-2ak+a^3s)^3}>0$ when $k>\overline{k}^4$; $\frac{\partial\pi_R^{PA*}}{\partial a}=\frac{k(-64k^3+96a^2k^2s-58a^4ks^2+15a^6s^3)}{8(-2ak+a^3s)^3}<0$ when $\underline{k}_4<k<\overline{k}^4$; $\frac{\partial\pi_R^{PA*}}{\partial s}=\frac{k^2(3k-2a^2s)}{2(2k-a^2s)^3}>0$ when $k>\frac{2a^2s}{3}=\overline{k}^5$; $\frac{\partial\pi_R^{PA*}}{\partial s}=\frac{k^2(3k-2a^2s)}{2(2k-a^2s)^3}<0$ when $k<\frac{2a^2s}{3}=\overline{k}^5$. Note that the expressions of $\underline{k}_4$ and $\overline{k}^4$ are very complicated, and we omit them.

Under the self-implement model, we have:

(i) $\frac{\partial p^{PS*}}{\partial k}=-\frac{a^2}{(a^2-4k)^2}<0$, $\frac{\partial p^{PS*}}{\partial a}=\frac{2ak}{(a^2-4k)^2}>0$.

(ii) $\frac{\partial i^{PS*}}{\partial k}=-\frac{2a}{(a^2-4k)^2}<0$, $\frac{\partial i^{PS*}}{\partial a}=\frac{a^2+4k}{2(a^2-4k)^2}>0$.

(iii) $\frac{\partial\pi^{PS*}}{\partial k}=-\frac{a^2}{4(a^2-4k)^2}<0$, $\frac{\partial\pi^{PS*}}{\partial a}=\frac{ak}{2(a^2-4k)^2}>0$. ■

Proof of Proposition 5.1. (i) We have $p^{PA*}-p^{PS*}=\frac{-8k^2-a^4s+a^2(k+6ks)}{2(4k-a^2)(2k-a^2s)}>0$ when $s>\frac{a^2k-8k^2}{a^2(a^2-6k)}=\tilde{s}_1^P$. Comparing $\tilde{s}_1^P$ and $\tilde{s}_1$, we have $\tilde{s}_1^P-\tilde{s}_1=-\frac{(a^2-4k)^2}{2a^2(a^2-6k)}>0$ because $4k>a^2$. (ii) We have $i^{PA*}-i^{PS*}=\frac{-16k^2-5a^4s+4a^2k(2+3s)}{4a(4k-a^2)(2k-a^2s)}>0$ when $s>\frac{8(a^2k-2k^2)}{a^2(5a^2-12k)}=\tilde{s}_2^P$. Comparing $\tilde{s}_2^P$ and $\tilde{s}_2$, we have $\tilde{s}_2^P-\tilde{s}_2=\frac{8(a^2k-2k^2)}{a^2(5a^2-12k)}>0$ because $4k>a^2$, and $2k>a^2s$. (iii) We have $\pi_M^{PA*}-\pi_M^{PS*}=-\frac{k(4k(-2+s)+a^2(1+s))}{8(4k-a^2)(2k-a^2s)}>0$ when $s>\frac{-a^2+8k}{a^2+4k}=\tilde{s}_3^P$. Comparing $\tilde{s}_3^P-\tilde{s}_3=\frac{-a^2+8k}{a^2+4k}>0$ because $4k>a^2$. (vi) We have $CS^{PA*}-CS^{PS*}=\frac{a^2(a^2-8k)}{32(4k-a^2)^2}<0$. (v) we have $c^{PA*}-c^{PS*}=\frac{2k-a^2s}{2a^2s}>0$. ■

Proof of results shown in Table 3: Under the agency model, we have:

i. $\frac{\partial i^{FA*}}{\partial k}=-\frac{aps}{2k^2}<0$, $\frac{\partial i^{FA*}}{\partial a}=\frac{ps}{2k}>0$, $\frac{\partial i^{FA*}}{\partial s}=\frac{pa}{2k}>0$.

ii. $\frac{\partial\pi_M^{FA*}}{\partial k}=\frac{a^2p^2(-1+s)s}{2k^2}<0$, $\frac{\partial\pi_M^{FA*}}{\partial a}=-\frac{ap^2(-1+s)s}{k}>0$, $\frac{\partial\pi_M^{FA*}}{\partial s}=(-1+p)p+\frac{a^2p^2(1-2s)}{2k}>0$ when $0<p<-\frac{2k}{-a^2-2k+2a^2s}=\overline{p}_1$; $\frac{\partial\pi_M^{FA*}}{\partial s}=(-1+p)p+$

$\frac{a^2p^2(1-2s)}{2k} < 0$ when $p > -\frac{2k}{-a^2-2k+2a^2s} = \overline{p}_1$.

iii. $\frac{\partial \pi_S^{FA^*}}{\partial k} = -\frac{a^2p^2s^2}{4k^2} < 0$, $\frac{\partial \pi_S^{FA^*}}{\partial a} = \frac{ap^2s^2}{2k} > 0$, $\frac{\partial \pi_S^{FA^*}}{\partial s} = \frac{1}{2}p\left(2+p\left(-2+\frac{a^2s}{k}\right)\right) > 0$ when $0 < p < -\frac{2k}{-2k+a^2s} = \overline{p}_2$; $\frac{\partial \pi_S^{FA^*}}{\partial s} = \frac{1}{2}p\left(2+p\left(-2+\frac{a^2s}{k}\right)\right) < 0$ when $p > -\frac{2k}{-2k+a^2s} = \overline{p}_2$

Under the self-implement model, we have:

i. $\frac{\partial i^{FS^*}}{\partial k} = -\frac{ap}{2k^2} < 0$, $\frac{\partial i^{FS^*}}{\partial a} = \frac{a}{2k} > 0$.

ii. $\frac{\partial \pi_M^{FS^*}}{\partial k} = -\frac{a^2p^2}{4k^2} < 0$, $\frac{\partial \pi_M^{FS^*}}{\partial a} = \frac{ap^2}{2k} > 0$. ∎

Proof of Proposition 5.2. We have $i^{FA^*} - i^{FS^*} = \frac{ap(-1+s)}{2k} < 0$ (recall that $0 < s < 1$). We have $\pi_M^{FA^*} - \pi_M^{FS^*} = (-1+p)ps - \frac{a^2p^2(1-2s+2s^2)}{4k} < 0$ when $0 < s < 1$. We have $CS^{FA^*} - CS^{FS^*} = \frac{a^2p(-1+s)\left(-4k(-1+p)+a^2p(1+s)\right)}{8k^2} < 0$. ∎