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RESEARCH ARTICLE

Blockchain Introduction and Live Streaming Strategy for a Dual-Channel Supply Chain

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ABSTRACT This study examines blockchain introduction and live streaming strategy for a dual-channel supply chain consisting of a supplier and an e-tailer. The supplier distributes products through the e-tailer and develops a direct sales channel. Four scenarios are assumed for the blockchain adoption of the supplier and the live streaming sales adoption of the e-tailer: Neither party adopts blockchain or live streaming sales, or only one does; The supplier uses blockchain and the e-tailer uses live streaming sales. The two supply chain members are also assumed to play a Stackelberg game where the supplier is a leader and the e-tailer is a follower. Furthermore, the profit optimization models are developed under the four scenarios and these models are then resolved by backward induction to derive the closed forms of the equilibrium solutions. The impacts of the key parameters on equilibrium decisions and profits are further explored. The results show that a high information accuracy induces the supply chain member to shift from a low-price to a high-price strategy under a certain condition. When the e-tailer uses live streaming sales, the supply chain member should shift from a high-price to a low-price strategy if this sales attracts more consumers in the direct sales channel. The two members should always work in cooperation, with the supplier using blockchain and the e-tailer using live streaming sales regardless of the product information and live streaming effect. However, their cooperation on the introduction of blockchain and live streaming sales is affected by the wholesale price and the competition intensity.

INDEX TERMS Blockchain introduction, live streaming strategy, dual-channel supply chain, channel competition, game model.

I. INTRODUCTION

With the advancement of the internet and the evolution of consumer behavior, the live streaming sales mode has seen a surge in growth, emerging as a new driving force for economic expansion. Live streaming sales in the U.S. reach \$50 billion by 2023 and will grow 36% by 2026, according to a research report.[1] The development of live streaming sales in China also exhibits a similar growth trend. The sales generated from live streaming contributed to a sales volume of \$25.7 billion during the double 11 shopping festival in China in 2022, representing a remarkable year-on-year growth rate of 146.1%.[2] Estimates suggest that live streaming selling in China will experience substantial growth, potentially reaching \$3 trillion by 2024.[3] Different from traditional online sales, a streamer in live streaming sales can engage in real-time communication with consumers on live streaming platforms, addressing their product inquiries, leading to a low uncertainty in their perception of products.

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[1]https://www.statista.com/statistics/1276120/livestream-e-commerce-sales-united-states/

[2]https://www.yicaiglobal.com/news/e-commerce-sales-during-this-year-double-11-shopping-gala-jump-14-to-usd157-billion

[3]https://www.globaldata.com/media/banking/e-commerce-market-china-willreach-us3-trillion-2024-forecasts-globaldata/

However, the adoption of live streaming sales poses certain challenges for businesses. Firstly, introducing this sales mode may lead to intense competition with existing sales modes for the same products, resulting in low performance for businesses. Secondly, employing a streamer can incur specific operational costs or commissions for businesses, unlike traditional online operations which typically do not have these additional costs. Finally, this sales mode can also inconvenience consumers, requiring them to wait and watch live streaming. Live streaming sales for specific products usually occur at specific times, causing hesitation among consumers sensitive to time costs when considering purchasing through live streaming. Thus, it remains uncertain whether the adoption of live streaming sales is beneficial to businesses.

Although an online store offers convenience to consumers, products sold by this store may suffer from a negative perception of low quality and consumer skepticism. On the one hand, the supervision of product procurement channels and sales is challenging. On the other, unethical business practices have expanded on a large scale for the past few years. For instance, the global economic losses from online counterfeit products amounted to a staggering $323 billion in just 2017.[4] The lack of transparency in production information and fraudulent behavior not only undermines consumer trust in products but also negatively impacts the profits of businesses. To address these gaps, blockchain as a disruptive innovation technology is proposed [1]. This technology can ensure that information about product quality in production is transparent and immutable to stakeholders in the supply chain [2]. Moreover, blockchain technology can also improve consumer purchasing preferences. As a result, this technology has attracted extensive attention.

For instance, Walmart partnered with IBM and JD.com to implement blockchain in specific food (e.g. beef and apple) supply chains.[5] Consumers increase confidence in the safety of these food products, as they can scan QR codes on the packaging to track product origin. Luxury industry leaders such as LVMH and Chow Tai Fook enable consumers to access detailed product information within the supply chain using blockchain. The integration of blockchain allows consumers to effortlessly verify the authenticity of products with precision and confidence [3]. However, the complexity and high costs of this technology are obstacles to businesses [4]. Other contentious issues also contribute to business hesitation in using blockchain, such as a higher cost for privacy and information disclosure corrections, as errors can be permanently recorded [5]. Some businesses even declare refusal to adopt blockchain technology.[6]

To respond to demand more effectively, the e-tailer sources products from diverse upstream suppliers and manufacturers, reselling them on e-commerce platforms like Amazon, JD.com and Taobao. Furthermore, upstream suppliers can develop direct sales channels to directly reach consumers in the market. These e-commerce platforms can facilitate e-tailers in selling lesser-known products. Thus, e-tailers, rather than suppliers, need to consider whether to adopt live streaming sales in e-commerce platforms to raise sales of such products. However, the supplier should pay more attention to how they can help consumers understand the quality and safety of products to enhance product reputation, and thus, need to consider whether to use blockchain. Motivated by the above observations, this work integrates both blockchain and live streaming sales into a dual-channel supply chain. In a dual-channel supply chain, four scenarios are proposed based on the supplier using or not using blockchain and the e-tailer using or not using live streaming sales. Especially, three key questions are examined as follows: (1) How should supply chain members make the optimal decisions under different scenarios? (2) How does the introduction of blockchain and live streaming sales affect the optimal decisions? (3) Which scenario generates a win-win situation for the supplier and the e-tailer?

To deal with the above questions, this work considers a dual-channel supply chain comprising a supplier and an e-tailer. The supplier distributes products to the e-tailer and develops a direct sales channel. The e-tailer resells them to consumers. The supplier competes with the e-tailer on sales prices. Four scenarios are analyzed concerning the supplier and the e-tailer: (a) Neither of the supply chain members introduces blockchain or live streaming sales. (b) The e-tailer does not adopt live streaming sales but the supplier introduces blockchain. (c) The e-tailer adopts live streaming sales but the supplier does not introduce blockchain. (d) The supplier uses blockchain and the e-tailer uses live streaming sales. In practice, a supplier and a retailer typically have a leader-follower relationship, i.e., play a Stackelberg game in the decision-making process. The supplier makes decisions first as a leader and the retailer then makes decisions as a follower based on those of the supplier. Thus, the Stackelberg game models under different scenarios are proposed in which the supplier is a leader and the e-tailer is a follower. Specifically, the profit maximization models for each supply chain member are proposed and are solved then using backward induction. The relationships between the equilibrium decisions are examined under the four scenarios. The impacts of the key parameters on the equilibrium decisions are further analyzed and several numerical studies are employed to examine their impacts on profits for the two members.

This work contributes to the relevant literature in three ways. First, the impacts of the introduction of both blockchain and live streaming sales on dual-channel supply chain decisions are examined for the first time. The existing studies explored only blockchain adoption or only live streaming sales introduction for a supply chain, but did not examine their synergic impacts on optimal decisions [6], [7]. Second, this work is pioneering in presenting scenarios where the

[4]https://www.researchandmarkets.com/reports/4438394/globalbrand-counterfeiting-report-2018#src-pos-1

[5]https://newsroom.ibm.com/2017-12-14-Walmart-JD-com-IBM-and-Tsinghua-University-Launch-a-Blockchain-Food-Safety-Alliance-in-China

[6]https://shippingwatch.com/carriers/Container/article10602520.ece

supplier chooses two scenarios, i.e., not using and using blockchain, based on the e-tailer choices on not introducing or introducing live streaming sales. Finally, the closed forms of the optimal decisions are derived and the theoretical comparisons of optimal decisions among different scenarios are provided. The synergic impacts of the key parameters on a win-win situation for both supply chain members are further analyzed and discussed.

The rest of this study is organized as follows. The relevant literature is reviewed and the contributions are highlighted in Section II. The problem descriptions are provided in Section III. The models are formulated and the optimal results in four scenarios are investigated in Section IV. The optimal decisions in four scenarios are compared in Section V. Several numerical experiments are conducted in Section VI. The main research results are summarized and the future research directions are stated in Section VII. All proofs of propositions and corollaries are provided in the Appendix.

II. LITERATURE REVIEW

This work is related to three streams, i.e., dual-channel supply chain, blockchain technology and live streaming selling. These streams of literature are reviewed separately in this section.

Recent research in the field of dual-channel supply chains has examined various aspects, including pricing strategies, market competition, and consumer behavior. Yang et al. investigated optimization models for suppliers with limited capacity [8]. He et al. developed pricing models to analyze the dynamics of dual-channel supply chains under changing market conditions, and highlighted price competition [9]. Hamzaoui et al. explored the influence of consumer loyalty on pricing decisions within dual-channel supply chains [10]. Additionally, the phenomenon of showrooming in dual-channel supply chains has garnered attention, with studies such as those by [11] and [12]. They examined the impact of consumer travel costs on pricing and profit. Chai et al. explored brand promotion strategies [11], while Qiu et al. highlighted the potential profitability of virtual showrooms for manufacturers [12]. Furthermore, some works have focused on price policies. Kireyev et al. used game theory to investigate the strategic implications of price-matching policies across competitive scenarios [13]. Shang and Cai identified the potential for price competition policies to engender detrimental competition between channels [14]. Lastly, Guo et al. analyzed a game-theoretic model of dual-channel supply chains with product offerings and price match guarantees [15].

Traditional supply chains face challenges such as low levels of information sharing and lack of transparency. As an effective technology for tracing product information, blockchain has been widely applied in supply chains. Accordingly, supply chain strategies with blockchain have attracted widespread attention from researchers and practitioners. Chod et al. studied whether to adopt blockchain in the supply chain [16]. Some works also analyzed the impacts of blockchain technology on cross-border supply chains. Li et al. demonstrated the benefits of blockchain implementation in a global sustainable supply chain [17]. Zhang et al. developed Stackelberg game models to study the impacts of blockchain implementation [18]. Blockchain technology includes blockchain traceability and information disclosure features. Liu et al. studied the sales mode selection with blockchain for e-commerce platforms [19]. Zhong et al. investigated the added value from supplier blockchain technology adoption to trace and disclose information in a dual-channel supply chain [20]. Zhang et al. explored three blockchain technology adoption scenarios in a dual-channel supply chain [21]. Zhao et al. studied the manufacturer blockchain adoption strategies in a dual-channel e-commerce platform supply chain [22]. Li et al. developed Stackelberg game models to investigate the impact of blockchain adoption for consumer privacy protection on an e-commerce supply chain [23]. Liu et al. investigated the impacts of blockchain on imported fresh food supply chains during the COVID-19 pandemic [24].

The surge in live-streaming sales has sparked considerable interest in both academic and practical domains, prompting extensive research efforts to understand its impact. Wongkitrungrueng et al. examined live-streaming commerce from the perspective of sellers and proposed insights into customer acquisition and retention strategies [25]. Park and Lin explored the phenomenon of celebrity endorsement in live-stream shopping [26]. Fei et al. developed a framework to study the effects of interaction text on consumer purchase intentions within live streaming [27]. He et al. explored the impact factors of consumer live streaming shopping [28]. In recent research, scholars used game-theoretic models to investigate optimal strategies. Zhang et al. specifically explored how product lines influence live streaming strategies [31], while Zhang et al. assessed the feasibility and consequences of integrating live streaming services into a supply chain [31]. Furthermore, other studies examined post-live streaming operational management and addressed topics such as optimal cooperation strategies with streamers [32], pricing and quality decisions [33], sale formats, and pricing strategies [34], [35].

Although a host of existing works have examined various aspects of dual-channel supply chains, blockchain and live-streaming selling have received relatively little attention within this context. Table 1 summarizes the contributions of the related studies and shows the difference between this study and the other literature. Previous studies, such as those by Yang et al. and Hamzaoui et al., primarily focused on dynamic pricing decisions and the impact of consumer loyalty on pricing decisions [8], [10]. However, these studies did not explore the integration of blockchain technology or live-stream selling into a dual-channel supply chain. The works by Dong et al. and Chod et al. investigated the blockchain introduction in supply chain finance and cross-border supply chain, respectively [6], [16]. While these studies shed light on the advantages of blockchain technology in supply chains, they do not consider its interaction with dual-channel supply chains. Moreover, Chen et al. and Huang et al. focused on live streaming sales for a supply chain [7], [36]. However, these studies did not address the integration of live streaming into dual-channel supply chains. Although Du et al. studied live streaming sales in a dual-channel supply chain, but neglected the introduction of blockchain [37]. In contrast, this study fills these gaps by the following three ways: (1) Both blockchain and live streaming sales are integrated into a dual-channel supply chain and their synergic impacts on this supply chain are explored. (2) Four scenarios are analyzed where neither member introduces blockchain and live streaming sales, either of the two members adopts blockchain or live streaming sale, and the supplier uses blockchain and the e-tailer uses live streaming sales. (3) The closed forms of the optimal decisions are derived and the optimal decisions among four scenarios are compared. The synergic impacts of the key parameters on a win-win situation for the two members are examined.

TABLE 1. The comparison of the related works.

	Dual-channel	Block-chain	Live stream	Key contributions
Yang et al. (2018)	✓			Studied the optimal distribution strategy of a supplier with limited capacity in a dual-channel supply chain.
Hamzaoui et al. (2024)	✓			Explored the effect of consumer loyalty to the retail channel on pricing decisions.
Dong et al. (2023)		✓		Developed a game model to address supply chain disruption risks in a multi-echelon supply chain using blockchain.
Chod et al. (2020)		✓		Realized an ability to secure favorable financing terms at low signaling costs in supply chains with blockchain.
Du et al. (2023)	✓		✓	Investigated the manufacturer live streaming strategy in a dual-channel supply chain
Zhang et al. (2024)			✓	Studied the live streaming strategy for an e-commerce platform supply chain.
Chen et al. (2023)			✓	Studied whether an online retailer in a supply chain is introducing live streaming selling.
Huang et al. (2023)			✓	Explored the live streaming strategy for the two competitive retailers.
This study	✓	✓	✓	Integrated both blockchain and live streaming into dual-channel supply chain models.

III. PROBLEM DESCRIPTION

Considers a two-tier supply chain comprising a supplier and an e-tailer. The e-tailer orders products from the supplier at the unit wholesale price w and resells them to consumers through the retail channel at the unit sales price p_r. The supplier also develops a direct sales channel with the unit sales price p_s and competes with the e-tailer on sales prices. The two supply chain members, i.e., two members, play a Stackelberg game where the supplier is a leader and the e-tailer is a follower. The wholesale price is assumed to be pre-negotiated and exogenous by the supplier and the e-tailer, which are extensively used in operational management [38]. In addition, to avoid triviality, the unit production cost is assumed to be zero under the four scenarios [39].

The supplier products enter the market only after the direct sales channel is developed, resulting in relatively low performance and reputation within the industry. This delayed market entry puts the supplier at a disadvantage. As a result, the consumer perception of the product information from the direct sales channel is uncertain, potentially leading to their reluctance to make purchasing decisions, inhibiting the growth of the demand in this channel [40]. This consumer perception uncertainty can be presented as a random variable ξ with a mean 0 and a variance σ^2. Following Wen and Siqin [41], the impact of consumer perception uncertainty on direct sales channel demand can be formulated as $E[\xi] - Var[\xi] = -\sigma^2$. A larger σ^2 means that consumers have a high uncertainty about products.

When the supplier introduces blockchain into the direct sales channel, consumers can easily access reliable and transparent product information in the direct sales channel, thereby enhancing their confidence in the product [42]. Following Shang et al. [43], product information accessed by consumers can be expressed as Γ, and its unbiased estimator is given by $E[\Gamma|\xi] = \xi$. A larger Γ means that product information disclosed by blockchain shows a higher product quality and safety. Consumers are satisfied with product quality and safety information if $\Gamma \geq 0$ and dissatisfied if $\Gamma < 0$. Furthermore, the absolute information accuracy is given by $t = 1/E[Var[\xi|\Gamma]]$, where t is the information accuracy. A larger t indicates that the higher capability of the supplier to disclose product information using blockchain technology, and the more comprehensive and accurate product information that consumers can access through high-precision blockchain. Moreover, a larger t also means that the supplier invests more costs in blockchain since enhancing the capability to disclose information via blockchain requires more funding. On this basis, according to Ericson [44], the mean and the variance of consumer perception uncertainty in the presence of blockchain can be derived as $E[\xi\,|\,\Gamma] = \Gamma t\sigma^2/(1+t\sigma^2)$ and $Var[\xi\,|\,\Gamma] = \sigma^2/(1+t\sigma^2)$, where $t\sigma^2/(1+t\sigma^2)$ is the weight of the product information Γ. Thus, the impact of consumer perception uncertainty on the direct sales channel demand is given by $E[\xi\,|\,\Gamma] - Var[\xi\,|\,\Gamma] = \sigma^2/1+t\sigma^2(t\Gamma - 1)$. In addition, the introduction of blockchain incurs fixed blockchain costs C, such as blockchain software development and network node equipment installation [45].

As streaming media gains prominence, the adoption of live streaming sales by e-tailers has emerged as a prevailing trend. E-tailers use the immediacy and interactivity of streaming media to establish direct and immersive with consumers, surpassing the limitations of traditional online sales. This sales mode may attract more consumers who prefer its characteristic, leading to an effect, i.e., the live streaming effect μ. A larger μ means that consumers are more interested in live streaming sales. The live streaming effect boosts channel demands with live streaming sales but dampens those without it. Live streaming sales may divert consumers from non-live streaming channels [46]. Furthermore, the adoption of live streaming sales involves the choice of streamers, live streaming promotion and others, meaning live streaming sales effort e for the e-tailer. This sales effort also boosts live streaming channel demands. Live streaming selling used by the e-tailer generates a certain cost, which can be expressed as a quadratic form $e^2/2$ [47].

Four scenarios are proposed for the supplier and the e-tailer as follows: (1) The e-tailer does not adopt live streaming sales and the supplier does not adopt blockchain live streaming sales, denoted as NN. (2) The e-tailer does not use live streaming sales but the supplier introduces blockchain, denoted as NB. (3) The e-tailer uses live streaming sales but the supplier does not adopt blockchain, denoted as LN. (4) The e-tailer uses live streaming sales and the supplier uses blockchain, denoted as LB. The profits maximization models are examined under the above four scenarios. Note that the superscript N is the scenario where the member does not introduce blockchain or live streaming sales, B is the scenario where the supplier adopts blockchain, and F is the scenario where the e-tailer uses live streaming sales. Moreover, the subscript 'r' ('s') indicates the e-tailer (supplier). The notations used in this work are listed in Table 2, where $i \in \{s, r\}$ and $j \in \{NN, NB, LN, LB\}$.

TABLE 2. Notations and descriptions.

Parameters	Descriptions
a	Market potential, $a > 0$
θ	Market share of the direct sales channel, $0 \le \theta \le 1$
β	Competition intensity, $0 < \beta < 1$
w	Wholesale price
ξ	Consumer perception uncertainty
Γ	The product information of the direct sales channel
t	The information accuracy
C	Blockchain cost
μ	Live streaming effect
η	Live streaming followership factor
D_i^j	Channel demand
Π_i^j	Supply chain member profit
Decision variables	
p_i^j	Selling price
e^j	Live streaming sales effort

IV. UNITS

For the supplier and the e-tailer, the optimization models under the NN, NB, LN and LB scenarios are proposed to derive the optimal decisions. Furthermore, sensitivity analyses are conducted to examine the impact of the key parameters on the equilibrium results.

A. SCENARIO NN

The scenario NN as a benchmark is first considered where the e-tailer does not introduce the live streaming sales into the retail channel and the supplier does not introduce the blockchain into the direct sales channel. The results of the benchmark are compared with those of the other three scenarios. The supplier decides firstly the direct sales price p_s^{NN}, and the e-tailer decides then the sales price p_r^{NN}. Consumers cannot obtain product information in the direct sales channel if the supplier does not introduce blockchain. From Section III, consumer perception uncertainty for products is σ^2. In addition, the direct sales demand consists of two parts, one part is affected by sales prices, and the other is converted by consumer perception uncertainty. However, the retailer channel demand without live streaming sales is only dependent on sales prices. Thus, the demand functions for different channels based on the linear demand function can be formulated as

$$D_s^{NN} = \theta a - p_s^{NN} + \beta p_r^{NN} - \sigma^2, \quad (1)$$

$$D_r^{NN} = (1-\theta)a - p_r^{NN} + \beta p_s^{NN}, \quad (2)$$

where θ is the supplier market share, with $\theta \in [0, 1]$, β is the competition intensity between the e-tailer and the supplier, with $\beta \in (0, 1)$. The market is monopolized by the supplier if $\theta = 1$, and by the e-tailer if $\theta = 0$. The competition between the different channels is virtually absent if β tends to 0, and is extremely fierce if β tends to 1.

Therefore, the profit maximization models of the supplier and the e-tailer can be described as

$$\max_{p_s^{NN}} \Pi_s^{NN} = p_s^{NN} D_s^{NN} + w D_r^{NN}, \quad (3)$$

$$\max_{p_r^{NN}} \Pi_r^{NN} = (p_r^{NN} - w) D_r^{NN}, \quad (4)$$

The above optimization models (3) and (4) are resolved using backward induction, and the equilibrium solutions under the scenario NN are then obtained and are stated in Proposition 1.

Proposition 1: When neither member introduces the live streaming sales or blockchain, the equilibrium decisions for the two members are $p_r^{NN*} = \frac{(1-\theta)(4-\beta^2)a+4w+2\beta(\theta a-\sigma^2)}{4(2-\beta^2)}$ and $p_s^{NN*} = \frac{[2\theta+(1-\theta)\beta]a-2\sigma^2+2\beta w}{2(2-\beta^2)}$.

From Proposition 1, the pricing decisions for the e-tailer and the supply are negatively affected by consumer perception uncertainty. The pricing decisions for the two members decrease with consumer perception uncertainty. When consumers have a high perception uncertainty about products, the probability of consumers refraining from purchasing products is relatively high. Thus, the two members should use a low-price strategy to attract consumers.

B. SCENARIO NB

In this setting, the e-tailer does not adopt the live streaming sales in the retail channel but the supplier introduces the blockchain into the direct sale channel. The supplier decides firstly the direct sales price p_s^{NB}, and the e-tailer decides then the sales price p_r^{NB}. Blockchain can alleviate consumer concerns about counterfeit products since this technology can help them understand product information. From Section III, consumer perception uncertainty is $\frac{\sigma^2}{1+t\sigma^2}(t\Gamma-1)$ if the supplier uses blockchain. From (1) and (2), the demand functions for different channels are given by

$$D_s^{\mathrm{NB}} = \theta a - p_s^{\mathrm{NB}} + \beta p_r^{\mathrm{NB}} - \frac{\sigma^2}{1+t\sigma^2}(1-t\Gamma), \quad (5)$$
$$D_r^{\mathrm{NB}} = (1-\theta)a - p_r^{\mathrm{NB}} + \beta p_s^{\mathrm{NB}}, \quad (6)$$

Therefore, the profit maximization models of the supplier and the e-tailer under the scenario NB can be described as

$$\max_{p_s^{\mathrm{NB}}} \Pi_s^{\mathrm{NB}} = p_s^{\mathrm{NB}} D_s^{\mathrm{NB}} + wD_r^{\mathrm{NB}} - C, \quad (7)$$
$$\max_{p_r^{\mathrm{NB}}} \Pi_r^{\mathrm{NN}} = (p_r^{\mathrm{NB}} - w)D_r^{\mathrm{NB}}, \quad (8)$$

The above optimization models (7) and (8) are resolved by the approach used in subsection IV-A, and the equilibrium solutions are then obtained and are stated in Proposition 2.

Proposition 2: When the e-tailer does not introduce live streaming sales and the supplier introduces blockchain, the equilibrium decisions for the two members are $p_r^{\mathrm{NB}*} = \frac{(1-\theta)(4-\beta^2)a+4w-2\beta(\Lambda_1-a\theta)}{4(2-\beta^2)}$ and $p_s^{\mathrm{NB}*} = \frac{[2\theta+(1-\theta)\beta]a-2\Lambda_1+2\beta w}{2(2-\beta^2)}$, where $\Lambda_1 = \frac{(t\Gamma-1)\sigma^2}{1+t\sigma^2}$.

Corollary 1: Under the scenario NB, the impacts of the product information of the direct sales channel on the equilibrium decisions: (1) $\frac{\partial p_r^{\mathrm{NB}*}}{\partial \Gamma} > 0$; (2) $\frac{\partial p_s^{\mathrm{NB}*}}{\partial \Gamma} > 0$.

From Corollary 1, the supplier invests more costs to produce products with high quality and safety, which induces them to have a stronger incentive to raise the direct sales price and wholesale price. Thus, the retailer also set an aggressive, i.e., high, sales price to obtain more returns. These results imply that both the retailer and the supplier should use a high-price strategy in the presence of the high quality and safety of products disclosed by the blockchain.

Corollary 2: Under the scenario NB, the impacts of the information accuracy of the direct sales channel on the equilibrium decisions: (1) $\frac{\partial p_r^{\mathrm{NB}*}}{\partial t} \geq 0$ if $\Gamma \geq -\sigma^2$, and $\frac{\partial p_r^{\mathrm{NB}*}}{\partial t} < 0$ otherwise; (2) $\frac{\partial p_s^{\mathrm{NB}*}}{\partial t} \geq 0$ if $\Gamma \geq -\sigma^2$, and $\frac{\partial p_s^{\mathrm{NB}*}}{\partial t} < 0$ otherwise.

Corollary 2 shows that when the information disclosed by the blockchain shows that products have high quality and safety, the more comprehensive and accurate information consumers acquire about such products, the stronger their intentions to purchase. Thus, the supplier sets an aggressive sales price to obtain high profits, which induces the e-tailer to follow them to set an aggressive sales price, avoiding their monopolization of the market. Conversely, when the blockchain discloses products to have low quality and safety, high information accuracy helps consumers to understand the low quality and safety, leading to fewer orders from the supplier in the direct sales channel. Thus, the supplier reduces the direct sales price to attract consumers, resulting in a low sales price for the e-tailer. In summary, when the blockchain discloses products to have sufficiently high quality and safety, the supplier and e-tailer should shift from a low-price to a high-price strategy under high information accuracy.

C. SCENARIO LN

Under the scenario LN, the e-tailer introduces the live streaming sales in the retail channel but the supplier does not introduce the blockchain into the direct sales channel. The supplier decides firstly the direct sales price p_s^{LN}, and the e-tailer decides then the sales price p_r^{LN} and the live streaming sales effort level e^{LN}. Live streaming sales of the retail channel may affect the direct sales channel demand since this channel may have potential live streaming sales followers. Thus, the direct sales channel demand depends not only on sales prices and consumer perception uncertainty but also on the live streaming effect. In addition, the retail channel demand with live streaming sales also consists of two parts, one part being affected by sales prices and the other being converted by live streaming sales. Thus, the demand functions for different channels are given by

$$D_s^{\mathrm{LN}} = \theta a - p_s^{\mathrm{LN}} + \beta p_r^{\mathrm{LN}} - \eta\mu - \sigma^2, \quad (9)$$
$$D_r^{\mathrm{LN}} = (1-\theta)a - p_r^{\mathrm{LN}} + \beta p_s^{\mathrm{LN}} + \mu + e^{\mathrm{LN}}, \quad (10)$$

where η ($\eta > 0$) is the live streaming followership factor. A larger η indicates that more consumers in the direct sales channel are attracted by the live streaming sales of the e-tailer.

Therefore, the profit maximization models of the supplier and the e-tailer under the scenario LN can be described as

$$\max_{p_s^{\mathrm{LN}}} \Pi_s^{\mathrm{LN}} = p_s^{\mathrm{LN}} D_s^{\mathrm{LN}} + wD_r^{\mathrm{LN}}, \quad (11)$$
$$\max_{p_r^{\mathrm{LN}}, e^{\mathrm{LN}}} \Pi_r^{\mathrm{LN}} = (p_r^{\mathrm{LN}} - w)D_r^{\mathrm{LN}} - \frac{(e^{\mathrm{LN}})^2}{2}, \quad (12)$$

The above optimization models (11) and (12) are resolved by the approach used in Subsection IV-A, and the equilibrium solutions are then obtained and are stated in Proposition 3.

Proposition 3: When the e-tailer introduces live streaming and the supplier does not introduce blockchain, the equilibrium decisions for the two members are $p_r^{\mathrm{LN}*} = \frac{\mu}{1-\beta^2} + \frac{\delta_1 a - \delta_2\beta}{2(1-\beta^2)}$, $e^{\mathrm{LN}*} = \frac{2(w-\mu)-\delta_1 a+\delta_2\beta}{2(\beta^2-1)}$ and $p_s^{\mathrm{LN}*} = \frac{\beta[\mu+(1-\theta)a]-\sigma^2+a\theta-\eta\mu+\beta w}{2(1-\beta^2)}$, where $\delta_1 = (1-\theta)(2-\beta^2)+\theta\beta$ and $\delta_2 = \sigma^2 + \eta\mu + \beta(\mu - w)$.

Corollary 3: Under the scenario LN, the impacts of the live streaming effect on the equilibrium decisions: (1) $\frac{\partial p_r^{\mathrm{LN}*}}{\partial \mu} \geq 0$ if $\eta \leq \beta$, and $\frac{\partial p_r^{\mathrm{LN}*}}{\partial \mu} < 0$ otherwise; (2) $\frac{\partial e^{\mathrm{LN}*}}{\partial \mu} \geq 0$ if $\eta \leq \frac{2-\beta^2}{\beta}$, and $\frac{\partial e^{\mathrm{LN}*}}{\partial \mu} < 0$ otherwise; (3) $\frac{\partial p_s^{\mathrm{LN}*}}{\partial \mu} \geq 0$ if $\eta \leq \frac{2-\beta^2}{\beta}$, and $\frac{\partial p_s^{\mathrm{LN}*}}{\partial \mu} < 0$ otherwise.

Corollary 3 shows that when the live streaming selling has fewer followers in the direct sales channel, the supplier loses fewer orders. However, a high live streaming effect raises concerns for the supplier regarding the outward shift of more demands, leading to an aggressive direct sales price to resist losses. Meanwhile, the retailer invests more sales efforts in the live streaming sales to attract more consumers, especially in the direct sales channel, resulting in a high cost, and thus, they have a stronger incentive to raise the sales price. On the contrary, more live streaming followers mean that the supplier has less demand in the direct channel. Note that live streaming followers are consumers who demonstrate a market preference for engaging with live streaming, and more live streaming followers means a larger number of consumers who favor live streaming sales. The supplier has a stronger incentive to less the sales price to obtain more orders when the live streaming effect is high. Accordingly, the retailer does not need to put in much sales effort since live streaming sales have more followers, leading to a low sales price. Therefore, when live streaming selling used by the e-tailer has fewer followers in the direct sales channel, the two members should use a high-price strategy and the retailer should use a high sales effort strategy under a high live streaming effect. The two members should use a low-price strategy and the retailer should use a low sales effort strategy otherwise. Furthermore, the two members should shift from a low-price to a high-price strategy, and the retailer should use a sales effort strategy similar to the pricing strategy when the live streaming selling has sufficiently more followers in the direct sales channel.

D. SCENARIO LB

Under the Scenario LB, the e-tailer adopts the live streaming sales in the retail channel and the supplier introduces the blockchain into the direct sales channel. The supplier decides firstly the direct sales price p_s^{LB}, and the e-tailer decides then the sales price p_r^{LB} and the live streaming sales effort e^{LB}. In this scenario, consumers can obtain product information and may be affected by live streaming sales of the other channel, in the direct sales channel. The retail channel demand is affected by live streaming sales. Thus, from (5), (9) and (10), the demand functions for different channels are given by

$$D_s^{\mathrm{LB}} = \theta a - p_s^{\mathrm{LB}} + \beta p_r^{\mathrm{LB}} - \frac{\sigma^2}{1+t\sigma^2}(1 - t\Gamma) - \eta\mu, \quad (13)$$

$$D_r^{\mathrm{LB}} = (1-\theta)a - p_r^{\mathrm{LB}} + \beta p_s^{\mathrm{LB}} + \mu + e^{\mathrm{LB}}, \quad (14)$$

Thus, the profit maximization models of the supplier and the e-tailer under the scenario LB can be described as

$$\max_{p_s^{\mathrm{LB}}} \Pi_s^{\mathrm{LB}} = p_s^{\mathrm{LB}} D_s^{\mathrm{LB}} + w D_r^{\mathrm{LB}} - C, \quad (15)$$

$$\max_{p_r^{\mathrm{LB}}, e^{\mathrm{LB}}} \Pi_r^{\mathrm{LB}} = (p_r^{\mathrm{LB}} - w) D_r^{\mathrm{LB}} - \frac{(e^{\mathrm{LB}})^2}{2}, \quad (16)$$

The above optimization models (15) and (16) are resolved by the approach used in Subsection IV-A, and the equilibrium solutions are then obtained and are stated in Proposition 4.

Proposition 4: When the e-tailer introduces the live streaming sales and the supplier introduces blockchain, the equilibrium decisions for the two members are $p_r^{\mathrm{LB}*} = \frac{\mu}{1-\beta^2} + \frac{[2(1-\theta)+\beta\theta(\beta+1)]a - \beta[\Lambda_1+\eta\mu+\beta(a+\mu-w)]}{2(1-\beta^2)}$, $e^{\mathrm{LB}*} = \frac{-[(2-\beta^2)(1-\theta)]a+\beta[\Lambda_1 - a\theta+\eta\mu+\beta(\mu-3w)]}{2(\beta^2-1)} + \frac{w-\mu}{\beta^2-1}$ and $p_s^{\mathrm{LB}*} = \frac{\beta[\mu+(1-\theta)a]+\theta a-\eta\mu+\beta w-\Lambda_1}{2(1-\beta^2)}$, where $\Lambda_1 = \frac{(t\Gamma-1)\sigma^2}{1+t\sigma^2}$.

Corollary 4: Under the scenario LB, the impacts of the product information of the direct sales channel on the equilibrium decisions: (1) $\frac{\partial p_r^{\mathrm{LB}*}}{\partial \Gamma} > 0$; (2) $\frac{\partial p_s^{\mathrm{LB}*}}{\partial \Gamma} > 0$; (3) $\frac{\partial e^{\mathrm{LB}*}}{\partial \Gamma} = 0$.

From Corollary 4, the two members should always use a high-price strategy when the blockchain discloses the high quality and safety of products. The pricing strategies for the supplier and the e-tailer under the scenario LB are similar to those under the scenario NB when the product information changes. These results imply that whether the e-tailer introduces live streaming sales does not affect the relationship between the pricing strategy and the product information when the supplier introduces the blockchain.

Corollary 5: Under the scenario LB, the impacts of the information accuracy of the direct sales channel on the equilibrium decisions: (1) $\frac{\partial p_r^{\mathrm{LB}*}}{\partial t} \geq 0$ if $\Gamma \geq -\sigma^2$, and $\frac{\partial p_r^{\mathrm{LB}*}}{\partial t} < 0$ otherwise; (2) $\frac{\partial e^{\mathrm{LB}*}}{\partial t} \geq 0$ if $\Gamma \geq -\sigma^2$, and $\frac{\partial e^{\mathrm{LB}*}}{\partial t} < 0$ otherwise; (3) $\frac{\partial p_s^{\mathrm{LB}*}}{\partial t} \geq 0$ if $\Gamma \geq -\sigma^2$, and $\frac{\partial p_s^{\mathrm{LB}*}}{\partial t} < 0$ otherwise.

From Corollary 5, the supplier and the e-tailer are suggested to the following guidelines when the blockchain offers high information accuracy: the supplier should use a high-price strategy and the e-tailer should use the high price and high live streaming sales effort strategies when products disclosed by blockchain have the high quality and safety; Otherwise, the two members should use a low-price strategy and the retailer should use a low sales effort strategy. If the product quality and safety disclosed by the blockchain are sufficiently high, the two members should shift from a low-price to a high-price strategy and the retailer should the sales effort strategy similar to the pricing strategy as the information accuracy changes. Furthermore, the pricing and sales effort strategies under the scenario LB are similar to those under the scenario NB when the information accuracy changes. Whether the e-tailer introduces live streaming sales does not affect the relationships of the pricing and sales effort strategies to the information accuracy.

Corollary 6: Under the scenario LB, the impacts of the live streaming effect on the equilibrium decisions: (1) $\frac{\partial p_r^{\mathrm{LB}*}}{\partial \mu} \geq 0$ if $\eta \leq \frac{2-\beta^2}{\beta}$, and $\frac{\partial p_r^{\mathrm{LB}*}}{\partial \mu} < 0$ otherwise; (2) $\frac{\partial e^{\mathrm{LB}*}}{\partial \mu} \geq 0$ if $\eta \leq \frac{2-\beta^2}{\beta}$, and $\frac{\partial e^{\mathrm{LB}*}}{\partial \mu} < 0$ otherwise; $\frac{\partial p_s^{\mathrm{LB}*}}{\partial \mu} \geq 0$ if $\eta \leq \beta$, and $\frac{\partial p_s^{\mathrm{LB}*}}{\partial \mu} < 0$ otherwise.

From Corollary 6, the supplier and the e-tailer are suggested to the following guidelines when the live streaming effect is high: the two members should use a high-price strategy and the retailer should use a high sales effort strategy when the direct sales channel has fewer live streaming followers; Otherwise, the two members should use a low-price strategy and the retailer should use a low sales effort strategy. When the direct sales channel has sufficiently more live streaming followers, the member should shift from a low to a high strategy for the pricing and sales effort as the live streaming effect changes. The comparison of Corollary 6 and Corollary 3 shows that the relationships of pricing and sales effort strategies to the live streaming effect are not dependent on whether the supplier introduces the blockchain.

V. COMPARISONS AND ANALYSES

To examine the impacts of the introductions of the blockchain and live streaming on the equilibrium decisions, the equilibrium decisions for the two members under different scenarios are compared and analyzed in this section. Specifically, the equilibrium solutions with and without live streaming, and those with and without the blockchain are mainly compared.

Proposition 5: (1) The equilibrium decisions of the supplier under Scenarios NB and NN satisfy $p_s^{NB^*} \geq p_s^{NN^*}$ if $\Gamma \geq -\sigma^2$, and $p_s^{NB^*} < p_s^{NN^*}$ otherwise; (2) The equilibrium decisions of the supplier under Scenarios LB and LN satisfy $p_s^{LB^*} \geq p_s^{LN^*}$ if $\Gamma \geq -\sigma^2$, and $p_s^{LB^*} < p_s^{LN^*}$ otherwise.

Proposition 5 shows that when the supplier introduces the blockchain, higher product information may attract more consumers, and thus, they raise the sales price to obtain more returns compared to that in the absence of the blockchain. On the contrary, lower product information disclosed by the blockchain may lead to a decrease in consumer demands, and thus, the supplier reduces the sales price to attract more consumers compared to in the absence of the blockchain. Furthermore, whether the retailer introduces live streaming sales does not affect the comparisons of the sales price for the supplier with and without the blockchain.

Proposition 6: (1) The equilibrium decisions of the e-tailer under Scenarios NB and NN satisfy $p_r^{NB^*} \geq p_r^{NN^*}$ if $\Gamma \geq -\sigma^2$, and $p_r^{NB^*} < p_r^{NN^*}$ otherwise; (2) The equilibrium decisions of the e-tailer under Scenarios LB and LN satisfy $p_r^{LB^*} \geq p_r^{LN^*}$ and $e^{LB^*} \geq e^{LN^*}$ if $\Gamma \geq -\sigma^2$, and $p_r^{LB^*} < p_r^{LN^*}$ and $e^{LB^*} < e^{LN^*}$ otherwise.

From Proposition 6, regardless of whether the e-tailer introduces the live streaming sales, they are advised to adhere to the following guidelines when the supplier introduces blockchain: They should set a sales price higher than the supplier without blockchain, if the product information is higher; Otherwise, they should set a sales price lower than the supplier without it. Specifically, when the e-tailer introduces live streaming sales, the comparison of the live streaming sales effort with and without blockchain is determined by product information. As early stated, product high quality and safety information may attract more consumers, leading to a high direct sale price compared to that without blockchain. Thus, the e-tailer also follows the supplier to set a sales price in these two scenarios to resist monopolization by competitors, and invests more live steaming sales efforts to attract more consumers compared to that without blockchain. Instead, the product low quality and safety information leads the e-tailer to set a sales price lower and to invest live streaming sales efforts lower than those without blockchain.

Proposition 7: (1) The equilibrium decisions of the supplier under Scenarios LN and NN satisfy $p_s^{LN^*} \geq p_s^{NN^*}$ if $\eta \leq \eta_1$, and $p_s^{LN^*} < p_s^{NN^*}$ otherwise, where $\eta_1 = \frac{\beta\Lambda_3}{\mu(2-\beta^2)}$; (2) The equilibrium decisions of the supplier under Scenarios LB and NB satisfy $p_s^{LB^*} \geq p_s^{NB^*}$ if $\eta \leq \eta_2$, and $p_s^{LB^*} < p_s^{NB^*}$ otherwise, where $\eta_2 = \frac{\beta(t\sigma^2((1-\theta)a+\Lambda_2+\beta\Gamma)+\Lambda_3)}{\mu(2-\beta^2)(t\sigma^2+1)}$, $\Lambda_2 = \mu(2-\beta^2)+\beta(\beta w+\theta a)$ and $\Lambda_3 = (1-\theta)a+\Lambda_2-\beta\sigma^2$.

From Proposition 7, whether the supplier introduces blockchain, they are advised to adhere to the following guidelines when the e-tailer introduces the live streaming sales: They should set a sales price higher than that when the e-tailer does not if the live streaming selling attracts fewer consumers in the direct sales channel; Otherwise, they should set a sales price lower than that when the e-tailer does not. When the live streaming sales mode does not have more followers in the direct sales channel, the supplier raises the sales price to obtain more returns compared to that without the live streaming sales. Similarly, more followers in the direct sales channel for the live streaming sales induce the supplier to reduce the sales price to attract more consumers compared with that in the absence of the live streaming sales. Furthermore, whether the supplier introduces blockchain does not affect the relationship between the direct sales price with and without live streaming sales.

Proposition 8: (1) The equilibrium decisions of the e-tailer under Scenarios NB and NN satisfy $p_r^{LN^*} \geq p_r^{NN^*}$ if $\eta \leq \eta_3$, and $p_r^{LN^*} < p_r^{NN^*}$ otherwise, where $\eta_3 = \frac{\theta\beta^2(3-\beta^2)a+\Lambda_4-2\beta\sigma^2}{2\beta\mu(2-\beta^2)}$; (2) The equilibrium decisions of the e-tailer under Scenarios LB and LN satisfy $p_r^{LB^*} \geq p_r^{NB^*}$ if $\eta \leq \eta_4$, and $p_r^{LB^*} < p_r^{NB^*}$ otherwise, where $\eta_4 = \frac{t\sigma^2(2\beta\Gamma+\theta\beta^2(3-\beta^2)a+\Lambda_4)+\theta\beta^2(3-\beta^2)a+\Lambda_4-2\beta\sigma^2}{2\beta\mu(2-\beta^2)(t\sigma^2+1)}$ and $\Lambda_4 = 4(1-\theta)a+2\mu(\beta^2-2)^2-2(\beta^4-4\beta^2+2)w+\beta(\beta^3-3\beta+2\theta)a$.

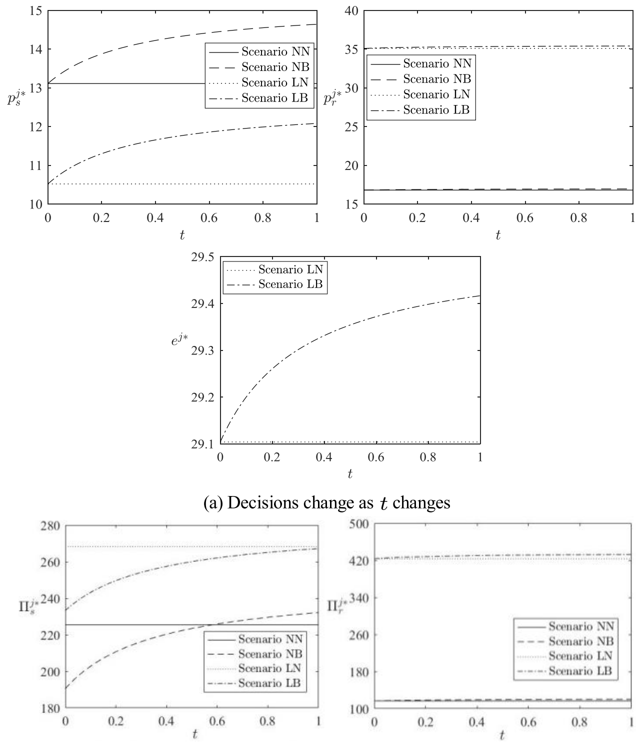
From Proposition 8, whether the supplier introduces blockchain, the e-tailer is advised to adhere to pricing guidelines similar to those of the supplier from Proposition 7 when they introduce live streaming sales. These results imply that the relationships between the e-tailer sales price with and without live streaming sales are affected by the quantity of live streaming sales followers in the direct sale channel, but not whether the supplier introduces blockchain.

VI. NUMERICAL STUDIES

Several numerical experiments are conducted to provide more managerial insights. The sensitivity analyses are performed to investigate the impact of the important parameters on the equilibrium profits for the supplier and the e-tailer. The equilibrium profits among the NN, NB, LN and LB scenarios are then compared and discussed to investigate the optimal choice for the supplier and the e-tailer. Finally, the synergic impacts of the important parameters on equilibrium profits are further investigated. The relevant parameters are set to $a = 50$, $\theta = 0.5$, $\beta = 0.2$, $w = 6$, $\eta = 1.2$, $\mu = 1.2$, $\sigma^2 = 3$, $t = 0.8$, $\Gamma = 1$ and $C = 35$. These parameter values are used as defaults unless specifically mentioned otherwise.

A. THE EFFECTS OF THE INFORMATION ACCURACY

To examine the impacts of the information accuracy on the optimal profits for the supplier and the e-tailer, the parameter t is set to operate within the range [0, 1] in steps of 0.2. The results are plotted in Fig. 1.



(a) Decisions change as t changes

(b) Profits change as t changes

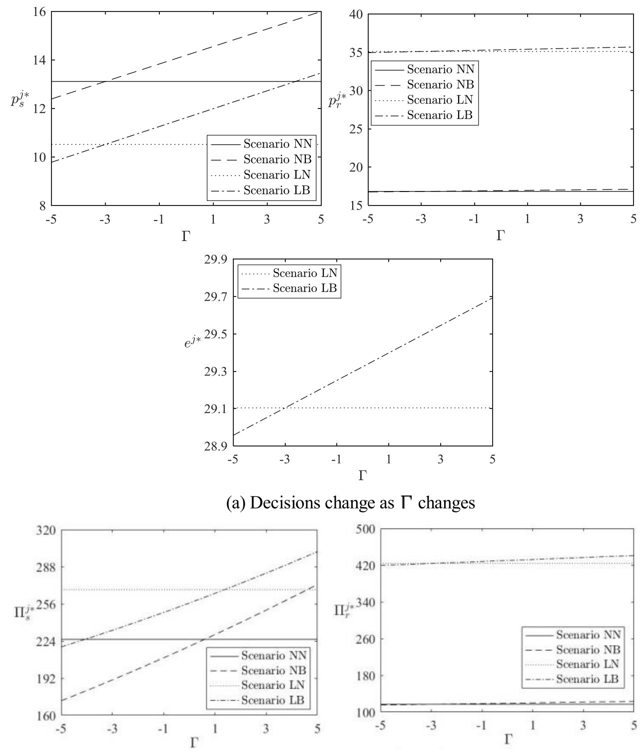
FIGURE 1. Equilibrium decisions and profits change as t increases.

Fig. 1 (a) verifies the results of Corollaries 2 and 5. Moreover, Fig. 1 (a) also shows the comparisons of decisions among the four scenarios. The supplier should set the highest sales price under the scenario NB and the lowest sales price under the scenario LN. The e-tailer should set the highest price under the scenario NB and the lowest price under the scenario NN. The e-tailer should invest sales effort more under the scenario LB than the scenario LN when using live streaming sales.

Fig. 1 (b) shows that when the supplier introduces blockchain, the profits for the two members increase as the information accuracy increases. However, the equilibrium profits are not affected by the information accuracy when the supplier does not introduce blockchain. A higher information accuracy is beneficial for the two members when the supplier introduces blockchain. Thus, the supplier should invest more costs to improve information accuracy in the introduction of blockchain. The e-tailer should work with the supplier who introduces blockchain with high information accuracy. Furthermore, the supplier can obtain the highest profit under the scenario LN, but the e-tailer can obtain the highest profit under the scenario LB. The supplier benefits most when they do not introduce blockchain and the e-tailer introduces live streaming sales. Similarly, the retailer benefits most when they develop live streaming sales and the supplier uses blockchain. Thus, the two members are suggested as follows when information accuracy changes: The supplier should not use blockchain while supporting the e-tailer to introduce live streaming sales; The e-tailer should develop live streaming sales and should support the supplier to introduce blockchain.

B. THE EFFECTS OF THE PRODUCT INFORMATION

To examine the impacts of the product information on the optimal profits for the supplier and the e-tailer, the parameter Γ is set to operate within the range [−5, 5] in steps of 2. The results are plotted in Fig. 2.



(a) Decisions change as Γ changes

(b) Profits change as Γ changes

FIGURE 2. Equilibrium decisions and profits change as Γ increases.

Fig. 2 (a) verifies the results of Corollaries 1 and 4. Also from Fig. 2 (a), the supplier should set the highest price under the scenario NB if the product information is higher and those under the NN otherwise. However, the e-tailer should set the highest price under the scenario LB if the product information is higher and those under the scenario LN otherwise. When adopting live streaming sales, the e-tailer should invest the sales effort most under the scenario LB and those under scenario LN otherwise.

Fig. 2 (b) shows that when the supplier introduces blockchain, the equilibrium profits for the two members increase as the product information increases. The high quality and high safety information is beneficial for the two members. Thus, the supplier should produce products with high quality and high safety when introducing blockchain and the e-tailer should work with the supplier who produces high-safety products in the presence of blockchain. Furthermore, both the supplier and the e-tailer obtain the highest profit under the scenario LN if the product information is lower than consumer expectation, and under the scenario LB otherwise. The supplier and e-tailer prefer scenario LN if consumers are not satisfied with product information, and scenario LB otherwise. Thus, the supplier should support the retailer in introducing live streaming sales while being suggested as follows: they should not use blockchain if product quality and safety are lower than consumer expectations, and should do it otherwise. The retailer should use the live streaming sales while being suggested as follows: they should work with the supplier who does not introduce blockchain if product quality and safety are lower than consumer expectations, and with the supplier who does it.

C. THE EFFECTS OF LIVE STREAMING EFFECT

To examine the impacts of the live streaming effect on the optimal profits for the supplier and the e-tailer, the parameter μ is set to operate within the range [5, 10] in steps of 1. The results are plotted in Fig. 3.

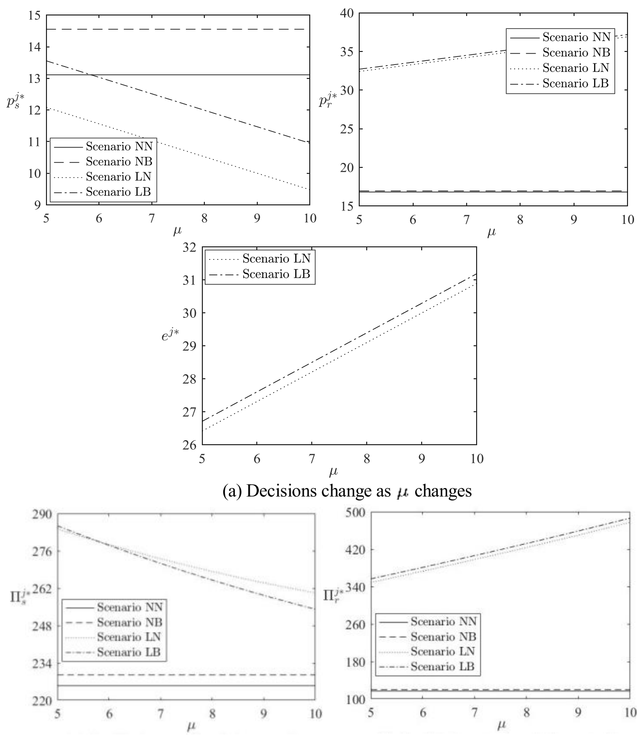


FIGURE 3. Equilibrium decisions and profits change as μ increases.

Fig.3 (a) verifies the results of Corollaries 3 and 6. From Fig. 3 (a), the supplier should set the highest price under the scenario NB and the lowest price under the scenario LN. However, the e-tailer should set the highest price under the scenario LB and the lowest price under the scenario NN. When the e-tailer adopts live streaming sales, they invest sales effort more under the scenario LB than the scenario LN.

Fig.3 (b) shows that when the e-tailer uses live streaming sales, the equilibrium profits for the supplier decrease but those for the e-tailer increase as the live streaming effect increases. Obviously, a high live streaming effect is unfavorable to the supplier but beneficial to the e-tailer. Thus, the supplier should use measures such as providing personalized service and coupons to weaken live streaming effect. However, the e-tailer should employ a famous streamer and promote product live streaming to increase its impact on consumers. Moreover, the supplier obtains the highest profit under the scenario LB when the live streaming effect is smaller, and those under the scenario LN otherwise. The e-tailer always obtains the highest profit under the scenario LB. The supplier prefers the scenario LB under a low live streaming effect and the scenario LN under a high live streaming effect, and the e-tailer prefers always the scenario LB. Thus, the supplier should support the e-tailer in introducing live streaming sales while being suggested as follows: They should not introduce blockchain if the live streaming effect is smaller and should do otherwise. The e-tailer should use live streaming sales and should work with the supplier who introduces blockchain.

Also from Figs 1-3, the introduction of blockchain can improve profits for the supplier under a certain condition, but the profit growth rate is lower than that of the e-tailer when comparing scenarios with and without live streaming sales. Thus, the supplier needs to measure the product information, information accuracy and live streaming effect, and use it to determine if they should introduce blockchain. Different from the supplier, the introduction of live streaming sales always improves profit for the e-tailer at any product information, information accuracy and live streaming effect and the profit growth rate is high. The profits of the e-tailer are lower than those of the supplier if the live streaming selling is not used. The introduction of live streaming selling helps the e-tailer obtain a profit higher than that of the supplier. Thus, the e-tailer should use live streaming sales regardless of product information, information accuracy and live streaming effect.

D. SYNERGIC IMPACTS OF IMPORTANT PARAMETERS

To examine the synergic impacts of important parameters on a win-win situation for the supplier and the e-tailer, the parameter β is to operate within the range [0, 1] in steps of 0.2, the parameter w is set to operate within the range [0, 10] in steps of 2, and other parameters are set as described. The results are plotted in Fig. 4.

Fig 4 shows that the scenario LB always generates a win-win situation for the two members if Γ and μ are any value. The two members should always work in cooperation, with the supplier using blockchain and the e-tailer using live streaming sales regardless of product information and live streaming effect. Blockchain allows the supplier to record and trace the entire production and shipping process of products, enabling all parties to trust the authenticity and quality of the

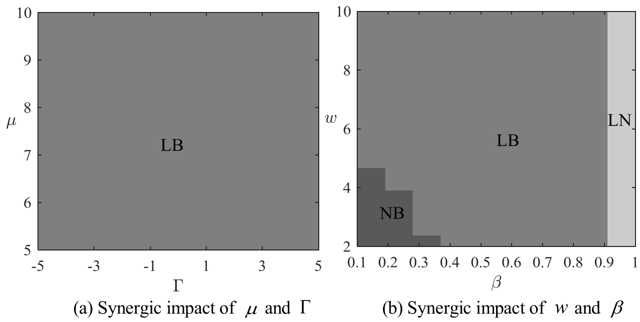


FIGURE 4. Win-win situations with different parameter values.

products, thereby reducing the risk of counterfeit products. The e-tailer using live streaming sales can directly interact with consumers, increasing consumer engagement and purchase intent. This also provides the supplier with valuable market information, helping them to adjust production and supply strategies. Therefore, the cooperation between the supplier using blockchain and the e-tailer using live streaming sales not only enhances the transparency and efficiency of the supply chain but also builds consumer trust, driving supply chain management towards greater intelligence and flexibility. The relevant factors of blockchain and live streaming sales do not affect optimal choices for both the supplier and e-tailer.

Both the wholesale price and competitive intensity may affect the profits of the two supply chain members, leading to a change in comparisons of profits among NN, NB, LN and LB scenarios. Thus, they also affect the blockchain introduction of the supplier and the live streaming sales adoption of the e-tailer. Fig. 4 also shows that the wholesale price and competition intensity can affect the win-win situation for the two members. The scenario NB generates a win-win situation for the supplier and the e-tailer if w is lower and β is lower, the scenario LB does if w is higher and β is moderate, and the scenario LN does otherwise. Any one of the NB, LB and LN scenarios can generate a win-win situation for the two members under a certain condition. Thus, the cooperation between the two members is suggested as follows: the supplier introduces blockchain but the e-tailer does not introduce live streaming sales if the wholesale price is lower and competition is mitigated; the supplier uses blockchain and the e-tailer uses live streaming sales if the wholesale price is higher and competition level is moderate; otherwise, the supplier does not use blockchain and the e-tailer uses live streaming sales.

VII. CONCLUSION

This work examines blockchain introduction and live streaming strategy in a dual-channel supply chain consisting of a supplier and an e-tailer. The four scenarios are proposed based on the blockchain introduction of the supplier and the live streaming adoption of the e-tailer. The key findings are stated as follows:

(1) The pricing decisions of the supplier and the e-tailer increase if the quality information exceeds a threshold, and decrease otherwise. These pricing decisions and live streaming sales effort level increase if the live streaming followership factor is lower than a threshold, and decrease otherwise.

(2) The sales prices of the two supply chain members are higher with than without blockchain if the product information is high, and vice versa. These sales prices are higher with than without live streaming sales if the live streaming followership factor is lower, and are lower with than without live streaming sales otherwise.

(3) The profits of the supplier and the e-tailer increase as the product information or information accuracy increases. The profit of the supplier decreases but that of the e-tailer increases as the live streaming effect increases.

(4) The scenario LB always generates a win-win situation for the supplier and the e-tailer if product information and live streaming effect are any value. The scenario NB generates a win-win situation if the wholesale price and the competition intensity both are lower, the scenario LB does if the wholesale price is higher and the competition intensity is moderate, and the scenario LN does otherwise.

Managerial implications from the above findings are stated as follows:

(1) When the supplier introduces blockchain, both members should use a high-price strategy if product quality and safety disclosed by blockchain are higher. However, a high information accuracy induces the supplier and e-tailer to shift from a low-price to a high-price strategy when product quality and safety disclosed by blockchain are sufficiently high. When the e-tailer uses live streaming sales, the two members should shift from a high-price to a low-price strategy if the live streaming followers are more in the direct sales channel. Accordingly, the retailer uses live streaming sales effort strategy similar to the pricing strategy.

(2) When the supplier introduces blockchain, both members should set a higher sales price if the disclosed product quality is high, and set a lower sales price otherwise, compared to prices without blockchain. When the e-tailer uses live streaming sales, both members should set a higher sales price if live streaming attracts fewer consumers from the direct sales channel, and set a lower sales price otherwise, compared to prices without live streaming sales.

(3) Higher product quality information and higher information accuracy are beneficial to both the supplier and the e-tailer. Thus, the supplier should invest more costs to improve the product quality and to increase information accuracy in the presence of blockchain. The e-tailer should work with the supplier who discloses high quality information or highly accurate product information in the blockchain. However, a higher live streaming effect is unfavorable to the supplier and beneficial to the e-tailer. Thus, the supplier should use personality service, coupons and other measures, to weaken the impact of live streaming on consumers. The e-tailer should employ a celebrity streamer and promote heavily their live streaming about products.

(4) The two members should always work in cooperation, with the supplier using blockchain and the e-tailer using live streaming sales regardless of the product information and live streaming effect. However, cooperation between the two members with different wholesale prices and competition intensities is suggested as follows: the supplier introduces blockchain but the e-tailer does not use live streaming sales if the wholesale price is lower and competition is mitigated; the supplier introduces blockchain and the e-tailer uses live streaming sales if the wholesale price is higher and competition level is moderate; otherwise, the supplier does not use blockchain and the e-tailer uses live streaming sales.

Several extensions of this work include integrating an uncertain demand with or without both the mean and the variance and using a robust optimization approach or a data-driven approach to investigate joint pricing and ordering decisions. Another extension is to examine an omnichannel supply chain, where the supplier, e-tailer or both is assumed to develop omnichannel. Finally, cross-channel return processing is incorporated into a direct sales channel or retail channel to examine ordering decisions.

APPENDIX

A. PROOF OF PROPOSITION 1

The second partial derivative of Π_r^{NN} in (4) with respect to p_r^{NN} is $\frac{\partial^2 \Pi_r^{NN}}{\partial (p_r^{NN})^2} = -2 < 0$, and thus, Π_r^{NN} is concave in p_r^{NN}. By the first-order condition of Π_r^{NN}, the optimal retail price $p_r^{NN^*}(p_s^{NN^*})$ in $p_s^{NN^*}$ is derived as $p_r^{NN} = \frac{w+\beta p_s^{NN}+(1-\theta)a}{2}$. After substituting $p_r^{NN^*}(p_s^{NN^*})$ into Π_s^{NN} in (3), the second partial derivative of Π_s^{NN} with respect to $p_s^{NN^*}$ is $\frac{\partial^2 \Pi_s^{NN}}{\partial (p_s^{NN})^2} = \beta^2 - 2 < 0$, and thus, Π_s^{NN} is concave in $p_s^{NN^*}$. Setting $\frac{\partial \Pi_s^{NN}}{\partial p_s^{NN}} = 0$, $p_s^{NN^*} = \frac{[2\theta+(1-\theta)\beta]a-2\sigma^2+2\beta w}{2(2-\beta^2)}$ and $p_r^{NN^*} = \frac{(1-\theta)(4-\beta^2)a+4w+2\beta(\theta a-\sigma^2)}{4(2-\beta^2)}$ are then derived.

B. PROOF OF PROPOSITION 2

The second partial derivative of Π_r^{NB} in (8) with respect to p_r^{NB} is $\frac{\partial^2 \Pi_r^{NB}}{\partial (p_r^{NB})^2} = -2 < 0$, and thus, Π_r^{NB} is concave in p_r^{NB}. By the first-order condition of Π_r^{NB}, the optimal retail price $p_r^{NB^*}(p_s^{NB^*})$ in $p_s^{NB^*}$ is derived as $p_r^{NB^*} = \frac{w+\beta p_s^{NB}+(1-\theta)a}{2}$. After substituting $p_r^{NB^*}(p_s^{NB^*})$ into Π_s^{NB} in (7), the second partial derivative of Π_s^{NB} with respect to p_s^{NB} is $\frac{\partial^2 \Pi_s^{NB}}{\partial (p_s^{NB})^2} = \beta^2 - 2 < 0$, and thus, Π_s^{NB} is concave in p_s^{NB}. Setting $\frac{\partial \Pi_s^{NB}}{\partial p_s^{NB}} = 0$, $p_s^{NB^*} = \frac{[2\theta+(1-\theta)\beta]a-2\Lambda_1+2\beta w}{2(2-\beta^2)}$ and $p_r^{NB^*} = \frac{(1-\theta)(4-\beta^2)a+4w-2\beta(\Lambda_1-a\theta)}{4(2-\beta^2)}$ are then derived, where $\Lambda_1 = \frac{(t\Gamma-1)\sigma^2}{1+t\sigma^2}$.

C. PROOF OF COROLLARY 1

The first partial derivatives of $p_r^{NB^*}$ and $p_s^{NB^*}$ with respect to Γ are given by $\frac{\partial p_r^{NB^*}}{\partial \Gamma} = \frac{t\beta\sigma^2}{2(2-\beta^2)(t\sigma^2+1)} > 0$ and $\frac{\partial p_s^{NB^*}}{\partial \Gamma} = \frac{t\sigma^2}{(2-\beta^2)(t\sigma^2+1)} > 0$.

D. PROOF OF COROLLARY 2

The first partial derivatives of $p_r^{NB^*}$ and $p_s^{NB^*}$ with respect to t are given by $\frac{\partial p_r^{NB^*}}{\partial t} = \frac{\beta\sigma^2(\Gamma+\sigma^2)}{2(2-\beta^2)(t\sigma^2+1)^2}$ and $\frac{\partial p_s^{NB^*}}{\partial t} = \frac{\sigma^2(\Gamma+\sigma^2)}{(2-\beta^2)(t\sigma^2+1)^2}$. Then, $\frac{\partial p_r^{NB^*}}{\partial t} \geq 0$ and $\frac{\partial p_s^{NB^*}}{\partial t} \geq 0$ if $\Gamma \geq -\sigma^2$, and $\frac{\partial p_r^{NB^*}}{\partial t} < 0$ and $\frac{\partial p_s^{NB^*}}{\partial t} < 0$ otherwise.

E. PROOF OF PROPOSITION 3

The second partial derivatives of Π_r^{LN} in (12) with respect to p_r^{LN} and e^{LN} are $\frac{\partial^2 \Pi_r^{LN}}{\partial (p_r^{LN})^2} = -2 < 0$, $\frac{\partial^2 \Pi_r^{LN}}{\partial (e^{LN})^2} = -1 < 0$ and $\frac{\partial^2 \Pi_r^{LN}}{\partial p_r^{LN} \partial e^{LN}} = \frac{\partial^2 \Pi_r^{LN}}{\partial e^{LN} \partial p_r^{LN}} = 1$. Thus, the Hessian matrix of Π_r^{LN} is $\begin{vmatrix} -2 & 1 \\ 1 & -1 \end{vmatrix} = 1 > 0$. Π_r^{LN} is jointly concave in p_r^{LN} and e^{LN}. By the first-order condition of Π_r^{LN}, $p_r^{LN^*}(p_s^{LN^*})$ and $e^{LN^*}(p_s^{LN^*})$ are derived as $p_r^{LN^*} = \mu + \beta p_s^{LN} + (1-\theta)a$ and $e^{LN^*} = \mu - w + \beta p_s^{LN} + (1-\theta)a$. After substituting $p_r^{LN^*}(p_s^{LN^*})$ and $e^{LN^*}(p_s^{LN^*})$ into Π_s^{LN} in (11), the second partial derivative of Π_s^{LN} with respect to p_s^{LN} is $\frac{\partial^2 \Pi_s^{LN}}{\partial (p_s^{LN})^2} = 2(\beta^2-1) < 0$, and thus, Π_s^{LN} is concave in p_s^{LN}. Setting $\frac{\partial \Pi_s^{LN}}{\partial p_s^{LN}} = 0$, $p_s^{LN^*} = \frac{\beta[\mu+(1-\theta)a]-\sigma^2+a\theta-\eta\mu+\beta w}{2(1-\beta^2)}$, $e^{LN^*} = \frac{2(w-\mu)-\delta_1 a+\beta}{2(\beta^2-1)}$, and $p_r^{LN^*} = \frac{\delta_1 a+2\mu-\delta_2\beta}{2(1-\beta^2)}$ are then derived, where $\delta_1 = (2-\beta^2)(1-\theta)+\beta\theta$ and $\delta_2 = \sigma^2+\eta\mu+\beta(\mu-3w)$.

F. PROOF OF COROLLARY 3

The first partial derivatives of $p_r^{LN^*}$, e^{LN^*}, and $p_s^{LN^*}$ with respect to μ are given by $\frac{\partial p_r^{LN^*}}{\partial \mu} = \frac{\beta^2+\eta\beta-2}{2(\beta^2-1)}$, $\frac{\partial e^{LN^*}}{\partial \mu} = \frac{\beta^2+\eta\beta-2}{2(\beta^2-1)}$, and $\frac{\partial p_s^{LN^*}}{\partial \mu} = \frac{\beta-\eta}{2(1-\beta^2)}$. Then, $\frac{\partial p_r^{LN^*}}{\partial \mu} \geq 0$ if $0 < \eta \leq \frac{2-\beta^2}{\beta}$, and $\frac{\partial p_r^{LN^*}}{\partial \mu} < 0$ otherwise; $\frac{\partial e^{LN^*}}{\partial \mu} \geq 0$ if $0 < \eta \leq \frac{2-\beta^2}{\beta}$, and $\frac{\partial e^{LN^*}}{\partial \mu} < 0$ otherwise; $\frac{\partial p_s^{LN^*}}{\partial \mu} \geq 0$ if $0 < \eta \leq \beta$, and $\frac{\partial p_s^{LN^*}}{\partial \mu} < 0$ otherwise.

G. PROOF OF PROPOSITION 4

The second partial derivatives of Π_r^{LB} in (16) with respect to p_r^{LB} and e^{LB} are $\frac{\partial^2 \Pi_r^{LB}}{\partial (p_r^{LB})^2} = -2 < 0$, $\frac{\partial^2 \Pi_r^{LB}}{\partial (e^{LB})^2} = -1 < 0$ and $\frac{\partial^2 \Pi_r^{LB}}{\partial p_r^{LB} \partial e^{LB}} = \frac{\partial^2 \Pi_r^{LB}}{\partial e^{LB} \partial p_r^{LB}} = 1$. Thus, the Hessian matrix of Π_r^{LB} is $\begin{vmatrix} -2 & 1 \\ 1 & -1 \end{vmatrix} = 1 > 0$. Π_r^{LB} is jointly concave in p_r^{LB} and e^{LB}. By the first-order condition of Π_r^{LB}, $p_r^{LB^*}(p_s^{LB^*})$ and $e^{LB^*}(p_s^{LB^*})$ are derived as $p_r^{LB} = \mu + \beta p_s^{LB} + (1-\theta)a$ and $e^{LB} = \mu - w + \beta p_s^{LB} + (1-\theta)a$. After substituting $p_r^{LB^*}(p_s^{LB^*})$ and $e^{LB^*}(p_s^{LB^*})$ into Π_s^{LB} in (15), the second partial derivative of Π_s^{LB} with respect to p_s^{LB} is $\frac{\partial^2 \Pi_s^{LB}}{\partial (p_s^{LB})^2} = 2(\beta^2-1) < 0$, and thus, Π_s^{LB} is concave in p_s^{LB}. Setting $\frac{\partial \Pi_s^{LB}}{\partial p_s^{LB}} = 0$, $p_s^{LB^*} = \frac{\beta[\mu+(1-\theta)a]+\theta a-\eta\mu+\beta w-\Lambda_1}{2(1-\beta^2)}$, $e^{LB^*} = \frac{2(w-\mu)-[(2-\beta^2)(1-\theta)]a+\beta[\Lambda_1-a\theta+\eta\mu+\beta(\mu-3w)]}{2(\beta^2-1)}$, and

$p_r^{\mathrm{LB}*} = \frac{[2(1-\theta)+\beta\theta(\beta+1)]a+2\mu-\beta[\Lambda_1+\eta\mu+\beta(a+\mu-w)]}{2(1-\beta^2)}$ are then derived, where $\Lambda_1 = \frac{(t\Gamma-1)\sigma^2}{1+t\sigma^2}$.

H. PROOF OF COROLLARY 4

The first partial derivatives of $p_r^{\mathrm{LB}*}$, $e^{\mathrm{LB}*}$, and $p_s^{\mathrm{LB}*}$ with respect to Γ are given by $\frac{\partial p_r^{\mathrm{LB}*}}{\partial \Gamma} = \frac{\beta t\sigma^2}{2(1-\beta^2)(t\sigma^2+1)} > 0$, $\frac{\partial e^{\mathrm{LB}*}}{\partial \Gamma} = \frac{\beta t\sigma^2}{2(1-\beta^2)(t\sigma^2+1)} > 0$, and $\frac{\partial p_s^{\mathrm{LB}*}}{\partial \Gamma} = \frac{t\sigma^2}{2(1-\beta^2)(t\sigma^2+1)} > 0$.

I. PROOF OF COROLLARY 5

The first partial derivatives of $p_r^{\mathrm{LB}*}$, $e^{\mathrm{LB}*}$, and $p_s^{\mathrm{LB}*}$ with respect to t are given by $\frac{\partial p_r^{\mathrm{LB}*}}{\partial t} = \frac{\beta\sigma^2(\Gamma+\sigma^2)}{2(1-\beta^2)(t\sigma^2+1)^2}$, $\frac{\partial e^{\mathrm{LB}*}}{\partial t} = \frac{\beta\sigma^2(\Gamma+\sigma^2)}{2(1-\beta^2)(t\sigma^2+1)^2}$, and $\frac{\partial p_s^{\mathrm{LB}*}}{\partial t} = \frac{\sigma^2(\Gamma+\sigma^2)}{2(1-\beta^2)(t\sigma^2+1)^2}$. Then, $\frac{\partial p_r^{\mathrm{LB}*}}{\partial t} \geq 0$, $\frac{\partial e^{\mathrm{LB}*}}{\partial t} \geq 0$, and $\frac{\partial p_s^{\mathrm{LB}*}}{\partial t} \geq 0$ if $\Gamma \geq -\sigma^2$, and $\frac{\partial p_r^{\mathrm{LB}*}}{\partial t} < 0$, $\frac{\partial e^{\mathrm{LB}*}}{\partial t} < 0$, and $\frac{\partial p_s^{\mathrm{LB}*}}{\partial t} < 0$ otherwise.

J. PROOF OF COROLLARY 6

The first partial derivatives of $p_r^{\mathrm{LB}*}$, $e^{\mathrm{LB}*}$, and $p_s^{\mathrm{LB}*}$ with respect to μ are given by $\frac{\partial p_r^{\mathrm{LB}*}}{\partial \mu} = \frac{\beta^2+\eta\beta-2}{2(\beta^2-1)}$, $\frac{\partial e^{\mathrm{LB}*}}{\partial \mu} = \frac{\beta^2+\eta\beta-2}{2(\beta^2-1)}$, and $\frac{\partial p_s^{\mathrm{LB}*}}{\partial \mu} = \frac{\beta-\eta}{2(1-\beta^2)}$. Then, $\frac{\partial p_r^{\mathrm{LB}*}}{\partial \mu} \geq 0$ if $0 < \eta \leq \frac{2-\beta^2}{\beta}$, and $\frac{\partial p_r^{\mathrm{LB}*}}{\partial \mu} < 0$ otherwise; $\frac{\partial e^{\mathrm{LB}*}}{\partial \mu} \geq 0$ if $0 < \eta \leq \frac{2-\beta^2}{\beta}$, and $\frac{\partial e^{\mathrm{LB}*}}{\partial \mu} < 0$ otherwise; $\frac{\partial p_s^{\mathrm{LB}*}}{\partial \mu} \geq 0$ if $0 < \eta \leq \beta$, and $\frac{\partial p_s^{\mathrm{LB}*}}{\partial \mu} < 0$ otherwise.

K. PROOF OF PROPOSITION 5

Comparing $p_s^{\mathrm{NB}*}$ with $p_s^{\mathrm{NN}*}$, $p_s^{\mathrm{NB}*} - p_s^{\mathrm{NN}*} = \frac{t\sigma^2(\Gamma+\sigma^2)}{(2-\beta^2)(t\sigma^2+1)}$. Then, comparing $p_s^{\mathrm{LB}*}$ with $p_s^{\mathrm{LN}*}$, $p_s^{\mathrm{LB}*} - p_s^{\mathrm{LN}*} = \frac{t\sigma^2(\Gamma+\sigma^2)}{2(1-\beta^2)(t\sigma^2+1)}$. Therefore, $p_s^{\mathrm{NB}*} \geq p_s^{\mathrm{NN}*}$ and $p_s^{\mathrm{LB}*} \geq p_s^{\mathrm{LN}*}$ if $\Gamma \geq -\sigma^2$, and $p_s^{\mathrm{NB}*} < p_s^{\mathrm{NN}*}$ and $p_s^{\mathrm{LB}*} < p_s^{\mathrm{LN}*}$ otherwise.

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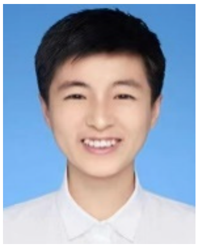

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