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Decisions and coordination in the live streaming e-commerce supply chain of agricultural products considering poverty alleviation preferences

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ABSTRACT

Due to the need to maintain the freshness of agricultural products, farmers must use cold chain logistics, which increases the cost of preservation. Live streaming e-commerce (LSEC) platforms may offer poverty alleviation support and share part of these costs. This study examines an agricultural product supply chain that includes a farmer and an LSEC platform. Using the Stackelberg game approach, four decision-making models are developed to analyze the strategic choices and optimal profits of the supply chain participants. Since the decentralized model without poverty alleviation support cannot reach an equilibrium solution, the study proposes a cost-revenue sharing coordination contract that includes poverty alleviation preferences. The results indicate that poverty alleviation preferences improve the profits of the farmer and the overall supply chain, although they reduce the profit of the LSEC platform. The profit outcomes for each participant depend on factors such as the sales price, the level of freshness-keeping effort, and the cost of that effort. Through contract coordination, the supply chain can achieve full efficiency. This study offers insights for promoting cooperation among participants in the agricultural product LSEC supply chain.

1. Introduction

Recent years have witnessed a spurt of progress in live streaming e-commerce (LSEC). According to Ministry of Commerce of the People's Republic of China in 2023, the scale of China's LSEC market reached 4.9 trillion yuan, a year-on-year increase of 35.2%, and the scale of online LSEC users has reached 540 million; the e-commerce online retail sales surpassed 15.42 trillion yuan, and the online retail sales of agricultural products reached 587.03 billion yuan (Wan et al., 2024). LSEC improves supply chain efficiency by shortening the sales chain and promotes agricultural assistance plans. A notable example is the "Taobao Live" platform in China, which has successfully implemented poverty alleviation initiatives by partnering with rural farmers. Since its launch in 2019, Taobao Live's "Village Live Plan" has seen over 110,000 farmer live streamers conduct a cumulative total of 3.3 million live streaming on Taobao, driving agricultural product sales exceeding 15 billion yuan. The "Village Live Plan" has achieved remarkable results in promoting the sale of agricultural products (Li et al., 2025).

Since 2016, LSEC has become the main channel for rapid sales of agricultural products, especially to solve the plight of agricultural products that cannot be sold offline during the COVID-19 epidemic in China. The LSEC helps farmers achieve seamless integration of production→sellers→shoppers, reduces information asymmetry, reduces the cost of intermediate channels (Guo et al., 2022), provides shoppers with a more realistic shopping experience, optimizes the display of online products, and adds the interaction of online consumption, attracting shoppers to purchase and further stimulating consumption potential.

Agricultural products move from farms to consumers through a complex supply chain that involves many participants. Uncertainty exists at every stage of this process. Because each participant often prioritizes their own interests, coordination and cooperation are limited. This lack of alignment frequently results in alternating situations where agricultural products are either difficult to sell or

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difficult to purchase, preventing the achievement of integrated supply chain optimization. At the same time, sudden increases in demand for LSEC services make it challenging to maintain product freshness. In China, the LSEC industry has expanded rapidly, supported by the development of strong supply chains. However, the sustainability of these supply chains depends on effective profit distribution and coordination among all participants (Liu et al., 2022).

This research endeavors to probe into four distinct yet interrelated questions: First, what is the impact of the magnitude of freshness-keeping efforts on the optimal decisions within the agricultural product LSEC supply chain? Second, what are the strategic decisions that emerge when the LSEC platform incorporates poverty alleviation preferences into its operations? Third, how does the coefficient of poverty alleviation preference correlate with the overall profitability of the agricultural product LSEC supply chain system? Fourth, what mechanisms can facilitate the coordination of the agricultural product LSEC supply chain system when poverty alleviation preferences are taken into account?

This study makes the following contributions: Firstly, the poverty alleviation preference is introduced to characterize the impact of supply chain players' cooperation on the supply chain decisions of agricultural products LSEC. Secondly, a cost-revenue sharing contract with poverty alleviation preference is formulated to harmonize the relationship between supply chain players and achieve the optimal decision of the agricultural product LSEC supply chain system. Thirdly, in the context of LSEC, the influence of freshness-keeping effort levels on market demand and the profitability of the agricultural products LSEC supply chain is considered.

The subsequent sections of this research are structured in the following manner. Section 2 is a literature review. Section 3 constructs and solves the models. Section 4 presents the results and discussion. Section 5 provides a numerical analysis. Section 6 concludes this study.

2. Literature review

This research intersects with three distinct study domains within the extant literature: Optimal decisions of agricultural product LSEC supply chain, poverty alleviation preference in supply chain management, and facilitation of coordination within agricultural product LSEC supply chain.

Beamon (1998) introduced the research on supply chain optimal decisions. Some literature suggests that the freshness-keeping effort level affects the optimal decision within the supply chain framework. For example, Wang et al. (2018) considered the influence of freshness-keeping efforts on cold chain decisions. Yang and Tang (2019) explored freshness-keeping effort decisions under different sales models. Cui et al. (2024) proposed that fresh-keeping logistics has an impact on the decisions of fresh e-commerce supply chains. Other scholars have also confirmed that freshness-keeping efforts play a decisive role in the decision-making and coordination of agricultural product supply chains. For example, Ma et al. (2019) showed that in a three-echelon fresh agricultural products supply chain, freshness-keeping effort directly affects coordination under asymmetric information. Similarly, Yang and Yao (2024) analyzed fresh-keeping decisions under carbon cap-and-trade, finding that the degree of freshness effort significantly alters coordination outcomes. Li et al. (2023) further demonstrated that profit-sharing contracts incorporating freshness preservation improve sustainability in community group purchase models. In the same vein, Wang et al. (2025) confirmed that dynamic freshness-keeping efforts strongly influence decision-making and coordination in a three-tier supply chain, while Ma et al. (2020) emphasized the importance of freshness efforts under cap-and-trade policies for optimizing cold chain operations. Collectively, these studies highlight that freshness-keeping is not merely a technical issue but a central factor shaping contracts, profit distribution, and long-term sustainability in agricultural supply chains.

In recent years, the e-commerce economic system has gradually developed and matured, and "live streaming + e-commerce" has gradually become a new engine to help farmers increase their income and get rid of poverty, and promote rural revitalization. Therefore, scholars have also conducted research on poverty alleviation via LSEC. The rise of livestreaming e-commerce (LSEC) has generated substantial economic and social benefits, particularly for rural communities. By expanding digital market access, LSEC enhances farmers' employment opportunities and income, thereby supporting poverty alleviation initiatives. As Yin et al. (2025) demonstrated, farmers' participation in e-commerce significantly increases household income, with the effect being especially pronounced among lower-income groups. This indicates that the marketing function of LSEC not only raises farmers' earnings but also serves as an effective mechanism for alleviating relative poverty in rural areas. The LSEC model has generated substantial economic and social benefits, most notably by increasing farmers' incomes and contributing to poverty alleviation among disadvantaged rural households. Recent evidence shows that participation in e-commerce significantly raises household income, with the greatest gains observed among lower-income farmers, thereby helping to reduce relative poverty (Wang et al., 2024). A live streaming platform or exclusive channel for poverty alleviation with Chinese characteristics should be created. Peng et al. (2021) proposed an empirical research on the impact of e-commerce on rural poverty alleviation.

In actual decisions, each player of the supply chain often makes independent decisions, which will cause a "double marginal effect" and reduce the benefits of the supply chain. Supply chain players should actively introduce coordination contracts to achieve cooperation. To achieve the optimal decision effect of a centralized decision, it is necessary to reach a consensus on the sharing ratio of both players through a contract. The sharing method can be profit sharing, cost sharing, or adjusting the wholesale price of agricultural products. The specific plan depends on the form and content of the cooperation between the two players (Guo et al., 2023). Therefore, some scholars have studied the issue of agricultural product supply chain contracts and coordination regarding freshness-keeping efforts (Cai et al., 2013; Fan et al., 2022). Research has shown that the above contract coordination can effectively improve the system profits of the supply chain.

From the above literature, scholars have conducted many studies on the development of the agricultural product supply chain. However, with the rapid development of LSEC, theoretical research in this field still has the following deficiencies: First, although agricultural product supply chain optimal decisions have been extensively and continuously studied by many scholars, the study results are primarily focused on the fields of traditional supply chain and platform e-commerce supply chain, while the research literature in the field of LSEC is still not rich. In addition, there are a few mathematical simulation model studies in the literature on LSEC. Second, when constructing the market demand function, most literature considers the impact of sales prices, but rarely considers the freshness-keeping efforts; when constructing the supply chain profit function, the existing literature often ignores the issues of profit distribution and effective coordination among players under different supply chain structures. Third, when constructing supply chain decision models, people often analyze the impact of sales price, market demand, and effort cost on supply chain profits from the perspective of the economic man hypothesis in a completely rational way. There is little literature that discusses the influence of poverty alleviation preferences on optimal decisions within the supply chain from the perspective of the bounded rational social man hypothesis. More research on this unexplored area will certainly provide information to minimize the literature gap in the research on the agricultural product LSEC supply chain in China.

Different from the existing literature, this research centers on the agricultural product LSEC supply chain, considers the poverty alleviation preference, compares four supply chain models: centralized decision, decentralized decision without poverty alleviation preference, decentralized decision with poverty alleviation preference, and contract coordination decision with poverty alleviation preference, and discusses the effect of cost-revenue sharing contract coordination among supply chain players under poverty alleviation preference, with the aim to furnish theoretical support and pragmatic instruction for the optimal decisions and coordination among agricultural product supply chain players in the LSEC environment.

3. Model construction and solving

This study examines a supply chain in which farmers provide agricultural products and make efforts to maintain their freshness, while selling them through an LSEC platform. Together, the farmer and the LSEC platform form the agricultural product LSEC supply chain. Since farmers face high costs for keeping products fresh, ensuring the long-term stability of the supply chain becomes important. To support this, the government encourages live streaming to assist farmers and offers certain policy incentives. In response, LSEC platforms may adopt poverty alleviation measures.

3.1. Model description

This study constructs four decision models: centralized, decentralized without poverty alleviation preferences, decentralized with poverty alleviation preferences, and contract coordination with poverty alleviation preferences to compare the decisions and profits of the players. Since the decentralized model cannot obtain an incentive-compatible coordination solution, a cost-revenue sharing with poverty alleviation preferences is proposed.

Agricultural products with a freshness-keeping effort level of s are sold to the LSEC platform by the farmer at a wholesale price w, and then offered to shoppers at a sales price p. The framework of the model is depicted in Fig. 1.

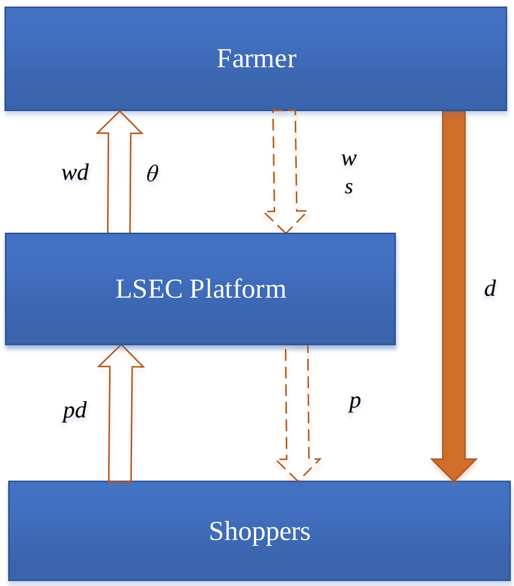


Fig. 1: LSEC supply chain model framework

The demand model $d = a - \beta p + \mu s$, identified as d, incorporates the upper limit of market demand, indicated by $a > 0$, and the demand responsiveness to sales price and freshness-keeping effort levels, with coefficients $0 < \beta < 1$ and $0 < \mu < 1$, respectively. The farmer is responsible for executing freshness-keeping efforts and incurring the related total costs within a given period, expressed as $hs^2/2$, where h represents the cost coefficient for freshness-keeping efforts. This framework for cost analysis is an extension of the earlier studies conducted by Nair and Narasimhan (2006) and Zhou et al. (2016). This study assumes that the LSEC platform considers poverty alleviation preference, while the farmer is neutral and has no preference, both players are risk-neutral, and possess symmetrical information. The profits function of the farmer, LSEC platform, and LSEC supply chain system are as follows:

$$\begin{aligned} \pi_{fl} &= w(a - \beta p + \mu s) - hs^2/2 \\ \pi_p &= (p - w)(a - \beta p + \mu s) \\ \pi &= p(a - \beta p + \mu s) - hs^2/2 \end{aligned} \quad (1)$$

3.2. Model research hypothesis

Hypothesis 1: The LSEC platform's poverty alleviation preference can improve the profit of farmers and the system, yet reduce its own profit.

Hypothesis 2: The wholesale price, freshness-keeping effort level, and market demand are higher under poverty alleviation preference. But the direction of sales price alterations remains uncertain, with the potential for both positive and negative trends.

Hypothesis 3: The profits of the farmer and the LSEC platform exhibit a downward trend in response to the growth of the freshness-keeping effort cost coefficient and the sales price sensitivity coefficient, and an upward trend in response to the growth of the demand elasticity coefficient for freshness-keeping effort.

Hypothesis 4: Under the coordination contract, while the cost-revenue sharing coefficient is within a fixed threshold range, the Pareto improvement of the economic benefits of each player in the agricultural product LSEC supply chain system will be achieved.

3.3. Model construction and solving

Subsequently, four models are considered: centralized decision, decentralized decision without the poverty alleviation preference, decentralized decision with the poverty alleviation preference, and cost-revenue sharing contract with poverty alleviation preference represented by c, n, d, and s respectively.

3.3.1. Centralized model (c)

In the centralized model, the farmer and the LSEC platform collaborate by selecting p and s to optimize the system profit. Optimal choices and the highest system revenue can be readily derived using Eq. 1. That is, $s^{c*} = \frac{a\mu}{2\beta h - \mu^2}$, $p^{c*} = \frac{ah}{2\beta h - \mu^2}$, $d^{c*} = \frac{a\beta h}{2\beta h - \mu^2}$, $\pi^{c*} = \frac{a^2 h}{2(2\beta h - \mu^2)}$, $2\beta h - \mu^2 > 0$.

3.3.2. Decentralized model without poverty alleviation preference (n)

The farmer and the LSEC platform as independent economic players striving for profit maximization. The LSEC platform decides on variable p, which is followed by the farmer jointly determining variables w and s. Should the LSEC platform neglect poverty alleviation preferences, the optimal strategies and profits for both players can be extracted through a backward induction method. Let $p = \delta + w$, here, δ is the unit profit of the LSEC platform. The profit function is,

$$\begin{aligned} \pi_{fl} &= w[a - \beta(\delta + w) + \mu s] - hs^2/2 \\ \pi_p &= \delta[a - \beta(\delta + w) + \mu s] \\ \pi &= pd - hs^2/2 \end{aligned} \quad (2)$$

As indicated in Eq. 2, the Hessian matrix for $\pi_{fl}(w,s)$ is represented $H_{fl} = \begin{bmatrix} \frac{\partial^2 \pi_{fl}}{\partial w^2} & \frac{\partial^2 \pi_{fl}}{\partial w \partial s} \\ \frac{\partial^2 \pi_{fl}}{\partial s \partial w} & \frac{\partial^2 \pi_{fl}}{\partial s^2} \end{bmatrix} = \begin{bmatrix} -2\beta & \mu \\ \mu & -h \end{bmatrix}$. Since $-2\beta < 0$ and $2\beta h - \mu^2 > 0$, $\pi_{fl}(w,s)$ reaches its highest potential value. Upon the resolution of $\frac{\partial \pi_{fl}}{\partial w} = 0$, and $\frac{\partial \pi_{fl}}{\partial s} = 0$, we obtain $w = \frac{h(a - \beta\delta)}{2\beta h - \mu^2}$, $s = \frac{\mu(a - \beta\delta)}{2\beta h - \mu^2}$. Substituting w and s and $p = \delta + w$ into the LSEC platform's profit function, we have $\frac{\partial^2 \pi_p}{\partial \delta^2} = -\frac{2h\beta^2}{2\beta h - \mu^2} < 0$, so π_p is maximized when the LSEC platform fixes the unit profit at $\delta^{n*} = \frac{a}{2\beta}$. Substituting $\delta^{n*} = \frac{a}{2\beta}$ into w and s, we can obtain other decisions. That is, $w^{n*} = \frac{ah}{2(2\beta h - \mu^2)}$, $s^{n*} = \frac{a\mu}{2(2\beta h - \mu^2)}$, $p^{n*} = \frac{a}{2\beta} + \frac{ah}{2(2\beta h - \mu^2)}$, $d^{n*} = \frac{a\beta h}{2(2\beta h - \mu^2)}$, $\pi_{fl}^{n*} = \frac{a^2 h}{8(2\beta h - \mu^2)}$, $\pi_p^{n*} = \frac{a^2 h}{4(2\beta h - \mu^2)}$, $\pi^{n*} = \frac{3a^2 h}{8(2\beta h - \mu^2)}$.

3.3.3. Decentralized model with poverty alleviation preference (d)

This section uses the utility function. This research incorporates a utility function that is founded on the principles of advantageous inequality, a theory introduced by Zhou et al. (2016). In the field of behavioral economics, this function is an extension of the traditional model of rationality, which is centered on self-interest (Thorgeirsson and Kawachi, 2013). Refer to Wang et al. (2021), $U_p = \pi_p - \theta(\pi_p - \pi_{fl})$. Therefore, the utility function, as it is defined in this study, is presented hereinafter.

$$\begin{cases} \max\limits_{\delta} U_p = (1 - \theta)\pi_p + \theta \pi_{fl} \\ \qquad s.t. \pi_p \geq \pi_{fl} \end{cases} \quad (3)$$

Here, θ $(0 < \theta < 1)$ denotes the coefficient for poverty alleviation preferences. Based on the body of experimental literature on social preferences and analytical studies within the supply chain framework (Fehr and Schmidt, 1999; Zhou et al., 2016; Nie and Du, 2017), the poverty alleviation preference coefficient is established at (0,1). The magnitude of θ is indicative of the intensity of the preference for poverty alleviation. This utility function, which reflects the preference for poverty alleviation, is directly related to the seminal works of Bester and Güth (1998) and Charness and Rabin (2002).

With the backward induction, we input the values w and s into Eq. 3, resulting in the expression,

$$\begin{cases} \max_{\delta} U_p = (1-\theta)\frac{(a-\beta\delta)h\beta\delta}{2\beta h-\mu^2} + \theta\frac{(a-\beta\delta)^2 h}{2(2\beta h-\mu^2)} \\ s.t. \delta \geq \frac{a}{3\beta} \end{cases} \quad (4)$$

The Lagrange construct for Eq. 4 is identified as

$$L = (1-\theta)\frac{(a-\beta\delta)h\beta\delta}{2\beta h-\mu^2} + \theta\frac{(a-\beta\delta)^2 h}{2(2\beta h-\mu^2)} + m\left(\delta - \frac{a}{3\beta}\right) \quad (5)$$

According to Eq. 5, there is $\frac{\partial^2 L}{\partial \delta^2} = -\frac{\beta^2 h(2-3\theta)}{2\beta h-\mu^2}$. To guarantee that Eq. 5 attains its optimal solution, $0 < \theta < 2/3$ can be calculated through $\frac{\partial^2 L}{\partial \delta^2} < 0$. The KKT requirement for Eq. 5 is formulated as $\begin{cases} \frac{\partial L}{\partial \delta} = 0 \\ \delta - \frac{a}{3\beta} \geq 0 \\ m\left(\delta - \frac{a}{3\beta}\right) = 0 \\ m \geq 0 \end{cases}$. When $m = 0$, we obtain $\delta_1 = \frac{a(1-2\theta)}{\beta(2-3\theta)}$ by having $\frac{\partial L}{\partial \delta} = 0$. The relationship of $0 < \theta \leq 1/3$ can be obtained based on $\delta_1 \geq \frac{a}{3\beta}$. When $m > 0$, we can obtain $\delta_2 = \frac{a}{3\beta}$ from $m\left(\delta - \frac{a}{3\beta}\right) = 0$. Since $m > 0$, $0 < \theta \leq 1/3$ can be obtained. Therefore, optimal decisions can be obtained. That is, $\delta^{d*} = \frac{a(1-2\theta)}{\beta(2-3\theta)}$, $w^{d*} = \frac{ah(1-\theta)}{(2-3\theta)(2\beta h-\mu^2)}$, $s^{d*} = \frac{a\mu(1-\theta)}{(2-3\theta)(2\beta h-\mu^2)}$, $p^{d*} = \frac{ah(1-\theta)}{(2-3\theta)(2\beta h-\mu^2)} + \frac{a(1-2\theta)}{\beta(2-3\theta)}$, $d^{d*} = \frac{ah\beta(1-\theta)}{(2-3\theta)(2\beta h-\mu^2)}$, $\pi_{fl}^{d*} = \frac{a^2 h(1-\theta)^2}{2(2-3\theta)^2(2\beta h-\mu^2)}$, $\pi_p^{d*} = \frac{a^2 h(1-2\theta)(1-\theta)}{(2-3\theta)^2(2\beta h-\mu^2)}$, $U_p^{d*} = \frac{a^2 h(1-\theta)^2}{2(2-3\theta)(2\beta h-\mu^2)}$, $\pi^{d*} = \frac{a^2 h(1-\theta)(3-5\theta)}{2(2-3\theta)^2(2\beta h-\mu^2)}$.

3.3.4. Contract model with poverty alleviation preference (s)

The parameter γ $(0 < \gamma < 1)$ representing the cost-sharing proportion, which reflects the LSEC platform's contribution to the freshness-keeping effort cost, is incorporated to align their actions. With a poverty alleviation preference coefficient denoted by $\theta = 1/3$, the LSEC platform also covers a portion of the combined logistics cost incurred by the farmer. Additionally, the LSEC platform determines the per-unit profit margin, denoted as δ, by referencing the wholesale price to equate the sales price with that of the centralized model, indicated by p^{c*}. In this case, $\delta = p - w$. The selected values for γ and δ are designed to establish a sales price of p^{c*} and to encourage the farmer to elevate the freshness-keeping effort to the desired level s^{c*}. The profit function is

$$\begin{aligned} \pi_{fl} &= w[a - \beta(\delta + w) + \mu s] - (1-\gamma)hs^2/2 \\ \pi_p &= \delta[a - \beta(\delta + w) + \mu s] - \gamma hs^2/2 \end{aligned} \quad (6)$$

Assume that the LSEC platform determines the unit profit to be δ, by employing backward induction, the Hessian matrix is $H_{fl} = \begin{bmatrix} -2\beta & \mu \\ \mu & -h(1-\gamma) \end{bmatrix}$. When $2\beta h(1-\gamma) - \mu^2 > 0$, π_{fl} has a maximal value, and w and s can be derived by $\frac{\partial \pi_{fl}}{\partial w} = 0$ and $\frac{\partial \pi_{fl}}{\partial s} = 0$. That is, $w = \frac{h(1-\gamma)(a-\beta\delta)}{2h\beta(1-\gamma)-\mu^2}$, $s = \frac{\mu(a-\beta\delta)}{2h\beta(1-\gamma)-\mu^2}$. Substituting w and s into Eq. 6, according to $\frac{\partial \pi_p}{\partial \delta} = 0$ there is $\delta^* = \frac{a[2\beta h(1-\gamma)^2-(1-2\gamma)\mu^2]}{\beta[4\beta h(1-\gamma)^2-(2-3\gamma)\mu^2]}$. The most beneficial choices within the framework of a cost-sharing contract are detailed below: $w^* = \frac{ah(1-\gamma)^2}{4\beta h(1-\gamma)^2-(2-3\gamma)\mu^2}$, $s^* = \frac{a\mu(1-\gamma)}{4\beta h(1-\gamma)^2-(2-3\gamma)\mu^2}$, $p^* = \frac{a[3\beta h(1-\gamma)^2-(1-2\gamma)\mu^2]}{\beta[4\beta h(1-\gamma)^2-(2-3\gamma)\mu^2]}$, $d^* = \frac{a\beta h(1-\gamma)^2}{4\beta h(1-\gamma)^2-(2-3\gamma)\mu^2}$, $\pi_{fl}^* = \frac{a^2 h(1-\gamma)^3[2\beta h(1-\gamma)-\mu^2]}{2[4\beta h(1-\gamma)^2-(2-3\gamma)\mu^2]^2}$, $\pi_p^* = \frac{a^2 h(1-\gamma)^2}{2[4\beta h(1-\gamma)^2-(2-3\gamma)\mu^2]}$, $\pi^* = \frac{a^2 h(1-\gamma)^2[6\beta h(1-\gamma)^2-(3-4\gamma)\mu^2]}{2[4\beta h(1-\gamma)^2-(2-3\gamma)\mu^2]^2}$.

Following the precepts of incentive compatibility, the contract must fulfill condition $s^* = s^{c*}$ and $p^* = p^{c*}$ if it is to be coordinated. It can be demonstrated that there is no equilibrium solution by applying equation simplification methodologies. Consequently, coordination cannot be solely accomplished through a cost-sharing contract. We need to design a cost-revenue sharing contract.

Assume that the cost-sharing coefficient is γ $(0 < \gamma < 1)$ and the revenue sharing factor is φ $(0 < \varphi < 1)$. The LSEC platform establishes the sales price equivalent to that of the centralized model and requires the farmer not to determine the wholesale price. The LSEC platform shares the revenue-sharing factor φ to the farmer and adjusts the freshness-keeping effort level to s^{c*}. The farmer sharing factor of freshness-keeping effort cost is γ. The profit function is,

$$\begin{aligned} \pi_{fl} &= \varphi p(a - \beta p + \mu s) - (1-\gamma)hs^2/2 \\ \pi_p &= (1-\varphi)p(a - \beta p + \mu s) - \gamma hs^2/2 \end{aligned} \quad (7)$$

The farmer and the LSEC platform are designed to optimize their individual profit margins. As a leader, the LSEC platform initially establishes the sales price, denoted as p^{c*}, namely, $p^{s*} = p^{c*}$. For the farmer, the freshness-keeping effort level is adjusted to s^{c*}. According to $\frac{\partial \pi_{fl}}{\partial s} = 0$, $s^{s*} = \frac{p\mu\varphi}{h(1-\varphi)}$ can be solved. Substitute $p^{s*} = p^{c*}$ into s^{s*}, and the revenue sharing coefficient $\varphi = 1-\gamma$ is obtained through the resolution of the equation $s^{s*} = s^{c*}$.

Through Eq. 7, there are π_{fl}^{s*} and π_{p}^{s*}. $\pi_{fl}^{s*} \geq \pi_{fl}^{n*}$ and $\pi_{p}^{s*} \geq \pi_{p}^{n*}$ need to be satisfied, that is, $\begin{cases} \varphi p^{c*}(a-\beta p^{c*}+\mu s^{c*})-(1-\gamma)hs^{c*2}/2 \geq \pi_{fl}^{n*} \\ (1-\varphi)p^{c*}(a-\beta p^{c*}+\mu s^{c*})-\gamma hs^{c*2}/2 \geq \pi_{p}^{n*} \end{cases}$. After solving, γ satisfies $1/2 \leq \gamma \leq 3/4$. When (φ, γ) satisfies $\begin{cases} 1/4 \leq \varphi \leq 1/2 \\ 1/2 \leq \gamma \leq 3/4 \end{cases}$, the coordination can be attained through a cost-revenue sharing contract.

4. Results and discussion

4.1. Decisions analysis

Proposition 1. $\pi_{fl}^{n*} < \pi_{p}^{n*}$ and $\pi_{p}^{n*} = 2\pi_{fl}^{n*}$. The LSEC platform, empowered by its market strength, realizes higher profit margins than the farmer. The farmer is responsible for the considerable expenses of freshness-keeping effort provision, which greatly diminishes their profits relative to the LSEC platform. This notable profit imbalance can adversely affect the supply chain's cooperative dynamics and may result in the fracturing of these alliances. Therefore, the LSEC platform may consider a poverty alleviation preference to increase the farmer profit and avoid the adverse effect.

Proposition 2. To attain greater profitability for the LSEC platform than the farmer, the coefficient of poverty alleviation preference satisfies $0 < \theta \leq 1/3$.

As the solution is determined, the LSEC platform's poverty alleviation preference coefficient, indicated by $0 < \theta \leq 1/3$, ensures that the platform's profit is not inferior to that of the farmer. With condition $\theta = 1/3$ in place, the corresponding result is $\pi_{fl} = \pi_{p}$. The poverty alleviation preference coefficient range is smaller than the $0 \leq \theta \leq 1/2$ in Bester and Güth (1998), and consistent with Wang et al. (2021).

Proposition 3. $\frac{\partial s^{d*}}{\partial \theta} > 0$, $\frac{\partial w^{d*}}{\partial \theta} > 0$, $\frac{\partial d^{d*}}{\partial \theta} > 0$, $\frac{\partial \pi_{f}^{d*}}{\partial \theta} > 0$, $\frac{\partial U_{p}^{d*}}{\partial \theta} < 0$, $\frac{\partial \pi_{p}^{d*}}{\partial \theta} < 0$, $\frac{\partial \pi^{d*}}{\partial \theta} > 0$; when $\mu^2 < \beta h < 2\mu^2$, $\frac{\partial p^{d*}}{\partial \theta} > 0$, when $\mu^2 > \beta h$, $\frac{\partial p^{d*}}{\partial \theta} < 0$.

Proof. Since $0 < \theta \leq 1/3$, $2\beta h - \mu^2 > 0$, it follows that $\frac{\partial s^{d*}}{\partial \theta} = \frac{a\mu}{(2-3\theta)^2(2\beta h-\mu^2)} > 0$, $\frac{\partial w^{d*}}{\partial \theta} = \frac{ah}{(2-3\theta)^2(2\beta h-\mu^2)} > 0$, $\frac{\partial d^{d*}}{\partial \theta} = \frac{a\beta h}{(2-3\theta)^2(2\beta h-\mu^2)} > 0$, $\frac{\partial \pi_{fl}^{d*}}{\partial \theta} = \frac{a^2h(1-\theta)}{(2-3\theta)^3(2\beta h-\mu^2)} > 0$, $\frac{\partial U_{p}^{d*}}{\partial \theta} = -\frac{a^2h(1-\theta)(1-3\theta)}{2(2-3\theta)^2(2\beta h-\mu^2)} < 0$, $\frac{\partial \pi_{p}^{d*}}{\partial \theta} = -\frac{a^2h\theta}{(2-3\theta)^3(2\beta h-\mu^2)} < 0$, $\frac{\partial \pi^{d*}}{\partial \theta} = \frac{a^2h(1-2\theta)}{(2-3\theta)^3(2\beta h-\mu^2)} > 0$; when $\mu^2 < \beta h < 2\mu^2$, $\frac{\partial p^{d*}}{\partial \theta} = \frac{a(\beta h-\mu^2)}{\beta(2-3\theta)^2(2\beta h-\mu^2)} > 0$, when $\mu^2 > \beta h$, $\frac{\partial p^{d*}}{\partial \theta} = \frac{a(\beta h-\mu^2)}{\beta(2-3\theta)^2(2\beta h-\mu^2)} < 0$.

Proposition 3 illustrates that, aside from the LSEC platform's profit, all optimal decisions increase as θ rises, aligning with prior research on altruistic preferences, which found that the wholesale price and the level of freshness-keeping efforts decline with the preference coefficient (Wang et al., 2021). Considering the LSEC platform's inclination towards poverty alleviation, the farmer is motivated to enhance the freshness-keeping effort. However, the sales price is a joint outcome of the LSEC platform's unit profit and the wholesale price. That is, β, μ and h dictate the sales price's variation in response to θ. The preference for poverty alleviation tends to elevate the sales price if $\beta h < \mu^2$, but it could lower the sales price if $\beta h > \mu^2$. Without loss of generality, assume that the additional benefits of improving freshness-keeping efforts are greater than the input costs, that is $h < \mu$. In this case, when $h < \mu$, with a reduction of θ, the sales price will also go down.

The profit generated by the system when incorporating poverty alleviation preferences is expected to surpass that of the decentralized model which does not include such preferences. As the value θ within the specified range $(0 < \theta \leq 1/3)$ increases, the system's profit is likely to rise correspondingly. This indicates that a higher coefficient for poverty alleviation preferences plays a significant role in enhancing the enduring viability of the supply chain for agricultural products LSEC. While the implementation of poverty alleviation preferences positively impacts the profits of farmer, it simultaneously leads to a decrease in the profits of the LSEC platform itself. In practical terms, the LSEC platform's poverty alleviation preference is often due to policy pressures and social image or out of a desire of maintain supply chain system stability.

4.2. Comparison analysis

When the coefficient of the LSEC platform's poverty alleviation preference meets $0 < \theta \leq 1/3$, conclusions 1 and 2 are derivable.

Conclusion 1. The sales price is influenced by the following conditions: When $\beta h > \mu^2$, then $p^{n*} > p^{d*} > p^{c*}$; when $\beta h < \mu^2$, then $p^{c*} > p^{d*} > p^{n*}$.

Proof. Since $0 < \theta \leq 1/3$, when $\mu^2 < \beta h$, $p^{n*} - p^{d*} = \frac{a\theta(\beta h-\mu^2)}{2\beta(2-3\theta)(2\beta h-\mu^2)} > 0$, $p^{n*} - p^{c*} = \frac{a(\beta h-\mu^2)}{2\beta(2\beta h-\mu^2)} > 0$, $p^{d*} - p^{c*} = \frac{a(1-2\theta)(\beta h-\mu^2)}{\beta(2-3\theta)(2\beta h-\mu^2)} > 0$, then $p^{n*} > p^{d*} > p^{c*}$; on the contrary, when $\mu^2/2 < \beta h < \mu^2$, $p^{n*} - p^{d*} = \frac{a\theta(\beta h-\mu^2)}{2\beta(2-3\theta)(2\beta h-\mu^2)} < 0$, $p^{n*} - p^{c*} = \frac{a(\beta h-\mu^2)}{2\beta(2\beta h-\mu^2)} < 0$, $p^{d*} - p^{c*} = \frac{a(1-2\theta)(\beta h-\mu^2)}{\beta(2-3\theta)(2\beta h-\mu^2)} < 0$, then $p^{c*} > p^{d*} > p^{n*}$.

When $\beta h > \mu^2$, the sales price of the centralized decision is the minimum, and the sales price of the decentralized decision without poverty alleviation preferences is the maximum. That is, the centralized decision provides the most advantageous resolution for shoppers. A larger h amount means that freshness-keeping effort costs have a significant impact on farmer profits, so in a decentralized model without poverty alleviation preferences, it will charge a higher wholesale price to ensure its profits, thus resulting in double marginalization. Resulting in a higher sales price. When $\beta h < \mu^2$, the sales price of the centralized decision is the maximum, and the sales price of the decentralized decision without poverty alleviation preferences is the minimum, which is consistent with Wang et al.'s 2021) study on the decentralized decision without altruistic preferences in low-carbon supply chains. The larger the amount of μ, the higher the influence of freshness-keeping effort on demand. In the centralized decision, in order to obtain higher system profits, farmer tends to increase the level of freshness-keeping effort and sales price at the same time; while in the decentralized model, farmer needs to bear the freshness-keeping effort cost, so it lacks the motivation to improve the level of freshness-keeping effort, which leads to an increase in wholesale price, which conforms to Conclusion 2.

Conclusion 2. The market demand, freshness-keeping effort level, and supply chain profits follow the relationship of $s^{c*} > s^{d*} > s^{n*}$, $d^{c*} > d^{d*} > d^{n*}$, $\pi_{fl}^{n*} < \pi_{fl}^{d*}, \pi_p^{d*} < \pi_p^{n*}, \pi_{fl}^{d*} \le \pi_p^{d*}, \pi^{d*} > \pi^{n*}$.

Proof. Since $0 < \theta \le 1/3$, $2\beta h - \mu^2 > 0$, it follows that $s^{n*} - s^{d*} = -\frac{\alpha\mu\theta}{2(2-3\theta)(2\beta h-\mu^2)} < 0$, $s^{n*} - s^{c*} = -\frac{\alpha\mu}{2(2\beta h-\mu^2)} < 0$, $s^{d*} - s^{c*} = -\frac{\alpha\mu(1-2\theta)}{(2-3\theta)(2\beta h-\mu^2)} < 0$, $s^{c*} > s^{d*} > s^{n*}$; $d^{n*} - d^{d*} = -\frac{\alpha\beta h\theta}{2(2-3\theta)(2\beta h-\mu^2)} < 0$, $d^{n*} - d^{c*} = -\frac{\alpha\beta h}{2(2\beta h-\mu^2)} < 0$, $d^{d*} - d^{c*} = -\frac{\alpha\beta h(1-2\theta)}{(2-3\theta)(2\beta h-\mu^2)} < 0$, $d^{c*} > d^{d*} > d^{n*}$; $\pi^{n*} - \pi^{d*} = -\frac{\alpha^2 h\theta(4-7\theta)}{8(2-3\theta)^2(2\beta h-\mu^2)} < 0$, $\pi^{n*} - \pi^{c*} = -\frac{\alpha^2 h}{8(2\beta h-\mu^2)} < 0$, $\pi^{d*} - \pi^{c*} = -\frac{\alpha^2 h(1-2\theta)^2}{2(2-3\theta)^2(2\beta h-\mu^2)} < 0$, $\pi^{c*} > \pi^{d*} > \pi^{n*}$; $\pi_{fl}^{n*} - \pi_{fl}^{d*} = -\frac{\alpha^2 h\theta(4-5\theta)}{8(2-3\theta)^2(2\beta h-\mu^2)} < 0$, $\pi_{fl}^{n*} < \pi_{fl}^{d*}$; $\pi_p^{n*} - \pi_p^{d*} = \frac{\alpha^2 h\theta^2}{4(2-3\theta)^2(2\beta h-\mu^2)} > 0$, $\pi_p^{n*} > \pi_p^{d*}$; $\pi_{fl}^{n*} - \pi_p^{n*} = -\frac{\alpha^2 h}{8(2\beta h-\mu^2)} < 0$, $\pi_{fl}^{n*} < \pi_p^{n*}$; $\pi_{fl}^{d*} - \pi_p^{d*} = -\frac{\alpha^2 h(1-\theta)(1-3\theta)}{2(2-3\theta)^2(2\beta h-\mu^2)} < 0$, $\pi_{fl}^{d*} < \pi_p^{d*}$.

Findings from Conclusion 2 indicate that within the centralized framework, s^{c*} and d^{c*} achieve the maximum values. This observation substantiates the superiority of the centralized approach over its counterparts in terms of addressing freshness-keeping efforts. It can be proven that $s^{d*} > s^{n*}$, and $d^{d*} > d^{n*}$ for $\theta > 0$, which suggests that poverty alleviation preference can simultaneously enhance the level of freshness-keeping effort and stimulate market demand. Under different models, the change of s^* is consistent with the change of p^*, which shows that s^* is a factor affecting p^* and they are positively correlated.

According to Proposition 1, in decentralized decisions without poverty alleviation preferences, the profit of the LSEC platform is twice that of the farmer. However, in the case of poverty alleviation benefits, as θ increases, the profits of farmers tend to increase, while the profits of the LSEC platform decrease. Therefore, it is deduced that, despite the fact that the LSEC platform contemplates poverty alleviation preferences, the associated coefficient is anticipated to remain minimal, which is consistent with the coefficient $0 < \theta \le 1/3$ in Proposition 2. In environments shaped by governmental policy directives or driven by external market forces, including competitive pressures from peer LSEC platforms and the imperative to improve public perception, will the LSEC platform consider poverty alleviation preferences. This further illustrates that the LSEC platform can help farmers increase profits by sacrificing a small part of its own profits in exchange for securing lasting collaboration.

Under the decentralized decisions, when the poverty alleviation preference satisfies $0 < \theta \le 1/3$, the profits of the supply chain system with poverty alleviation preference are surpass that without poverty alleviation preference, which corresponds to the results of Wang et al. (2021) on altruistic preference research, but inconsistent with the conclusion of Qiu-Xiang et al. (2018) on fairness concern research. When the LSEC platform adopts an appropriate poverty alleviation preference $0 < \theta \le 1/3$, there is always $\pi_{fl}^{d*} \le \pi_p^{d*}$, and a higher poverty alleviation preference will reduce the profit of the LSEC platform, but can positively promote the profits of the supply chain system and the farmer.

4.3. Coordination contract analysis

Proposition 4. Fulfilling conditions $1/2 \le \gamma \le 3/4$ and $1/4 \le \varphi \le 1/2$, the cost-revenue sharing contract that incorporates a poverty alleviation preference can successfully establish coordination.

From the analysis, it emerges that the freshness-keeping effort cost and revenue sharing factors have a lowest threshold of 1/2 and 1/4, respectively, and a highest cap of 3/4 and 1/2. The LSEC platform assumes a segment of the freshness-keeping effort cost and a share of the revenue, indicating a redistribution of certain logistics cost and revenue elements. This arrangement is beneficial for the farmer. For every coefficient of poverty alleviation preference, there exists a matching cost-revenue sharing contract that enhances the supply chain system's profitability. The cost-revenue sharing contract with an embedded poverty alleviation preference deviates from the conventional model.

Firstly, the profit source in the coordination contract differs; traditionally, the objective of each play in profit coordination is to achieve Pareto improvement, meaning to secure a greater profit margin post-coordination than before. Hence, the conventional cost-revenue sharing contract essentially distributes the surplus profits generated through coordinated efforts. In the cost-revenue sharing contract with poverty alleviation preference, the LSEC platform must take into account the profits of farmers due to policy pressure and the stability of the supply chain system. Therefore, the coordination contract with poverty alleviation preference is actually the result of the LSEC platform sacrificing a portion of the profit.

Secondly, the conventional cost-revenue coordination contract aims to maximize the system profit, while the coordination contract with poverty alleviation preference in this study aims to ensure that farmers obtain a specified profit amount, thus ensuring the consistency within the supply chain system, emphasizing the profit distribution among players, and better reflecting public accountability.

Thirdly, the conventional cost-revenue coordination contract emphasizes win-win cooperation among all players, while the coordination contract with poverty alleviation preference guides leaders to actively express their willingness to cooperate with followers, which is more conducive to the LSEC platform and farmers to reduce transaction costs and form a more stable cooperative relationship.

5. Numerical example analysis

Based on theoretical analysis, this study conducted a field survey of a cold storage facility built by farmers in a fruit-producing area and constructed relevant numerical examples to further verify the correctness and applicability of the theoretical model presented in this paper. During the production season of seasonal fresh agricultural products such as apples and peaches, farmers store some of the fruit in the cold storage to maintain its freshness.

The live streaming e-commerce platforms, such as Oriental Selection, purchase the corresponding quantity of agricultural products from the farmers, and the cold storage is responsible for the delivery. During the delivery process, packaging materials and structures suitable for the freshness-keeping of agricultural products are adopted. For example, for perishable fresh agricultural products, packaging materials with good breathability and strong thermal insulation are used, and preservatives or ice packs are added to the packaging to extend the shelf life of the agricultural products. This model is consistent with the two-stage cold chain operation model of farmers and live streaming e-commerce platforms studied in this paper.

5.1. Sensitivity analysis of poverty alleviation parameter

As per Proposition 3, the influence of factor θ on the sales price remains indeterminate. Subsequent numerical examinations are conducted to explore the fluctuations in the wholesale price, sales price, freshness-keeping effort level, market demand, and system profit in relation to the poverty alleviation preference coefficient. Based on the field survey of this enterprise and referring to references Wang et al. (2021) and Qiu-Xiang et al. (2018), the initial values of the relevant parameters in this numerical example are set as $a = 1$, $\mu = 0.3$, $\beta = 0.6$, $\theta \in (0,1/3]$.

Fig. 2a shows that s, w and d all increase as θ increases. The conclusion is consistent with Proposition 3. Fig. 2b illustrates that the correlation between the sales price and the poverty alleviation preference, denoted as θ, exhibits a strong dependence on factor μ, h and β. $h = 0.1$ corresponds to the case of $\beta h < \mu^2$; and $h = 0.2$ corresponds to $\beta h > \mu^2$. With a low value of h, the escalation in the freshness-keeping effort level minimally affects the profits of the farmer. Conversely, augmenting the freshness-keeping effort level is beneficial for boosting market demand. The conclusion is consistent with Conclusion 2.

Consequently, with the increase in the factor θ, the LSEC platform opts to elevate the sales price to amplify profits. Nevertheless, under conditions where the factor h is substantial, the freshness-keeping effort cost exerts a greater impact on the interests of the farmer. In such scenarios, an increase in the factor θ leads to a reduction in the sales price, aiming to secure profits by broadening market demand at a reduced price point. Hence, when accounting for the poverty alleviation preference, it becomes imperative for the LSEC platform to conduct a judicious assessment of the circumstances surrounding the farmer and to prudently manage the sales price. When $\beta h < \mu^2$, shoppers pay more attention to the level of freshness-keeping effort, and the sales price will increase with the increase of the poverty alleviation preference. Fig. 2c demonstrates that as the coefficient for poverty alleviation preference escalates, the profits of farmers rise, whereas the profits of the LSEC platform exhibit a decline. Conversely, Fig. 2d illustrates that the overall system profit ascends in tandem with the augmentation of the poverty alleviation preference coefficient. The conclusions of Fig. 2c and Fig. 2d are consistent with Conclusion 2.

5.2. Comparison analysis

The following are numerical examples of comparative conclusions. Assume the parameters are $a = 1$, $h = 0.2$, $\theta = 0.15$, $\mu \in [0.15,0.3]$, $\beta \in [0.3,0.6]$. According to Fig. 3, in the centralized decision, the freshness-keeping effort is maximized, and concurrently, the system profit reaches its peak. Under the condition where the parameter $\beta h > \mu^2$ is met, the centralized model is characterized by the most minimal sales price and is most beneficial to shoppers. However, when the parameter $\beta h < \mu^2$ is satisfied, the centralized model's sales price is at its peak. The conclusion is consistent with Conclusion 1.

This is because when shoppers pay more attention to the freshness-keeping effort level, players will pour investments into refining the freshness-keeping effort, which will lead to an increase in freshness-keeping effort costs and sales prices. Under the decentralized decision without poverty alleviation preference, the freshness-keeping effort, wholesale price, and market demand are lessened, the farmer profits and system profits are also smaller than the decentralized decision with poverty alleviation preference. The conclusion is consistent with Conclusion 2.

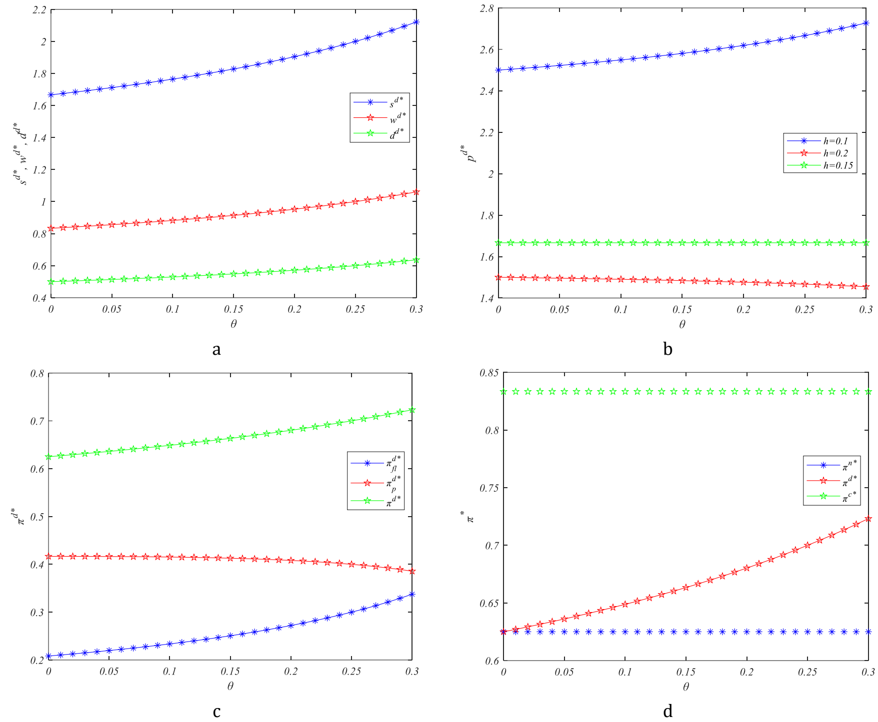


Fig. 2: Changes of s, w, d, p and π with θ: (a) s, w, and d increase; (b) sales price–preference relation under μ, h, β; (c) farmers' profit rises, platform profit falls; (d) system profit increases

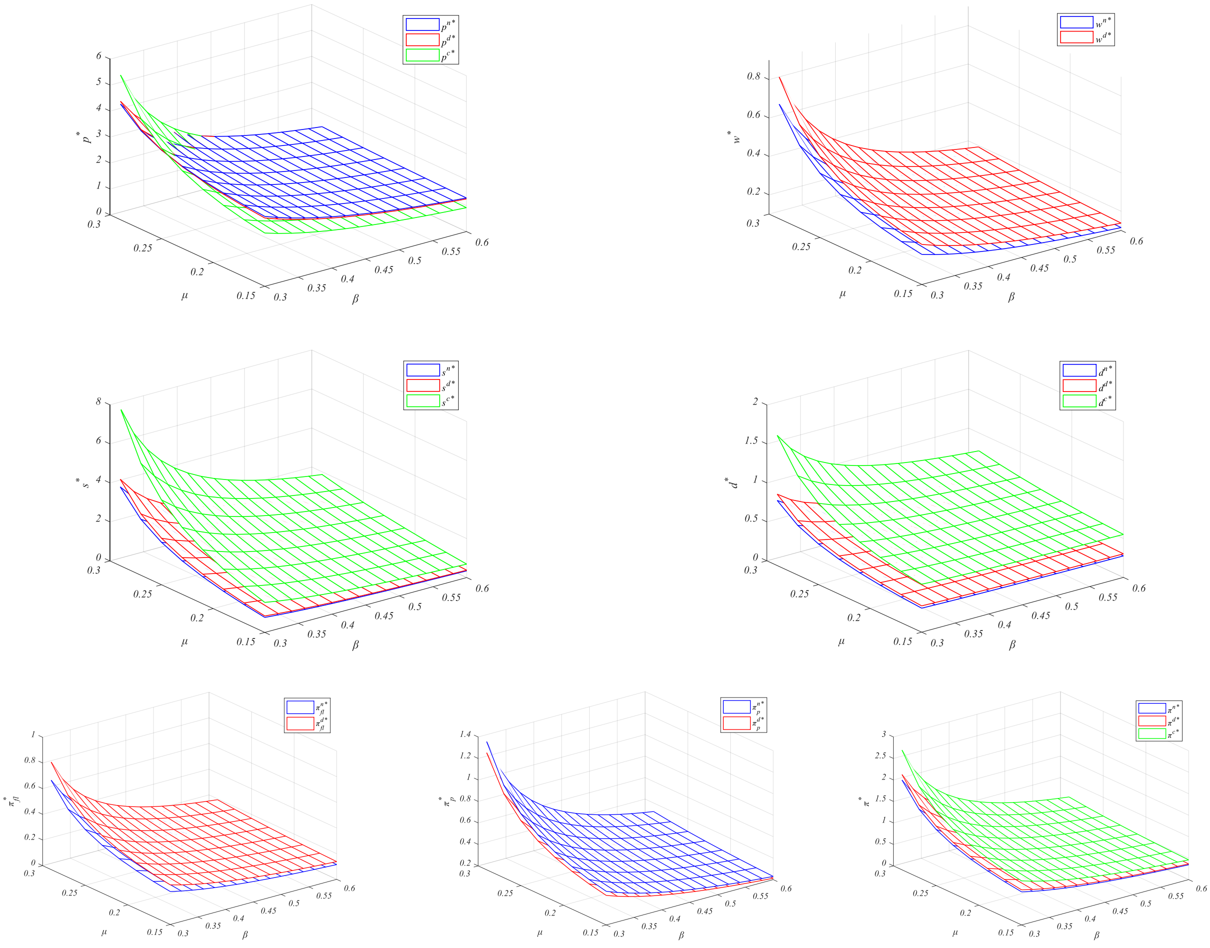


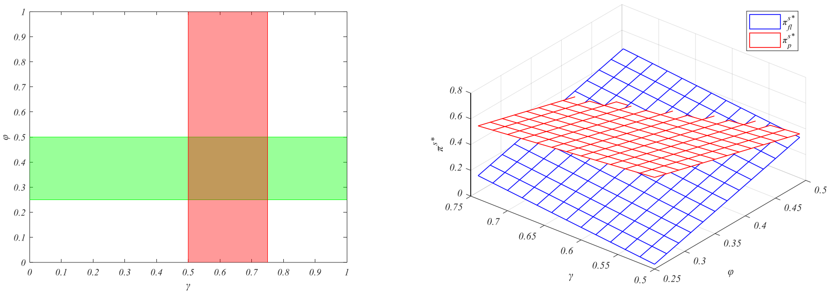
Fig. 3: Changes in optimal decisions with β and μ

As shown in Fig. 3, as the demand factors of sales price decreases and the demand factors of freshness-keeping effort level increases, freshness-keeping effort levels, sales prices, market demand, wholesale prices, profits of each player of the supply chain, and system profits all increase accordingly, among which the sales price increase is the largest in the centralized model. Therefore, the growth in the demand factors of freshness-keeping effort level and the decline in the demand factors of sales price will increase freshness-keeping effort levels and agricultural product sales prices, expand the scale of market demand, and raise the profits of each player of the supply chain. The supply chain system profit under the decentralized decision with poverty alleviation preference is higher than that under the decentralized decision without poverty alleviation preference, indicating that the poverty alleviation preference can effectively improve the supply chain system operating efficiency. When the poverty alleviation preference increases, shoppers' sensitivity to freshness-keeping effort levels increases, thereby increasing market demand, and all players of the agricultural product LSEC supply chain can benefit from it.

5.3. Coordination contract analysis

As can be seen from Fig. 4a, when $\gamma \in [0.5,0.75]$ and $\varphi \in [0.25,0.5]$, the overlapping portion of γ and φ enables perfect coordination among the players in the supply chain. Assume that $\beta = 0.6$, $\mu = 0.4$, and $h = 0.3$, $\gamma \in [0.5,0.75]$, and $\varphi \in [0.25,0.5]$, the impact of γ and φ on π_{fl}^{S*} and π_p^{S*} is depicted in Fig. 4b.

It is illustrated in Fig. 4b, when $\gamma \in [0.5,0.75]$ and $\varphi \in [0.25,0.5]$, the LSEC platform profits decrease with the increase of the cost-sharing coefficient and the revenue-sharing coefficient, but the farmer profits increase with the increase of γ and φ. Ultimately, the Pareto improvement of the economic benefits of each player in the agricultural product LSEC supply chain system will be achieved. The primary reason is that the LSEC platform proactively absorbs a portion of the freshness-keeping effort costs and shares part of the profits with the farmer. The cost-revenue sharing coefficient is exclusively influenced by the LSEC platform's poverty alleviation preference. The larger the LSEC platform's poverty alleviation preference coefficient, the greater the profit the farmer gets. The conclusion is consistent with Proposition 4.



a b

Fig. 4: Changes of π^{S*} with γ and φ: (a) overlapping ranges of γ and φ; (b) impact on π_{fl}^{S*} and π_p^{S*}

6. Conclusions

6.1. Summary of findings

This research considers the LSEC platform's poverty alleviation preference. Four decision models are constructed for comparative analysis. In addition, the cost-revenue sharing contract, which incorporates a preference for poverty alleviation, is crafted to coordinate the operations between the LSEC platform and the farmer. The outcomes, derived from theoretical examinations, are substantiated through numerical simulations.

In the Stackelberg game, the social preference will reduce the system profit (Fan et al., 2019). However, we prove that the LSEC platform's poverty alleviation preference can increase the profit of farmers and the system profit, but reduce its own profit. Compared with the case without poverty alleviation preference, the wholesale price, freshness-keeping effort level, and market demand are higher under poverty alleviation preference. In addition, as the poverty alleviation preference increases, the freshness-keeping effort level will increase, but fluctuations in the sales price are bidirectional. Comparatively, the system's profitability is augmented in poverty alleviation preferences, as opposed to scenarios lacking poverty alleviation preferences.

In the context of devising coordination contracts, it is noted that traditional cost-sharing contracts are ineffective for achieving coordination, as evidenced by Zhou et al. (2016) and Wang et al. (2021). This study introduces an innovative cost-revenue sharing contract that integrates a focus on poverty alleviation and evaluates its positive influence on the coordination mechanism. The proposed coordination contract indicates that when the LSEC platform participates in both revenue distribution and logistics cost burden, where specific conditions are met $1/2 \leq \gamma \leq 3/4$ and $1/4 \leq \varphi \leq 1/2$ for the cost-sharing and revenue-sharing factors, the supply chain can reach a state of coordination. The contract mandates that parameters associated with the sales price and freshness-keeping efforts fulfill particular prerequisites ($\mu^2 < \beta h$). According to the contract, the wholesale price and the unit profit of the LSEC platform tend to decline as the freshness-keeping effort cost coefficient and the sales price sensitivity coefficient rise, while they are positively affected by an increase in the freshness-keeping effort's demand elasticity coefficient.

6.2. Research recommendations

A direct managerial insight is that the LSEC platform's poverty alleviation preference for farmers has a positive impact on improving freshness-keeping effort levels and system profits. Moderate poverty alleviation preferences should be encouraged to improve supply chain performance while maintaining LSEC platform profitability. In order to solve the increasingly serious environmental problems faced by the agricultural product freshness-keeping supply chain, the government or other organizations should encourage LSEC platforms to adopt poverty alleviation preferences to improve freshness-keeping effort levels, particularly in instances where the freshness-keeping efforts have a substantial impact on operational costs. In addition, as a prerequisite for coordination contracts, poverty alleviation preferences can boost the propensity of the LSEC platform to engage in collaborative efforts with farmers.

This study highlights the importance of poverty alleviation preferences in enhancing supply chain performance and supporting rural development. Policymakers in rural China can leverage these findings to encourage LSEC platforms to adopt poverty alleviation preferences through subsidies or incentives. Promote coordination contracts to improve supply chain efficiency and stability. Develop policies that support the integration of farmers into e-commerce supply chains, reducing their reliance on external support.

6.3. Research limitations and directions for further research

This study acknowledges certain constraints. The scope of the research model is confined to the LSEC supply chain, which includes a farmer and an LSEC platform. However, in real-world applications, the LSEC platform has the potential to establish cooperative relationships with a variety of suppliers, and these relationships may interact through competition between suppliers and the LSEC platform's system profit and poverty alleviation concerns, so the LSEC platform's poverty alleviation preferences for multiple farmers need further exploration.

List of parameters

p	Sales price
w	Wholesale price
s	Freshness-keeping effort level
β	The demand responsiveness to sales price
μ	The demand responsiveness to freshness-keeping effort level
a	The upper limit of market demand
h	The cost coefficient for freshness-keeping efforts
s	Freshness-keeping effort level
d	Market demand
π_{fl}	The profits of farmer
π_p	The profits of LSEC platform
π	The profits of LSEC supply chain system
s^{c*}	The optimal freshness-keeping effort level under model *c*
p^{c*}	The optimal sales price under model *c*
d^{c*}	The optimal market demand under model *c*
π^{c*}	The highest profits of LSEC supply chain system under model *c*
δ	The unit profit of the LSEC platform
U_p	The utility function of the LSEC platform
θ	The coefficient for poverty alleviation preferences
L	The Lagrange function
m	Lagrange multiplier
γ	The cost-sharing factor
φ	The revenue-sharing factor
s^{d*}	The optimal freshness-keeping effort level under model *d*
p^{d*}	The optimal sales price under model *d*
d^{d*}	The optimal market demand under model *d*
π^{d*}	The highest profits of LSEC supply chain system under model *d*
s^{n*}	The optimal freshness-keeping effort level under model *n*
p^{n*}	The optimal sales price under model *n*
d^{n*}	The optimal market demand under model *n*
π^{n*}	The highest profits of LSEC supply chain system under model *n*
π_{fl}^{d*}	The optimal profits of farmer under model *d*
π_{fl}^{n*}	The optimal profits of farmer under model *n*
π_p^{d*}	The optimal profits of LSEC platform under model *d*
π_p^{n*}	The optimal profits of LSEC platform under model *n*

Compliance with ethical standards

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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