



Impact of Fairness Concerns on the e-Commerce Supply Chain Considering the Spillover Effect of Live Streaming

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Abstract. Considering the spillover effect of live streaming and the impact of fairness concerns of agribusinesses, we designed a dual-channel supply chain for agricultural products, i.e., online shop channel and live streaming channel, with centralized and decentralized decision structures. By constructing a game-theoretic model, we explore the impact of fairness concerns on the optimal decision-making and profits of agribusinesses and celebrities in the supply chain. In addition, we propose a cost-sharing joint commission mechanism to achieve supply chain coordination. We find that: 1) The fairness concerns of agribusiness have a negative influence on the supply chain. 2) The cost-sharing joint commission mechanism can coordinate the supply chain.

Keywords: Fairness concerns · The spillover effect · Cost sharing contract · E-commerce supply chain

1 Introduction

With the vigorous development of Internet technology, live streaming commerce has seen rapid development [1]. As a result, many agribusinesses are selling their products through their online shop channels and through live streaming channels hosted by celebrities. Despite the benefit of live streaming, agribusinesses face certain difficulties in cooperating with celebrities. When agribusinesses invite celebrities to live stream their products, they often must pay high transaction commission sharing [2], leading to low-profit margins. When agribusinesses think that their returns are not proportional to their investment, they tend to have a strong desire for the fairness of channel profit distribution and pay more attention to the profit gap between themselves and celebrities [3]. Few researchers have attention to the live streaming commerce supply chain [4]. Therefore, the following issues will be addressed in this paper: What is the impact of fairness concerns of agribusiness on the supply chain? And how to coordinate the supply chain?

2 Fairness Concerns Model

In this study, we consider a dual-channel supply chain in which one agribusiness sells products through an online shop at price p as well as live streaming at price $p\theta$ hosted by a celebrity. The agribusiness makes brand-building efforts (f) and the celebrity makes sales efforts (s), which will also convert purchasers in live streaming rooms to loyal customers in online shops, generating the live streaming spillover effect (λ). In the cooperation, the agribusiness has to share a certain proportion (ϕ) of revenue for the celebrity as commission and pay fixed blanket fees (F). For ease of exposition, we use the pronoun “he” to represent the agribusiness and “she” to denote the celebrity in the remainder of this study. Table 1 summarizes all notations and subscripts used in the paper. The demand function of the online shop channel (D_1) as well as the live streaming channel (D_2) and the profit function of the agribusiness (π_m) as well as the celebrity (π_T) are respectively given as follows [5, 6]:

$$D_1 = (1 - \rho)a - ep + f + \lambda s \tag{1}$$

$$D_2 = \rho a - ep\theta + f + s \tag{2}$$

$$\pi_m = (1 - \phi)p\theta D_2 + pD_1 - \frac{1}{2}f^2 - F \tag{3}$$

$$\pi_T = \phi p\theta D_2 - \frac{1}{2}s^2 + F \tag{4}$$

2.1 Decentralized Model

An agribusiness will consider the profit distribution fair if the profit of her can be δ times that of the celebrity. So the utility function of agribusiness considering fairness concerns is

$$U_m = \pi_m - \gamma(\delta\pi_T - \pi_m) \tag{5}$$

Proposition 1. In the decentralized model, the optimal solution is as follows:

$$p^{d*} = -\frac{a(1 + \gamma)B}{A} \tag{6}$$

$$f^{d*} = \frac{a(\gamma\delta\theta\phi + (\theta(\phi - 1) - 1)(1 + \gamma))B}{A} \tag{7}$$

$$s^{d*} = -\frac{a\theta\phi(1 + \gamma)B}{A} \tag{8}$$

$$\pi_m^{d*} = \frac{a^2B \left(2A(B - \gamma\delta\theta\rho\phi) + B \left(\begin{matrix} -\theta^2\phi^2(\gamma(\gamma\delta^2 + \gamma + 2) + 1) - (\gamma + 1)^2 \\ (2e(\theta^2 + 1) - (\theta + 1)^2) \\ + 2(\gamma + 1)^2\theta\phi(e\theta + \lambda - 1) \end{matrix} \right) - 2A^2F \right)}{2A^2} \tag{9}$$

Table 1. Denotations for modeling

Symbol	Description
Parameter	
θ	Price discount coefficient in the live streaming room ($0 < \theta < 1$)
ϕ	Commission rate ($0 < \phi < 0.3$)
F	Blanket fee
ρ	The proportion of agricultural products sold in the live-streaming room ($0 < \rho < 1$)
e	Price sensitivity of customers ($e > 0$)
a	Potential online market demand ($a > 0$)
λ	The coefficient of live streaming's spillover effect ($\lambda > 0$)
γ	The coefficient of agribusiness's fairness concerns ($0 < \gamma < 1$)
η	Sharing cost ratio of celebrity ($0 < \eta < 1$)
Decision variable	
p	The sales price in the online shop
f	The level of the brand-building efforts
s	The level of sales efforts
Derived function	
$D_\xi (\xi = 1, 2)$	Demand for online shop channel ($\xi = 1$) and live streaming channel ($\xi = 2$)
π_m	Profit of the agribusiness
π_T	Profit of the celebrity
π_C	Profit of supply chain system, $\pi_C = \pi_a + \pi_o$
Superscript	
c	The model of centralized decision-making
d	The model of decentralized decision-making
co	The coordination model
*	The optimal decision

$$\pi_T^{d*} = F - \frac{a^2 B (\gamma + 1) \theta \phi (2A\rho + B\theta\phi(2\gamma\delta + \gamma + 1) + 2B(\gamma + 1)((e - 1)\theta - 1))}{2A^2} \quad (10)$$

$$A = -\gamma^2 \delta^2 \theta^2 \phi^2 + \gamma \delta \theta \phi (1 + \gamma) (2 - \theta(2e + \phi - 2))$$

$$- (1 + \gamma)^2 \left(2e(\theta^2(\phi - 1) - 1) - \theta\phi(\theta\phi - 2\lambda + 2) + (\theta + 1)^2 \right)$$

$$B = (\gamma \delta \theta \rho \phi + (1 + \gamma)(\theta \rho(\phi - 1) + \rho - 1))$$

Proposition 2. Under the decentralized decision-making model, the impact of fairness concerns on the optimal decision variables is: $\frac{\partial p^{d*}}{\partial \gamma} > 0$, $\frac{\partial s^{d*}}{\partial \gamma} > 0$, $\frac{\partial f^{d*}}{\partial \gamma} > 0$.

With the fairness concerns raising, the level of sales efforts of the celebrity and sales prices will increase, while the level of brand-building efforts of agribusiness will decrease.

2.2 Centralized Model

Under centralized decision-making, the agribusiness and celebrity make decisions together as a whole. The total profit of the supply chain is

$$\pi_C^C = p\theta(\rho a - e p\theta + f + s) + p((1 - \rho)a - e p + f + \lambda s) - \frac{1}{2}f^2 - \frac{1}{2}s^2 \quad (11)$$

Proposition 3. In the centralized model, the optimal solution is as follows:

$$p^{c*} = -\frac{a + a(-1 + \theta)\rho}{1 + 2\theta(1 + \theta) - 2e(1 + \theta^2) + 2\theta\lambda + \lambda^2} \quad (12)$$

$$f^{c*} = -\frac{(1 + \theta)(a + a(-1 + \theta)\rho)}{1 + 2\theta(1 + \theta) - 2e(1 + \theta^2) + 2\theta\lambda + \lambda^2} \quad (13)$$

$$s^{c*} = \frac{(\theta + \lambda)(a - a\rho + a\theta\rho)}{-1 + 2e - 2\theta - 2\theta^2 + 2e\theta^2 - 2\theta\lambda - \lambda^2} \quad (14)$$

$$\pi_C^{c*} = \frac{(a + a(-1 + \theta)\rho)^2}{4e(1 + \theta^2) - 2(1 + 2\theta(1 + \theta) + 2\theta\lambda + \lambda^2)} \quad (15)$$

Proposition 4. The optimal decision variables in the fairness concerns model of decentralized and centralized decision-making structures are in the following order: $p^{c*} > p^{d*}$, $f^{c*} > f^{d*}$, $s^{c*} > s^{d*}$, $\pi_C^{c*} > \pi_C^{d*}$.

Proposition 4 states that the centralized model is an ideal decision-making method in which the agribusiness and the celebrity cooperate to make optimal decisions. Therefore, it is essential to design a coordination mechanism to coordinate the decentralized decision-making model.

3 Coordination Mechanism

In this section, agribusiness shares η proportion of sales efforts cost and the celebrity adjusts the commission rate ($\bar{\phi}$). The profits of the agribusiness and celebrity are:

$$\pi_m^{dco} = (1 - \bar{\phi})p\theta\rho a - e p\theta + f + s + p((1 - \rho)a - e p + f + \lambda s) - \frac{1}{2}\eta s^2 - \frac{1}{2}f^2 - F \quad (16)$$

$$\pi_T^{dco} = \bar{\phi}p\theta(\rho a - e p\theta + f + s) - \frac{1}{2}(1 - \eta)s^2 + F \quad (17)$$

$$U_m^{co} = \pi_m - \gamma(\delta\pi_T - \pi_m) = ((1 + \gamma)\eta - \gamma\delta(1 - \eta))\pi_C^C \quad (18)$$

Proposition 5. The cost-sharing joint commission mechanism can achieve system coordination, if $(\bar{\phi}, \eta)$ satisfies $\begin{cases} \bar{\phi} = \phi_1 \\ \eta = \delta \end{cases}$, where δ represents the agribusiness’s sharing proportion of the system profit and

$$\bar{\phi} = -\frac{(\eta - 1)(2e(\theta^2 + 1) - (\theta + 1)^2)(a(\theta - 1)\rho + a)^2 + 2F(-2e(\theta^2 + 1) + 2\theta\lambda + 2\theta(\theta + 1) + \lambda^2 + 1)^2}{2a^2\theta((\theta - 1)\rho + 1)(-\rho(-e(\theta^2 + \theta + 2) + \theta(\lambda + 3) + \lambda^2 + \lambda + 2) - e\theta + 2\theta + \lambda + 1)} \tag{19}$$

$$\frac{\pi_m}{\pi_C^{c*}} \leq \eta \leq 1 - \frac{\pi_T}{\pi_C^{c*}} \tag{20}$$

4 Numerical Analysis

In this section, we use the computer software “MATLAB” for numerical analysis. The parameter assignment is as follows: $a = 600, \lambda = 3, \theta = 0.8, \rho = 0.4, e = 9, F = 500, \phi = 0.3, \delta = 8, \gamma \in (0, 1)$. Figure 1 illustrates the impact of agribusiness’s fairness concerns coefficient on the optimal decision making and profits of the supply chain.

The optimal profit under the decentralized decision-making structure is $\pi_m^{d*} = 408.475, \pi_T^{d*} = 185.051, \pi_C^{d*} = 593.526$. Using the cost-sharing joint commission mechanism, the following calculation results shown in Table 2 can be obtained.

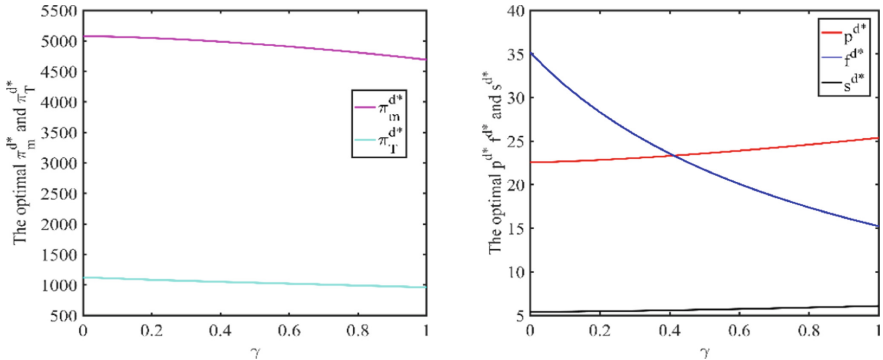


Fig. 1. Optimal decisions and profits of the supply chain

Table 2. Values of parameters and change rate after coordination

The profit of the agribusiness, the celebrity, and the supply chain system	
$\eta = 0.67$	$\pi_m^{co*} = 427.232(\uparrow 4.3\%), \pi_T^{co*} = 209.61(\uparrow 11.6\%), \pi_C^{c*} = 636.842$
$\eta = 0.68$	$\pi_m^{co*} = 431.991(\uparrow 5.8\%), \pi_T^{co*} = 204.85(\uparrow 10.7\%), \pi_C^{c*} = 636.842$
$\eta = 0.69$	$\pi_m^{co*} = 436.751(\uparrow 6.9\%), \pi_T^{co*} = 200.091(\uparrow 8.1\%), \pi_C^{c*} = 636.842$
$\eta = 0.70$	$\pi_m^{co*} = 446.783(\uparrow 9.4\%), \pi_T^{co*} = 190.059(\uparrow 2.7\%), \pi_C^{c*} = 636.842$

5 Conclusion

The main conclusion is that agribusiness's fairness concerns can be detrimental to the dual-channel supply chain. The higher the fairness concerns, the higher the price of agricultural products and the level of brand-building efforts as well as sales efforts. But the profits of agribusiness and celebrity will fall. Therefore, a cost-sharing joint commission coordination mechanism can coordinate the supply chain. The overall supply chain profit under decentralized decision-making is improved to the profit level under centralized decision-making, and perfect coordination is achieved.

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