Research Article

Decision Model of Contract-Farming Supply Chain Considering Producer’s Fairness Concerns under Random Yield

Yangang Feng,1,2 Rui Chen,1 and Lin He3

1School of Business, Fuyang Normal University, Fuyang 236037, China
2Key Laboratory of Regional Logistics Planning and Modern Logistics Engineering of Anhui Province, Fuyang 236037, China
3School of Information Engineering, Fuyang Normal University, Fuyang 236037, China

Correspondence should be addressed to Yangang Feng; fengyg99@163.com

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Supply chain management is critical for addressing uncertainties caused by random demand and production yield. In this study, a random yield supply chain, in which the production process of fresh agricultural products is easily affected by factors, such as weather, soil, or plant diseases and insect pests, was considered. Therefore, the actual output is typically less than the planned output. A model in which the producer faces yield uncertainty was considered, and the influence of the producer’s fairness concerns on the planned output of the contract-farming supply chain was considered. Methods to motivate the producer to increase planned output through reasonable contracts were investigated. The results revealed that the producer’s fairness concern considerably influences the optimal expected profit. In the case of the random output, the planned output and maximum expected profits reduce when the farmer exhibits fairness concerns. As the degree of the producer’s fairness concern increases, the planned output and expected profit gradually decrease. The cost-sharing contract can effectively encourage the producer to increase his planned output and expected utility. Finally, the results were verified numerically.

1. Introduction

Fresh agricultural products are indispensable necessities in daily life and play a crucial role in the retail consumer market. Data from I Research reveals that China’s fresh agricultural products market in 2018 was 4.40 trillion Yuan. In 2020, this market increased to 5 trillion Yuan [1]. Although the scale of China’s fresh agricultural market is increasing exponentially, producers are small individual farmers and cannot mass produce their products on a large scale. Therefore, the problem of “small production and large market” arises. The practice has revealed that the development of contract agriculture is an effective method to alleviate this problem. Contract-farming is an agricultural business model in which a company or an intermediate organization purchases fresh agricultural products produced by the producer as per a contract. This practice is widely used in the production and management process of fresh agricultural products [2].

Because fresh agricultural products are susceptible to uncertain factors such as climate, seasons, plant diseases, and insect pests during the production process, the actual output of fresh agricultural products differs from the planned output; that is, the output of fresh agricultural products exhibits random characteristics. The random yield of fresh agricultural products affects the producers’ income and their enthusiasm for production. To mitigate the effect of the randomness of the output on enterprises, many producers do not wish to expand agricultural inputs, which leads to an obvious difference between actual output and retailer’s ordering needs. Consequently, the market supply of fresh agricultural products and retail sales revenue are affected.

A critical factor affecting the enthusiasm of producers is their concern about fairness. In practice, some retailers typically purchase large quantities of products from producers at a low price and sell the produce at prices several times higher than the purchase price. Thus, producers not
only consider maximizing their interests when making agricultural inputs decisions but also wonder whether they are treated fairly in the supply chain. Thus, producers have fairness concerns. The randomness of the output and the fairness concerns of decision-makers increases the complexity of the decision-making process of the supply chain. When a producer has a fairness concern, an optimal planned output change should be implemented with the increase in fairness concern. Reasonable contracts should be designed to encourage producers to improve the planned output and the overall efficiency of the supply chain.

This study established a contract-farming agricultural supply chain decision model in which producers’ fairness concerns under random yield were considered, and the influence of producers’ fairness concerns on their optimal decision-making was analyzed to design a reasonable supply chain contract to motivate producers to increase production enthusiasm and overall supply chain efficiency.

This article is structured as follows: Section 2 provides a literature review; Section 3 details the model and symbols; Section 4 describes a supply chain decision model that does not consider the fairness concerns of producers; Section 5 indicates a supply chain decision model that considers the fairness concerns of producers; Section 6 is a supply chain decision model based on a cost-sharing contract; Section 7 is the numerical example and analysis; Section 8 provides the conclusion of this paper.

2. Literature Review

The research related to this paper can be summarized into three aspects: (1) randomness of the output, (2) fairness concern of decision-makers, and (3) contract farming.

2.1. Randomness of the Output. Yano and Lee [3] investigated the effect of centralized and decentralized decision-making modes on the supply chain under the random output condition. Nahmias [4] revealed that, regardless of the effort, the output loss of the semiconductor industry may exceed 80%. Zvi and Nir [5] categorized the random output models of producers into additive and multiplicative models. Comparative analysis of the two models was performed to investigate the effect of these two models on the input of the supply chain. Hu et al. [6] constructed a simple two-level supply chain and studied the influence of suppliers’ random output on retailers’ ordering decisions. Random output research has been extended to the fresh agricultural products supply chain field and achieved excellent results. For example, Chopra and Sodhi [7] revealed that the output of some agricultural products (vegetables, fruits) cannot be determined because their yield is affected not only by the number of inputs that have been invested but also by seasons and weather. Kazaz et al. [8] conducted a study on the supply chain of olive oil and revealed that the uncertainty of olive oil production severely affects its sales price and subsequently relevant decisions in the supply chain. Barrowclough et al. [9] investigated the effect of farmer-supermarket direct purchase on the performance of the agricultural product supply chain, farmers’ income, and consumer surplus value.

Ye and Lin [10] investigated the coordination of the contract-farming agricultural supply chain when the producer has risk aversion characteristics, whereas Cai et al. [11] studied the coordination of the contract-farming agricultural supply chain when the retailer has risk aversion characteristics. Feng et al. [12] studied the effects of business models on the operation of the fresh agricultural product supply chain.

2.2. Fairness Concerns Decision-Makers. Decision-makers in the supply chain care not only about their interests but also about whether they are treated fairly in the supply chain. Fehr and Schmidt [13] proposed vertical fairness concern and postulated that the criterion for decision-makers to determine fairness is the difference in the distribution of benefits between the retailer and producer. Cui et al. [14] investigated fairness concerns in a dual-channel supply chain and revealed that when channel members have fairness concerns, manufacturers use a wholesale price higher than their marginal cost. Li et al. [15] studied the dual-channel supply chain advertising cooperation strategy and revealed that the manufacturers’ fairness concern affects the profits of retailers and the market share of products. Bisi et al. [16] introduced fairness concerns into the research field of green clothing supply chains and studied the influence of the fairness concerns of supply chain members on green decision-making and pricing decisions. Zhang et al. [17] studied the profit distribution model of the closed-loop supply chain with the characteristics of fairness concerns for retailers and proposed an innovative weighted distribution method. Jian et al. [18] studied the green closed-loop supply chain with fair concern characteristics of manufacturers and analyzed the influence of manufacturers’ fair concern behaviors on the environmental performance of green products and the retail prices of products. The fairness concern of decision-makers was investigated in the fresh agricultural product supply chain. For example, Yan et al. [19, 20] studied the decision-making problem of the fresh agricultural product supply chain. Moon et al. [21] analyzed the effect of retailers’ fairness concerns on investment decisions in the fresh produce supply chain.

2.3. Contract-Farming. In the supply chain of contract-farming, the classic model of “company + farmer” has been considered the research object to analyze factors’ effect on the operation of the contract-farming supply chain, such as the weak position of farmer households [22], weather influence [23], and differentiated pricing mechanism [24]. Decision makers’ behavioral factors such as risk aversion and fairness concerns have been considered in contract agriculture supply chains to analyze the influence of decision makers’ behavioral factors on the operation of contract-farming supply chains. For example, Peng et al. [25] studied the optimal strategy of the contract-farming supply chain under random output when farmers have risk aversion characteristics.
A review of the literature reveals that limited studies have been conducted on the contract-farming supply chain and the fairness concern of decision-makers. Furthermore, the randomness of fresh produce output and the fairness concerns of decision-makers is yet to be simultaneously studied. Because of the random yield of fresh agricultural products and a large gap exists between the wholesale price and retail price, producers of fresh agricultural products focus more on fairness than on retailers. Based on the aforementioned reasons, a contract-farming supply chain decision model that considers producers’ fairness concerns under random output, analyzes the influence of producers’ fairness concerns on their optimal decisions, and studies the incentivization of producers to improve their planned output was proposed to improve the efficiency of the supply chain. The main contribution of this paper is the randomness of product output and the fairness concerns of farmers in one model simultaneously. This model is consistent with practical problems, and the content of the study can enrich the theory of contract-farming supply chain management.

3. Model Descriptions and Symbol Explanation

3.1. Model Description. We considered a “company + farmer” type contract-farming supply chain system consisting of a single fresh agricultural product retailer and a single fresh agricultural product producer. Before the production season, retailers send an order request to the producer based on the sales of the previous sales cycle and the current market situation. The order quantity is \( q_r \). The producer determines the planned output \( Q \) according to the retailer’s order and market conditions. Because of the influence of weather, season, production technology, and other factors, the actual output of the producer \( Y \) is uncertain. Following the method of literature [12], we assume the actual output \( Y = Qx \), here \( x \in (a, b), 0 \leq a < b \) is a random variable, its density function is \( f(x) \), and its cumulative distribution function of \( x \) is \( F(x) \); here, \( F(x) \) is a differentiable and strictly increasing function.

For convenience, we conduct research based on the following assumptions. (1) Assume that both the producer and the retailer maximize their interests as their decision-making goals. (2) In the “company + farmer” model, retailers generally select nearby producers; therefore, logistics losses and transportation costs are ignored in this study. (3) Because fresh agricultural products are perishable, the residual value of fresh agricultural products at the end of the period is not considered.

3.2. Symbol Explanation. The main symbols used in the text are shown in Table 1.

| Symbol | Definition |
|--------|------------|
| \( q_r \) | Retailer’s order quantity |
| \( Q \) | Producer’s planned output |
| \( Y \) | Producer’s actual output |
| \( x \) | Random output factor |
| \( p \) | Retail price of fresh agricultural products |
| \( w \) | The unit wholesale price of fresh agricultural products |
| \( c \) | The unit production cost of fresh agricultural products |
| \( c_r \) | The retailer’s unit out-of-stock cost |
| \( \pi_r \) | The retailer’s total revenue |
| \( \pi \) | The producer’s total revenue |
| \( E(\pi_r) \) | Expected revenue of the retailer |
| \( E(\pi) \) | Expected revenue of the producer |

4. Supply Chain Decision-Making Model That Does Not Consider the Fairness Concerns of Producer

4.1. The Producer’s Production Decision. When the producer’s fairness concerns are not considered, the producer determines planned output according to the retailer’s order to maximize his revenue. The revenue function of the producer can be expressed as follows:

\[
\pi_r = w \min (Qx, q_r) - c_w Q. \tag{1}
\]

Proposition 1. Assume that the optimal planned output of the producer is \( Q^* \), then \( Q^* \) should satisfy 
\[
\int_a^b \min \{Qx, q_r\} f(x) dx = c_w Q, \text{ and the maximum is } E(\pi_r)_{\text{max}} = wq_r \int_a^b Qx f(x) dx.
\]

The proof of Proposition 1 is presented in Appendix A.

4.2. Retailer’s Ordering Decision. When the producer’s fairness concerns are not considered, the decision problem of the retailer is similar to a newsvendor problem. Because we focused on the retailer’s optimal order quantity, for convenience, according to the treatment method in literature [26, 27], we assume that the wholesale price and retail price are determined. The revenue function of the retailer can be expressed as follows:

\[
\pi_r = (p - w - c_r) \min (Qx, q_r) - v_r, \text{ max}(q_r - Qx, 0). \tag{2}
\]

Proposition 2. When both the wholesale price and the retail price are determined, an optimal order quantity \( q_r^* \), exists that satisfies 
\[
\int_a^{Q^*} f(x) dx = v_r/p - w - c_r + v_r, \text{ which maximizes the retailer’s expected revenue, and the expected revenue of the retailer is } E(\pi_r)_{\text{max}} = (p - w - c_r + v_r)Q \int_a^{Q^*} xf(x) dx.
\]

The proof of Proposition 2 is presented in Appendix B.

5. Supply Chain Decision-Making Model considering the Fairness Concerns of Producer

Assume that the producer has the characteristic of fairness concern, and fairness is not a concern for the retailer. To characterize the utility function of the producer, according to the method of literature [28], the parameter \( \lambda \) is introduced as the fairness coefficient, and the utility function of the fairness concern of the producer is obtained as follows:
When \( \lambda > 0 \), the producer has a fairness concern; when \( \lambda = 0 \), the producer does not care about fairness. To simplify the analysis, we set \( U(\pi_s) = u(\pi_s)/(1 + \lambda) \), let \( \hat{\lambda} = \lambda/1 + \lambda \), here \( \hat{\lambda} \) is an increasing function of \( \lambda \), and it is obvious that \( \hat{\lambda} \) satisfies \( \hat{\lambda} \in (0, 1) \). When \( \lambda = 0, \hat{\lambda} = 0 \), the producer does not care about fairness, and when \( \lambda \to +\infty, \hat{\lambda} = 1 \), in this case, the producer has strong concerns about fairness and would pay great costs for maintaining fairness. Based on the aforementioned transformation, (3) can be reformulated as follows:

\[
U(\pi_s) = \pi_s - \hat{\lambda}(\pi_s - \pi_r) = (1 + \hat{\lambda})\pi_s - \hat{\lambda}\pi_r.
\]

(3)

Proposition 3. When the producer has the characteristics of fairness concerns, if \( \hat{\lambda} \) satisfies \( \hat{\lambda} < w/p + v_r - w/c_r \), assuming that the optimal expected output of the producer is \( Q^* \), then \( Q^* \) satisfies \( \int_{a}^{Q^*} f(x)dx = c_r/w - \hat{\lambda}(p + v_r - w/c_r) \), and \( \lambda Q^* < \lambda Q^\ast \).

The proof of Proposition 3 is presented in Appendix C.

Proposition 3 reveals that the uncertainty of output and the characteristics of the producer’s fairness concern affect the optimal planned output. Furthermore, the optimal planned output of the producer decreases as its fairness concern increases, which leads to the retailer’s order not being satisfied, which affects the revenue of the retailer. To encourage the producer to increase his planned output, the retailer should consider certain incentive measures. The cost-sharing contract is a common cooperative mechanism in supply chain management that can mitigate the risk of the supply chain members [29, 30]. Next, we discuss how the retailer uses cost-sharing contracts to motivate the producer to increase his planned output.

6. Supply Chain Incentive Mechanism Based on Cost-Sharing Contract

To encourage the producer to increase his planned output, we designed a cost-sharing contract under which the retailer promises to share a proportion of the production cost of the producer \( \phi \in (0, 1) \). Under the cost-sharing contract, the producer’s revenue function becomes

\[
\pi_s = w \min((Qx, q_r)) - (1 - \phi)c_rQ.
\]

(5)

Proposition 4. Under the cost-sharing contract, when the retailer’s cost-sharing ratio satisfies \( \phi = \hat{\lambda}(w - c_r + v_r)/(1 + \lambda)w \), the optimal planned output of the fair concern producer is equal to the optimal planned output when he does not have fair concern characteristic, and the retailer’s proportion of cost-sharing increases as the fairness concerns degree of the producer increases.
maximum, the corresponding planned output is its optimal planned output. Figure 1 reveals that the optimal planned output of the producer increases with the increase in the order quantity of the retailer. In practice, to incentivize the producer to increase his planned output, the retailer should increase his order quantity of products appropriately.

Let the retailer’s order quantity \( q = 30 \). Figure 2 reflects the influence of the producer’s degree of fairness concerns on its optimal planned output when the retailer’s order quantity remains unchanged.

Figure 2 reveals that when the retailer’s order quantity remains unchanged, the producer’s degree of fairness concerns increases, his optimal planned output continues to decrease, which verifies the conclusion of Proposition 3. In particular, when the manufacturer’s fairness concern coefficient reaches 0.8, its optimal planned output becomes lower than the retailer’s order quantity, which obviously cannot satisfy the ordering demand of the retailer. Therefore, when the producer has characteristics of fairness concerns, the retailer adopts certain strategies to encourage the producer to increase his planned output.

Figure 3 reflects the situation under the cost-sharing contract when the retailer’s cost-sharing ratio changes with the producer’s degree of fairness concerns.

Figure 3 reveals that, under the cost-sharing contract, with the increase in the producer’s fairness concerns degree, to encourage the producer to increase his planned output, the retailer should increase his cost-sharing ratio, which is consistent with Proposition 4. To encourage the producer to increase his planned output, the retailer can select an appropriate cost-sharing ratio based on the producer’s concern for fairness.

8. Conclusions

The decision-making model of the contract-farming agricultural supply chain that considers the fairness concerns of producers under the random output situation was investigated. We analyzed the influence of the producer’s fairness concern characteristics on his optimal decision-making and studied how retailers encourage producers to increase their planned output by using the investment cost-sharing contract. The relevant conclusions are as follows:

1. The planned output of the producer increased with the increase in the retailer’s order quantity, and because of the randomness of the output, the optimal planned output was higher than the order quantity.
2. When the producer exhibits fairness concerns, the planned output and maximum expected return decrease, and as the producer is more concerned about fairness, the planned output and expected return gradually reduce.
3. The retailer can use a cost-sharing contract to incentivize the producer to increase his planned output. When the retailer’s cost-sharing ratio satisfies certain conditions, the optimal planned output of the producer with fairness concerns equals that without fairness concerns, and the cost-sharing ratio of the retailer increases with the increase in the fairness concerns of producers.

The conclusions of this paper provide a theoretical reference for investigating the decision-making problem of the contract-farming supply chain in which the fairness concerns of producers under the random output situation are considered. The follow-up research can also be expanded from the following two aspects. First, only the fairness concern characteristics of the producer were considered; the effects of retailer fairness concerns on supply chain decision-making should be investigated. Related problems should be studied; second, besides the randomness of output, the market demand for fresh agricultural products is also random. Under double random production and demand, the retailer and the producer should make decision-making should be investigated.
Appendix

A. Proof of Proposition 1

The expected revenue function of the producer is

$$\text{E}(\pi_r) = wQ \left( \int_a^{q_r/Q} xf(x)dx + \frac{q_r}{Q} \int_{q_r/Q}^b f(x)dx \right) - c_rQ.$$  \hspace{1cm} (A.1)

Therefore, we can get

$$\frac{\partial \text{E}(\pi_r)}{\partial Q} = w \int_a^{q_r/Q} xf(x)dx - c_r.$$  \hspace{1cm} (A.2)

It is obvious that $\frac{\partial^2 \text{E}(\pi_r)}{\partial Q^2} = -f(q_r/Q)p^2/Q^3w < 0$, the producer’s expected revenue function $\text{E}(\pi_r)$ is a strictly concave function of $Q$, and the maximum expected revenue exists. Assume that when the expected revenue of the producer is maximized, the optimal planned output of the producer is $Q^*$; let $\partial \text{E}(p_r)/\partial Q \equiv 0$; we can get

$$\int_a^{q_r/Q} xf(x)dx = \frac{c_r}{w}.$$  \hspace{1cm} (A.3)

Plugging (A.3) into (A.1), we can get the maximum expected revenue of the producer which is

$$\text{E}(\pi_r)_{\text{max}} = wq_r \int_{q_r/Q}^b f(x)dx.$$  \hspace{1cm} (A.4)

B. Proof of Proposition 2

The expected revenue function of the producer is

$$\text{E}(\pi_r) = (p-w-c_r+\nu_r)Q \left( \int_a^{q_r/Q} xf(x)dx + \frac{q_r}{Q} \int_{q_r/Q}^b f(x)dx \right) - \nu_rq_r.$$  \hspace{1cm} (B.1)

Therefore, we can get

$$\frac{\partial \text{E}(\pi_r)}{\partial q_r} = (p-w-c_r+\nu_r) \int_{q_r/Q}^b f(x)dx - \nu_r.$$  \hspace{1cm} (B.2)

Then,

$$\frac{\partial^2 \text{E}(\pi_r)}{\partial q_r^2} = -(p-w-c_r+\nu_r)Qf(q_r/Q).$$  \hspace{1cm} (B.3)

It is easy to get $\frac{\partial^2 \text{E}(\pi_r)}{\partial q_r^2} < 0$.

Therefore, the retailer’s expected revenue function $\text{E}(\pi_r)$ is a strictly concave function of $q_r$, Maximum expected revenue exists. Let $\partial \text{E}(\pi_r)/\partial Q \equiv 0$; we can get

$$\int_a^{q_r/Q} f(x)dx = \frac{\nu_r}{p-w-c_r+\nu_r}.$$  \hspace{1cm} (B.4)

Incorporating (B.4) into (B.1), the maximum expected revenue of the retailer is

$$\text{E}(\pi_r)_{\text{max}} = (p-w-c_r+\nu_r)Q \int_{q_r/Q}^b xf(x)dx.$$  \hspace{1cm} (B.5)

C. Proof of Proposition 3

The expected revenue function of the producer is

$$\text{E}(\pi_r) = [w-\lambda(p-w-c_r)]$$

$$\cdot \left( \int_a^{q_r/Q} xf(x)dx + \frac{q_r}{Q} \int_{q_r/Q}^b f(x)dx \right)$$

$$+ \lambda \nu_r \int_a^{q_r/Q} (q_r-x)f(x)dx - c_rQ.$$  \hspace{1cm} (C.1)

For (C.1), we can obtain the first derivative and the second derivative of $Q$

$$\frac{\partial \text{E}(\pi_r)}{\partial Q} = [w-\lambda(p+w_r-w-c_r)] \int_a^{q_r/Q} xf(x)dx - c_rQ,$$  \hspace{1cm} (C.2)

$$\frac{\partial^2 \text{E}(\pi_r)}{\partial Q^2} = \frac{q_r^2}{Q^2} \int_a^{q_r/Q} f(x)dx.$$  \hspace{1cm} (C.3)

The following are divided into three situations for discussion.

(1) When $w-\lambda(p+w_r-w-c_r) < 0$, in other words, when $\lambda \equiv w/p+w_r-w-c_r$, the expected utility function of the producer is a strictly convex function, and the planned output that maximizes the utility is distributed at two extreme points (0 and the producer’s maximum production capacity). This situation is generally not in line with reality and is relatively rare in the market.

(2) When $w-\lambda(p+w_r-w-c_r) = 0$, which means $\lambda \equiv w/p+w_r-w-c_r$, meanwhile $\frac{\partial \text{E}(U(\pi_r))}{\partial Q} = [w-\lambda(p+w_r-w-c_r)] \int_a^{q_r/Q} xf(x)dx - c_rQ < 0$, the expected utility function of the producer is a monotonically decreasing function, and the maximum planned output is at $Q = 0$, which does not meet the realistic conditions.

(3) When $w-\lambda(p+w_r-w-c_r) > 0$, that is, when $\lambda \equiv w/p+w_r-w-c_r$, the expected utility function of the producer is a strictly concave function, and there is a unique optimal planned output $Q^{\ast\ast}$, and let $[w-\lambda(p+w_r-w-c_r)] \int_a^{q_r/Q} xf(x)dx - c_rQ = 0$; we can get

$$\int_a^{q_r/Q^{\ast\ast}} xf(x)dx = \frac{c_r}{w-\lambda(p+w_r-w-c_r)}.$$  \hspace{1cm} (C.4)
Due to $\hat{\lambda}(w/p + v_r - v_r)$, therefore $w - \hat{\lambda}(p + v_r - v_r)$, and we can easily get $Q^* = Q^*$.

Plugging (C.4) into (C.1), we can obtain the maximum excepted utility value of the producer considering fairness which is

$$E[U(\pi_s)]_{\text{max}} = \left[ w - \hat{\lambda}(p + v_r - v_r) \right] q_p \int_{q_p/Q^*}^b f(x)dx + \hat{\lambda}v_r q_r. \quad (C.5)$$

D. Proof of Proposition 4

Under the cost-sharing contract, the utility function of the producer is

$$U(\pi_s) = \pi_s - \hat{\lambda}\pi_r = \left[ w - \hat{\lambda}(p - w - c_r) \right] \min(Qx, q_r) - \left[ 1 - \phi(1 + \hat{\lambda}) \right] c_r Q + \hat{\lambda}v_r \max(q_r - Qx, 0). \quad (D.1)$$

The expected utility function of the producer is

$$E(U(\pi_s)) = \left[ w - \hat{\lambda}(p - w - c_r + v_r) \right] Q \int_a^b f(x)dx + \frac{q_r}{Q} \int_a^b f(x)dx \quad (D.2)$$

$$+ \hat{\lambda}v_r q_r - \left[ 1 - \phi(1 + \hat{\lambda}) \right] c_r Q.$$ 

From (D.2), we can get

$$\frac{\partial E[U(\pi_s)]}{\partial Q} = \left[ w - \hat{\lambda}(p - w - c_r + v_r) \right] \int_a^b f(x)dx$$

$$- \left[ 1 - \phi(1 + \hat{\lambda}) \right] c_r, \quad (D.3)$$

$$\frac{\partial^2 E[U(\pi_s)]}{\partial Q^2} = \left[ w - \hat{\lambda}(p - w - c_r + v_r) \right] \left( -\frac{q}{Q^2} \right) f(q_r). \quad (D.4)$$

It is obvious that $\frac{\partial^2 E[U(\pi_s)]}{\partial Q^2} = 0$, which means that the producer’s expected utility function is a concave function with respect to $Q$, and the maximum expected utility exists. Let $\left[ w - \hat{\lambda}(p - w - c_r + v_r) \right] \int_a^b f(x)dx = \left[ 1 - \phi(1 + \hat{\lambda}) \right] c_r = 0$; then, we can get the optimal planned output of the producer $Q^*$ that should satisfy

$$\int_a^b f(x)dx = \frac{\left[ 1 - \phi(1 + \hat{\lambda}) \right] c_r}{w - \hat{\lambda}(p - w - c_r + v_r)} \quad (D.5)$$

Let $Q^* = Q^*$; then $\left[ 1 - \phi(1 + \hat{\lambda}) \right] c_r / w - \hat{\lambda}(p - w - c_r + v_r) = c_r / w$; the optimal planned output of the fair concern producer reaches the level when the fairness is not considered.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare no conflicts of interest.

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