APEM journal

Advances in Production Engineering & Management | **ISSN 1854-6250**
Volume 17 | Number 2 | June 2022 | pp 219–230 | Journal home: apem-journal.org
https://doi.org/10.14743/apem2022.2.432 | Original scientific paper

Supply chain coordination contract design: The case of farmer with capital constraints and behavioral preferences

Wang, Y.L.[a,b], Yin, X.M.[b], Zheng, X.Y.[b], Cai, J.R.[a,b,*], Fang, X.[c]

[a]Research Center for Enterprise Management, Chongqing Technology and Business University, Chongqing, P.R. China
[b]School of Business Administration, Chongqing Technology and Business University, Chongqing, P.R. China
[c]School of Management Science and Engineering, Chongqing Technology and Business University, Chongqing, P.R. China

A B S T R A C T

Coordination mechanism design is an important issue in agricultural supply chain. This study investigates agricultural supply chain coordination contracts in the presence of output uncertainty. It considers a two-level supply chain comprising a farmer and a retailer, where the farmer faces capital constraints and shows stockout-averse (SA), waste-averse (WA), or stockout- and waste-averse (SW) preferences. The results show that the retailer order, production input, and supply chain expected utility in the decentralized decision framework are lower than those realized under the centralized decision model; hence, the wholesale price contract cannot coordinate the supply chain. Nevertheless, the designed coordination contract mechanism coordinates the supply chain efficiently and realizes a flexible distribution of benefits between the farmer and the retailer. Furthermore, when the revenue-sharing coefficient meets specific conditions, both the farmer and the retailer achieve a win-win situation. Finally, we verify the coordination contract design using numerical simulations and analyze the effects of SA and WA preferences on decision-making and the supply chain expected utility. This study provides theoretical guidance for the coordination mechanism design of agricultural supply chain with capital constraints and behavioral preferences.

A R T I C L E   I N F O

Keywords:
Supply chain;
Supply chain coordination;
Contract design;
Capital constraints;
Waste-averse preferences;
Stockout-averse preferences;
Behavioral preferences

**Corresponding author:*
caijr@ctbu.edu.cn
(Cai, J.R.)

Article history:
Received 9 February 2022
Revised 8 August 2022
Accepted 13 August 2022

1. Introduction

Agricultural production is influenced by uncertain environmental factors (such as the weather, war crisis, human factors, etc.). Hence, farmers are cautious regarding the amount of production input needed. Before the production season, retailers pre-order agricultural products from farmers based on the predicted market demand. Then, farmers organize the agricultural production according to the retailer's orders. However, uncertainty in the output may lead to a mismatch between agricultural output and retailer orders. Overproduction or underproduction generates losses to farmers; hence, they may become waste-averse (WA) or stockout-averse (SA) [1]. In addition, some farmers have limited funds; due to the long production cycle of agricultural products, they may face capital constraints. Therefore, designing an effective supply chain coordination contract mechanism is crucial for managing farmers' financial constraints and behavioral preferences.

When faced with capital constraints, farmers may seek financing from formal financial institutions or other legal channels [2], such as trade credit and bank credit [3-6], advance payment discounts (advance payment) [7-9], and purchase order financing [9]. Therefore, research has begun focusing on financing services and financing strategies [10-13]. However, a financing strategy may benefit the individual but may not the entire supply chain. Hence, a coordination contract mechanism is needed for achieving coordination in the supply chain and a "win-win" situation for all participants. The literatures indicate that the wholesale price contract [14], option contract [15], revenue-sharing contract and buyback contract [16-19], output penalty contract and cost-sharing contract [19], general contract based on risk compensation [20], and two-way revenue-sharing contract [21] may coordinate the supply chain efficiently.

However, when addressing supply chain coordination problems in the presence of financial constraints, the above literatures assume that the output is determined, and participants are risk neutral. Therefore, this study's original contribution lies in the following three aspects:

- The output is assumed to be randomly determined owing to the uncertainty in the agricultural production.
- Agricultural products may be in excess or insufficient; hence, we consider that the farmer may have behavioral preferences: stockout- and waste-averse (SW), WA, or SA preferences.
- We design a supply chain coordination contract mechanism and analyze the influence of behavioral preferences on participants' decision-making and the expected utility of the supply chain.

The remainder of this paper is organized as follows. Section 2 describes the problems, assumptions, and notations. Section 3 presents the model. Section 4 introduces the design of the coordinated contract mechanism. Section 5 provides a numerical simulation analysis, and Section 6 provides our concluding remarks.

2. Model's setup, assumptions, and notations

2.1 Problem description

We address the case of a two-level supply chain comprising a financially constrained farmer and a retailer. According to the predicted market demand, the retailer books agricultural products Q to the farmer in advance. The farmer determines its production input q according to the retailer's order. Since the output of agricultural products is randomly determined, the farmer's output is uq, where u is the random output factor, with $u \in (0, B)$ [22]. In the sales season, the farmer sells agricultural products to the retailer at the unit wholesale price w agreed in the contract. The retailer resells them to consumers at unit price p, satisfying consumer demand. This mechanism is shown in Fig. 1.

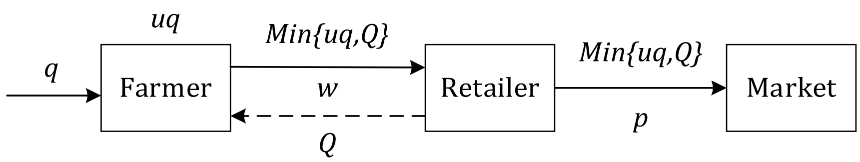

Fig. 1 Schematic diagram of the study structure

2.2 Model assumptions

Assumption 1: The market price of agricultural products p is inversely proportional to the number of agricultural products $\min\{Q, uq\}$, namely, $p = A - \min\{Q, uq\}$ [23]. A is the highest price that consumers are willing to pay, and $\min\{Q, uq\}$ is the transaction volume of the farmer and retailer, namely:

$$min\{Q, uq\} = \begin{cases} Q, Q \leq uq \\ uq, Q > uq \end{cases}$$

Assumption 2: The farmer has SA preferences when the production cannot meet the retailer's order, as $Q > uq$. In the case of insufficient production, an additional penalty $\lambda(Q - uq)^+$ is generated; λ is the shortage aversion coefficient. On the other hand, the farmer has WA preferences when the output is in excess, namely, $Q < uq$. In this case, an additional penalty $\beta(uq - Q)^+$ is imposed on the excess production; β is the WA coefficient. Similar assumptions are made in the literature [1].

Assumption 3: Since farmers may have different behavioral preferences, we consider situations where the farmer has WA, SA and SW preferences.

Assumption 4: We consider a scenario in which a farmer faces capital constraints, namely, $cq > T$. To supplement the insufficient funds $(cq - T)^+$, the farmer obtains financing from a third party. The financing rate is r, and the financing cost is $r(cq - T)^+$; c is the unit production cost of agricultural products, and T indicates the funds held by the farmer.

Assumption 5: $p > w > c$.

Assumption 6: The farmer and the retailer have symmetrical information.

2.3 Notations

All the symbols used in this article are summarized in Table 1.

Table 1 The listing of notations

Symbols	Descriptions	Symbols	Descriptions
c	Unit production cost	λ	Stockout-aversion coefficient
w	Wholesale price	β	Waste-aversion coefficient
p	Retail price	C (top right corner)	Centralized decision model
q	Production input	B (top right corner)	Decentralized decision model
Q	Order quantity	H (top right corner)	Coordination contract mechanism
u	Random output factor	SA	Stockout-aversion
$F(u)$	Cumulative distribution function of u	WA	Waste-aversion
$f(u)$	Probability density function of u	SW	Stockout- and waste-averse
T	Funds held by the farmer	r	Financing rate
Π_R^j	Retailer's expected profit	*	Optimal value
Π_i^j	Supply chain expected utility	U_F^j	The farmer's expected utility
$i \in \{SW, SA, WA\}, j \in \{C, B, H\}$			

3. Alternative models

3.1 Centralized decision model

In the centralized decision-making framework, the farmer and retailer belong to the same collective, and both aim to maximize the expected utility of the entire supply chain. When the farmer has SW preferences, the utility of the supply chain is:

$$\pi_{SW}^C = (A - \min\{Q, uq\})\min\{Q, uq\} - \lambda(Q - uq)^+ - \beta(uq - Q)^+ - cq - r(cq - T)^+ \tag{1}$$

In Eq. 1, $(A - \min\{Q, uq\})\min\{Q, uq\}$represents sales revenue, and $\lambda(Q - uq)^+$ and $\beta(uq - Q)^+$ are punishments for production shortage and overproduction, respectively; cq is the production cost, and $r(cq - T)^+$ is the financing interest cost.

According to Eq. 1, the expected utility of the supply chain is:

$$\Pi_{SW}^C = (A + \lambda + \beta)\left[Q - q\int_0^{\frac{Q}{q}} F(u)du\right] + 2q^2\int_0^{\frac{Q}{q}} F(u)du - Q^2 - \lambda Q - [\beta\mu + (1 + r)c]q + rT \tag{2}$$

The first partial derivatives of $\Pi_{SW}^C$with respect to Q and q are, respectively:

$$\frac{\partial \Pi_{SW}^C}{\partial Q} = (A + \lambda + \beta)\left[1 - F\left(\frac{Q}{q}\right)\right] - 2\left[Q - q\left(\frac{Q}{q}\right)\right] - \lambda = 0 \tag{3}$$

$$\frac{\partial \Pi_{SW}^{C}}{\partial q} = (4q - A - \lambda - \beta)\int_0^{\frac{Q}{q}} F(u)du + \frac{(A+\lambda+\beta-2q)Q}{q} F\left(\frac{Q}{q}\right) - \beta\mu - (1+r)c = 0 \tag{4}$$

By solving Eqs. 3 and 4 simultaneously, we obtain the optimal order quantity Q_{SW}^{C*} and production input quantity q_{SW}^{C*} in the centralized decision framework:

$$\begin{cases} (A+\lambda+\beta)\left[1 - F\left(\frac{Q_{SW}^{C*}}{q_{SW}^{C*}}\right)\right] - 2\left[Q_{SW}^{C*} - q_{SW}^{C*} F\left(\frac{Q_{SW}^{C*}}{q_{SW}^{C*}}\right)\right] - \lambda = 0 \\ (4q_{SW}^{C*} - A - \lambda - \beta)\int_0^{\frac{Q_{SW}^{C*}}{q_{SW}^{C*}}} F(u)du + \frac{(A+\lambda+\beta-2q_{SW}^{C*})Q_{SW}^{C*}}{q_{SW}^{C*}} F\left(\frac{Q_{SW}^{C*}}{q_{SW}^{C*}}\right) - \beta\mu - (1+r)c = 0 \end{cases} \tag{5}$$

We then obtain the optimal expected utility of the supply chain, as follows:

$$\begin{aligned}\Pi_{SW}^{C*} = (A+\lambda+\beta)\left[Q_{SW}^{C*} - q_{SW}^{C*}\int_0^{\frac{Q_{SW}^{C*}}{q_{SW}^{C*}}} F(u)du\right] + 2{q_{SW}^{C*}}^2 \int_0^{\frac{Q_{SW}^{C*}}{q_{SW}^{C*}}} F(u)du - {Q_{SW}^{C*}}^2 - \lambda Q_{SW}^{C*} \\ - [\beta\mu + (1+r)c]q_{SW}^{C*} + rT\end{aligned} \tag{6}$$

If the farmer only has SA preferences, $\lambda > 0$, and $\beta = 0$; however, if the farmer only has WA preferences, $\lambda = 0$ and $\beta > 0$. The optimal decision and the supply chain expected utility in the centralized decision framework may be obtained in the same way; this analysis step is, therefore, omitted.

3.2 Decentralized decision model

In the decentralized decision framework, the farmer determines the amount of production input q to maximize their expected utility, and the retailer determines the order quantity Q to maximize their expected profit. We assume that the farmer and retailer have the same decisional power; hence, they play a Cournot game. When the farmer has SWpreferences, the expected utility of the farmer and the expected profit of the retailer are as follows:

$$\begin{aligned}U_F^B = E[w\min\{Q, uq\} - \lambda(Q - uq)^+ - \beta(uq - Q)^+ - cq - r(cq - T)] = (w + \beta)Q - \\ \beta\mu q - q(w+\lambda+\beta)\int_0^{\frac{Q}{q}} F(u)du - cq - r(cq - T)\end{aligned} \tag{7}$$

$$\begin{aligned}\Pi_R^B = E[(A - \min\{Q, uq\})\min\{Q, uq\} - w\min\{Q, uq\}] = (A - w)Q - Q^2 - (A - \\ w)q\int_0^{\frac{Q}{q}} F(u)du + 2q^2\int_0^{\frac{Q}{q}} F(u)du\end{aligned} \tag{8}$$

The first and second partial derivatives of U_F^B with respect to q are:

$$\frac{\partial U_F^B}{\partial q} = (w+\lambda+\beta)\left(\frac{Q}{q}F\left(\frac{Q}{q}\right) - \int_0^{\frac{Q}{q}} F(u)du\right) - \beta\mu - (1+r)c \tag{9}$$

$$\frac{\partial^2 U_F^B}{\partial q^2} = -\frac{Q^2}{q^3}(w+\lambda+\beta)f\left(\frac{Q}{q}\right) < 0 \tag{10}$$

The first and second partial derivatives of Π_R^B with respect to Q are:

$$\frac{\partial \Pi_R^B}{\partial Q} = (A - w)\left[1 - F\left(\frac{Q}{q}\right)\right] - 2\left[Q - qF\left(\frac{Q}{q}\right)\right] \tag{11}$$

$$\frac{\partial^2 \Pi_R^B}{\partial Q^2} = -\frac{(A-w)}{q} f\left(\frac{Q}{q}\right) - 2\left[1 - f\left(\frac{Q}{q}\right)\right] < 0 \tag{12}$$

Since $\frac{\partial^2 U_F^B}{\partial q^2} < 0$, and $\frac{\partial^2 \Pi_R^B}{\partial Q^2} < 0$, when $\frac{\partial U_F^B}{\partial q} = 0$, and $\frac{\partial \Pi_R^B}{\partial Q} = 0$, in the decentralized decision framework, the optimal order quantity Q_{SW}^{B*} and production input quantity q_{SW}^{B*} may be obtained as follows:

$$\begin{cases} (A-w)\left[1-F\left(\frac{Q_{SW}^{B*}}{q_{SW}^{B*}}\right)\right]-2\left[Q_{SW}^{B*}-q_{SW}^{B*}F\left(\frac{Q_{SW}^{B*}}{q_{SW}^{B*}}\right)\right]=0 \\ (w+\lambda+\beta)\left(\frac{Q_{SW}^{B*}}{q_{SW}^{B*}}F\left(\frac{Q_{SW}^{B*}}{q_{SW}^{B*}}\right)-\int_0^{\frac{Q_{SW}^{B*}}{q_{SW}^{B*}}}F(u)du\right)-\beta\mu-(1+r)c=0 \end{cases} \tag{13}$$

Under decentralized decisions, the optimal expected utility of the farmer, the optimal expected profit of the retailer, and the optimal expected utility of the supply chain are, respectively:

$$U_F^{B*} = (w+\beta)Q_{SW}^{B*} - \beta\mu q_{SW}^{B*} - q_{SW}^{B*}(w+\lambda+\beta)\int_0^{\frac{Q_{SW}^{B*}}{q_{SW}^{B*}}}F(u)du - c(1+r)q_{SW}^{B*} + r\mathrm{T} \tag{14}$$

$$\Pi_R^{B*} = (A-w)Q_{SW}^{B*} - {Q_{SW}^{B*}}^2 - (A-w)q_{SW}^{B*}\int_0^{\frac{Q_{SW}^{B*}}{q_{SW}^{B*}}}F(u)du + 2{q_{SW}^{B*}}^2\int_0^{\frac{Q_{SW}^{B*}}{q_{SW}^{B*}}}F(u)du \tag{15}$$

$$\begin{aligned}\Pi_{SW}^{B*} = (A+\lambda+\beta)\left[Q_{SW}^{B*} - q_{SW}^{B*}\int_0^{\frac{Q_{SW}^{B*}}{q_{SW}^{B*}}}F(u)du\right] + 2{q_{SW}^{B*}}^2\int_0^{\frac{Q_{SW}^{B*}}{q_{SW}^{B*}}}F(u)du - {Q_{SW}^{B*}}^2 - \lambda Q_{SW}^{B*} \\ - [\beta\mu + (1+r)c]q_{SW}^{B*} + rT\end{aligned} \tag{16}$$

If the farmer only has SA preferences, $\lambda > 0$, and $\beta = 0$; however, if the farmer has WA preferences, $\lambda = 0$, and $\beta > 0$. The optimal decision behavior and supply chain expected utility under decentralized decision may be obtained using the above procedure; hence, this analysis step is omitted.

The above model analysis suggests the following proposition:

Proposition 1: Supply chain coordination under decentralized decisions cannot be realized.

Proof: Under decentralized decisions, if the supply chain realizes coordination, $Q_{SW}^{B*} = Q_{SW}^{C*}$, and $q_{SW}^{B*} = q_{SW}^{C*}$. A comparison between Eqs. 5 and 13 indicates that supply chain coordination may only be realized when both $w = -\beta$ and $w = -(\lambda+\beta)$ are satisfied, which contradicts $w > 0$; thus, supply chain coordination cannot be realized in this context.

4. Coordination contract mechanism design

In the decentralized decision-making framework, both the farmer and the retailer aim to maximize their interests, ignoring the best interests of the entire supply chain. Therefore, to maximize the expected utility of the supply chain, an effective coordination contract mechanism is needed, so that both the farmer and the retailer are willing to participate in the mechanism.

Inspired by the literature [16, 19, 24], we design a coordination contract mechanism in which the retailer gives $\Phi(0 \le \Phi \le 1)$ times of their sales income to farmers, and the retailer shares $\Delta(0 \le \Delta \le 1)$ times of the shortage punishment, θ $(0 \le \theta \le 1)$ times the overproduction punishment, and $k(0 \le k \le 1)$ times the financing interest costs of the farmer.

Under the proposed coordination contract mechanism, if the farmer has SA and WA preferences, the farmer's expected utility and the retailer's expected profit are, respectively:

$$\begin{aligned}U_F^H = E[w\min\{Q,uq\} + \Phi(A-\min\{Q,uq\})\min\{Q,uq\} - (1-\Delta)\lambda(Q-uq)^+ \\ - (1-\theta)\beta(uq-Q)^+ - cq - (1-k)r(cq-T)]\end{aligned} \tag{17}$$

$$\begin{aligned}\Pi_R^H = E[(1-\Phi)(A-\min\{Q,uq\})\min\{Q,uq\} - w\min\{Q,uq\} - kr(cq-T) \\ - \Delta\lambda(Q-uq)^+ - \theta\beta(uq-Q)^+]\end{aligned} \tag{18}$$

Hence, we obtain the following proposition:

Proposition 2:

- Under the proposed coordination contract mechanism, if the coefficient satisfies Eq. 19, the supply chain may be coordinated;
- the farmer's behavioral preferences do not affect the coordination contract mechanism design:

$$\begin{cases} \theta = 1 + \dfrac{w}{\beta} - \Phi \\ \Delta = 1 - \Phi \\ k = \dfrac{w\mu + (1-\Phi)(1+r)}{rc} \end{cases} \tag{19}$$

Proof: Substituting Eq. 19 into Eqs. 17 and 18, we obtain:

$$\begin{cases} U_F^H = \Phi\Pi_{SW}^C + \dfrac{(w\mu + \Phi c - c)T}{c} \\ \Pi_R^H = (1-\Phi)\Pi_{SW}^C - \dfrac{(w\mu + \Phi c - c)T}{c} \end{cases} \tag{20}$$

Eq. 20 indicates that $\frac{\partial U_F^H}{\partial q} = \frac{\partial \Pi_{SW}^C}{\partial q} = 0$ and $\frac{\partial \Pi_R^H}{\partial Q} = \frac{\partial \Pi_{SW}^C}{\partial Q} = 0$ are both valid; hence, $Q_{SW}^{H*} = Q_{SW}^{C*}$ and $q_{SW}^{H*} = q_{SW}^{C*}$, achieving coordination in the supply chain. In addition, Eq. 19 also shows that θ, Δ, k are independent of λ and β; in other words, the behavioral preferences of the farmer do not affect the design of the coordination contract mechanism.

The premise that the farmer and retailer are willing to participate in the coordination contract mechanism is a Pareto improvement of benefits; we, thus, derive Eq. 21, and we obtain the following proposition:

$$\begin{cases} U_F^H = \Phi\Pi_{SW}^C + \dfrac{(w\mu + \Phi c - c)T}{c} > U_F^{B*} \\ \Pi_R^H = (1-\Phi)\Pi_{SW}^C - \dfrac{(w\mu + \Phi c - c)T}{c} > \Pi_R^{B*} \end{cases} \tag{21}$$

Proposition 3: If the revenue-sharing coefficient Φ meets $\Phi_1 \leq \Phi \leq \Phi_2$, , both the farmer and retailer are willing to participate in the coordination contract mechanism, and both achieve a win-win situation, where Φ_1 and Φ_2 satisfy Eqs. 22 and 23:

$$\begin{cases} \Phi_1 = \dfrac{c(T + U_F^{B*}) - Tw\mu}{c(T + \Pi_{SW}^{C*})} \\ \Phi_2 = \dfrac{c\left(T + \Pi_{SW}^{C*} - \Pi_R^{B*}\right) - Tw\mu}{c(T + \Pi_{SW}^{C*})} \end{cases} \tag{22}$$

$$\Phi_1 - \Phi_2 = \frac{U_F^{B*} + \Pi_R^{B*} - \Pi_{SW}^{C*}}{T + \Pi_{SW}^{C*}} < 0 \tag{23}$$

5. Results and discussion: numerical simulation

We resort to the numerical simulation method to further verify the correctness of the above conclusions and obtain more robust findings. Without loss of generality, the parameters are set as follows: A = 100, r = 0.1, B = 2, c = 1, w = 3, T = 5, λ = β =1.

Table 2 Calculation results under different models

Model	Φ	Q	q	Farmer's expected utility	Retailer's expected profit	Expected utility of supply chain
Centralized decision model	—	86.36	300.95	—	—	3729.91
Decentralized decision model	—	26.34	34.17	26.43	1655.64	1682.07
Coordination contract mechanism	0	86.36	300.95	10	3719.91	3729.91
	0.1	86.36	300.95	383.49	3346.42	3729.91
	0.2	86.36	300.95	756.98	2972.93	3729.91
	0.4	86.36	300.95	1503.96	2225.95	3729.91
	0.8	86.36	300.95	2997.93	731.98	3729.91

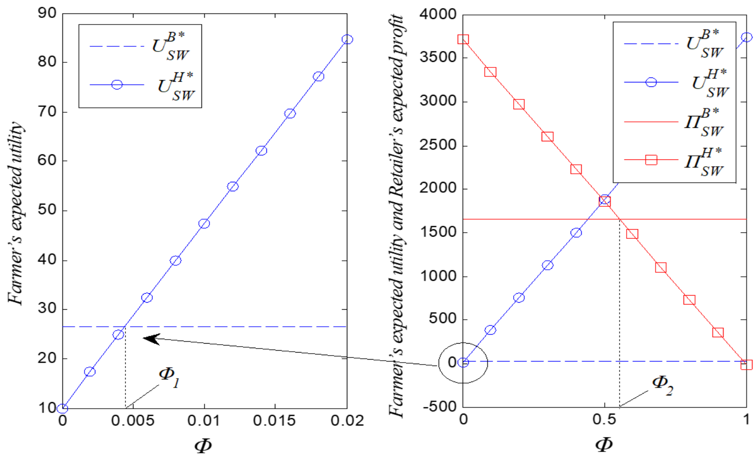

Fig. 2 Effect of Φ on farmer's expected utility and retailer's expected profit

5.1 Analysis of the coordination contract

Table 2 and Fig. 2 indicate that the optimal order, production input, and expected supply chain utility in the decentralized decision framework are lower than those realized under the centralized decision model. The designed coordination contract mechanism coordinates the supply chain and realizes a flexible distribution of benefits between the farmer and retailer. In particular, when the revenue-sharing coefficient is $0.0044 < \Phi < 0.5527$, the farmer and retailer achieve a win-win situation.

5.2 Sensitivity analysis

To further understand the impact of farmers' behavior preferences on decision-making and the expected utility of the supply chain, we separately analyze three different scenarios.

Analysis of SW preferences

If the farmer has SW preferences, namely, λ>0 and $\beta > 0$, we obtain the findings reported in Figs. 3-7. The following five conclusions may be drawn:

- In the centralized decision model, the optimal order, production input, and expected supply chain utility are greater than those realized under the decentralized decision model.
- The optimal order in the centralized and decentralized decision models decreases with WA coefficient β.
- The optimal order in the centralized decision model decreases with SA coefficient λ, while the retailer order in the decentralized decision framework increases with SA coefficient λ.
- Whether in a centralized or decentralized decision model, the optimal production input is an increasing and decreasing function of SA coefficient λ and WA coefficient β, respectively.
- Whether in a centralized decision model or decentralized decision model, the expected utility of the supply chain is an increasing and decreasing function of SA coefficient λ and WA coefficient β, respectively.

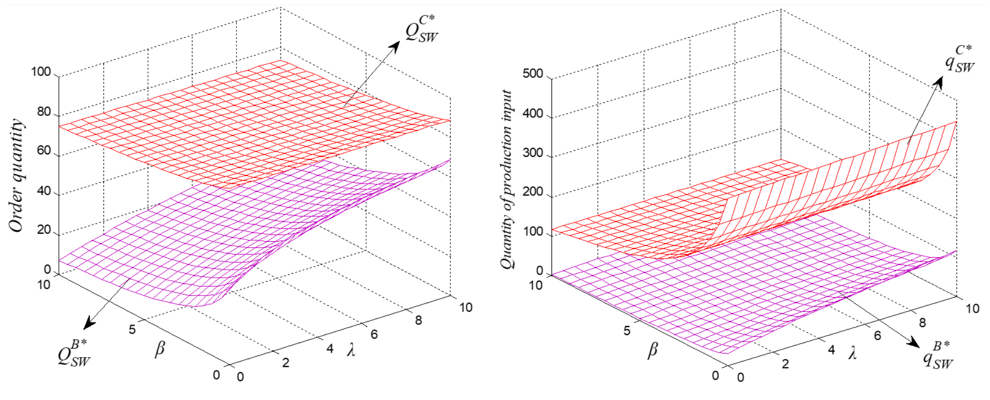

Fig. 3 Effect of λ and β on retailer's order and farmer's production input

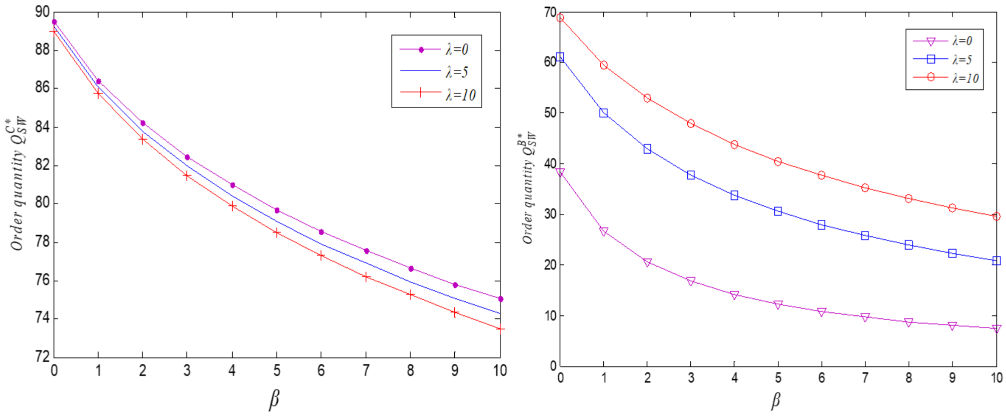

Fig. 4 Effect of λ and β on retailer's order under centralized decision and decentralized decision model

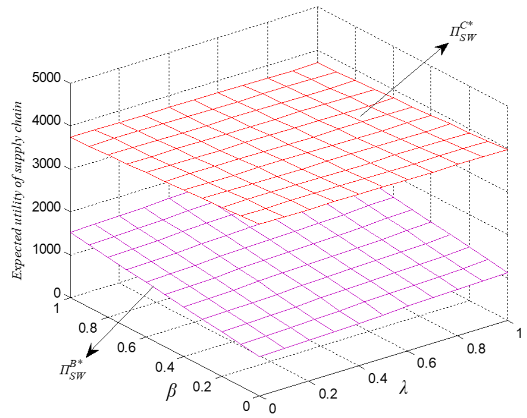

Fig. 5 Effect of λ and β on expected utility of supply chain under centralized decision and decentralized decision model

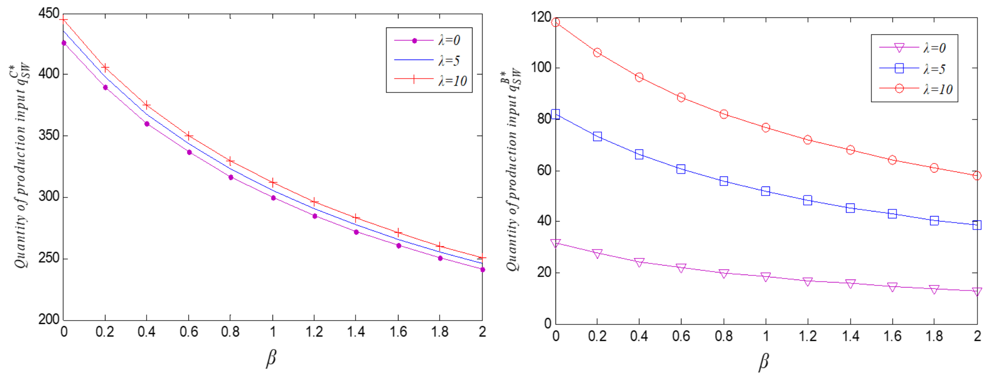

Fig. 6 Effect of λ and β on farmer's production input under centralized decision and decentralized decision model

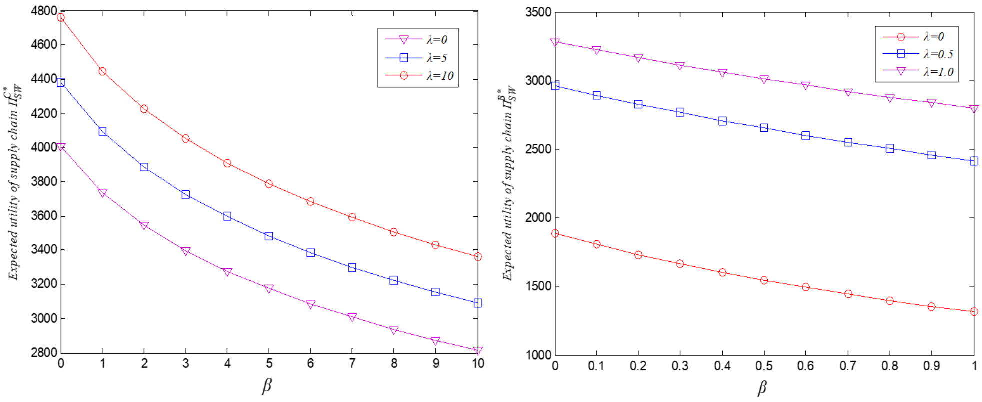

Fig. 7 Effect of λ and β on expected utility of supply chain under centralized decision and decentralized decision model

Analysis of SA preferences

If the farmer has SA preferences, that is, $\lambda > 0$ and $\beta = 0$, we obtain the results reported in Figs. 8 and 9. Therefore, the following three conclusions can be drawn:

- The optimal order (expected supply chain utility) in the decentralized decision model increases with SA coefficient λ, while the opposite result is obtained in the centralized decision model.
- Whether in the centralized or decentralized decision model, the optimal production input increases with the SA coefficient λ.
- The optimal order, production input, and expected supply chain utility in the centralized decision model are greater than those realized under the decentralized decision framework.

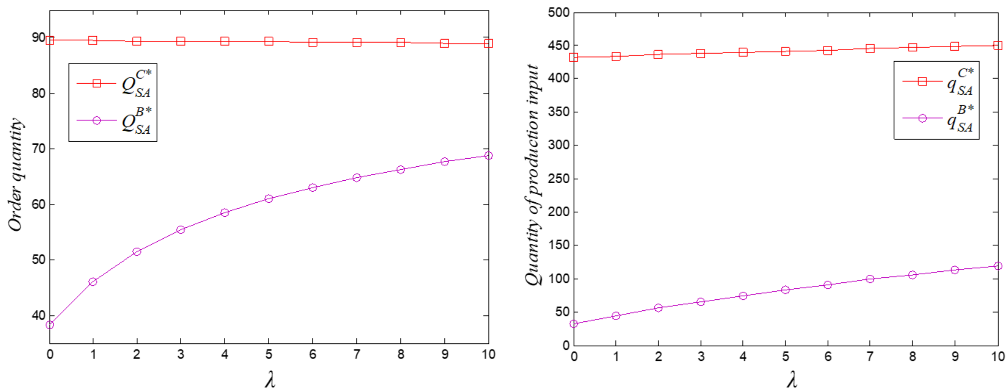

Fig. 8 Effect of λ on retailer's order and farmer's production input under centralized decision and decentralized decision model

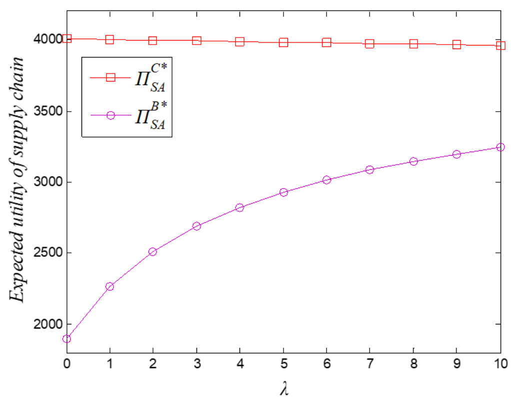

Fig. 9 Effect of λ on expected utility of supply chain under centralized decision and decentralized decision model

Analysis of WA preferences

If the farmer only WA preferences, that is, $\lambda = 0$ and $\beta > 0$, we obtain the results reported in Figs. 10 and 11. The following two conclusions can be drawn:

- Whether in the centralized or decentralized decision model, the optimal order, production input, and expected utility of supply chain decrease with WA coefficient β.
- The optimal order, production input, and expected supply chain utility in the centralized decision model are greater than those realized under the decentralized decision framework.

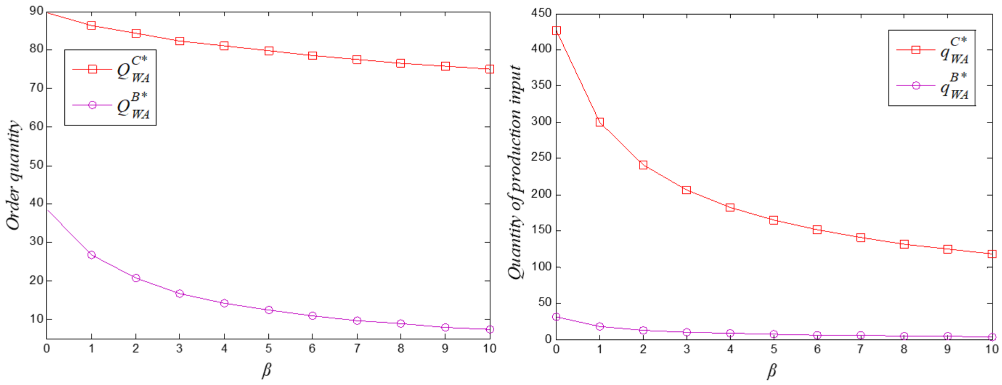

Fig. 10 Effect of β on retailer's order and farmer's production input under centralized decision and decentralized decision model

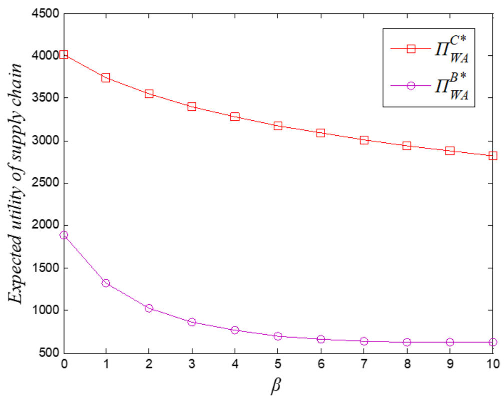

Fig. 11 Effect of β on expected utility of supply chain under centralized decision and decentralized decision model

6. Conclusion

This study examines the design of supply chain coordination contracts in the presence of farmer's capital constraints and behavioral preferences. It addresses the case of a two-level supply chain comprising a farmer and a retailer. The farmer faces capital constraints, seeks financing from a third party, and may have SW, SA, and WA preferences. The full-text analysis suggests the following conclusions:

- In the decentralized decision framework, the supply chain cannot be coordinated. However, the designed coordination contract mechanism coordinates the supply chain efficiently and realizes a flexible distribution of benefits between the farmer and the retailer. Furthermore, when the revenue-sharing coefficient is small ($0.0044 < \Phi < 0.5527$), both the farmer and the retailer achieve a win-win situation.
- In the centralized decision model, regardless of the behavioral preferences of the farmer, the optimal order, production input, and expected utility of the supply chain are always greater than those realized under the decentralized decision scheme.

- The farmer's optimal production input is always an increasing and decreasing function of SA coefficient λ and WA coefficient β, respectively.
- In the centralized decision model, the retailer's optimal order always decreases with SA coefficient λ, but the opposite result holds in the decentralized decision framework. The retailer's order always decreases with WA coefficient β.
- The expected utility of the supply chain is always an increasing and decreasing function of SA coefficient λ and WA coefficient β, respectively.

The coordination method proposed in this paper can be applied in other industries with similar backgrounds. However, it may not be applicable in the cases of random demand, supply chain competition, and information asymmetry. These are all future research directions.

Acknowledgement

This work was supported by the Humanities and Social Science Research Project of Ministry of Education of China (20XJC630007), the Humanities and Social Sciences Foundation of Chongqing Education Commission of China (22SKJD103), the Project of Science and Technology Research Program of Chongqing Education Commission of China (KJQN202000809), and the Open Project of Research Center for Enterprise Management of Chongqing Technology and Business University in 2021.

References

[1] Jian, M., Wang, Y.L. (2018). Decision-making strategies in supply chain management with a waste-averse and stockout-averse manufacturer, *Advances in Production Engineering & Management*, Vol. 13, No. 3, 345-357, doi: 10.14743/apem2018.3.295.

[2] Vanaga, R., Sloka, B. (2020). Financial and capital market commission financing: Aspects and challenges, *Journal of Logistics, Informatics and Service Science*, Vol. 7, No. 1, 17-30, doi: 10.33168/LISS.2020.0102.

[3] Yu, X., Wan, Z. (2020). Supply chain financing model under a new mechanism of bankruptcy guarantee, *Economic Computation and Economic Cybernetics Studies and Research*, Vol. 54, No. 2, 243-262, doi: 10.24818/18423264/54.2.20.15.

[4] Hua, S., Liu, J., Cheng, T.C.E., Zhai, X. (2019). Financing and ordering strategies for a supply chain under the option contract, *International Journal of Production Economics*, Vol. 208, 100-121, doi: 10.1016/j.ijpe.2018.10.008.

[5] Kouvelis, P., Zhao, W. (2018). Who should finance the supply chain? Impact of credit ratings on supply chain decisions, *Manufacturing & Service Operations Management*, Vol. 20, No. 1, 19-35, doi: 10.1287/msom.2017.0669.

[6] Jin, W., Zhang, Q., Luo, J. (2019). Non-collaborative and collaborative financing in a bilateral supply chain with capital constraints, *Omega*, Vol. 88, 210-222, doi: 10.1016/j.omega.2018.04.001.

[7] Shah, N., Shah, P., Patel, M. (2020). Inventory policies with retailer's flexible payment time and customer's fixed credit time for manufacturer-retailer supply chain, *Economic Computation and Economic Cybernetics Studies and Research*, Vol. 54, No. 4, 87-102, doi: 10.24818/18423264/54.4.20.06.

[8] Jin, W., Luo, J., Zhang, Q. (2018). Optimal ordering and financing decisions under advance selling and delayed payment for a capital-constrained supply chain, *Journal of the Operational Research Society*, Vol. 69, No. 12, 1978-1993, doi: 10.1080/01605682.2017.1415643.

[9] Zhao, L., Huchzermeier, A. (2019). Managing supplier financial distress with advance payment discount and purchase order financing, *Omega*, Vol. 88, 77-90, doi: 10.1016/j.omega.2018.10.019.

[10] Zhang, L.-L.., Kim, H.-K. (2020). The influence of financial service characteristics on use intention through customer satisfaction with mobile fintech, *Journal of System and Management Sciences*, Vol. 10, No. 2, 82-94, doi: 10.33168/J SMS.2020.0206.

[11] Hua, S., Liu, J., Cheng, T.C.E., Zhai, X. (2019). Financing and ordering strategies for a supply chain under the option contract, *International Journal of Production Economics*, Vol. 208, 100-121, doi: 10.1016/j.ijpe.2018.10.008.

[12] Jin, W., Luo, J., Zhang, Q. (2018). Optimal ordering and financing decisions under advance selling and delayed payment for a capital-constrained supply chain, *Journal of the Operational Research Society*, Vol. 69, No. 12, 1978-1993, doi: 10.1080/01605682.2017.1415643.

[13] Yang, H., Zhuo, W., Shao, L. (2017). Equilibrium evolution in a two-echelon supply chain with financially constrained retailers: The impact of equity financing, *International Journal of Production Economics*, Vol. 185, 139-149, doi: 10.1016/j.ijpe.2016.12.027.

[14] Yan, N., Sun, B. (2013). Coordinating loan strategies for supply chain financing with limited credit, *OR Spectrum*, Vol. 35, 1039-1058, doi: 10.1007/s00291-013-0329-4.

[15] Liang, Y., Qiao, P.L., Luo, Z.Y., Song, L.L. (2016). Constrained stochastic joint replenishment problem with option contracts in spare parts remanufacturing supply chain, *International Journal of Simulation Modelling*, Vol. 15, No. 3, 553-565, doi: 10.2507/IJSIMM15(3)CO13.

[16] Moon, I., Feng, X.-H., Ryu, K.-Y. (2015). Channel coordination for multi-stage supply chains with revenue-sharing contracts under budget constraints, *International Journal of Production Research*, Vol. 53, No. 16, 4819-4836, doi: 10.1080/00207543.2014.993438.

[17] Feng, X., Moon, I., Ryu, K. (2015). Supply chain coordination under budget constraints, *Computers & Industrial Engineering*, Vol. 88, 487-500, doi: 10.1016/j.cie.2015.08.005.

[18] Shi, J., Du, Q., Lin, F., Li, Y., Bai, L., Fung, R.Y.K., Lai, K.K. (2020). Coordinating the supply chain finance system with buyback contract: A capital-constrained newsvendor problem, *Computers & Industrial Engineering*, Vol. 146, Article No.106587, doi: 10.1016/j.cie.2020.106587.

[19] Xu, X., Cheng, X., Sun, Y. (2015). Coordination contracts for outsourcing supply chain with financial constraint, *International Journal of Production Economics*, Vol. 162, 134-142, doi: 10.1016/j.ijpe.2015.01.016.

[20] Phan, D.A., Vo, T.L.H., Lai, A.N. (2019). Supply chain coordination under trade credit and retailer effort, *International Journal of Production Research*, Vol. 57, No. 9, 2642-2655, doi: 10.1080/00207543.201 9.1567950.

[21] Zhao, L., Li, L., Song, Y., Li, C., Wu, Y. (2018). Research on pricing and coordination strategy of a sustainable green supply chain with a capital-constrained retailer, *Complexity*, Vol. 2018, Article ID 6845970, doi: 10.1155/2018/6845970.

[22] Fang, X., Wang, R., Yuan, F.J., Gong, Y., Cai, J.R., Wang, Y.L. (2020). Modelling and simulation of fresh-product supply chain considering random circulation losses, *International Journal of Simulation Modelling*, Vol. 19, No. 1, 169-177, doi: 10.2507/IJSIMM19-1-CO5.

[23] Cachon, G.P., Lariviere, M.A. (2005). Supply chain coordination with revenue-sharing contracts: Strengths and limitations, *Management Science*, Vol. 51, No. 1, 30-44, doi: 10.1287/mnsc.1040.0215.

[24] Yan, K., Cui, L., Zhang, H., Liu, S., Zuo, M. (2022). Supply chain information coordination based on blockchain technology: A comparative study with the traditional approach, *Advances in Production Engineering & Management*, Vol. 17, No. 1, 5-15, doi: 10.14743/apem2022.1.417.