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SIMULATION OF FINANCING DECISIONS WITH BEHAVIOURAL PREFERENCES AND YIELD UNCERTAINTY

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Abstract
We consider a two-level supply chain comprising a retailer and capital-constrained farmer, with three cases of behavioural preferences: stockout aversion (SA), waste aversion (WA), and stockout and waste aversion (SW); the farmer can solve financial constraints through bank loans and internal financing. We analyse the financing decision simulation of the farmer in a yield uncertain environment. The results show that – regardless of the preferences of the farmer – the largest expected utility and production input of the farmer and the expected profit and order quantity of the retailer are those under internal financing, followed by bank loans and non-financing. Finally, we analyse the influence of the farmer's SA and WA on the expected utility (profit) and decision-making of supply chain members by numerical simulation. Most supply chain studies do not factor in the high risk faced by farmers. Our study provides data on various option outcomes for those advising farmers facing difficult financing decisions.
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Key Words: Financing Decisions, Stockout Aversion, Waste Aversion, Yield Uncertainty, Supply Chain

1. INTRODUCTION

In the supply chain of agricultural products, production is often affected by weather, the environment, and human factors and is exposed to uncertainty risks, which significantly affect the production and operation activities of farmers [1, 2]. In the face of uncertain yield risks, different farmers may show different behavioural preferences, such as risk aversion [3], fairness concerns [4], stockout aversion (SA), waste aversion (WA), or stockout and waste aversion (SW) preferences [5]. Additionally, owing to the long production cycle and recovery cost time of agricultural products, farmers face financial pressure and usually adopt a specific financing mode to solve financial constraints, such as bank loans, advance payments, trade credits, and internal financing.

To study the financial constraints of enterprises, most of the literature uses the classic newsboy model and revolves around the following three aspects:

(1) *Research on the capital constraint problem of downstream enterprises in the supply chain.* When a retailer has financial constraints, Xiao et al. examine supply chain coordination when trade credit is used to solve the retailer's capital constraints [6]. Hua et al. study whether a retailer should seek financing from a supplier or banks when placing order through option contracts [7]. Jin et al. discuss the impact of advance selling and delayed payment financing strategies on ordering decisions, participant performance, and supply chain performance [8]. Based on a supply chain composed of a single supplier and two competitive retailers, Yang et al. analyse the influence of external financing on supply chain decision-making and performance [9]. Other scholars focus on retailers' choice of trade credit and bank credit [10, 11], supply chain coordination when a retailer can get trade credit [12], ordering and pricing decisions under supplier financing, and supplier investment modes [13].

(2) *Research on the capital-constraint problem of upstream enterprises in the supply chain.* In case of financial constraints for either the supplier or manufacturer, Zhao and Huchzermeier analyse the retailer's preference between advance payment discount and purchase order financing [14]. Yang et al. consider supply chain financing and pricing decisions when there is internal or bank financing [15]. Ding and Wan explore supply chain decision-making in the presence of bank loans or advance financing [16]. Other studies mainly study the choice of suppliers between three financing modes: bank loans, full delay-in-payment with bank loans, and partial delay-in-payment with bank loans [17]. Suppliers' choice is between partial trade credit with bank loans, full trade credit with bank loans and pure bank loans [18], and the supply chain ordering decision in the case of demand information updating [19].

(3) *Research on the capital-constraint problem of upstream and downstream enterprises in the supply chain.* In the case of financial constraints for both the manufacturer and retailer, Srinivasa Raghavan and Mishra conduct a comparative analysis of participants' co-financing and individual loans [20]. Kouvelis and Zhao explore supply chain coordination in the presence of bankruptcy costs and analyse the coordination of revenue-sharing contracts, buyback contracts, and quantity-discount contracts [21]. Kouvelis and Zhao examine the impact of credit ratings on supply chain operations and financial decisions [22]. Other studies explore participants' choice between financing decisions, namely advance payment, on-time payment and deferred payment, and supply chain coordination [23], as well as supply chain decision-making under three financing modes: bank financing, trade credit, and bank financing with the supplier's guarantee [24].

The above-mentioned studies are based on the risk neutrality of supply chain participants (except [13]) and most of them do not consider the random yield of products (except [1, 16]). Therefore, this paper studies the agricultural product supply chain composed of a capital-constrained farmer and a retailer. Among them, the yield of agricultural products is uncertain and we consider three cases where the farmer has behavioural preferences in the face of yield uncertainty risk: SA, WA, and SW preferences. Considering three financing modes – bank loans, internal financing, and non-financing – this study analyses the influence of the farmer's behavioural preferences on supply chain decision-making and financing decisions through numerical simulation.

2. MODEL DESCRIPTION AND ASSUMPTIONS

2.1 Model description

We consider a two-level supply chain composed of a capital-constrained farmer and a retailer. The retailer first order quantity Q of agricultural products from the farmer with the goal of maximising its own interests, and then the farmer decides production input q based on the retailer's order and the predicted yield. The actual yield of agricultural products is uncertain because of the many uncertainties, such as the weather, so the actual yield is uq, u being a random yield factor, $u \in (0, B)$. At the same time, the difference between the actual yield of agricultural products and the retailer's order is uncertain, so the actual trading volume between the farmer and retailer is $\min\{Q, uq\}$; as a result, the farmer may have either SA or WA preferences due to stockout and inventory [5].

Additionally, the long production cycle of agricultural products may lead the farmer to face financial constraints, and the farmer can adopt different financing methods (channels) to obtain funds for production: bank loans or internal financing. This paper considers the retailer as the leader and studies the financing decisions of a farmer with capital constraints and behaviour preferences in the environment of yield uncertainty. The analysis framework is shown in Fig. 1.

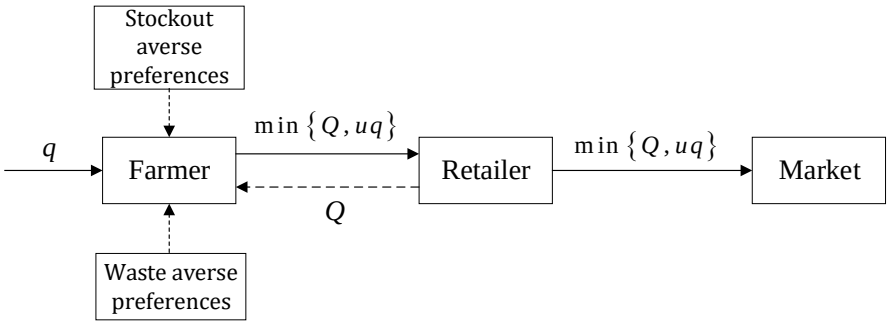

Figure 1: Research framework.

2.2 Model assumptions

For convenience, this paper makes the following assumptions:

(1) The farmer has capital constraints, that is, the initial capital of the farmer is less than the production input cost, $T < cq$. T is the farmer's initial capital, c is the farmer's unit input cost, and q is the farmer's production input.

(2) The retail price of agricultural products is inversely proportional to the yield quantity, that is, $p = A - \min\{Q, uq\}$, where A is a constant and $\min\{Q, uq\} = \begin{cases} Q, & Q \le uq \\ uq, & Q > uq \end{cases}$.

(3) The behaviour preferences of different farmers may differ. Therefore, this paper considers three situations: the farmer has only SW preferences, only SA preferences, and only WA preferences.

(4) The farmer has three modes of financing: bank loans, internal financing, and non-financing.

(5) There is information symmetry for the farmer and retailer.

(6) $p > w > c$.

The variables and definitions used in this paper are shown in Table I.

Table I: Variables and definitions.

Variable	Definition	Variable	Definition
c	Production cost	λ	SA coefficient
u	Random yield factor	β	WA coefficient
μ	Expected value of u	q^i	Production investment of the farmer under financing model i
w	Wholesale price	Q^i	Order quantity of retailer under financing model i
T	Farmer's initial funds	U_F^i	Farmer's expected utility under financing model i
r	Financing interest rate	π_R^i	Retailer's expected profit under financing model i
A	Constant	$i = B$	Bank loans financing
p	Retail price	$i = I$	Internal financing
$*$	Optimal value	$i = N$	Non-financing

3. FINANCING MODEL

3.1 Bank loans financing model

Due to the many uncertainties, the difference between the actual output of agricultural products, uq, and the order quantity, Q, cannot be determined. When the order quantity Q is greater than the actual output uq, the farmer will have SA preferences, while when the order quantity Q is less than the actual output uq, the farmer will have WA preferences. If the bank's periodic loans interest rate is r, the expected utility of farmer with SW preferences is:

$$U_F^B = E\{w\min\{Q,uq\} - \lambda(Q-uq)^+ - \beta(uq-Q)^+ - cq - r(cq-T)^+ \quad (1)$$

The retailer's expected profit is:

$$\pi_R^B = E\{(A-\min\{Q,uq\})\min\{Q,uq\} - w\min\{Q,uq\} \quad (2)$$

The inverse induction method is used to solve the equation, and optimal order quantity Q^{I*} and production investment q^{B*}satisfying the following equation:

$$\begin{cases} (A-w)\left[1-\dfrac{q^{B*}}{Q^{B*}}\displaystyle\int_0^{Q^{B*}/q^{B*}} F(u)du\right] - 2Q + \dfrac{4(q^{B*})^2}{Q}\displaystyle\int_0^{Q^{B*}/q^{B*}} F(u)du = 0 \\ (w+\lambda+\beta)\left[\dfrac{Q^{B*}}{q^{B*}}F\left(\dfrac{Q^{B*}}{q^{B*}}\right) - \displaystyle\int_0^{Q^{B*}/q^{B*}} F(u)du\right] - \beta\mu - (1+r)c = 0 \end{cases} \quad (3)$$

Under the bank loans model, the optimal expected utility of the farmer and the optimal expected profit of the retailer are, respectively, as follows:

$$U_F^{B*} = (w+\beta)Q^{B*} - \beta\mu q^{B*} - q^{B*}(w+\lambda+\beta)\int_0^{Q^{B*}/q^{B*}} F(u)du - (1+r)cq^{B*} + rT \quad (4)$$

$$\pi_R^{B*} = (A-w)\left[Q^{B*} - q^{B*}\int_0^{Q^{B*}/q^{B*}} F(u)du\right] - (Q^{B*})^2 + 2(q^{B*})^2\int_0^{Q^{B*}/q^{B*}} F(u)du \quad (5)$$

3.2 Internal financing model

If internal financing is adopted, the farmer will make additional payments to the retailer at the financing interest rate *r*. When the farmer has SW preferences, its expected utility is:

$$U_F^I = E\{w\min\{Q,uq\} - \lambda(Q-uq)^+ - \beta(uq-Q)^+ - cq - r(cq-T)^+ \quad (6)$$

The retailer's expected profit is:

$$\pi_R^I = E\{(A-\min\{Q,uq\})\min\{Q,uq\} - w\min\{Q,uq\} + r(cq-T)^+ \quad (7)$$

We can obtain the optimal order quantity Q^{I*} and production investment q^{I*} that satisfies the following equation:

$$\begin{cases} (A-w)\left[1-\dfrac{q^{I*}}{Q^{I*}}\displaystyle\int_0^{Q^{I*}/q^{I*}} F(u)du\right] - 2Q^{I*} + \dfrac{4(q^{I*})^2}{Q^{I*}}\displaystyle\int_0^{Q^{I*}/q^{I*}} F(u)du + \dfrac{rcq^{I*}}{Q^{I*}} = 0 \\ (w+\lambda+\beta)\left[\dfrac{Q^{I*}}{q^{I*}}F\left(\dfrac{Q^{I*}}{q^{I*}}\right) - \displaystyle\int_0^{Q^{I*}/q^{I*}} F(u)du\right] - \beta\mu - (1+r)c = 0 \end{cases} \quad (8)$$

The optimal expected utility of the farmer and the optimal expected profit of the retailer under the internal financing model are as follows:

$$U_F^{I*} = (w+\beta)Q^{I*} - \beta\mu q^{I*} - q^{I*}(w+\lambda+\beta)\int_0^{Q^{B*}/q^{I*}} F(u)du - (1+r)cq^{I*} + rT \quad (9)$$

$$\begin{aligned} \pi_R^{I*} = {} & (A-w)\left[Q^{I*} - q^{I*}\int_0^{Q^{I*}/q^{I*}} F(u)du\right] - (Q^{I*})^2 \\ & + 2(q^{I*})^2\int_0^{Q^{I*}/q^{I*}} F(u)du + r(cq^{I*} - T) \end{aligned} \quad (10)$$

3.3 Non-financing model

If the farmer conducts production by holding funds, the actual production investment is:

$$q^{N*} = \frac{T}{c} \tag{11}$$

When the farmer has SW preferences, the farmer's expected utility and retailer's expected profit are as follows:

$$\begin{cases} U_F^N = E\{w\min\left\{Q, \frac{uT}{c}\right\} - \lambda\left(Q - \frac{uT}{c}\right)^+ - \beta\left(\frac{uT}{c} - Q\right)^+ - T \\ \pi_R^N = E\{\left(A - \min\left\{Q, \frac{uT}{c}\right\}\right)\min\left\{Q, \frac{uT}{c}\right\} - w\min\left\{Q, \frac{uT}{c}\right\} \end{cases} \tag{12}$$

From Eq. (12), there is a unique optimal order quantity, Q^{N*}, that satisfies:

$$(A-w)\left[1 - \frac{T}{cQ^{N*}}\int_0^{cQ^{N*}/T} F(u)du\right] - 2Q^{N*} + \frac{4T^2}{c^2Q^{N*}}\int_0^{cQ^{N*}/T} F(u)du = 0 \tag{13}$$

Substituting q^{N*} and Q^{N*} into the Eq. (12), we can get the optimal U_F^{N*} and π_R^{N*}. If the farmer only has SA preferences, $\lambda > 0$ and $\beta = 0$; if the farmer only has WA preferences, $\lambda = 0$ and $\beta > 0$, which is omitted here.

4. SIMULATION OF THE FINANCING MODEL

As the distribution of random yield factor u of agricultural products is uncertain, for further analysis, the general assumption is that u follows a uniform distribution within $(0, 2)$ and the other coefficients are: A = 100, c = 1, w = 3, B = 2, r = 0.1 and T = 10.

4.1 Farmer with SA preferences

If the farmer only has SA preferences, $\lambda > 0$ and $\beta = 0$, and the relationship between the farmer's expected utility, retailer's expected profit, farmer's production input, retailer's order quantity, and SA coefficient λ is shown in Table II.

The following conclusions can be drawn from Table II: (1) The expected utility and production input of the farmer, as well as the expected profit and order quantity of the retailer are the largest in the internal financing model, followed by the bank loans financing model and non-financing model. (2) Regardless of the financing model, the expected utility of the farmer is a decreasing function of SA coefficient λ. (3) Under the bank loans financing and internal financing models, the expected profit and order quantity of the retailer and the production input of the farmer are increasing functions of SA coefficient λ. (4) Under the non-financing model, the expected profit and order quantity of the retailer and the production input of the farmer have nothing to do with SA coefficient λ.

Table II: The effect of λ on participants' decisions and utility (profit).

λ	U_F^{B*}	U_F^{I*}	U_F^{N*}	π_R^{B*}	π_R^{I*}	π_R^{N*}	Q^{B*}	Q^{I*}	Q^{N*}	q^{B*}	q^{I*}	q^{N*}
0.1	79.56	79.65	18.43	2319.44	2324.16	804.19	68.11	68.19	16.58	57.17	57.24	10
0.5	73.45	73.55	15.69	2436.74	2441.97	804.19	69.81	69.90	16.58	62.26	62.34	10
1.0	65.58	65.67	12.25	2560.87	2566.70	804.19	71.57	71.66	16.58	68.24	68.33	10
2.0	49.62	49.69	5.38	2756.64	2763.56	804.19	74.25	74.36	16.58	79.15	79.27	10

4.2 Farmer with WA preferences

If the farmer has only WA preferences, $\lambda = 0$ and $\beta > 0$, the relationship between the expected utility and production input of the farmer, the expected profit and order quantity of the retailer, and WA coefficient β is shown in Table III.

From Table III, we conclude that: (1) The expected utility and production input of the farmer, as well as the expected profit and order quantity of the retailer are the largest in the internal financing model, followed by the bank loans financing model and non-financing models. (2) In the bank loans financing and internal financing models, the expected utility and production input of the farmer, as well as the expected profit and order quantity of the retailer are all decreasing functions of WA coefficient β. (3) In the non-financing model, the farmer's expectation utility is a decreasing function of WA coefficient β, and the retailer's expected profit and order quantity, as well as the farmer's production input, have nothing to do with WA coefficient β.

Table III: The effect of β on participants' decisions and utility (profit).

β	U_F^{B*}	U_F^{I*}	U_F^{N*}	π_R^{B*}	π_R^{I*}	π_R^{N*}	Q^{B*}	Q^{I*}	Q^{N*}	q^{B*}	q^{I*}	q^{N*}
0.1	79.27	79.36	19.09	2232.77	2237.14	804.19	66.82	66.91	16.58	53.70	53.77	10
0.5	73.78	73.89	18.98	2061.33	2065.09	804.19	64.21	64.28	16.58	47.48	47.54	10
1.0	69.15	69.23	18.83	1913.23	1916.50	804.19	61.86	61.93	16.58	42.69	42.73	10
2.0	63.52	63.58	15.54	1729.37	1732.11	804.19	58.81	58.87	16.58	37.35	37.39	10

4.3 Farmer with SW preferences

If the farmer has SW preferences, $\lambda > 0$ and $\beta > 0$, the relationship between the expected utility and production input of the farmer, the expected profit and order quantity of the retailer, and SA coefficient λ and WA coefficient β is shown in Figs. 2 to 5.

As shown in Figs. 2 and 3: (1) The expected utility of the farmer and the expected profit of the retailer are the largest under the internal financing model, followed by the bank loans financing model and the non-financing models. (2) Regardless of the financing model, the farmer's expected utility is a decreasing function of SA coefficient λ and WA coefficient β. (3) In the bank loans and the internal financing models, the retailer's expected profit and the farmer's production input are increasing functions of SA coefficient λ and decreasing functions of WA coefficient β, respectively. (4) In the non-financing model, the retailer's expected profit has nothing to do with SA coefficient λ and WA coefficient β.

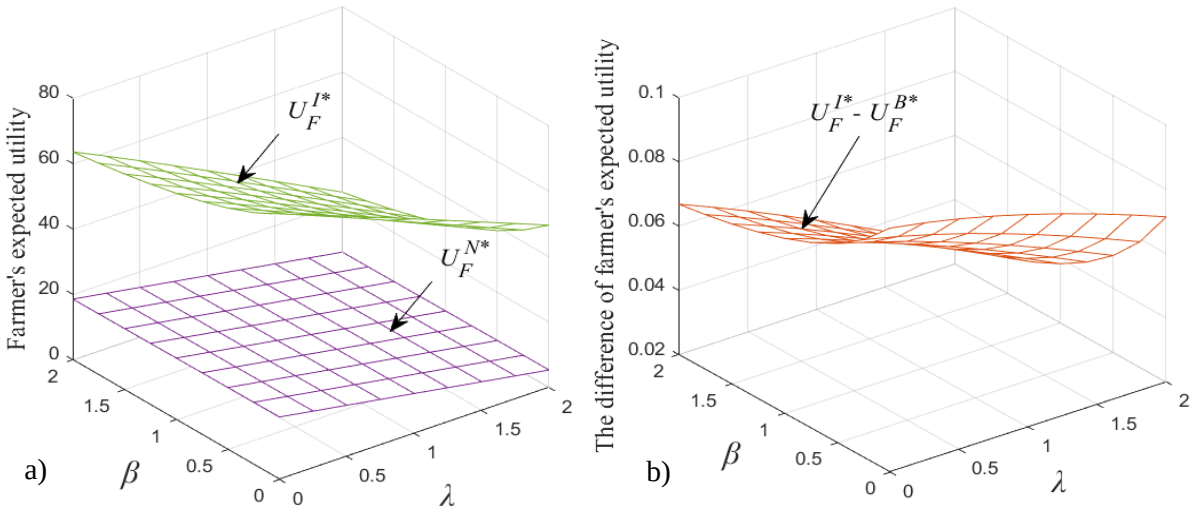

Figure 2: The effect of λ and β on farmer's expected utility under the three financing models.

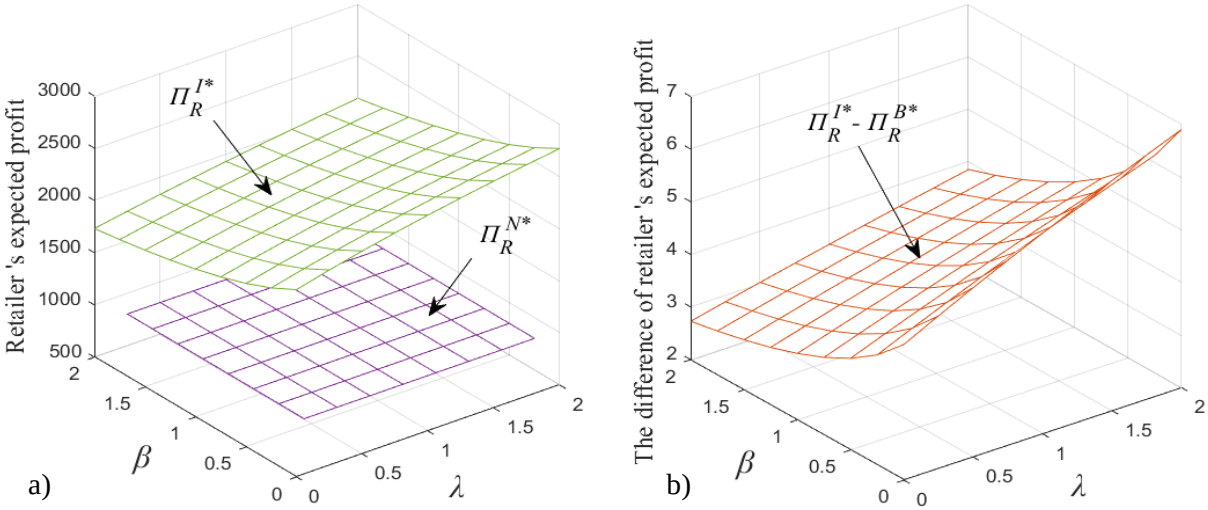

Figure 3: The effect of λ and β on retailer's expected profit under the three financing models.

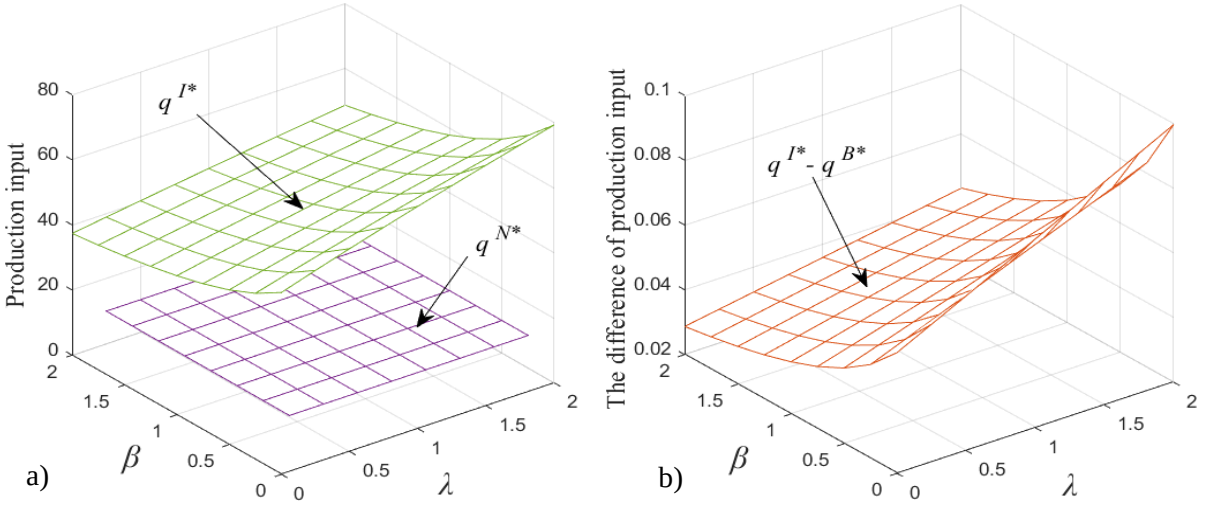

Figure 4: The effect of λ and β on production input under the three financing models.

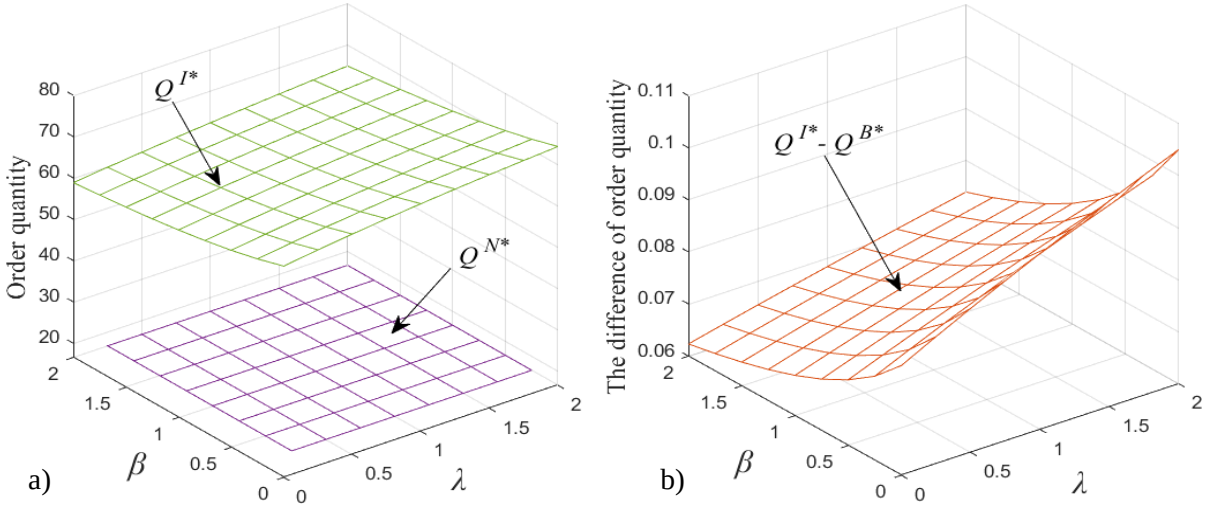

Figure 5: The effect of λ and β on order quantity under the three financing models.

As shown in Figs. 4 and 5: (1) The production input of the farmer and the order quantity of the retailer are the largest under the internal financing model, followed by the bank loans

financing model and the non-financing models. (2) In the bank loans and the internal financing models, the retailer's order quantity and the farmer's production input are increasing functions of SA coefficient λ and decreasing functions of WA coefficient β, respectively. (3) In the non-financing model, the retailer's order quantity and the farmer's production input have nothing to do with SA coefficient λ and WA coefficient β.

5. CONCLUSION

This study takes the two-level supply chain composed of a follower farmer and a leading retailer and considers three situations for the capital-constrained farmer in terms of behavioural preferences: SA, WA, and SW preferences. At the same time, three financing models-bank loans financing, internal financing, and no financing-are considered to study the farmer's financing decision in the uncertain yield environment.

From the analysis, the following conclusions can be drawn: (1) Regardless of the behavioural preferences of the farmer, the expected utility and production input of the farmer and the expected profit and order quantity of the retailer are the largest, followed by the bank loans financing and the non-financing models. (2) In the three financing models, the expected utility of the farmer is a decreasing function of SA coefficient λ and WA coefficient β. (3) In the bank loans financing and internal financing models, the retailer's expected profit is an increasing function of SA coefficient λ and a decreasing function of WA coefficient β, respectively. (4) In the bank loans financing and internal financing models, the production input of the farmer is an increasing function of SA coefficient λ and a decreasing function of WA coefficient β, respectively. In the non-financing model, the production input of the farmer is independent of SA coefficient λ and WA coefficient β. (5) In the bank loans financing and internal financing models, the retailer's order quantity is an increasing function of SA coefficient λ and a decreasing function of WA coefficient β, respectively. In the non-financing model, the retailer's order quantity has nothing to do with SA coefficient λ and WA coefficient β.

Most supply chain studies do not factor in the high risk faced by farmers. Our study provides some data for various option outcomes for those advising farmers facing difficult financing decisions.

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