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Combined presale and crowdfunding financing strategy for fresh product supply chains under capital constraints

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Abstract: Addressing farmers' financial constraints in the fresh agricultural product supply chain, this study examines a two-stage supply chain involving farmers and e-commerce platforms and explores a hybrid financing strategy that integrates presale financing and multistage crowdfunding. Recognizing that farmers' presale revenues through e-commerce platforms often fail to cover production costs, this study innovatively constructs a combined financing model of presale and multistage crowdfunding. First, farmers obtain a portion of their start-up capital through presales on e-commerce platforms. Second, crowdfunding is initiated in stages to address the funding gap (planting, growing, and harvesting periods), with the proportion of investor revenue-sharing in each stage dynamically adjusted to balance risk premiums. This study establishes a dynamic planning model to maximize farmers' profits. The objective function integrates the production volume decision, multistage financing cost, and investor revenue share constraints and solves the model's equilibrium solution using the Karush-Kuhn-Tucker (KKT) condition and the backward induction method. Numerical simulations show that unlike the traditional single presale model, multistage crowdfunding enhances farmers' financing capacity while reducing fluctuations in investors' returns through a dynamic revenue-sharing mechanism. When the number of crowdfunding stages increases to three, the overall efficiency of the supply chain improves relative to single-stage financing, which verifies that stage- by-stage financing enhances fund-matching efficiency. This study provides a theoretical basis for addressing the mismatch problem of "short-term loan and long-term investment" in agricultural supply chain financing, and offers reliable suggestions for e-commerce platforms to design financing portfolio strategies.

Key words: capital constraints; fresh product; revenue-sharing; presale financing; multistage crowdfunding

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In the fresh agricultural product supply chain, especially for high-value products, farmers face substantial financial pressures due to high initial production costs and the perishable nature of their products. These product characteristics and short shelf life expose farmers to a highly uncertain and risky production environment, compelling farmers to seek flexible and efficient financial support, especially during the early production stage when expenditures on seeds, fertilizers, and labor are maximum. According to the Ministry of Agriculture and Rural Affairs (2023), the average production cost for fruit and vegetable farmers in China increased by 28% from 2019, while the financing gap widened to 41%. In Shouguang City, Shandong Province, strawberry greenhouse construction costs 120-150 million yuan per km^2, with liquidity demands of 52.5 million yuan per km^2[1].

In Shandong Province, strawberry farmers depend on presale channels offered by e-commerce platforms such as JD Fresh and Hema Fresh. However, long production cycles and large capital requirements preharvest create severe financial constraints, which can interrupt production, reduce yields, or result in missed sales seasons. In the "farmers + e-commerce platform" model, farmers secure part of the market demand in advance through presales and receive prepayments to fund production. In this framework, the platform provides not only sales channels but also financing support through presale mechanisms[2]. For example, JD Fresh allows farmers to access part of their presales revenue in advance for purchasing seeds, fertilizers, and labor[3-5]. Farmers can sell their products at discounted prices before harvest to receive production funds from consumer deposits, while platforms help reduce inventory risk.

However, presale financing alone rarely covers the entire production cycle. A 2023 Zhejiang University survey of 214 fresh produce farmers in the Yangtze River Delta found that 83.6% of farmers relying solely on presales faced mid-production funding shortages. Therefore, 27% of farmers reduced organic fertilizer use and 19% cut back on intelligent temperature-control equipment, causing a 21% drop in average yield and a decline of 15 percentage points in the premium products share[6]. These findings show structural deficiencies in the presale financing model, including limited early-stage funding, inadequate mid-term support, and weak risk mitigation.

Against this backdrop, multistage crowdfunding shows unique advantages. A 2023 pilot program at a blueberry farm in Qingdao tested a three-stage crowdfunding model, dividing the production cycle into planting (30%), growth (40%), and harvesting (30%). By offering differentiated investor return-sharing ratios across stages, the farm achieved a funding rate of 81.5%, thereby easing financial constraints, improving early-stage product quality, and enhancing market competitiveness. This dynamic financing model not only eases financial constraints but also supports production decisions based on early market demand signals. Theoretically, some scholars have shown that multistage crowdfunding mitigates dynamic risks through phased capital injection[7-8]. Similarly, phased crowdfunding has been found to enhance investors' trust and willingness to participate[9].

Given the farmers' dilemma of production fund shortages, many scholars have introduced diverse financing strategies. Early studies primarily examined traditional supply chain financial instruments, including bank loans, accounts receivable financing, and inventory pledges[10-15]. The issue of farmers securing funds through traditional financing channels under financial constraints has long drawn scholarly attention.

In recent years, research has increasingly focused on integrating traditional and digital finance (e.g., supply chain finance). Although conventional financing models (such as bank loans, bonds, and equity financing) can partially ease farmers' financial constraints, small and medium-sized farmers often remain excluded due to their limited scale, weak loan qualifications, information asymmetry, collateral requirements, and financial market inefficiencies. This problem is particularly acute in developing countries and immature market environments, where few farmers secure loan approvals. World Bank data show that only 18% of farmers in developing countries access loans through traditional banking channels (World Bank, 2023). This financing gap highlights the need for innovative solutions, driving the development of new supply chain finance models. If traditional tools cannot resolve capital shortages, which mechanisms can effectively bridge the gap?

Presale financing allows farmers to secure funds by selling products in advance. Promoted by e-commerce platforms, presale financing has become an effective means of easing farmers' financial pressures.

Crowdfunding is another innovative model that allows farmers to raise funds from the public via online platforms. This approach is particularly suited to small-scale projects and start-ups. Multistage crowdfunding allows gradual funding of production needs and effectively spreads risks while improving financing success rates. Several studies have examined crowdfunding as an alternative financing mechanism in agriculture. Some constructed evolutionary game models to analyze strategic interactions between farmers and crowdfunders and showed that the game equilibrium depends on the relative price differences between the growing and harvesting periods and social logistics costs[16]. Others developed a master-slave game model of the agricultural crowdfunding supply chain under three scenarios and examined how the time value of money affects producers' and crowdfunding platforms' decisions[17]. Other scholars have investigated agricultural crowdfunding mechanisms from different perspectives, including dynamic ordering and pricing decisions, behavioral finance, and empirical studies[18-23].

In multistage crowdfunding for farmers, the supply chain risk compensation mechanism is critical. As upstream players in the complex agricultural supply chain, farmers' ability to raise funds is influenced by multiple factors that affect the operational efficiency and stability of the entire supply chain. Investors face varied risks at different crowdfunding stages. These risks affect both the security of investors' returns and the farmers' ability to obtain financing, as well as the sustainable development of the supply chain.

This study introduces a risk subsidy coefficient as a quantitative tool for designing a risk compensation mechanism. This allows for differentiated compensation for investors across stages based on their risk levels, thereby ensuring higher returns for higher risks. This mechanism not only enhances investors' willingness to participate in crowdfunding but also helps farmers secure sufficient production capital, improve production efficiency, and strengthen the entire supply chain's competitiveness. From the supply chain perspective, a well-designed risk compensation mechanism effectively aligns the interests of farmers and investors, promotes collaborative development across supply chain nodes, and significantly enhances the agricultural supply chain's overall resilience.

Existing studies show several significant limitations in the analysis of farmers' production financing needs. First, most studies focus on single financing strategies and ignore the dynamic synergistic effects of combined financing approaches[24]. Second, although some have examined combined financing models such as "supply chain finance + crowdfunding," these studies often ignore the advantages of presale financing decisions[25]. Meanwhile, the stage-specific characteristics of farmers' financing demands remain underexplored, and no multistage financing models consistent with the agricultural production cycle have yet been established[24]. Third, existing risk compensation mechanisms are largely static and fail to capture the high uncertainty of fresh agricultural product yields. These limitations indicate that current research inadequately reflects farmers' financing behavior and investors' risk-taking decisions.

To address these shortcomings, this study proposes a combined "presale financing + multistage crowdfunding strategy." The key advantage of this combination is its dual mechanism: presale financing provides farmers with early partial funds, while multistage crowdfunding introduces an endogenous hedging mechanism through risk stratification, with different investor groups bearing different levels of risk and thereby reducing the overall financing failure rate. For capital-constrained farmers, this strategy bypasses collateral requirements and reduces financing risks through a "dual verification" mechanism of platform presale and staged crowdfunding. It thus offers a sustainable solution for smallholder financing within the broader framework of rural revitalization and provides theoretical and practical insights into agricultural digital finance.

Building on real-world cases, this study quantifies the financing gap thresholds at each production stage and designs a risk compensation mechanism for multistage crowdfunding. This study focuses on the following key issues.

(1) How can the combination of presale and multistage crowdfunding financing be designed to align with the distinct stages of agricultural production?

(2) How can a dynamic correlation mechanism between investors' return shares and output risks be established to provide effective risk compensation?

(3) How do farmers' planting decisions and multistage investors' financing decisions interact under the combined financing strategy, and how does the agricultural output rate affect the decision-making of supply chain members?

The main contributions of this study are as follows.

(1) This study develops a novel "capital demand-supply matching" model that integrates presale financing and multistage crowdfunding for fresh agricultural products.

(2) Risk compensation coefficients are introduced to capture the stage-specific risks faced by multistage crowdfunding investors, thereby enabling differentiated revenue-sharing schemes.

(3) This study explicitly incorporates agricultural output uncertainty into the model to examine its impact on the financing decisions of multistage investors.

Overall, this study extends the theories of output uncertainty and presale financing in the field of fresh agricultural products. By moving beyond traditional financing models and introducing a novel multistage crowdfunding framework, this study deepens understanding of agricultural supply chain financing strategies and contributes to the broader discourse on e-commerce platform-driven agricultural digital finance[26].

This study has both theoretical and practical implications. The proposed "presale + multistage crowdfunding" financing combination helps farmers in agricultural supply chains ease their financial constraints. Specifically, presale financing provides farmers with the initial production funds, and multistage crowdfunding offers phased capital support across production stages. This dynamic financing strategy effectively expands the overall financing scale and cross-validates market signals: presale demand endorses crowdfunding, while crowdfunding outcomes provide market feedback for presale pricing. Together, they form a two-way risk mitigation financing model that reduces the inherent uncertainty and financing risks of agricultural supply chains.

1 Problem Description and Assumption

This study examines a two-stage fresh product supply chain comprising farmers and e-commerce platforms, where farmers supply agricultural products to platforms, and platforms distribute them to consumers through presale and spot-sale channels[27].

In such supply chains, farmers often face substantial production and financial pressure due to limited initial capital. To ease this constraint, the "farmer + e-commerce platform" single presale financing model has been widely adopted[28]. However, presale funding alone is insufficient to cover all production costs. Supplementing presale financing with multistage crowdfunding allows farmers to secure the necessary capital across different production phases.

The decision sequence of participants is as follows: initially, the e-commerce platform places orders with upstream farmers and agrees on the presale and sale of agricultural products. If the platform presale is launched, the product presale volume is $Q_0(Q_0 > 0)$, and the consumer pays the corresponding amount to the e-commerce platform pQ_0. The market wholesale price w is exogenous[29]. The platform pays a part of the prepayment wQ_0 to the farmer in advance, who then determines the production input volume Q based on the presale and the wholesale market prices, and begins production after the presale concludes. The agricultural output is subject to uncertain factors such as weather, which poses a risk of output uncertainty. The actual output quantity is Qx, where x denotes the stochastic output rate per unit of input[30].

Assuming a random output rate x of agricultural products with expectation and variance $E(x) = \mu, D(x) = \sigma^2$, $f(x)$, $F(x)$ are the probability density function and probability distribution function of x, and $F(x)$ is strictly monotonically increasing and derivable. Farmers produce according to presale orders. The platform first delivers the agricultural products to consumers during the presale stage, then sells the agricultural products at the spot stage at price p[31-32]. Presale and spot-sale prices are consistent across different financing models[33]. Nevertheless, consumers are incentivized to participate in presales: first, presales ensure access to fresh products and, more importantly, help farmers overcome capital constraints in production. Thus, consumers support farmers' financing by participating in presales. The platform sells at a spot stage until the end of the inventory, with the remaining purchase price paid to the farmer.

Farmers' production capacity is limited; when planting exceeds a certain level, marginal costs increase, leading to uneconomic characteristics of the scale of agricultural production. Most previous studies assumed a linear production cost function of the volume Q[34]. In line with this, we assume the farmers' production cost function to be $C(Q) = c_1 + c_2Q + c_3Q^2$.

Currently, two main crowdfunding models exist: the all-or-nothing (AON) model, where crowdfunding fails when the funding target is not reached and all contributions are returned to investors, and the keep-it-all (KIA) model, where funds are retained regardless of whether the target is met. This study adopts the AON model and assumes that the funds raised at each stage fully cover the corresponding production costs and that the cumulative crowdfunding meets the farmers' total production costs[35].

To ensure simplicity and model tractability, the following assumptions are made: (1) Farmers obtain part of the required capital through presale financing; however, these funds are insufficient to cover total production costs, prompting them to seek supplementary financing through multistage crowdfunding. (2) Investors participate in crowdfunding at different production stages, each receiving stage-specific revenue-sharing ratios $k_t(t = 1, 2, 3)$ that reflect varying risk levels. Early-stage investors may bear higher risks and thus earn higher returns, while later-stage investors accept lower risk in exchange for relatively stable returns.

2 Model Formulation

Based on the problem description and underlying assumptions, this study constructs a combined decision model of presale financing in the fresh agricultural supply chain under farmers' financial constraints. In this model, farmers receive part of their funds through platform-based presales. When presale financing is insufficient, farmers obtain additional funds through multistage crowdfunding[36], which is divided into three stages according to varying funding needs to ensure smooth production.

The three-stage model includes production preparation crowdfunding (for initial inputs such as buying seedlings and fertilizers), mid-term production expansion crowdfunding (for scaling up production), and harvesting crowdfunding (for logistics and packaging). Each crowdfunding stage attracts investors with varying risk appetites and capital needs. Investor returns vary by risk levels, with early investors earning higher returns for higher risks and later investors earning more stable returns for lower risks. This combined model allows farmers to raise funds flexibly to ensure the smooth operation of the supply chain.

2.1 Presale financing

Farmers obtain part of their production capital L through presale financing, which is satisfied by

$$L = wQ_0 \tag{1}$$

However, presale financing must be supplemented through multistage crowdfunding because L is insufficient to fully cover the total production cost $C(Q) = c_1 + c_2Q + c_3Q^2$.

2.2 Multistage crowdfunding

(1) Investment and revenue-sharing in multistage crowdfunding

Suppose crowdfunding is divided into production preparation, production expansion, harvesting and logistics stages, and the investment amount of each stage is $I_t(t = 1, 2, 3)$, and the revenue-sharing ratio is k_t.

In the production preparation stage, when the amount of crowdfunding is I_1, the higher the risk, the higher the revenue share.

In the production expansion stage, a crowdfunding amount of I_2 leads to moderate risk with a more stable revenue share.

In the harvesting and logistics stage, crowdfunding amount of I_3 leads to lower risk with the lowest revenue share.

Crowdfunding needs are met when

$$I = \sum_{t=1}^{3} I_t \tag{2}$$

(2) Relationship between the risk subsidy coefficient and revenue-sharing

Suppose the risk coefficient of the investor at stage t is β_t, and the revenue-sharing ratio is k_t[34]. The early-stage risk is high ($\beta_1 > \beta_2 > \beta_3$), resulting in a higher revenue-sharing ratio ($k_1 > k_2 > k_3$).

The relationship between the investor's risk subsidy coefficient and the revenue-sharing ratio is expressed through the risk compensation model, where the general investment return share k_t is positively correlated with the investment risk β_t. In other words, higher risk brings higher returns. Their linear relationship is given by

$$k_t = \theta\beta_t \tag{3}$$

where θ denotes the risk subsidy coefficient.

Risk and return sharing across crowdfunding stages.

Stage 1: Prestage investors face the highest risk as the project is in its early stages with a low likelihood of success.

Stage 2: Mid-stage investors face moderate risk as the project is underway, but with uncertainties.

Stage 3: Late investors face the least risk as the project is near completion, and investment security is relatively higher.

(3) Conditions for investor participation in crowdfunding

Investors are risk-neutral[37], and their expected returns at each stage must at least match their opportunity cost r[38], which is defined as the market risk-free rate.

$$E(k_t\Pi_f) \geqslant I_t(1+r) \quad t=1,2,3 \tag{4}$$

2.3 Objectives of farmer financing

Farmers obtain funds L through presale financing, although insufficient to cover production costs $C(Q)$, i.e., $L < C(Q)$.

They obtain supplementary funding $\sum_{t=1}^{3} I_t$ through multistage crowdfunding, and the total financing satisfies at least $L + \sum_{t=1}^{3} I_t \geqslant C(Q)$.

Expected profit function for farmers:

$$\Pi_f = E\left\{wQx - C(Q) + \sum_{t=1}^{3} I_t - \sum_{t=1}^{3} k_t E(\Pi_f)\right\} \tag{5}$$

To simplify the model, we assume that platform commissions are ignored.

The investor's return in stage t is

$$E(\Pi_f) = E\left\{k_t\left[wxQ - C(Q) + \sum_{t=1}^{3} I_t\right]\right\} \tag{6}$$

Investor participation in crowdfunding depends on

$$\begin{gathered} E(k_t\Pi_f) \geqslant I_t(1+r) \quad t=1,2,3 \\ k_t E(\Pi_f) \geqslant I_t(1+r) \end{gathered} \tag{7}$$

where

$$E(\Pi_f) = E\left[wxQ - C(Q) + \sum_{t=1}^{3} I_t\right] = wuQ - (c_1 + c_2Q + c_3Q^2) + \sum_{t=1}^{3} I_t$$

Presale financing and multistage crowdfunding to cover farmers' production costs are

$$\sum_{t=1}^{3} I_t + wQ_0 \geqslant C(Q) \tag{8}$$

In addition, the investment at each crowdfunding stage satisfies the production cost of that stage. This gives the following constraints for multistage crowdfunding:

$$\begin{gathered} I_t \leqslant \frac{\theta\beta_t V_t}{1+r} \\ I_1 \geqslant c_1 - wQ_0 \\ I_2 \geqslant c_2 Q \\ I_3 \geqslant c_3 Q^2 \end{gathered} \tag{9}$$

where $V_t (t = 1, 2, 3)$ is the crowdfunding project valuation for each stage of the investor.

Drawing from this optimization model for multistage crowdfunding financing, the farmer's expected returns can be expressed as follows:

$$\max_{Q} \Pi_f = E\left[wQx - (c_1 + c_2Q + c_3Q^2) + \sum_{t=1}^{3} I_t - \sum_{t=1}^{3} k_t \Pi_f\right] \tag{10}$$

In the operations research model, the objective is to maximize the farmer's expected return while ensuring multistage investor participation under the condition that the expected return at each stage equals or exceeds the investment amount multiplied by the opportunity cost factor, namely satisfying the following inequality:

$$\theta\beta_t V_t \geqslant I_t(1+r) \tag{11}$$

$$\max_{Q} \Pi_f = E\left[wQx - (c_1 + c_2Q + c_3Q^2) + \sum_{t=1}^{3} I_t - \sum_{t=1}^{3} k_t \Pi_f\right]$$

$$\text{s.t.} \begin{cases} I_t \leqslant \dfrac{\theta\beta_t V_t}{1+r} \\ I_1 \geqslant c_1 - wQ_0 \\ I_2 \geqslant c_2 Q \\ I_3 \geqslant c_3 Q^2 \end{cases} \tag{12}$$

$$V_t = k_t E\left[wxQ - (c_1 + c_2Q + c_3Q^2) + \sum_{t=1}^{3} I_t\right] \tag{13}$$

$$\Pi_f = wxQ - (c_1 + c_2Q + c_3Q^2) + \sum_{t=1}^{3} I_t \tag{14}$$

The agricultural output rate x is a random variable. x follows a normal distribution and is assumed to be $E(x) = u$.

Therefore, substituting the expected value of u into Eq. (12) yields

$$V_t = k_t\left[wuQ - (c_1 + c_2Q + c_3Q^2) + \sum_{t=1}^{3} I_t\right] \quad t=1,2,3$$

Deriving a simplified operations research model

$$\max_{Q} \Pi_f = \left(1 - \sum_{t=1}^{3} k_t\right)\left[wuQ - (c_1 + c_2Q + c_3Q^2) + \sum_{t=1}^{3} I_t\right]$$

$$\text{s.t.} \begin{cases} I_t \leqslant \dfrac{\theta\beta_t k_t\left[wuQ - (c_1 + c_2Q + c_3Q^2) + \sum_{t=1}^{3} I_t\right]}{1+r} \\ I_1 \geqslant c_1 - wQ_0 \\ I_2 \geqslant c_2 Q \\ I_3 \geqslant c_3 Q^2 \end{cases} \tag{15}$$

2.3.1 Lagrange multiplier method (Karush-Kuhn-Tucker (KKT) conditional method)

(1) Constructing the Lagrange function

Introducing the Lagrange multipliers λ_t (corresponding to the lower-bound constraint) and μ_t (corresponding to the upper-bound constraint)

$$\mathcal{L} = (1-K)\left[wuQ - (c_1 + c_2Q + c_3Q^2) + \sum_{t=1}^{3} I_t\right] + \sum_{t=1}^{3}\lambda_t(I_t - I_t^{\min}) + \sum_{t=1}^{3}\mu_t\left(\frac{\theta\beta V_t}{1+r} - I_t\right) \quad (16)$$

Eq. (15) shows that the corresponding parameters of the Lagrangian function are expressed as

$$K = \sum_{t=1}^{3} k_t,\ C(Q) = c_1 + c_2Q + c_3Q^2$$
$$I_1^{\min} = c_1 - wQ_0,\ I_2^{\min} = c_2Q,\ I_3^{\min} = c_3Q^2 \quad (17)$$

(2) Derivation while establishing the KKT condition

The first-order condition is obtained by taking the partial derivatives of the variables Q and I_t.

The first-order condition for I_t:

$$(1-K)[wu - (c_2 + 2c_3Q)] + \lambda_2c_2 + 2\lambda_3c_3Q = 0 \quad (18)$$

For the first-order condition of I_t is

$$(1-K) + \lambda_t - \mu_t = 0 \quad t = 1, 2, 3 \quad (19)$$

Complementary relaxation conditions are

$$\lambda_t(I_t - I_t^{\min}) = 0,\quad \mu_t\left(\frac{\theta\beta V_t}{1+r} - I_t\right) = 0 \quad (20)$$

Original constraints:

$$I_t \geqslant I_t^{\min},\quad I_t \leqslant \frac{\theta\beta V_t}{1+r} \quad (21)$$

(3) Discussion of the activity of constraints by case

As the constraints are linear/quadratic inequalities, the optimal solution often occurs at the boundaries.

Lower-bound investment constraint is

$$I_t = I_t^{\min},\ \mu_t = 0,\ \lambda_t \geqslant 0$$

Upper-bound investment constraint is

$$I_t = \frac{\theta\beta V_t}{1+r},\ \lambda_t = 0,\ \mu_t \geqslant 0$$

Condition for the lower-bound investment constraint: When the investment reaches its minimum value and the constraint is at the boundary, the Lagrange multiplier relationship is

$$\lambda_t \geqslant 0,\quad \mu_t = 0$$

The conditions for complementary relaxation are as follows:

$$\lambda_t(I_t - I_t^{\min}) = 0 \Rightarrow \lambda_t > 0,\ I_t = I_t^{\min}$$
$$\mu_t\left(\frac{\theta\beta_t V_t}{1+r} - I_t\right) = 0 \Rightarrow \mu_t = 0 \quad (22)$$

Substituting $I_t = I_t^{\min}$ into the objective function and constraints, and eliminating any redundant I_t.

Solving the first-order conditions for the residual variable (Q_t, λ_t).

Verifying whether $I_t \leqslant \frac{\theta\beta_t V_t}{1+r}$ is satisfied, and if not, the equation is unsolved.

Condition for the upper-bound investment constraint: When the investment reaches its maximum value and the constraint is at the boundary, the relationship at this point is as follows.

The Lagrange multiplier relationship is

$$\mu_t \geqslant 0,\quad \lambda_t = 0$$

Conditions for complementary relaxation are

$$\lambda_t(I_t - I_t^{\min}) = 0 \Rightarrow \lambda_t = 0$$
$$\mu_t\left(\frac{\theta\beta_t V_t}{1+r} - I_t\right) = 0 \Rightarrow I_t = \frac{\theta\beta_t V_t}{1+r} \quad (23)$$

Substituting $I_t = \frac{\theta\beta_t V_t}{1+r}$ into the objective function and constraints, eliminating redundant I_t.

Solving the first-order conditions for the remaining variable C.

If $I_t \geqslant I^{\min}$ is satisfied, then the lower-bound constraints are verified; otherwise, the equations may have no solution.

2.3.2 Analysis of results

(1) Lower bound on investment

Optimal solution:

$$Q^* = -\frac{2c_2 - uw}{4c_3}$$
$$\lambda_1 = k_1 + k_2 + k_3 - 1$$
$$\lambda_2 = k_1 + k_2 + k_3 - 1$$
$$\lambda_3 = k_1 + k_2 + k_3 - 1 \quad (24)$$

Accordingly, the Lagrange multiplier is derived as follows:

$$\lambda_t = k_1 + k_2 + k_3 - 1$$

As k_t is the investors' share of returns at different stages, considering the farmer's objective of profit maximization, there exists $\lambda_t \leqslant 0$; however, according to the binding condition $\lambda_t \geqslant 0$ of the lower bound of investment, the two contradict each other; therefore, there is no solution at this point.

(2) Upper bound on investment

The following result is obtained:

$$Q^* = -\frac{c_2 - uw}{2c_3} \quad (25)$$

$$I_1^* = \frac{\beta_1 c_1 k_1 \theta}{r - \beta_1 k_1 \theta - \beta_2 k_2 \theta + 1} \quad (26)$$

2.4 Parameter constraints and sensitivity analysis

2.4.1 Conditions for the validity of the variables

Based on the farmer's optimal planting quantity, we obtain the parameter range as follows:

$$u > \frac{2c_2}{w} \quad (27)$$

Let

$$u_{\min} = \frac{2c_2}{w} > 0 \quad (28)$$

Thus, $0 < u < 1$, following two cases can be discussed: when $0 < u \leqslant u_{\min}$, $Q^* \leqslant 0$, the production is economically infeasible, and the farmer's optimal planting quantity is zero; when $u_{\min} < u \leqslant 1$, $Q^* > 0$, the farmer's planting quantity is positively correlated with the output rate and increases as the output rate increases.

As the farmer's planting decision is motivated by profit maximization, the analysis is conducted under the condition of $u_{\min} < u \leqslant 1$, $Q^* > 0$.

For the first-stage crowdfunding, investor's maximum investment amount is

$$I_1^* = \frac{\beta_1 c_1 k_1 \theta}{r - \beta_1 k_1 \theta - \beta_2 k_2 \theta + 1}$$

Assuming that the first-stage crowdfunding fully satisfies the farmer's production capital requirement, i. e.,

$$I_1^* = \frac{\beta_1 c_1 k_1 \theta}{r - \beta_1 k_1 \theta - \beta_2 k_2 \theta + 1} > c_1 - wQ_0$$

From this inequality, we obtain

$$\frac{(c_1 - wQ_0)(r+1)}{\beta_1 c_1 k_1 + (c_1 - wQ_0)(\beta_1 k_1 + \beta_2 k_2)} < \theta < \frac{r+1}{\beta_1 k_1 + \beta_2 k_2} \tag{29}$$

When the farmer's risk compensation coefficient lies within the specified interval, the first-stage crowdfunding funds are sufficient to meet the farmer's capital demand.

For the second-stage crowdfunding, investor's investment amount is

$$I_2^* = -\frac{\beta_2 c_1 k_2 \theta}{r - \beta_1 k_1 \theta - \beta_2 k_2 \theta + 1}$$

Similarly,

$$I_2^* = -\frac{\beta_2 c_1 k_2 \theta}{r - \beta_1 k_1 \theta - \beta_2 k_2 \theta + 1} \geqslant c_2 Q \tag{30}$$

From this inequality, we conclude that

$$0 \leqslant \theta \leqslant \min\left(\frac{\beta_1 k_1 c_2 Q - r c_2 Q - c_2 Q}{\beta_2 c_1 k_2 - \beta_1 k_1 c_2 Q - \beta_2 k_2 c_2 Q}, \frac{r+1}{\beta_1 k_1 + \beta_2 k_2}\right) \tag{31}$$

This inequality shows that

$$\frac{(c_1 - wQ_0)(r+1)}{\beta_1 c_1 k_1 + (c_1 - wQ_0)(\beta_1 k_1 + \beta_2 k_2)} < \theta < \frac{r+1}{\beta_1 k_1 + \beta_2 k_2} \tag{32}$$

For the third-stage crowdfunding, investor's investment amount is

$$I_3^* = -\frac{\beta_3 c_1 k_3 \theta}{r - \beta_1 k_1 \theta - \beta_3 k_3 \theta + 1}$$

Similarly,

$$I_3^* = -\frac{\beta_3 c_1 k_3 \theta}{r - \beta_1 k_1 \theta - \beta_3 k_3 \theta + 1} > c_3 Q^2 \tag{33}$$

This inequality shows that

$$0 \leqslant \theta < \min\left(\frac{c_3 Q^2 r - c_3 Q^2}{\beta_3 c_1 k_3 + c_3 Q^2 \beta_1 k_1 + c_3 Q^2 \beta_3 k_3}, \frac{r+1}{\beta_1 k_1 + \beta_3 k_3}\right) \tag{34}$$

2.4.2 Effect of parameters on the variables

(1) Effect of the u on the optimal planting quantity Q^*

Farmer's optimal planting quantity is

$$Q^* = -\frac{c_2 - uw}{2c_3}$$

Based on $\frac{\partial Q^*}{\partial u} = \frac{w}{2c_3} > 0$, the farmer's optimal planting quantity increases with the agricultural output rate. A higher output rate motivates the farmer to expand planting to achieve higher yields.

(2) Effect of the risk compensation coefficient θ on the three-stage investment level I_t^* ($t=1,2,3$)

First-stage investor's investment amount is

$$I_1^* = \frac{\beta_1 c_1 k_1 \theta}{r - \beta_1 k_1 \theta - \beta_2 k_2 \theta + 1}$$

$$\frac{\partial I_1^*}{\partial \theta} = \frac{\beta_1 c_1 k_1 (r+1) + \beta_1^2 c_1 k_1^2 \theta + \beta_1 \beta_2 c_1 k_1 k_2 \theta}{(r - \beta_1 k_1 \theta - \beta_2 k_2 \theta + 1)^2} \tag{35}$$

From $\frac{\partial I_1^*}{\partial \theta} > 0$, the investment amount is positively correlated with the risk compensation coefficient. As first-stage investors face the highest risk, a higher risk compensation coefficient increases their investment.

Second-stage investor's investment amount is

$$I_2^* = -\frac{\beta_2 c_1 k_2 \theta}{r - \beta_1 k_1 \theta - \beta_2 k_2 \theta + 1}$$

$$\frac{\partial I_2^*}{\partial \theta} = \frac{-\beta_2 c_1 k_2 (r+1) + \beta_2^2 c_1 k_2^2 \theta + \beta_1 \beta_2 c_1 k_1 k_2 \theta}{(r - \beta_1 k_1 \theta - \beta_2 k_2 \theta + 1)^2} \tag{36}$$

Given the parameter range $\frac{\partial I_2^*}{\partial \theta} > 0$, the second-stage investment amount also increases with the risk compensation coefficient, indicating that higher compensation increases investor participation under the corresponding risk.

Third-stage investor's investment amount:

$$I_3^* = -\frac{\beta_3 c_1 k_3 \theta}{r - \beta_1 k_1 \theta - \beta_3 k_3 \theta + 1}$$

(3) Effect of the revenue-sharing ratio k_1 on the investment amount I_1^*

As $\frac{\partial I_1^*}{\partial k_1} > 0$, we obtain I_1^*, which is strictly monotonically increasing with k_1.

When k_1 is near 0, the growth is slow, and when k_1 approaches 1, the growth accelerates.

If the first-stage revenue-sharing ratio remains unchanged, a higher risk subsidy coefficient θ leads to a higher investment I_1^* due to the same monotonicity, and this will not be repeated here.

Due to $\frac{\partial I_1^*}{\partial \beta_1} > 0$, investment amount I_1^* and risk subsidy coefficient θ are positively correlated.

Based on the model, the second-stage investment amount I_2^* can be expressed as a function, and a comparative analysis of the three stages of the investment amount of the formula is essentially the same. In each stage, the return on the share of the risk subsidy coefficient is positively correlated with the corresponding stage of the investment amount.

Similarly, the amount of investment in the third stage is positively related to the revenue-sharing ratio, risk subsidy coefficient, and amount of investment.

3 Numerical Analysis

To verify the model's validity and accuracy, a numerical simulation is conducted to make the research results more intuitive. Owing to the large number of parameters, values assigned to the relevant variables are as follows: $c_1=5$, $k_1=0.1$, $k_2=0.08$, $\theta=0.8$, $\beta_1=1.3$, $\beta_2=1.2$, $\beta_3=1.1$, $r=0.05$.

3.1 Farmers' planting quantity decision

According to the model, the planting quantity function of the farmer is obtained as follows:

$$Q^* = -\frac{c_2 - uw}{2c_3}$$

Fig. 1 shows that the output rate u is positively related to the amount of planting Q^* by farmers. When the agricultural product output increases, more agricultural products are produced at the same cost. Therefore, farmers increase the amount of planting to maximize their profits.

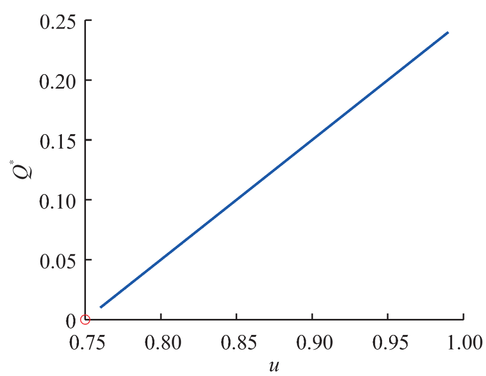

Fig. 1 Effect of output rate u on the amount of planting Q^*

3.2 Decision-making on investment volume

3.2.1 First stage investment decision-making

According to the model, parameters are assigned to analyze the impact of variables on the investment amount:

$$I_1^* = \frac{\beta_1 c_1 k_1 \theta}{r - \beta_1 k_1 \theta - \beta_2 k_2 \theta + 1}$$

(1) Effect of the revenue-sharing ratio k_1 on the amount of investment I_1^*

Fig. 2 shows that the investment amount is positively correlated with the revenue-sharing ratio. As the ratio increases and approaches 1, the investment grows rapidly, reflecting the reality of crowdfunding investors. A higher revenue-sharing ratio motivates investors to invest more to earn higher returns.

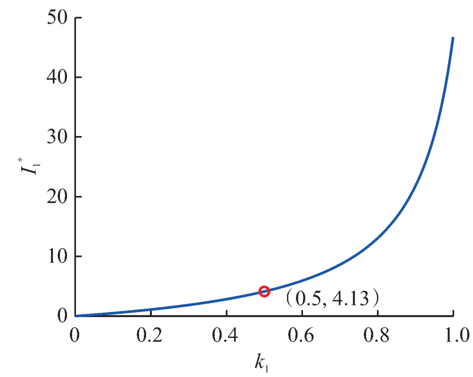

Fig. 2 Effect of k_1 on the amount of investment I_1^*

(2) Combined effect of the revenue-sharing ratio k_1 and risk subsidy coefficient θ on the investment amount I_1^*

The model $I_1^* = 4\beta_1 k_1/(0.954 - 0.8\beta_1 k_1)$ analyzes how the revenue-sharing ratio k_1 and risk subsidy coefficient θ influence the amount of investment in the first stage.

Fig. 3 shows that both the revenue-sharing ratio and the degree of the risk subsidy coefficient are positively correlated with the investment amount. Moreover, as either factor increases, investor investment also increases. Although first-stage investors face risks such as the output rate of agricultural products, the risk subsidy coefficient mitigates their hesitation. Meanwhile, farmers increase the revenue-sharing ratio to secure more production funds.

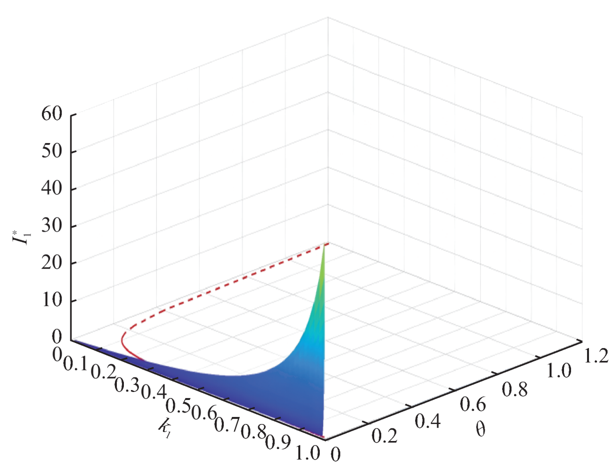

Fig. 3 Effect of k_1 and θ on the amount of investment I_1^*

3.2.2 Second-stage investment decision-making

According to $k_2 = \theta\beta_2$, a simplification is derived:

$$I_2^* = -\frac{c_1 k_2^2}{r - k_1^2 - k_2^2 + 1}$$

(1) Effect of the revenue-sharing ratio k_2 on the

amount of investment I_2^*

Fig. 4 shows that the second-stage investors' revenue-sharing ratio is positively correlated with the investment amount. As the revenue-sharing ratio increases, the investors' amount remains stable at low revenue-sharing ratios. However, as the revenue share rises further, the investment grows rapidly. This indicates that the revenue share significantly influences investors' investment decisions.

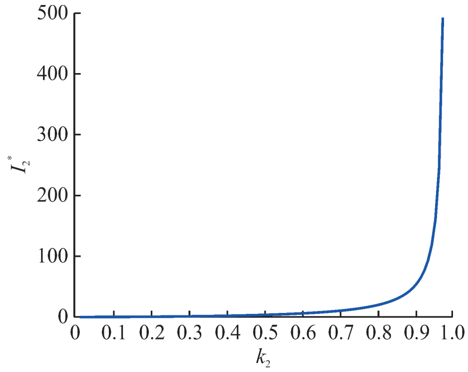

Fig. 4 Effect of k_2 on the amount of investment I_2^*

(2) Effect of the revenue-sharing ratio k_2 and the risk subsidy coefficient θ on the investment amount I_2^*

Fig. 5 shows that the revenue-sharing ratio and the risk subsidy coefficient are positively correlated with the investment amount, which increases as either factor increases.

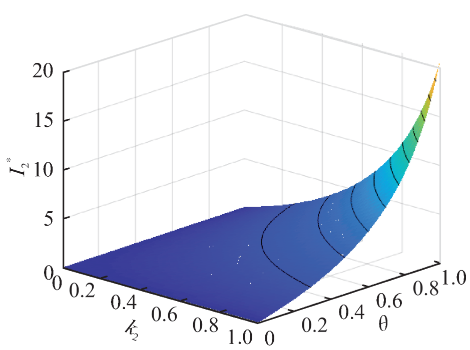

Fig. 5 Effect of k_2 and θ on the investment amount I_2^*

In the second stage, in which the investment risk is moderate, investors' decisions depend on the risk subsidy coefficient and the revenue-sharing ratio. When the investor faces risks, a higher revenue-sharing ratio and the risk subsidy coefficient can reduce their hesitation to invest.

3.2.3 Third-stage investment decision-making

The third stage of investment:

$$I_3^* = -\frac{\beta_3 c_1 k_3 \theta}{r - \beta_1 k_1 \theta - \beta_3 k_3 \theta + 1}$$

According to $k_3 = \theta\beta_3$, the simplification leads to $I_3^* = -\frac{c_1 k_3^2}{r - k_1^2 - k_3^2 + 1}$.

(1) Effect of k_3 on the amount of investment I_3^*

Fig. 6 shows that the revenue-sharing ratio is positively correlated with the investment amount. The initial revenue share of investors is small. Owing to the risks associated with agricultural products, investors make prudent and smaller investments. Later, to secure sufficient production funds, farmers increase the investors' revenue share. Then, the investment grows sharply. This indicates that the investors' revenue-sharing ratio significantly affects their investment decisions.

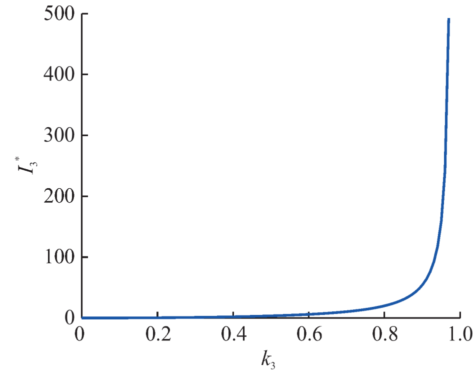

Fig. 6 Effect of k_3 on the investment amount I_3^*

(2) Effect of the revenue-sharing ratio k_3 and the risk subsidy coefficient θ on the investor's investment amount I_3^*

Fig. 7 shows that both the revenue-sharing ratio and the risk subsidy coefficient are positively correlated with the investment amount. The risk subsidy coefficient has a greater impact on the investor's investment amount, resulting in a sharp increase in the investment amount as the risk subsidy coefficient increases. The revenue share also affects the investment amount; however, it increases rapidly only when the revenue-sharing ratio is high.

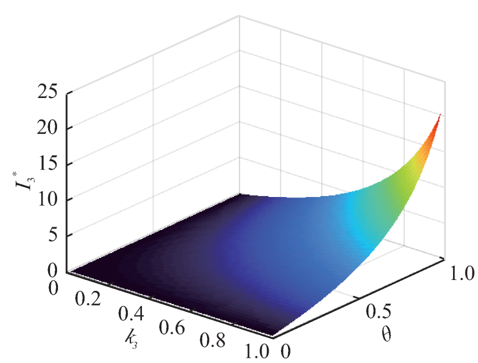

Fig. 7 Effect of k_3 and θ on the investment amount I_3^*

4 Conclusions

This study examines the fresh agricultural product supply chain under financial constraints, focusing on the "farmers + e-commerce platforms" cooperation model. To address supply chain disruptions caused by farmers' high production costs and insufficient initial presale funds, a combined financing strategy of "presale financing + multistage crowdfunding" is proposed. Using an operations research optimization model and numerical simulations, the study finds the following:

(1) This study shows that farmers face capital constraints across three stages of production, cultivation, and harvesting. Differentiated financing through presales and multistage crowdfunding effectively addresses these funding gaps. Unlike single-stage financing, multistage crowdfunding adapts to changing financing needs in response to dynamic capital requirements, which enhances both capital availability and production flexibility.

(2) The risk compensation return model shows that investors' revenue shares are positively correlated with agricultural output risk, specifically, offering higher expected returns at high-risk stages to attract investment. The multistage risk compensation mechanism distributes risks across investors and provides compensation through revenue-sharing, boosting investor participation, and sustaining fundraising activities.

(3) Under the "presale + multistage crowdfunding" strategy, farmers' optimal planting decisions are jointly influenced by production costs, wholesale prices, financing strategies, and output fluctuations. At the same time, investors' optimal decisions depend on production stages. They tend to increase investment shares during stages with higher output rates. Further analysis indicates that agricultural output rates have a dual impact on supply chain members' decisions. They not only boost farmers' planting incentives but also enhance investors' willingness to participate, thus improving the efficiency and stability of agricultural supply chain financing.

In conclusion, this study theoretically shows the coupling mechanism between presales and multistage crowdfunding and its effects on farmers' and investors' decisions. It also provides valuable practical insights for developing financing instruments tailored to agricultural production cycles, offering operational guidance to ease farmers' capital constraints and strengthen the resilience of agricultural supply chains.

In the fresh product supply chain, farmers often face production disruptions and market risks due to insufficient initial capital. To address these challenges, this study proposes a combined financing strategy of "presale financing + multistage crowdfunding." The results show that multistage crowdfunding, supported by a dynamic revenue-sharing mechanism, improves financing efficiency and reduces investor risk volatility. Based on theoretical derivations and numerical simulations, the proposed strategy achieves a dynamic alignment between capital demand and the agricultural production cycle. It also offers an innovative financing solution for e-commerce-driven agricultural supply chains. However, its practical implementation requires flexible adaptations to real-world factors such as farmers' operational scale, platform technical support, and investors' risk preferences.

(1) This study assumes that investors are risk-neutral and does not explicitly consider risk aversion. Future research could incorporate CVaR-based models to optimize risk-related decision-making.

(2) The division of crowdfunding stages and the design of revenue-sharing mechanisms require validation through real-world cases, including analyses of dynamic game strategies under asymmetric information.

(3) This study does not compare alternative combined financing models (e. g. , supply chain finance + crowdfunding), which represents a potential direction for future research.

Through theoretical modeling and numerical simulations, this study confirms the effectiveness of integrating presale financing with multistage crowdfunding in easing farmers' financial constraints and improving supply chain efficiency. The findings provide both theoretical support and practical guidance for advancing agricultural digital finance and offer feasible financing solutions for smallholder farmers within the broader context of rural revitalization.

References

[1] Qingdao Blueberry Industry Base. Experimental report on the application of multi-stage crowdfunding models in fresh agriculture[R]. Qingdao Modern Agricultural Innovation Center, 2023. (in Chinese)

[2] CHEN Z B, LI X, TIAN C Y, et al. Information transmit strategy of e-commerce platform with financially constrained supplier[J]. Electronic Commerce Research and Applications, 2024, 66: 101415.

[3] JD Fresh. 2022 annual pre-sale data white paper on fresh agricultural products[R]. Beijing: JD Group, 2022. (in Chinese)

[4] Pinduoduo Research Institute. Research report on pre-sale models and capital conversion rates in "Farm Produce Festival"[R]. Pinduoduo, 2023. (in Chinese)

[5] CHEN X F, LIU C J, LI S T. The role of supply chain finance in improving the competitive advantage of online retailing enterprises[J]. Electronic Commerce Research and Applications, 2019, 33: 100821.

[6] Institute of Agricultural Economics, Zhejiang University. Research report on the effectiveness of financing models for fresh produce farmers in the Yangtze River Delta region [R]. Hangzhou: Zhejiang University, 2023. (in Chinese)

[7] PU Y, FANG S H. The optimal portfolio size of venture capital under staged financing [J]. Procedia Computer Science, 2016, 91: 85-93.

[8] SUN Y H, CHEN Y R, LIN X X, et al. Self-operation or Authorization? Decision structure of crowdfunding supply chains with IP derivative products[J]. Electronic Commerce Research and Applications, 2024, 65: 101396.

[9] DAI N. Monitoring via staging: Evidence from private

investments in public equity[J]. Journal of Banking & Finance, 2011, 35(12): 3417-3431.

[10] DENG L R, YU X W. Optimal financing strategy in a dual-channel supply chain with agricultural product[J]. Mathematics, 2024, 12(18): 2835.

[11] WANG M M, JIANG W W, ZHU X X. Research on the optimization of supply chain financing strategies for fresh agricultural products under the cost-sharing contract [J]. Journal of Yunnan Agricultural University (Social Science), 2023, 17(2): 116-126. (in Chinese)

[12] LU Q H, LIAO C H, XU T T. Financing and coordination of the agricultural supply chain considering government-enterprise guarantee[J]. RAIRO-Operations Research, 2023, 57(5): 2363-2392.

[13] BAI S Z, JIA X L. The impact of the cost-sharing contract on capital-constrained agricultural supply chains [J]. Sage Open, 2023, 13: 21582440231156157.

[14] BI G B, WU Y, XU H. Financing options for logistics firms considering product quality loss [J]. Journal of Modelling in Management, 2024, 19(6): 2158-2194.

[15] TANG R H, YANG L. Financing strategy in fresh product supply chains under e-commerce environment [J]. Electronic Commerce Research and Applications, 2020, 39: 100911.

[16] YU Z Y, HAFEEZ M, LIU L H, et al. Evaluating the minor coarse cereals product crowdfunding platform through evolutionary game analysis[J]. Sustainability, 2019, 11(5): 1299.

[17] CHEN J, WANG N. Game analysis in crowdfunding supply chain of agri-food considering capital time value [J]. Operations Research and Management Science, 2023, 32(5): 71-77. (in Chinese)

[18] YANG H L, GAO M Y, XIAO Q Z, et al. Ordering and pricing decisions for perishable goods retailer with zero-inventory and capital constraints[J]. International Transactions in Operational Research, 2022, 29(5): 3107-3130.

[19] DU J J. How backers' behavior affects financing performance in agri-food reward-based crowdfunding: The moderating mechanism of initiator characteristics and project attributes [J]. PLoS One, 2024, 19(7): e0305752.

[20] LI Y K, DU J J, FU W Z. Thirty days are enough: What determines the crowd's cash time in agri-food crowdfunding? [J]. China Agricultural Economic Review, 2020, 12(3): 553-575.

[21] XUE Y, LI Y. Cohesion of agricultural crowdfunding risk prevention under sustainable development based on gray-rough set and FAHP-TOPSIS [J]. Sustainability, 2022, 14(19): 12709.

[22] QIN H F, KONG Y R, XU J. Suggestions on the development of agricultural products crowdfunding from the perspective of reward-based crowdfunding [J]. Hubei Agricultural Sciences, 2022, 61(21): 240-243, 251. (in Chinese)

[23] LJUMOVIĆ I, HANIĆ A D, KOVAČEVIĆ V. The role of reward-based crowdfunding in farm financing: What characterises successful campaign?[J]. Ekonomika Poljoprivrede, 2021, 68(3): 773-788.

[24] WANG Y, CHEN Y Q, HUANG S. Agricultural supply chain financing strategy with social responsibility consideration under platform financing mode[J]. Electronic Commerce Research and Applications, 2023, 62: 101337.

[25] CHEN Y T, ZHANG R, LIU B. New product financing decision: Crowdfunding, bank or supply chain?[J]. International Journal of Production Economics, 2022, 249: 108536.

[26] HE Y, ZHAO L D, HE J. Optimal pricing and production decisions in a supply chain with e-marketplace[J]. Journal of Southeast University (English Edition), 2007, 23(S1): 8-14.

[27] FAN J X, ZHANG X M, DAN B, et al. Advance selling of fresh produce e-tailer with uncertain demand and risk-averse consumers[J]. Managerial and Decision Economics, 2024, 45(3): 1702-1717.

[28] TIAN Y, DAN B, LIU M L, et al. Strategic introduction for competitive fresh produce in an e-commerce platform with demand information sharing [J]. Electronic Commerce Research, 2023, 23(4): 2907-2941.

[29] REINDORP M, TANRISEVER F, LANGE A. Purchase order financing: Credit, commitment, and supply chain consequences[J]. Operations Research, 2018, 66(5): 1287-1303.

[30] LIN Q, FU W H, WANG Y J. The internal financing decisions of "Company + Farmer" contract farming supply chain [J]. System Engineering Theory and Practice, 2021, 41(5): 1162-1178.

[31] SHEN Y, ZHONG W J, MEI S E. Influence of consumer information investment on supply chain advertising and pricing strategies[J]. Journal of Southeast University (English Edition), 2023, 39(3): 240-247.

[32] YAN L, LI P P, MEI S E, et al. Effect of advertising targeting fit and consumer privacy protection on the profits of media platforms[J]. Journal of Southeast University (English Edition), 2023, 39(2): 194-203.

[33] WANG X H, ZENG C H. A model of advance selling with consumer heterogeneity and limited capacity [J]. Journal of Economics, 2016, 117(2): 137-165.

[34] DAN B, LEI T, ZHANG X M, et al. Modeling of the subsidy policy in fresh produce wholesale markets under yield uncertainty[J]. Economic Modelling, 2023, 126: 106413.

[35] BELLEFLAMME P, LAMBERT T, SCHWIENBACHER A. Crowdfunding: Tapping the right crowd[J]. Journal of Business Venturing, 2014, 29(5): 585-609.

[36] REN X J, ZHAO L D. Contract stability and default risk control of pig farming in the company and farmer mode [J]. Journal of Southeast University (English Edition), 2022, 38(1): 97-102.

[37] TANG M Z, YOU T H, CAO B B. Comparative analysis of crowdfunding and bank financing: The effect of market uncertainty [J]. International Journal of Production Economics, 2025, 286: 109657.

[38] FERREIRA P, PEREIRA É. Investment decisions under risk neutrality and opportunity cost constraints[J]. Journal of Financial Economics, 2018, 130(2): 345-367.

考虑资金约束生鲜农产品供应链预售与众筹组合融资策略

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摘要： 针对生鲜农产品供应链中农户面临的资金约束问题，本文聚焦"农户–电商平台"两级农产品供应链，探究预售融资与多阶段众筹协同的混合融资策略。基于农户通过电商平台预售仍无法覆盖生产成本的现实困境，本文创新性地构建预售和多阶段众筹融资的组合融资模式：首先，农户通过平台预售获取部分启动资金；其次，针对资金缺口分阶段发起众筹（种植期、管护期、采收期），并动态调整各阶段投资者收益分成比例以平衡风险溢价。建立以农户利润最大化为目标的动态规划模型，目标函数整合生产量决策、多阶段融资成本及投资者收益分成约束，运用Karush-Kuhn-Tucker（KKT）条件与逆向归纳法求解模型均衡解。数值仿真表明：与传统单一预售模式相比，引入多阶段众筹可使农户融资规模提升，同时通过动态收益分成机制降低投资者回报率波动；当众筹阶段数增至3阶段时，供应链整体效益较单阶段融资提高，验证了分阶段融资对资金匹配效率的改进作用。本研究为破解农业供应链融资"短贷长投"错配问题提供理论依据，并为电商平台设计融资组合策略提出可靠的建议。

关键词： 资金约束；生鲜农产品；回报率；预售融资；多阶段众筹

中图分类号： O22