Research on Financing Strategies for Small and Medium-Sized Agricultural Machinery Manufacturers under the Guarantee of Agricultural Cooperatives

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Abstract. Agricultural cooperatives' guarantees are a crucial method to tackle the financial challenges faced by agribusinesses. This paper constructed a secondary supply chain for capital-constrained small and medium-sized agricultural machinery manufacturers and agricultural cooperatives. We created a Stackelberg game model to analyze the optimal decisions and expected profits of agricultural cooperatives and small to medium-sized agricultural machinery manufacturers. Moreover, we studied the effect of key parameters on the equilibrium results and demonstrated the above research through numerical analysis. The results showed: 1. optimal wholesale prices and order quantities increase with product success and harvest assessment indexes. 2. Small and medium-sized agricultural machinery manufacturers always have greater expected profits than agricultural cooperatives if the product success rate was large enough.

Keywords: Capital-constrained, Small and medium-sized agricultural machinery manufacturers, Agricultural cooperatives' guarantees.

1 Introduction

Agriculture is the basis of the country's economy. Many countries aim to establish modern agriculture for a stable supply of food. The use of agricultural machinery is a key symbol of modern agriculture, improving yields and ensuring a stable food supply. In China, a significant number of agricultural machines are utilized during the harvest of agricultural products, and for Chinese farmers, agricultural machinery is also indispensable[1]. This is not solely due to the "land transfer" policy but also because of the rapid growth of China's agricultural machinery industry. Small and medium-sized agricultural machinery manufacturers are located across the country, providing a significant contribution to the development of Chinese agriculture. However, small and medium-sized agricultural machinery manufacturing enterprises often face financing difficulties, resulting in reduced output or interrupted production. The existence of government subsidies has increased the willingness of agricultural machinery manufacturers to produce but has not improved their dilemma of production difficulties. Small and medium-

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sized agricultural machinery manufacturers often struggle to gain the trust of banks or financing platforms due to their low credit. Insufficient capital for production has become a common problem for many small and medium-sized agricultural machinery manufacturers. In recent years, the strong promotion of agricultural cooperatives in China has provided new financing solutions for small and medium-sized agricultural machinery manufacturers. Small and medium-sized agricultural machinery manufacturers can enter into agreements with agricultural cooperatives, which are responsible for providing financing guarantees to the manufacturers, who sell their products to the cooperatives through direct marketing channels. In China, some agricultural cooperatives have already played their role as financial guarantors, such as Meiyu Vegetable Specialized Cooperative in Zhejiang Province, Xinxiang Rice Farmers' Specialized Cooperative in Heilongjiang Province, etc. In this financing model, small and medium-sized agricultural machinery manufacturers replenish their production capital, and agricultural cooperatives enjoy both wholesale prices and high-quality three-guarantee services (Repair, Replacement, Return). This paper focuses on a financing model in which agricultural cooperatives provide credit guarantees to capital-constrained small and medium-sized agricultural machinery manufacturers and explores the impact of relevant parameters on supply chain financing decisions.

Agricultural cooperatives are established by farmers based on the principles of voluntariness and equality, mutual benefit and autonomy, and provide agricultural supply chain members with agricultural production, marketing, services, and agricultural insurance and credit. Agricultural cooperatives, as part of the agricultural/farm machinery supply chain, play an important role in solving the problem of difficult guarantees for agribusinesses or farmers[2]. At the same time, agricultural cooperative guarantees can broaden financing channels and promote the development of rural finance. Many researchers have conducted significant studies on agricultural cooperatives. Candemir et al. studied various economic behaviors of agricultural cooperatives and concluded that agricultural cooperatives have a sustainable role in developing the agricultural economy[3]. Zhang et al. believed that e-commerce and green credit support can improve the financing of agricultural cooperatives[4]. Mateos-Ronco et al. studied the determinants affecting the financing of agricultural cooperatives[5]. Zhu et al. confirmed that agricultural cooperatives have the advantage of risk sharing and benefit sharing[6]. Zheng et al. construct a theoretical analysis model of farmers' cooperatives' digital credit behavior[7]. Agricultural cooperatives, as social organizations arising from the process of land transfer, not only reach out to farmers but also have close links with the Government and agriculture-related enterprises. This advantage of agricultural cooperatives also makes them promising for agricultural machinery supply chain finance.

The existing literature on secured financing for agricultural cooperatives only covers guarantees for undercapitalized farmers, while overlooking small and medium-sized manufacturers of agricultural machinery that lack capital at the beginning of agricultural production. There is no literature on the financing of small and medium-sized agricultural machinery manufacturers from the perspective of agricultural cooperative guarantees. Therefore, this paper will examine the financing strategies of small and medium-sized farm machinery manufacturers under the guarantee of agricultural cooperatives.

2 Model description and assumptions

2.1 Model description

A secondary supply chain consisting of capital-constrained small and medium-sized agricultural machinery manufacturers and agricultural cooperatives is constructed in this chapter. In this model, agricultural cooperatives provide credit guarantees for agricultural machinery manufacturers. Next, small and medium-sized agricultural machinery manufacturers provide their products directly to agricultural cooperatives by constructing direct sales channels. In the direct marketing channel, agricultural cooperatives are only responsible for buying and not selling. Agricultural cooperatives generally provide their products to farmers or farms through the leasing of agricultural machinery. The specific operational flow in this model is shown in Figure 1.

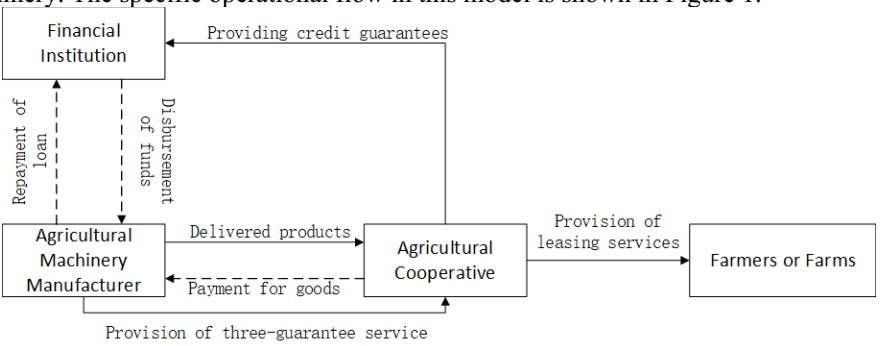

Fig. 1. Flowchart for Agricultural Cooperative Guarantee Model Supply Chain Operations

As shown in Figure 1, firstly, the agricultural cooperative places an order to the small and medium-sized agricultural machinery manufacturer and provides a credit guarantee, then the financial institution grants a loan, and the small and medium-sized agricultural machinery manufacturer produces the product after receiving the funds. Finally, delivers the product to the agricultural cooperative and provides the three-guarantee service of the product.

Based on this paper the following parameter descriptions are given as shown in Table 1.

Table 1. Parameter symbols and their meanings.

Symbol	Meaning
c	Production cost per unit product
w^N	Product wholesale price
p	Rent price
η	Manufacturer's initial capital
q^N	Number of orders
a_n	The capacity of the agricultural machinery product leasing market

b_n	The price of the product is sensitive to the price of orders
$\beta, (0 \leq \beta \leq 1)$	Product success rate
$L^N, (L^N = cq - \eta)$	Loan quota
g	Government subsidy
r^N	Financing interest rate
f	The recycling price after product failure
π_M^N	Manufacturer's expected profit
π_N	Agricultural cooperatives' expected profits
π^{M+N}	Supply chain expected profit
λ	Financial institution risk-sharing ratio
σ	three-guarantee ratio
θ	Crop harvest assessment index
z	The manufacturer's three-guarantee unit costs

2.2 Model assumptions

1. This paper assumed that demand follows a two-point distribution. To simplify the analysis, there are also more and more studies for operation and finance using a two-point distribution function to represent the market demand, similar to Chod[8]. The demand function for agricultural machinery products is:

$$d = \begin{cases} q & successful\ rate = \beta \\ 0 & failure\ rate = 1 - \beta \end{cases} \tag{1}$$

2. It is assumed that the rent price p^Ndecreases linearly with q^N orders and that there exists a harvest assessment index (θ) as an important factor affecting the rent price. when the agricultural cooperative has a positive attitude toward the crop harvest, The rent price function is: $p^N = a_n - b_n q^N + \theta, (\theta > 0)$. Conversely, when it has a negative attitude towards crop harvesting, $\theta < 0$.
3. To simplify the model, this paper assumes that the rental price of an agricultural machinery product is the total of the prices of multiple rental operations from harvesting the crop until the end.
4. It is assumed that the agricultural machinery manufacturer's unit cost of three packages is fixed.

3 Model Building and Parametric Analysis

3.1 Model Building

In this section, we will construct a profit function model for small and medium-sized agricultural machinery manufacturers and agricultural cooperatives. The agricultural machinery manufacturers have an initial capital η, and set the wholesale price w^N, the agricultural cooperatives decide on the number of orders q^N and provide a credit guarantee to the upstream manufacturers. Then small and medium-sized agricultural machinery manufacturers determine the amount of financing: $L^N = cq - \eta + zq\sigma$. Loan disbursement is carried out by the financial institution upon receipt of the financing application and the credit guarantee slip. Finally, the manufacturers fulfill the production order, provide three-guarantee and repay the loan: $L^N(1 + r^N)$. The profit function for small and medium-sized agricultural machinery manufacturers is:

$$\pi_M^N = \beta\left(q^N w^N + q^N g - L^N(1 + r^N)\right) - \eta. \tag{2}$$

The agricultural cooperatives' profit function is:

$$\pi_N = \beta(p^N q^N - q^N w^N) - (1 - \beta)((L^N(1 - \lambda) - f) \tag{3}$$

From equation (3), since the guarantee of the agricultural cooperatives makes it absorb part of the financial institution's risk, this part is to be subtracted as a cost in the expected profit function.

Our study gives the order of decision-making of the supply chain members: financial institutions decide on the lending rate, small and medium-sized agricultural machinery manufacturers decide on the wholesale price, then agricultural cooperatives decide on the quantity of products. Combining equations (2) and (3), the following lemma is obtained by the inverse solution method:

Lemma 1: The optimal interest rate, optimal wholesale price, and optimal product order quantity are:

$$r^{N^*} = r^N,$$

$$w^{N^*} = \frac{\begin{array}{c}\beta(a - g + \theta) + c\left(-1 + \lambda + \beta(2 + r^N - \lambda)\right) + \\ z(-1 + \lambda + \beta(2 + r - \lambda))\sigma\end{array}}{2\beta},$$

$$q^{N^*} = \frac{\begin{array}{c}\beta(a + g + \theta) + c\left(-1 + \lambda - \beta(r^N + \lambda)\right) \\ +z(-1 + \lambda - \beta(r + \lambda))\sigma\end{array}}{4b\beta}$$

The expected profits for small and medium-sized agricultural machinery manufacturers and agricultural cooperatives are:

$$\pi_M^{N^*} = \frac{\begin{array}{c}(\beta(-8b\eta + \beta(8b(1+r^N)\eta + (a+g+\theta)^2)) + \\ c^2\left(-1+\lambda-\beta(r^N+\lambda)\right)^2 - 2z\beta(a+g+\theta)\left(1-\lambda+\beta(r^N+\lambda)\right)\sigma \\ +z^2\left(-1+\lambda-\beta(r^N+\lambda)\right)^2\sigma^2 + 2c(1-\lambda+\beta(r+\lambda))(-\beta(a+g+\theta) \\ +z\sigma + z(r^N\beta + (-1+\beta)\lambda))\sigma)).\end{array}}{8b\beta}$$

$$\pi_N^* = \frac{\begin{array}{c}(-16b(-1+\beta)\beta(f-\eta(-1+\lambda)) + c^2\left(-1+\lambda-\beta(r^N+\lambda)\right)^2 \\ +2c\left(1-\lambda+\beta(r^N+\lambda)\right)(-\beta(a+g+\theta)+z\sigma+z(r^N\beta+(-1+\beta)\lambda)\sigma) \\ +(\beta(a+g+\theta)+z(-1+\lambda-\beta(r^N+\lambda))\sigma)^2).\end{array}}{16b\beta}$$

Proof: The parameter q^N in (3) is derived: $q^N = -\frac{-a\beta+w\beta-\beta\theta+(1-\beta)(1-\lambda)(c+z\sigma)}{2b\beta}$. Substitute q^N the into equation (2) and derive w^N to obtain the optimal wholesale price: $w^{N^*} = \frac{\begin{array}{c}\beta(a-g+\theta)+c\left(-1+\lambda+\beta\left(2+r^N-\lambda\right)\right)+ \\ z(-1+\lambda+\beta(2+r-\lambda)+)\sigma\end{array}}{2\beta}$. Substitute the optimal wholesale price into (3) to derive q^N to obtain the optimal orders: $q^{N^*} = \frac{\begin{array}{c}\beta(a+g+\theta)+c\left(-1+\lambda-\beta(r^N+\lambda)\right) \\ +z(-1+\lambda-\beta(r+\lambda))\sigma\end{array}}{4b\beta}$. The optimal profits of small and medium-sized agricultural machinery manufacturers and agricultural cooperatives can be found by substituting the obtained optimal wholesale prices and order quantities into (2)(3).

3.2 Parametric Analysis

Proposition 1: w^{N^*}, q^{N^*} increases as β increases, and presence thresholds β_{n_1}, β_{n_2}, $\beta_{n_1} > \beta_{n_2}$. when $\beta > \beta_{n_1}$, expected profits of small and medium-sized agricultural machinery manufacturers increase with product success β. when $\beta < \beta_{n_1}$, expected profits of agricultural cooperatives increase with product success β.

Proof: The first order derivative of the parameter β in w^{N^*}, q^{N^*} is given by: $\frac{dw^{N^*}}{d\beta} = \frac{(1-\lambda)(c+z\sigma)}{2\beta^2} > 0, \frac{dq^{N^*}}{d\beta} = \frac{(1-\lambda)(c+z\sigma)}{4b\beta^2} > 0$. And taking the second-order partial derivatives of the parameter β in the manufacturer's expected profit: $\frac{d^2\pi_M^{N^*}}{d(\beta)^2} = \frac{(-1+\lambda1+\lambda2)^2(c+z\sigma)^2}{4b\beta^3} > 0$, existence of minimal values. Then making the first order derivative equal to 0, we solve for β_{n_1}, β_{n_2}.(the results are too complex to be given)

Increased product success rate implies high product quality and market acceptance, so small and medium-sized agricultural machinery manufacturers can increase their revenue by raising wholesale prices. Increased product success rate means that agricultural cooperatives are more willing to collaborative with manufacturers and provide guarantees to them. Even in the face of higher wholesale prices, agricultural cooperatives are willing to respond to the leasing market by increasing the number of orders.

The expected profits of manufacturers and agricultural cooperatives increase only if the product success rate is greater than a certain threshold. Because when the product success rate is low, manufacturers have poor product quality or low market acceptance, even if they reduce the wholesale price, they cannot obtain more orders. The expected profit of small and medium-sized farm machinery manufacturers is at a low level. For agricultural cooperatives, a lower product success rate exposes them to greater guarantee risk, agricultural cooperatives also aim to benefit from a better success rate of their products. Our research also found that agricultural cooperatives have greater thresholds when profits increase than small and medium-sized agricultural machinery manufacturers, which may be due to the fact that cooperatives take on guarantee risks.

Proposition 2: w^{N^*}, q^{N^*} increases as θ increases, and presence thresholds θ_n, when $\theta > \theta_n$, expected profits of small and medium-sized agricultural machinery manufacturers increase with crop harvest assessment index θ. when $\theta < \theta_n$, expected profits of agricultural cooperatives decrease with θ.

Proof: The method of proof is the same as shown in Proposition 1.

A higher Harvest Assessment Index means that agricultural cooperatives are more optimistic about the agricultural machinery leasing market and therefore agricultural cooperatives will increase the number of orders. For small and medium-sized agricultural machinery manufacturers, the market appears to have more demand than supply, and manufacturers are able to make greater profits from high order quantities based on higher wholesale prices. Therefore, a higher Harvest Assessment Index is more favorable to supply chain members.

4 Numerical Analysis

In this section, the upper theoretical model will be analyzed numerically. This paper assigns specific values to the parameters as follows: $a_n = 12$, $b_n = 0.8, r^N = 0.008, f = 2, g = 0.5, \lambda = 0.6, c = 3, \eta = 0, \sigma = 0.75, z = 0.375$.

We analyze the model numerically by assuming $\theta = 1$. As shown in Figure 2, 3. As it is difficult for small and medium-sized agricultural machinery manufacturers and agricultural cooperatives to have transactions with low product success rate. Therefore, small and medium-sized agricultural machinery manufacturers should develop better and more marketable products to increase the product success rate in order to maximize the revenue of the entire supply chain.

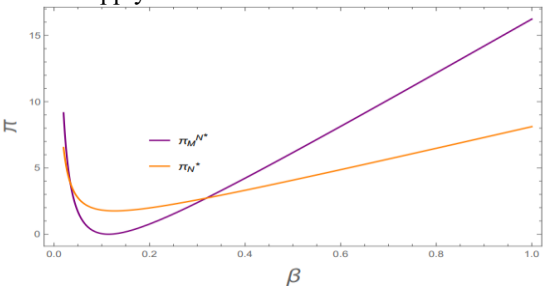

Fig. 2. β impact on expected profits

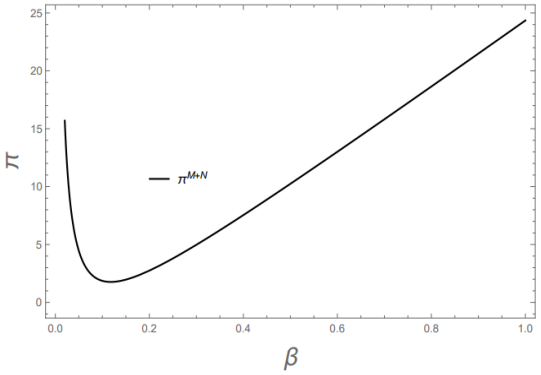

Fig. 3. β impact on supply chain profits

We analyze the model numerically by assuming $\beta = 0.8$. As shown in Figure 4, 5. The expected profits of manufacturers, agricultural cooperatives, and the supply chain are monotonically increasing over a given range, and the profits of manufacturers are always greater than the profits of agricultural cooperatives.

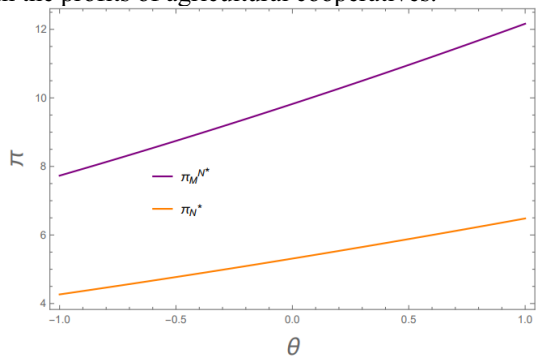

Fig. 4. θ impact on expected profits

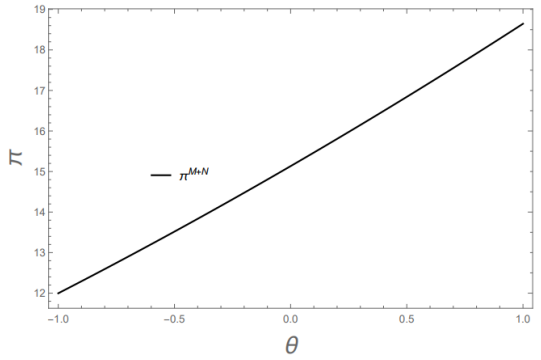

Fig. 5. θ impact on supply chain profits

5 Conclusions

The optimal wholesale price and order quantity increase with product success rate and harvest assessment index in the agricultural cooperative guarantee model. Agricultural cooperatives and agricultural machinery manufacturers want the existence of a high product success rate and harvest assessment index. Small and medium-sized agricultural machinery manufacturers should strive to improve the quality of their products and their market acceptance when they adopt direct sales channels to sell their products. Only then, agricultural cooperatives have a stronger willingness to guarantee and provide more purchase orders in order to maximize the profitability of the entire supply chain.

Reference

1. Jeetendra, P.A., Dil, B.R., Sofina, M., Olaf, E. (2019) Understanding factors associated with agricultural mechanization: A Bangladesh case. World Development Perspectives, 13: 1-9. https://doi.org/10.1016/j.wdp.2019.02.002.
2. Zhang, S.M., Wolz, A., Ding, Y. (2020) Is there a role for agricultural production cooperatives in agricultural development? Evidence from China. Outlook on Agriculture, 49(3): 256-263. https://doi.org/10.1177/0030727020913283.
3. Candemir, A., Duvaleix, S., Latruffe, L. (2021) Agricultural Cooperatives and Farm Sustainability - A Literature Review, Journal of Economic Surveys, 35(4):1118-1114. https: // doi.org/10.1111/joes.12417.
4. Zhang, L., Xin, B.-g. (2023) E-Commerce and Preferential Credit to Enable Farmers' Cooperative Financing [J/OL], Emerging Markets Finance and Trade: 1-19[2024-03-07]. https://doi.org/10.1080/1540496X.2023.2270135.
5. Mateos-Ronco, A., Guzmán-Asunción, S. (2018) Determinants of financing decisions and management implications: evidence from Spanish agricultural cooperative, International Food and Agribusiness Management Review. 21(6):701-721. https: //doi. org/ 10. 22434/ IFAMR2016.0178.
6. Zhu, X.-y., Wang, G.-y. (2024) Impact of Agricultural Cooperatives on Farmers' Collective Action: A Study Based on the Socio-Ecological System Framework, Agriculture-Basel. 14(1):96. https://doi.org/10.3390/agriculture14010096.
7. Zheng, Y.Y., Lou, J.H., Mei, L.F., Lin, Y.S. (2023) Research on Digital Credit Behavior of Farmers' Cooperatives-A Grounded Theory Analysis Based on the "6C" Family Model, Agriculture-Basel. 13(8):1597. https//:doi.org/10.3390/agriculture13081597.
8. Chod, J., Weber, M., (2020) On the Financing Benefits of Supply Chain Transparency and Blockchain Adoption. Management Science. 66 (10): 4378–4396. https: //doi. org/ 10. 1287/mnsc.2019.3434.