Supply Chain Pricing and Financing Strategies under Differentiated Green Credit

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Abstract—**Green credit financing is closely related to corporate credit rating, so conducting in-depth research on the differentiation of green credit has practical significance. For the three-stage supply chain system composed of risk avoidance suppliers, retailers and banks, suppliers face a capital gap to produce green products to meet market demand. Based on Stackelberg game theory, this paper establishes a bank green credit and mixed financing model to study the best financing strategy of suppliers under differentiated green credit. Research shows that credit rating is not always positively correlated with product greenness, and it is important for enterprises to improve their own credit rating; the higher the degree of suppliers' risk avoidance, the lower their utility profit; only when the green sensitivity coefficient is low, the conclusion that retailers are more willing to choose to cooperate with suppliers with high credit rating is inevitable; banks providing loans to suppliers with middle credit rating can maximize their profits, and providing loans to suppliers with high credit rating can better stimulate green production.**

Index Terms—**differentiated green credit, capital constraints, credit rating, risk avoidance**

I. Introduction

WITH the increase of the country's efforts on environmental protection, consumers' environmental awareness has gradually increased. Under the dual pressure of laws and regulations and the market, enterprises are gradually inclined to produce the products with high greenness and implement green supply chain management measures [1]. For example, Sony's environmental zero-load plan, Shanghai General Motors' green smart manufacturing strategy. Panasonic, HP and other international leading enterprises have also widely implemented green supply chain management, and environmental-friendly green products have gradually won the favor of consumers. Green technological innovation is the key to promoting the transformation and upgrading of industrial structure and achieving high-quality development [2]. However, the financial constraints caused by the R&D cost of green products have become one of the important reasons for restricting the development of enterprises. There are a wide range of financing channels to solve this problem. At present, the financing channels in the market are mainly divided into internal financing and external financing. Internal financing is mainly the trading credit between upstream and downstream enterprises, while external financing includes government subsidies, bank loans and stocks financing. For the problem of suppliers' financial constraints, the main solution is bank loans and paying part in advance by retailers for the goods. However, it usually needs to be mortgaged to obtain bank loans, which is difficult for some small and medium-sized enterprises to meet the conditions. Whether a company can repay the loan principal and interest after borrowing is also an important factor affecting bank performance. Therefore, the credit rating of suppliers is one of the important criteria affecting the bank's issuance of green credit. Enterprises with high credit rating are more likely to obtain multi-channel financing. Enterprises with low credit rating are likely to go bankrupt due to the breakage of capital chain or lose the market due to the lack of sufficient fund to produce competitive products. In addition, the risk of bankruptcy and the uncertainty of market demand brought by suppliers' credit rating cannot be ignored. So it is necessary to consider the impact of suppliers' risk avoidance on the pricing and financing strategies of supply chain members.

Starting from the reality of the financial constraints faced by suppliers, what kind of financing channels can encourage suppliers to manufacture the products with higher greenness? How does credit rating affect the pricing and financing decisions of enterprises? What kind of effect will differentiated green credit provided by banks have on the performance of supply chain? In view of this, this paper establishes a three-stage supply chain system composed of a risk-avoidance supplier with capital constraint, a retailer and a bank. It is of practical significance to analyze the impact of the interest rate of bank loan, the product greenness and the extent of risk avoidance on the pricing and financing strategy of the supply chain.

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II. Literature Review

The research related to this paper mainly involves three aspects: research on financing strategy in supply chain, credit rating and risk appetite under capital constraints. Domestic and overseas scholars have different opinions on the research of financing strategies under capital constraints. Zhou et al. [3] established a tripartite evolutionary game model for the government, banks and enterprises. Research showed that whether the government implements supervision played an important role in the strategic choices of banks and enterprises. Zhang et al. [4] divided government subsidies into green credit and green product subsidies, established a supply chain decision-making game model. And it is pointed out that the green sensitivity of consumers and the proportion of green inputs were important factors affecting the level of social welfare. When green manufacturers faced capital constraints, Huang et al. [5] looked for a kind of win-win subsidy in various models of green credit, manufacturing subsidies and sales subsidies. Tang et al. [6] considered the impact of financing mechanisms with different rights structures on social welfare levels in the context of a low-carbon environment, and the conclusion was still stable when it was expanded from risk neutrality to risk avoidance. Liu et al. [7] explored the impact of carbon tax and carbon reduction rate on investment strategies of high energy consuming enterprises when facing financial constraints when adopting low-carbon emission reduction technologies under different product subsidy models. Their conclusions provided management insights for carbon reduction plans. Huang et al. [8] considered the optimal pricing strategy of capital-constrained retailers under three channel power structures and two financing models. Lei et al. [9] studied the impact of initial capital on retailers' decision-making choices on green credit financing and mixed financing under a three-stage supply chain financing system composed of manufacturers, retailers and banks. Zhu et al. [10] introduced the uncertainty of freshness and market fluctuations of fresh products into the demand function, focusing on the impact of procurement subsidies and sales subsidies on pricing, market demand and social welfare. Research showed that the abundance extent of the government budget is closely related to the suppliers' operation strategy. Wang et al. [11] studied the way to alleviate the financial pressure through sharing the service cost by re-engineering manufactures under the capital constraints of e-commerce platforms. Research showed that the financial pressure can be greatly alleviated through sharing the recycling service cost by re-engineering manufactures combining with bank lending. Huang et al. [12] considered the decision-making of small and medium-sized enterprises facing financing problems when banks are at risk. Cao et al. [13] established the performance function of the supply chain members under the mixed strategy of payment in advance and bank credit, and studied the impact of different interest rates on the optimal decision-making of the supply chain. Hua et al. [14] found that under the situation of insufficient funds for retailers, because suppliers always provide trade credit to retailers at low risk-free interest rates, retailers always tend to choose the latter in bank loans and trade credit.

Bank credit financing has been the main financing channel for a long time, and credit rating can assess the repayment ability of enterprises and the degree to which banks bear risks. Kouvelis et al. [15] analyzed on equilibrium decisions when retailers and suppliers face different credit ratings. The results showed that suppliers were more willing to cooperate with retailers with higher credit rating, while the first choice for retailers was not the suppliers with the highest credit rating. Nigro et al. [16] considered the impact of credit rating and sales efforts on the best contract choice. When both suppliers and retailers face capital constraints, retailers may improve suppliers' profits and their own profits through sales efforts; when the operating capital of the supply chain is low, credit rating and sales efforts may support each other. Jiang et al. [17] established a two-stage supply chain composed of a well-capitalized supplier and a capital-constrained retailer to study the financing choices of supply chain members when retailers have a credit rating. Wang et al. [18] established a supply chain model composed of one supplier and two capital-constrained retailers, and tried to find the Pareto zone with different strategies by analyzing and comparing three trade credit strategies.

Most of the researches of the above scholars were carried out on the premise of risk neutrality, and in real life, the risk preference of supply chain members will greatly affect their decision-making. For different risk preferences, Cao et al. [19] established a two-channel supply chain system composed of risk-averse manufacturers and risk-neutral retailers to study the impact of initial capital, risk aversion degree and retailers' value-added services on channel selection and financing strategies. Tan et al. [20] analyzed the optimal financing strategy of retailers with risk-averse characteristics based on two-way options, and promotes supply chain coordination to a certain extent. Wang et al. [21] considered the optimal pricing decision of supply chain members based on risk aversion and fair preference, and on this basis, they further used the revenue sharing contract to study the coordination of the supply chain. Cai et al. [22], [23] not only studied the bilateral risk appetite, but also used the M-CVaR tool to quantify the risk appetite of suppliers and analyzed the conditions to affect the supply chain coordination under different financing models.

To sum up, the green supply chain pricing and financing strategies under green credit have attracted widespread attention from scholars at home and abroad. The existing research rarely considers the financing channel choices faced by suppliers under differentiated credit. Compared with the existing research, the innovative points of this paper are: (i) In the research related to green credit, banks are rarely regarded as one of the decision makers. On this basis, this paper takes the interest rate of the bank loan as an endogenous variable to compare and analyze supply chain pricing and financing decisions under different financing models; (ii) Most of the previous literature on credit rating consider retailers, and the financing problems of suppliers facing credit rating are rarely considered. This paper supplements this field of literature; (iii) The above research results do not consider the impact of factors such as capital constraints, supplier credit rating and risk preference on supply chain decision-making at the same time.

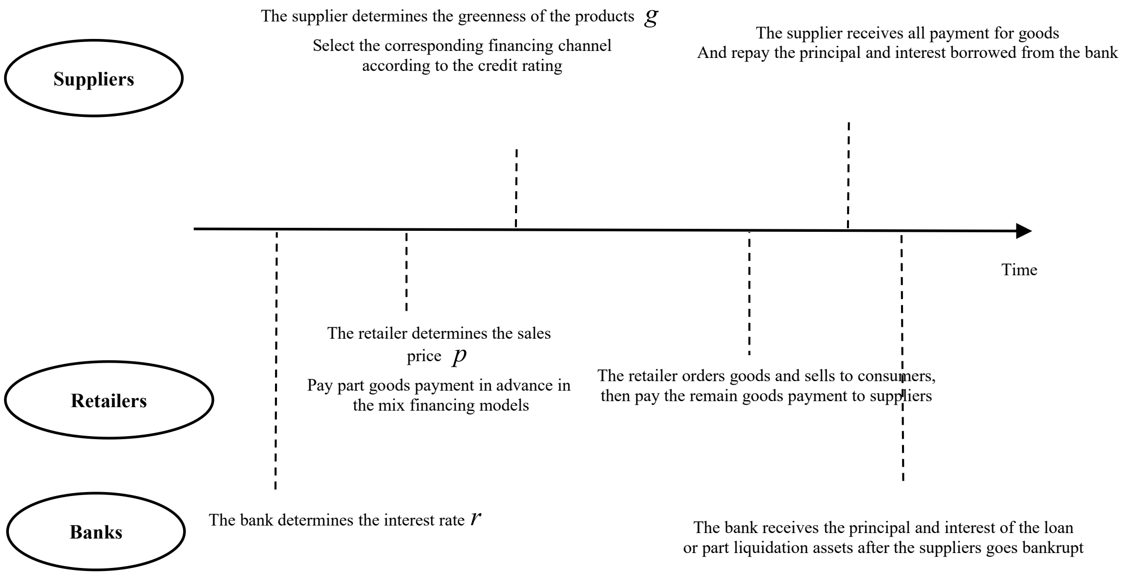


Fig. 1. The Order of Events Occurred in the Green Supply Chain System

III. Problem Description and Basic Assumptions

A. Figures

This paper builds a three-stage supply chain, consisting of suppliers with financial constraints, retailers with abundant funds and banks. Among them, suppliers are risk-avoidant, and retailers and banks are risk-neutral. The decision-making sequence in the supply chain is as follows. Firstly, as the leader of the supply chain, the bank determines the interest rates for loans. Secondly, the retailer determines the selling price of their products. Finally, the supplier determines the greenness of the products produced according to the interest rate and the retailers' order volume. The specific financial flows and information flows are shown in the Fig. 1.

B. Basic Assumptions

Assumption 1. The corresponding demand function of green products studied in this paper is $q = a - p + \lambda g + \varepsilon$, a is the potential scale of the market, p is the selling price of the product, g is the greenness of the product, and λ indicates the sensitivity coefficient of demand to greenness, in which $0 < \lambda < 1$, ε is the stochastic factors for demand, $E(\varepsilon) = 0$, $D(\varepsilon) = \sigma^2$.

Assumption 2. Suppliers have two business states, which is bankruptcy or operation. θ indicates the credit rating of the supplier, the possibility of the supplier going bankrupt is $\rho(\theta)$, $\rho(\theta) \in (0,1)$ and it is a strictly decreasing function about θ, which shows that the lower the credit rating of an enterprise, the more likely it is to go bankrupt. On the contrary, the probability of successful operation of the supplier is $1-\rho(\theta)$. $\rho(\theta)$ will be abbreviated as ρ in subsequent articles.

Assumption 3. All credit rating information of suppliers has been assessed by third-party rating agencies before supply chain transactions are executed.

Assumption 4. The supplier is risk-averse and uses the "mean-variance" model to represent the utility of the supplier. Then the utility function of the supplier is $U(\pi) = E(\pi) - \eta\sqrt{Var(\pi)}$, in which $\eta(\eta \ge 0)$ is the degree of risk avoidance of suppliers, The bigger η is, the more the supplier hates the risk; when $\eta = 0$, the supplier is risk-neutral.

C. Symbols Description

Table 1
Symbols Definition

Symbols	Implication
q	market demand
a	potential size of the market
p	product sales price (decision variables)
λ	demand sensitivity coefficient to greenness
g	product greenness (decision variables)
ε	stochastic factor of demand
w	wholesale price of products
c	production cost of products
k	cost coefficient of product greenness
r	interest rate of bank's loan (decision variables)
$\rho(\theta)$	bankruptcy probability of suppliers
η	degree of suppliers' risk avoidance
t	the proportion of retailers paying in advance
β	the proportion of liquidated assets obtained by banks when suppliers go bankrupt
Superscript L 、M 、H	respectively indicate the benchmark model, bank credit and mixed financing

Subscript s 、 r ; Y	respectively indicate suppliers, retailers and banks
π 、 U 、 E	respectively indicate profits, utility profits and expected profits

IV. Model Construction and Solution

Based on the different financing methods chosen by suppliers with different credit ratings, this paper builds the following three Stackelberg models corresponding to suppliers with low, medium and high credit ratings

A. Benchmark Model (Low Credit Rating L Model)

When the suppliers' credit rating is low, they can only rely on their own funds to produce green products. At this time, the risk of bankruptcy caused by the credit rating is jointly borne by the suppliers and the retailers. Only when the suppliers are operating normally and the supply chain is in operation can the members of supply chain get the income. At this time, the random profits of suppliers and retailers are respectively:

$$\pi_s^L(g)=\left(wq-cq-\frac{1}{2}kg^2\right)(1-\rho) \quad (1)$$

$$\pi_r^L(p)=(p-w)q(1-\rho) \quad (2)$$

Then the expected return and variance of the suppliers are:

$$E\left(\pi_s^L(g)\right)=\left((w-c)(a-p+\lambda g)-\frac{1}{2}kg^2\right)(1-\rho) \quad (3)$$

$$Var\left(\pi_s^L(g)\right)=(w-c)^2(1-\rho)^2\delta^2 \quad (4)$$

The mean-variance model is adopted. At this time, the decision-making objective functions of suppliers and retailers are:

$$U\left(\pi_s^L(g)\right)=\left((w-c)(a-p+\lambda g\text{-}\eta\delta)-\frac{1}{2}kg^2\right)(1-\rho) \quad (5)$$

$$E\left(\pi_r^L(p)\right)=(p-w)(a-p+\lambda g)(1-\rho) \quad (6)$$

In Model L, there exists:

Theorem 1: The optimal green degree of the supplier's products is $g^*=\frac{\lambda(w-c)}{k}$; The retailer's optimal sales price is $p^*=\frac{(a+w)k+\lambda^2(w-c)}{2k}$;

Proof of Theorem 1: To solve the problem using the inverse order induction method:

$$\frac{\partial U\left(\pi_s^L(g)\right)}{\partial g}=\left(\lambda(w-c)-kg\right)(1-\rho)$$

$$\frac{\partial U^2\left(\pi_s^L(g)\right)}{\partial g^2}=-k(1-\rho)<0$$

From $\frac{\partial U\left(\pi_s^L(g)\right)}{\partial g}=0$, it can be obtained:

$$g^*=\frac{\lambda(w-c)}{k}$$

Put g^* into $\partial E\left(\pi_r^L(p)\right)$, it can be obtained:

$$E\left(\pi_r^{L\sim}(p)\right)=(p-w)\left(a-p+\lambda\frac{\lambda(w-c)}{k}\right)(1-\rho)$$

$$\frac{\partial E\left(\pi_r^{L\sim}(p)\right)}{\partial p}=\left(a-p+\frac{\lambda^2(w-c)}{k}-(p-w)\right)(1-\rho)$$

$$\frac{\partial E^2\left(\pi_r^{L\sim}(p)\right)}{\partial p^2}=-2(1-\rho)<0$$

From $\frac{\partial E\left(\pi_r^L(p)\right)}{\partial p}=0$, it can be obtained:

$$p^*=\frac{(a+w)k+\lambda^2(w-c)}{2k}$$

Theorem 2: In order to ensure that the supplier's profit is greater than 0, the assumptions $a-w-2\eta\delta>0$ shall be established, then the best decision-making functions for suppliers and retailers are:

$$U\left(\pi_s^{L*}(g)\right)=\frac{1}{2}(w-c)(a-w-2\eta\delta)(1-\rho) \quad (7)$$

$$E\left(\pi_r^{L*}(p)\right)=\frac{\left((a-w)k+\lambda^2(w-c)\right)^2(1-\rho)}{4k^2} \quad (8)$$

Corollary 1:

(1) $\frac{\partial g^*}{\partial\lambda}>0$; $\frac{\partial p^*}{\partial\lambda}>0$; $\frac{\partial U\left(\pi_s^{L*}(g)\right)}{\partial\lambda}=0$; $\frac{\partial E\left(\pi_r^{L*}(p)\right)}{\partial\lambda}>0$;

(2) $\frac{\partial g^*}{\partial\eta}=0$; $\frac{\partial p^*}{\partial\eta}=0$; $\frac{\partial U\left(\pi_s^{L*}(g)\right)}{\partial\eta}<0$; $\frac{\partial E\left(\pi_r^{L*}(p)\right)}{\partial\eta}=0$;

(3) $\frac{\partial g^*}{\partial\rho}=0$; $\frac{\partial p^*}{\partial\rho}=0$; $\frac{\partial U\left(\pi_s^{L*}(g)\right)}{\partial\rho}<0$; $\frac{\partial E\left(\pi_r^{L*}(p)\right)}{\partial\rho}<0$.

Proof of Corollary 1:

$$\frac{\partial g^*}{\partial\lambda}=\frac{w-c}{k}>0;\ \frac{\partial p^*}{\partial\lambda}=\frac{\lambda(w-c)}{k}>0;$$

$$\frac{\partial E\left(\pi_r^{L*}(p)\right)}{\partial\lambda}=\frac{\lambda(w-c)(1-\rho)\left((a-w)k+\lambda^2(w-c)\right)}{k^2}>0;$$

$$\frac{\partial U\left(\pi_s^{L*}(g)\right)}{\partial\eta}=-\delta(w-c)(1-\rho)<0$$

$$\frac{\partial U\left(\pi_s^{L*}(g)\right)}{\partial\rho}=\frac{-(w-c)(a-w-2\eta\delta)}{2}<0$$

$$\frac{\partial E\left(\pi_r^{L*}(p)\right)}{\partial\rho}=-\frac{\left((a-w)k+\lambda^2(w-c)\right)^2}{4k^2}<0;$$

Inference 1 shows that in L model, the greenness of the product, the sales price, and the retailer's profit are directly proportional to the green sensitivity coefficient, and the supplier's profit has nothing to do with the green sensitivity coefficient. This means that when the parameter λ is large, suppliers will be encouraged to produce products with high greenness, and the research and development cost of green products will increase accordingly. At this time, the supplier's profit does not change significantly, and the retailer's profit will increase with the increase of sales prices. The supplier's profit is inversely proportional to the degree of its risk avoidance. The higher the degree of supplier's risk avoidance, the lower its corresponding profit is. The greenness of the product and the sales price have nothing to do with the supplier's credit rating, and the profits of suppliers and retailers are inversely proportional to the probability of bankruptcy. This means that the lower the credit rating obtained by the supplier, the higher the probability it goes to bankrupt, and the instability of the operation state will reduce the profits of supply chain members. Therefore, for the stable development of the green supply chain, it is very necessary to improve suppliers' credit rating.

B. Bank Loan (Middle Credit Rating M Model)

When the supplier's credit rating is medium, comparing to internal trade financing with less risk and more requirements, suppliers are easier to obtain external bank financing. The amount of bank financing is $L_0 = cq + \frac{1}{2}kg^2$. The risk of bankruptcy caused by credit ratings is shared by suppliers, retailers and banks. In this case, the profits of suppliers and retailers are:

$$\pi_s^M(g) = \left(wq - L_0(1+r)\right)(1-\rho) \tag{9}$$

$$\pi_r^M(p) = (p-w)q(1-\rho) \tag{10}$$

Similarly, their decision-making objective functions are:

$$U\left(\pi_s^M(g)\right) = \begin{pmatrix} w(a-p+\lambda g-\eta\delta) \\ -\left(c(a-p+\lambda g-\eta\delta)+\frac{1}{2}kg^2\right)(1+r) \end{pmatrix}(1-\rho) \tag{11}$$

$$E\left(\pi_r^M(p)\right) = (p-w)(a-p+\lambda g)(1-\rho) \tag{12}$$

When the supplier operates normally, the bank's income is the sum of the principal and interest $L_0(1+r)$; Conversely, when the supplier goes bankrupt, the bank can only get a part of the supplier's income $(1-\beta)wq$ (The cost of bankruptcy according to the law), so the bank's income is:

$$Y^M = \begin{cases} L_0(1+r) & ,1-\rho \\ (1-\beta)wq & ,\rho \end{cases} \tag{13}$$

Correspondingly, the expected profit of the bank is:

$$EY^M(r) = E\left((1-\rho)L_0(1+r) + \rho(1-\beta)wq\right) \tag{14}$$

The above formula can be simplified:

$$EY^M(r) = (1-\rho)\left(c(a-p+\lambda g)+\frac{1}{2}kg^2\right)(1+r) + \rho(1-\beta)w(a-p+\lambda g) \tag{15}$$

In M model, let $G = ck(a-w)(1-\rho)$, using the inverse order induction method to solve the problem, in order to ensure that the optimal solution is of practical significance, it is assumed that $\lambda w\sqrt{1-\beta\rho} > \sqrt{G} > \lambda c\sqrt{1-\beta\rho}$:

Theorem 3: The optimal green degree of the supplier's products is $g^* = \frac{G-\lambda c\sqrt{G(1-\beta\rho)}}{k\sqrt{G(1-\beta\rho)}}$, the retailer's optimal sales price is $p^* = \frac{\left((a+w)k-\lambda^2 c\right)\sqrt{G(1-\beta\rho)}+\lambda G}{2k\sqrt{G(1-\beta\rho)}}$, the bank's optimal interest rate of loan is $r^* = \frac{\lambda w\sqrt{G(1-\beta\rho)}-G}{G}$;

Proof of Theorem 3: To solve the problem using the inverse order induction method:

From $\frac{\partial U\left(\pi_s^M(g)\right)}{\partial g} = 0$, $\frac{\partial E\left(\pi_r^M(p)\right)}{\partial p} = 0$, it can be obtained:

$$g^{\sim} = \frac{\lambda\left(w-c(1+r)\right)}{k(1+r)}$$

$$p^{\sim} = \frac{1}{2}\left(a+w+\frac{\lambda^2\left(w-c(1+r)\right)}{k(1+r)}\right) = \frac{(a+w)k(1+r)+\lambda^2\left(w-c(1+r)\right)}{2k(1+r)}$$

Bring the above results back to $EY^M(r)$, from $\frac{\partial EY^M(r)}{\partial r} = 0$ the optimal solution of interest rates is obtained:

When $\lambda w\sqrt{G(1-\beta\rho)} - G > 0$, $r^* = \frac{\lambda w\sqrt{G(1-\beta\rho)}-G}{G}$

Then get the optimal greenness g^* and the optimal sales price p^*:

$$g^* = \frac{G-\lambda c\sqrt{G(1-\beta\rho)}}{k\sqrt{G(1-\beta\rho)}}$$

$$p^* = \frac{\left((a+w)k-\lambda^2 c\right)\sqrt{G(1-\beta\rho)}+\lambda G}{2k\sqrt{G(1-\beta\rho)}}$$

Theorem 4: The optimal decision-making functions for suppliers, retailers and banks are:

$$U\left(\pi_s^{M*}(g)\right) = \frac{w(a-w-2\eta\sigma)(1-\rho)\left(G-\lambda c\sqrt{G(1-\beta\rho)}\right)}{2G} \tag{16}$$

$$E\left(\pi_r^{M*}(p)\right) = \frac{(1-\rho)\left(\left(\lambda^2 c-ak+wk\right)\sqrt{G(1-\beta\rho)}-\lambda G\right)^2}{4k^2 G(1-\beta\rho)} \tag{17}$$

$$EY^{M*}(r) = \frac{w}{2k}\left(2\lambda\sqrt{G(1-\beta\rho)}+\rho k(1-\beta)(a-w)-\lambda^2 c(1-\beta\rho)\right) \tag{18}$$

Corollary 2:

(1) $\frac{\partial g^*}{\partial\lambda} < 0$; $\frac{\partial r^*}{\partial\lambda} > 0$; $\frac{\partial U\left(\pi_s^{M*}(g)\right)}{\partial\lambda} < 0$; $\frac{\partial EY^{M*}(r)}{\partial\lambda} > 0$;

(2) When $0 < \lambda < \frac{\sqrt{G}}{2c\sqrt{1-\beta\rho}}$, $\frac{\partial p^*}{\partial\lambda} > 0$, $\frac{\partial E\left(\pi_r^{M*}(p)\right)}{\partial\lambda} > 0$;

When $\frac{\sqrt{G}}{2c\sqrt{1-\beta\rho}} < \lambda < 1$, $\frac{\partial p^*}{\partial\lambda} < 0$, $\frac{\partial E\left(\pi_r^{M*}(p)\right)}{\partial\lambda} < 0$;

(3) $\frac{\partial U\left(\pi_s^{M*}(g)\right)}{\partial\eta} < 0$.

Proof of Corollary 2:

(1) $\frac{\partial g^*}{\partial \lambda}=-\frac{c}{k}<0$; $\frac{\partial r^*}{\partial \lambda}=\frac{w\sqrt{G(1-\beta\rho)}}{G}>0$;

$\frac{\partial U\left(\pi_s^{M*}(g)\right)}{\partial \lambda}=-\frac{wc(a-w-2\eta\sigma)(1-\rho)\sqrt{G(1-\beta\rho)}}{2G}<0$;

$\frac{\partial EY^{M*}(r)}{\partial \lambda}=\frac{w\left(\sqrt{G(1-\beta\rho)}-\lambda c(1-\beta\rho)\right)}{k}>0$;

(2) $\frac{\partial p^*}{\partial \lambda}=\frac{G-2\lambda c\sqrt{G(1-\beta\rho)}}{2k\sqrt{G(1-\beta\rho)}}$;

$$\frac{\partial E\left(\pi_r^{M*}(p)\right)}{\partial \lambda}$$
$$=\frac{(1-\rho)\left(\left(\lambda^2 c-ak+wk\right)\sqrt{G(1-\beta\rho)}-\lambda G\right)\left(2\lambda c\sqrt{G(1-\beta\rho)}-G\right)}{2k^2 G(1-\beta\rho)}$$

From $\frac{\partial p^*}{\partial \lambda}=0$, $\frac{\partial E\left(\pi_r^{M*}(p)\right)}{\partial \lambda}=0$, it is obtained: $\lambda=\frac{\sqrt{G}}{2c\sqrt{1-\beta\rho}}$;

So when $0<\lambda<\frac{\sqrt{G}}{2c\sqrt{1-\beta\rho}}$, $\frac{\partial p^*}{\partial \lambda}>0$, $\frac{\partial E\left(\pi_r^{M*}(p)\right)}{\partial \lambda}>0$;

When $\frac{\sqrt{G}}{2c\sqrt{1-\beta\rho}}<\lambda<1$, $\frac{\partial p^*}{\partial \lambda}<0$, $\frac{\partial E\left(\pi_r^{M*}(p)\right)}{\partial \lambda}<0$;

(3) $\frac{\partial U\left(\pi_s^{M*}(g)\right)}{\partial \eta}=-\frac{w\sigma(1-\rho)\left(G-\lambda c\sqrt{G(1-\beta\rho)}\right)}{G}<0$;

Inference 2 shows that, in the model M , with the increase of the green sensitivity coefficient, the optimal product greenness and the utility profit of the supplier with middle credit rating are reduced, and the optimal loan interest rate and the expected profit of the bank are gradually increased. When the value of λ is small, the optimal sales price and the expected profit of the retailer are in direct proportional to the green sensitivity coefficient. Conversely, when the value of λ is large, the optimal sales price and the expected profit of the retailer are inversely proportional to the green sensitivity coefficient. And the risk avoidance extent of suppliers is inversely proportional to their own utility profits. This shows that the increase of the green sensitivity coefficient will add the pressure to suppliers. Consumers' high environmental awareness is not an advantage for suppliers with middle credit rating, which may lead to the severe capital gap because of the increase of suppliers green R&D costs of. Therefore, with the increase of loan interest rates, the performance of banks also rises.

C. *Mixed Financing (High Credit Rating H Model)*

When the suppliers' credit rating is high, in order to encourage suppliers to produce products with higher greenness, retailers may pay part of the payment twq in advance without interest, then suppliers apply for a loan from the bank. At this time, the financing amount from the bank is $L_1=cq+\frac{1}{2}kg^2-twq$. Compared with bank loans that require collateral or guarantees and face outflow of profits from the supply chain, suppliers obviously prefer that retailers may pay in advance. The bankruptcy risk is still shared by suppliers, retailers and banks. Since part of the payment twq is paid to suppliers in advance, whether suppliers go bankrupt or not, retailers will have to pay this payment. The corresponding profits of suppliers and retailers are:

$$\pi_s^H(g)=\left((1-t)wq-L_1(1+r)\right)(1-\rho) \tag{19}$$

$$\pi_r^H(p)=\left(pq-(1-t)wq\right)(1-\rho)-twq \tag{20}$$

Similarly, their decision-making objective functions are:

$$U\left(\pi_s^H(g)\right)=(1-\rho)\begin{pmatrix}(1-t)w(a-p+\lambda g\text{-}\eta\delta)\\-\left((c-tw)(a-p+\lambda g\text{-}\eta\delta)+\frac{1}{2}kg^2\right)(1+r)\end{pmatrix} \tag{21}$$

$$E\left(\pi_r^H(p)\right)=\left(p-(1-t)w\right)(a-p+\lambda g)(1-\rho)-tw(a-p+\lambda g) \tag{22}$$

In a similar way, when the supplier operates normally, the bank's income is the sum of the principal and interest $L_1(1+r)$; Conversely, when the supplier goes bankrupt, the bank can only get a part of the supplier's income $(1-\beta)(1-t)wq$, so the bank's income and expected profit are:

$$Y^H=\begin{cases}L_1(1+r) & ,1-\rho\\(1-\beta)(1-t)wq & ,\rho\end{cases} \tag{23}$$

$$EY^H(r)=E\left((1-\rho)L_1(1+r)+\rho(1-\beta)(1-t)wq\right) \tag{24}$$

$$=(1-\rho)\left((c-tw)(a-p+\lambda g)+\frac{1}{2}kg^2\right)(1+r)+\rho(1-\beta)(1-t)w(a-p+\lambda g) \tag{25}$$

In the model H , let

Theorem 5:

$N=k(c-tw)(a-w-a\rho+w\rho-tw\rho)$

$A=a-w-a\rho+w\rho-tw\rho$

$B=k(c-tw)(a-w-a\rho+w\rho-tw\rho)-\lambda(c-tw)\sqrt{N(1-\beta\rho)}$

Similarly, it is assumed that the following conditions are established, and the optimal solution is of practical significance:

$\lambda w(1-t)\sqrt{1-\beta\rho}>\sqrt{N}>\lambda(c-tw)\sqrt{1-\beta\rho}>0$,

$A=a-w-a\rho+w\rho-tw\rho>2\eta\delta(1-\rho)$;

(1) The optimal green degree of the supplier's products is $g^*=\frac{B}{k\sqrt{N(1-\beta\rho)}}$,the retailer's optimal sales price is

$$p^*=\frac{(\lambda B(1-\rho)+(a+w-a\rho-w\rho+tw\rho)k\sqrt{N(1-\beta\rho)})}{2k(1-\rho)\sqrt{N(1-\beta\rho)}}$$

The bank's optimal interest rate of loan is $r^*=\frac{\lambda w(1-t)\sqrt{N(1-\beta\rho)}-N}{N}$;

Proof of Theorem 5:

From $\frac{\partial U\left(\pi_{s}^{H}(g)\right)}{\partial g}=0$, $\frac{\partial E\left(\pi_{r}^{H}(p)\right)}{\partial p}=0$, it can be obtained:

$$g^{\sim}=\frac{\lambda\left(w(1-t)-(c-tw)(1+r)\right)}{k(1+r)}$$

$$p^{\sim}=\frac{\left(a+\lambda g^{\sim}+(1-t)w\right)(1-\rho)+tw}{2(1-\rho)}$$

Bring the above results back to $EY^{H}(r)$, from $\frac{\partial EY^{H}(r)}{\partial r}=0$ the optimal solution of interest rates is obtained:

When $\lambda w(1-t)\sqrt{N(1-\beta\rho)}-N>0$, there exists

$$r^{*}=\frac{\lambda w(1-t)\sqrt{N(1-\beta\rho)}-N}{N}$$

Then get the optimal greenness g^{*} and the optimal sales price p^{*}

$$g^{*}=\frac{B}{k\sqrt{N(1-\beta\rho)}}$$

$$p^{*}=\frac{(a+w-a\rho-w\rho+tw\rho)k\sqrt{N(1-\beta\rho)}+\lambda B(1-\rho)}{2k(1-\rho)\sqrt{N(1-\beta\rho)}}$$

(2) The optimal decision-making functions for suppliers, retailers and banks are:

$$U\left(\pi_{s}^{H*}(g)\right)=\frac{w(1-t)(A-2\eta\delta+2\eta\delta\rho)B}{2N}$$

$$E\left(\pi_{r}^{H*}(p)\right)=\frac{\left(kA\sqrt{N(1-\beta\rho)}+\lambda B(1-\rho)\right)^{2}}{4k^{2}(1-\rho)N(1-\beta\rho)}$$

$$EY^{H*}(r)=\frac{(1-t)w}{2k(1-\rho)\sqrt{N(1-\beta\rho)}}\begin{pmatrix}\lambda(1-\rho)(1-\beta\rho)(N+B)\\+kA\rho(1-\beta)\sqrt{N(1-\beta\rho)}\end{pmatrix}$$

Corollary 3:

(1) $\frac{\partial g^{*}}{\partial\lambda}<0$; $\frac{\partial r^{*}}{\partial\lambda}>0$; $\frac{\partial U\left(\pi_{s}^{H*}(g)\right)}{\partial\lambda}<0$; $\frac{\partial EY^{H*}(r)}{\partial\lambda}>0$;

(2) When $0<\lambda<\frac{\sqrt{N}}{2(c-tw)\sqrt{1-\beta\rho}}$,

$\frac{\partial p^{*}}{\partial\lambda}>0,\frac{\partial E\left(\pi_{r}^{H*}(p)\right)}{\partial\lambda}>0$;

When $\frac{\sqrt{N}}{2(c-tw)\sqrt{1-\beta\rho}}<\lambda<1$,

$\frac{\partial p^{*}}{\partial\lambda}<0,\frac{\partial E\left(\pi_{r}^{H*}(p)\right)}{\partial\lambda}<0$;

(3) $\frac{\partial U\left(\pi_{s}^{H*}(g)\right)}{\partial\eta}<0$.

Proof of Corollary 3:

(1) $\frac{\partial g^{*}}{\partial\lambda}=-\frac{c-tw}{k}<0$; $\frac{\partial r^{*}}{\partial\lambda}=\frac{w(1-t)(1-\beta\rho)}{\sqrt{N(1-\beta\rho)}}>0$;

$$\frac{\partial U\left(\pi_{s}^{H*}(g)\right)}{\partial\lambda}=-\frac{w(1-t)(c-tw)(A-2\eta\delta+2\eta\delta\rho)\sqrt{N(1-\beta\rho)}}{2N}<0;$$

$\frac{\partial EY^{H*}(r)}{\partial\lambda}=\frac{w(1-t)(1-\beta\rho)B}{k\sqrt{N(1-\beta\rho)}}>0$;

(2) $\frac{\partial p^{*}}{\partial\lambda}=\frac{N-2\lambda(c-tw)\sqrt{N(1-\beta\rho)}}{2k\sqrt{N(1-\beta\rho)}}$,

$$\frac{\partial E\left(\pi_{r}^{H*}(p)\right)}{\partial\lambda}=\frac{2\left(kA\sqrt{N(1-\beta\rho)}+\lambda B(1-\rho)\right)\left(N-2\lambda(c-tw)\sqrt{N(1-\beta\rho)}\right)}{4Nk^{2}(1-\beta\rho)}$$

From $\frac{\partial p^{*}}{\partial\lambda}=0$, $\frac{\partial E\left(\pi_{r}^{H*}(p)\right)}{\partial\lambda}=0$, it is obtained:

$$\lambda=\frac{\sqrt{N}}{2(c-tw)\sqrt{1-\beta\rho}},$$

When $0<\lambda<\frac{\sqrt{N}}{2(c-tw)\sqrt{1-\beta\rho}}$,

$\frac{\partial p^{*}}{\partial\lambda}>0,\frac{\partial E\left(\pi_{r}^{H*}(p)\right)}{\partial\lambda}>0$;

When $\frac{\sqrt{N}}{2(c-tw)\sqrt{1-\beta\rho}}<\lambda<1$,

$\frac{\partial p^{*}}{\partial\lambda}<0,\frac{\partial E\left(\pi_{r}^{H*}(p)\right)}{\partial\lambda}<0$;

(3) $\frac{\partial U\left(\pi_{s}^{H*}(g)\right)}{\partial\eta}=-\frac{w\sigma(1-t)(1-\beta)B}{N}<0$;

Inference 3 shows that, in the model H , the optimal product greenness and the utility profit of the supplier are in inversely proportional to the green sensitivity coefficient, the optimal loan interest rate and the expected profit of the bank are direct proportional to the green sensitivity coefficient. When $0<\lambda<\frac{\sqrt{N}}{2(c-tw)\sqrt{1-\beta\rho}}$, the optimal sales price and the expected profit of the retailer are direct proportional to the green sensitivity coefficient. When $\frac{\sqrt{N}}{2(c-tw)\sqrt{1-\beta\rho}}<\lambda<1$, the optimal sales price and the expected profit of the retailer are inversely proportional to the green sensitivity coefficient. At the same time, the utility profit of suppliers with high credit rating will also decrease with the increase of their risk avoidance degree.

The sensitivity coefficient of high greenness does not correspond to high greenness products, which may be because consumers' preference for green products is not equivalent to paying for them in reality. On the one hand, green products seem to be associated with weak performance in the public's impression, for example, the range performance of green electric vehicles is always inferior to that of corresponding gasoline vehicles. On the other hand, the prices of green products are relatively high, and consumers have not paid for green products due to limited budgets. Therefore, enterprises and governments should vigorously promote green products, allowing consumers to experience the advantages of green products in addition to benefiting society. Subsidies can also be used to reduce consumer usage costs and promote green consumption.

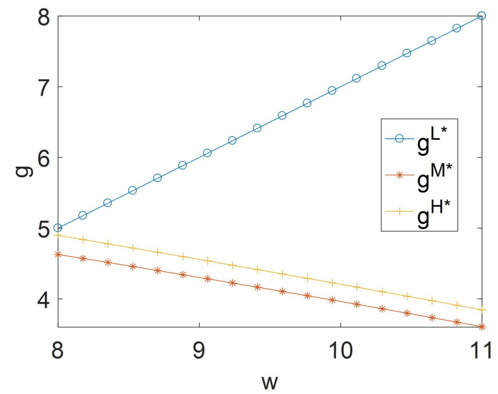
V. Numerical Examples

In this section, it uses MATLAB to conduct numerical experiments to visually analyze the impact of wholesale prices, green sensitivity coefficients and risk avoidance extent on the strategic choices of suppliers, retailers and banks and their respective profits. The assumptions of relevant parameter assignment are as follows:

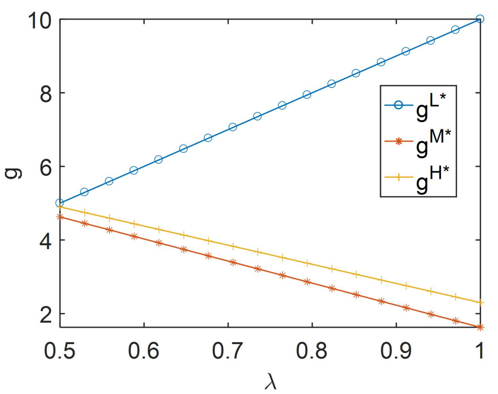
$a = 20$, $c = 3$, $\rho^L = 0.5$, $\rho^M = 0.2$, $\rho^H = 0.1$, $k = 0.5$, $t = 0.05$, $\beta = 0.05$, $\sigma = 10$.

A. The Impact of w and λ on the Optimal Greenness under Different Credit Ratings

Analyze how w and λ in different financing models under suppliers' credit rating index affect the optimal greenness of products, and how can motivate suppliers to produce products with higher greenness. Let $\eta = 0.5$, in Fig. 2 (a) - Fig. 7 (a), $w \in (8,11)$, $\lambda = 0.5$; in Fig. 2 (b) - Fig. 7 (b), $w = 8$, $\lambda \in (0.5,1)$.



(a)



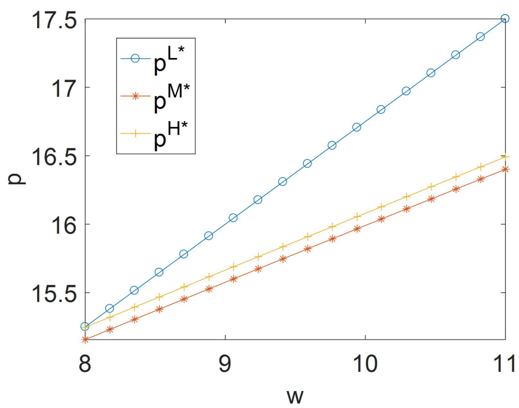
(b)

Fig. 2. The Optimal Greenness under Different Credit Rating

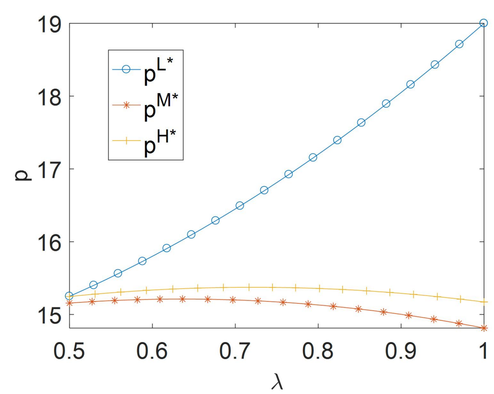
As illustrated in Fig. 2, the greenness of products produced by suppliers with low credit rating gradually increases with the increase of wholesale prices and green sensitivity coefficients. The greenness of products produced by suppliers with middle and high credit rating gradually decreases with the increase of wholesale prices and green sensitivity coefficients. In addition, the greenness of products under low credit ratings is always the highest, followed by high credit ratings, and finally middle credit ratings.

For small and medium-sized enterprises, they were initially rated as low-credit rating enterprises by third-party rating institutions due to insufficient solvency and capital turnover. During the process of operation, they may master core technologies to produce green products, which means that the enterprise has great potential for development, so they will apply to third-party institutions for credit rating again. The improvement of credit rating is of great significance to enterprises. With high credit rating, it will be easier to obtain financing from various channels, increase the risk resistance of enterprises, expand their scale, and improve their operating profits. By virtue of the advantages of financing channels, the greenness of products from suppliers with high credit rating is slightly higher than that of suppliers with middle credit rating. Research shows that when the credit rating is higher than a certain threshold, the improvement of enterprise credit rating will promote the improvement of product greenness.

B. The Impact of w and λ on the Optimal Sales Prices under Different Credit Ratings



(a)

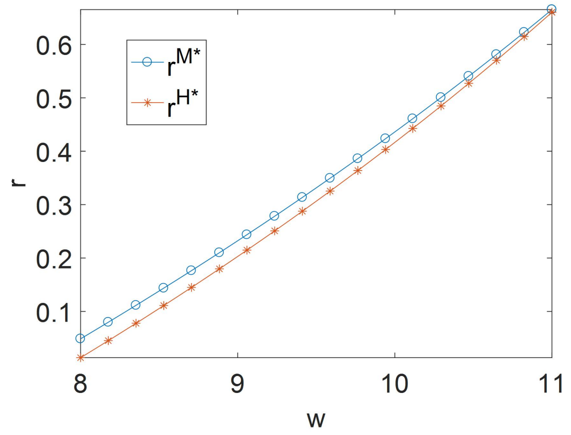


(b)

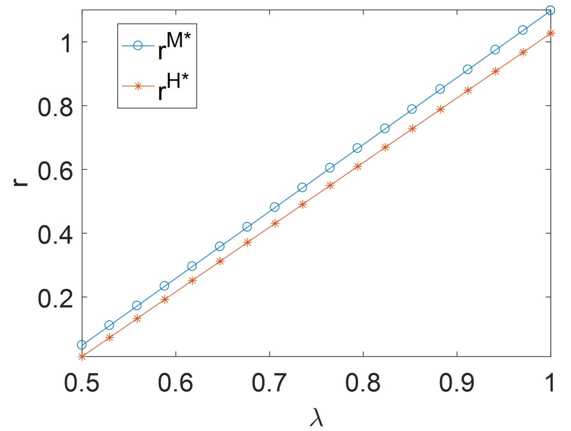
Fig. 3. The Optimal Sales Prices under Different Credit Rating

Fig. 3 illustrates that the increase of wholesale prices will lead to the increase of sales prices. The sales price under low credit rating is directly proportional to the green sensitivity coefficient, and the sales price under middle and high credit ratings increases firstly and then decreases with the increase of the green sensitivity coefficient. Similar results are presented about how the sales price is affected by the wholesale price and the greenness of the product under different credit ratings. When the green sensitivity coefficient is low, retailers may increase the sales price accordingly in order to maximize their own interests. When the green sensitivity coefficient is high, most consumers usually choose high green products sold by retailers who cooperate with low credit rating suppliers. In reality, some enterprises will maintain their performance through discount and other promotion means.

C. The Impact of w and λ on the Optimal Interest Rate of Loan under Different Credit Ratings



(a)

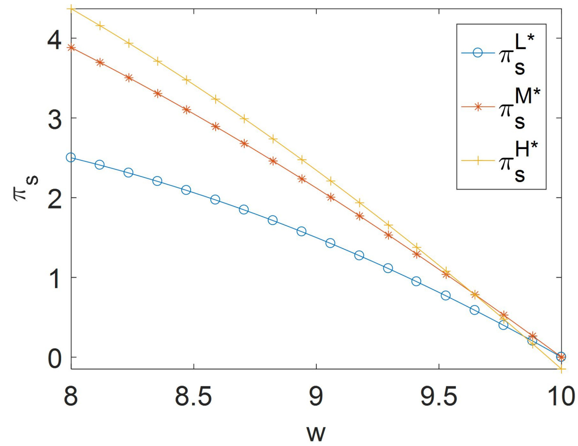


(b)

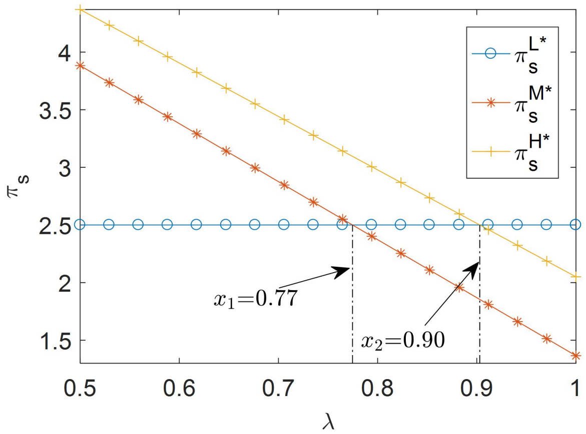
Fig. 4. The Optimal Interest Rate of Loan under Different Credit Rating

Fig. 4 shows that the wholesale price and the green degree sensitivity coefficient are directly proportional to the interest rate of bank loan. The loan interest rate of the middle credit rating is always higher than the loan interest rate under the high credit rating. And the higher the wholesale price, the similar the loan interest rate of the middle and high credit rating. While the lower the green degree sensitivity coefficient, the similar the loan interest rate of the middle and high credit rating. This shows that when the wholesale price of the product is high, the reference value of suppliers' credit rating is weaker for the interest rate bank loans. Correspondingly, the decline in the green sensitivity coefficient will reduce the influence of the enterprise's credit rating. In the market, suppliers with high credit rating can choose to produce products with low wholesale prices and high consumer demand to expand their own advantages. On the contrary, suppliers with middle credit rating may choose to produce products with high wholesale prices and low consumer demand.

D. The Impact of w and λ on Suppliers' Utility Profits under Different Credit Ratings



(a)



(b)

Fig. 5. Suppliers' Utility Profits under Different Credit Rating

As depicted in Fig. 5, as wholesale prices rise, the utility profits of suppliers will gradually decrease. The wholesale price is directly proportional to the credit rating and the utility profit of the supplier within a certain range. For the utility profit of suppliers with middle and high credit rating, the greenness sensitivity coefficient is inversely proportional to the credit rating. There are two thresholds, $\lambda_1 = 0.77$ and $\lambda_2 = 0.90$. When these two thresholds are exceeded, low rated suppliers have a moderate failure rate for random events, resulting in higher profits for low credit rated suppliers.

This shows that the supplier itself lacks the motivation to produce green products. Even having the financing channels, the suppliers' utility profit is still not considerable. In the later stage, suppliers can be stimulated to produce by coordinating contracts. At the same time, the improvement of credit rating may promote the increase of suppliers' profits. For suppliers with low credit rating, improving credit rating is a good way to improve the viability and operation capacity of enterprises.

E. The Impact of w and λ on Retailers' Expected Profits under Different Credit Ratings

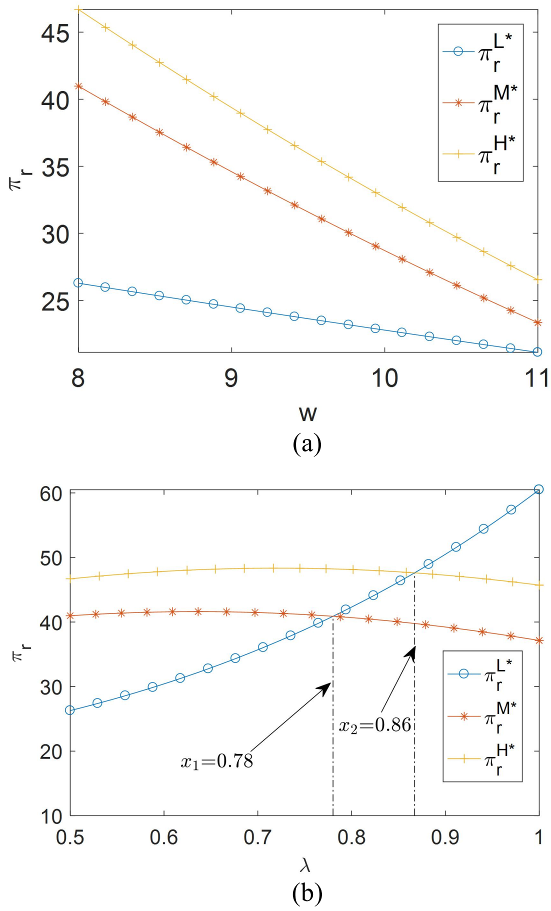


Fig. 6. Retailers' Expected Profits when Cooperating with Suppliers with Different Credit Rating

It can be seen from Fig. 6 that the wholesale price is always inversely proportional to the expected profit of retailers. On this basis, the expected profit of retailers increases with the improvement of credit rating. For retailers who cooperate with low credit rating suppliers, the green sensitivity coefficient is positively related to their expected profit. For retailers who work with middle and high rating suppliers, their expect profits will increase first and then gradually decrease as the green sensitivity factor increases.

Similar to the conclusion in Fig. 5, there are also two thresholds, $\lambda_1 = 0.78$ and $\lambda_2 = 0.86$. When these two thresholds are exceeded, partnering with low credit rated suppliers enables retailers to achieve higher profits than partnering with medium to high credit rated suppliers. In real life, when consumers' environmental awareness is not particularly strong, for retail enterprises, the higher the credit rating of suppliers they cooperating with is, the higher their expected profit will be. If consumers take green as the first consideration factor as they buy products, it may bring unexpected performance income when retailers cooperate with low-credit rating suppliers.

F. The Impact of w and λ on Banks' Expected Profits under Different Credit Ratings

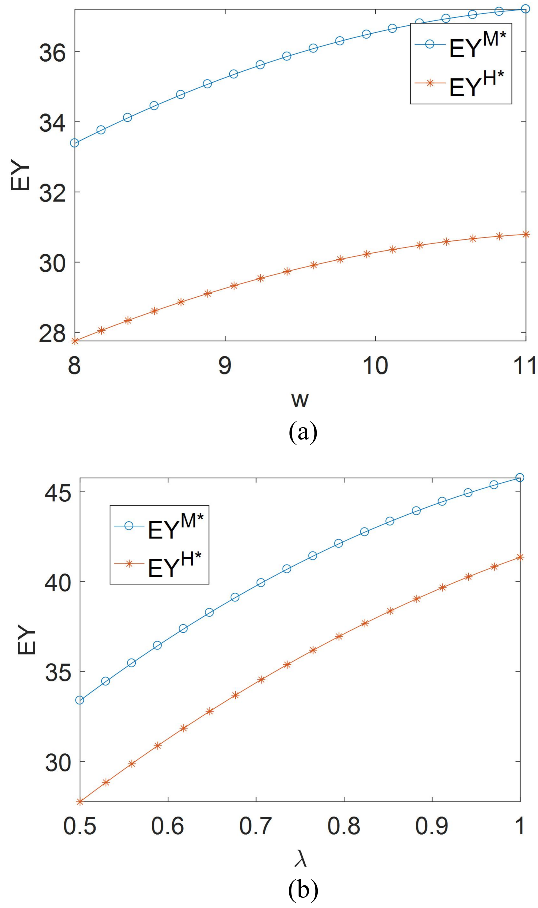


Fig. 7. Banks' Expected Profit when Cooperating with Suppliers with Different Credit Rating

As shown in Fig. 7, with the increase of wholesale price and green sensitivity coefficient, the expected profit of banks gradually increases. When the wholesale price and green sensitivity coefficient are high, the growth rate of banks' expected profit gradually slows. The expected profit of banks when cooperating with middle credit rating suppliers is higher than the expected profit when cooperating with high credit rating suppliers. In reality, the higher the credit rating of the supplier, the more favorable the loan interest rate it may obtain. In addition, the total amount of loans is relatively low. Although the risk of bankruptcy of suppliers is lower, working with such suppliers may not be the optimal choice for the banks' performance profits.

G. The Impact of η on the Suppliers' Utility Profit under Different Credit Ratings

The impact of suppliers' risk avoidance extent on their utility profits under different credit ratings is analyzed. The influence of risk neutral and risk avoidance factors on the decision-making of supply chain members is also studied. The relevant numerical values are assumed as follows: let $w = 8$, $\lambda = 0.5$, $\eta \in (0, 0.5)$, the corresponding results are showed in Fig. 8.

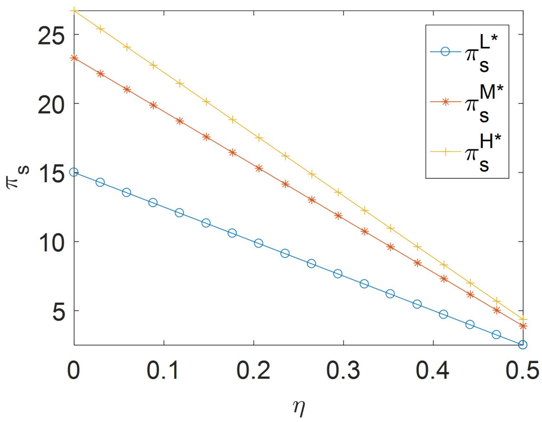


Fig. 8. Impact of Suppliers' Risk Avoidance Extent on their Utility Profits

As depicted in Fig. 8, with the increase of η, the suppliers' risk avoidance extent is inversely proportional to the suppliers' utility profit, that is, the higher the suppliers' risk aversion extent is, the lower their utility profit will be. When $\eta = 0$, the suppliers are risk-neutral, at this time, the suppliers' utility profit is the highest.

VI. Conclusion

Based on the practical problems of capital constraints faced by suppliers, this paper builds a suppliers utility function with risk preference and the expected profit function of retailers and banks. According to different credit ratings of suppliers, the optimal decision-making of suppliers and retailers and the differentiated green credit financing strategy of banks are given. The impact of product wholesale price, green sensitivity coefficient and suppliers' risk avoidance extent on the pricing and decision-making of supply chain members is analyzed, and the conclusions are as following:

(1) From the perspective of product greenness, the greenness of the products produced by suppliers with high credit rating is higher than that produced by suppliers with middle credit rating. But the greenness of products produced by suppliers with low credit rating is the highest among all of them. The accompanying R&D costs and capital constraints problems need to be alleviated by introducing financing instruments. Therefore, for suppliers with low credit rating, it is urgent to improve their credit ratings, which is also conducive to the virtuous circle of the whole market.

(2) In the two financing channels (banks' green credit and mixed financing), the banks' interest rate for the loans to different suppliers decreases as their credit rating increases. This means that for suppliers, improving their own credit rating makes it easier to obtain lower-interest bank loans.

(3) The higher the suppliers' risk avoidance extent is, the lower their utility profit will be. When suppliers are risk neutral, their utility profit is the highest. However, when suppliers develop and produce green products by themselves, their own utility profits are not very considerable. In fact, mid-stream and upper-stream enterprises can take measures to encourage suppliers to produce green products, so as to achieve win-win cooperation.

(4) In general, retailers prefer to cooperate with suppliers with high credit ratings. However, when consumers have a high environmental awareness, retailers who cooperate with suppliers with low credit ratings may obtain higher returns.

(5) For the banks, it is more inclined to cooperate with middle credit rating suppliers, at which time the banks' income will be maximized. However, based on the consideration of encouraging suppliers to produce green products, when banks cooperate with high credit rating suppliers, the greenness of products in the market will be improved. Which has a certain enlightening effect on government management.

There are still some shortcomings in our research. For example, this paper only considers the risk preferences of suppliers. Both retailers and banks are risk neutral. In real life, the risk preferences of retailers and banks will also affect the production, pricing and financing decisions of supply chain members. Therefore, considering the risk preferences of other members of the supply chain is of practical significance. In addition, the initial funds have not been taken into consideration in this paper, so the follow-up research may study from this direction in the future.

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