ABSTRACT

A financing model for bank loan financing, equity financing, and portfolio financing under the manufacturer’s capital constraints is constructed, and the manufacturer’s capital level and consumers are discussed in green preference on pricing, green input level, market demand for products, and selection strategies of financing methods. Finally, it is verified by numerical analysis. Consumers’ green preference is positively correlated with retail prices, wholesale prices and the level of green investment efforts, market demand for products, and equity transfer ratios acceptable to both parties in equity financing; when the manufacturer’s capital constraints are not financing, the manufacturer’s initial capital level is positively correlated with manufacturer’s wholesale price, and retailer’s retail price are negatively correlated, but it is positively correlated with the level of green investment efforts; the greater the bank loan interest rate, the larger the manufacturer’s acceptable share transfer ratio.

KEYWORDS

Debt Financing, Equity Financing, Fund Constraint, Portfolio Financing

1. INTRODUCTION

With the rapid development of human society and economy, it has also brought some threats to mankind, such as lack of resources, environmental pollution and climate warming (Zheng Y., Hu F., & Xu Y. J., 2012). As a result, people began to reflect on the social and economic development model. As the concept of “green” and “low-carbon” development gradually became popular, creating a sustainable, environmentally friendly and resource-saving society has gradually become the common development target in the whole society (Zhu Q. H., & Cote R. P., 2004). With the deepening of consumers’ awareness of environmental pollution and consumers’ demand for green products increases, the green production of enterprises can not only obtain more benefits, but also obtain better reputation and competitiveness (Srivastava S. K., 2007). Companies have joined the green production plan (Wati Y., & Koo C., 2010; Dai Y. S., 2011). BBMG’s (BBMG is a branding and social impact consultancy in NYC and San Francisco, https://bbmg.com/) consumer report shows that 51% of Americans are willing to buy green products at a higher price, and 67% regard the environmental performance of the product as a determinant of whether to purchase or not (Bemporad R., & Baranowski M., 2020).

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manufacturer can sell products to customers either through a direct marketing channel or through a traditional retail channel. The level of advertising investment and supply chain profits of centralized and decentralized dual-channel supply chains are analysed based on a Stackelberg game (Zhang X. M., et al, 2021). Then, the decision models of dual-channel supply chain under different contracts are constructed, and how manufacturers can optimize the profits of both sides through an effective coordination mechanism is analyzed. In determining long and short-term success of many companies, demand forecasting with maximum accuracy is absolutely critical to invest in various fields, which places the knowledge extract process in high demand. A hybrid approach of prediction into a demand forecasting process in supply chain is proposed based on the one hand, on the processes analysis for best professional knowledge for required competencies (Brahami M., et al, 2022). And on the other hand, the use of different data sources by supervised learning to improve the process of acquiring explicit knowledge, maximizing the efficiency of the demand forecasting. The establishment of online direct sales channels influences the selection of pricing strategies and promotion information disclosure strategies of manufacturers and retailers. The influence of different promotion information disclosure modes on the promotion effect and the income of supply chain members in the dual-channel supply chain with direct online channels are studied (Duan Q., & Li C. C., 2021). Based on hoteling model, the authors establish a model on market demand of the two channels and analyze the pricing and disclosure strategies of manufacturers and retailers under different concerns of consumers. It is found that there is a unique equilibrium threshold between the two disclosure modes. The corporate financial constraints has also become the focus of common concern in the business community and academia. This article does some research of investment and financing on green supply chain, so that each main body on the green supply chain can find a suitable way of investment and financing.

For the financing models of capital-constrained companies in the supply chain, there are mainly trade credit (deferred payment and advance payment) and bank loans. Trade credit requires companies with sufficient funds within the supply chain. The credit threshold for bank loans is relatively high. Due to various reasons such as lack of credit records, insufficient collateral, and imperfect financial service institutions, the vast majority of SMEs (Small and Medium Enterprises) still cannot solve the problem of financial constraints. This has also attracted great attention from the country and society, and has continuously increased the innovation of financial service structure and financial service products, such as asset mortgage, equity pledge, green finance and so on. As a result, the financing model of SMEs extends from debt financing to equity financing. Equity financing has become an important financing channel for growth companies to achieve leap-forward development. The revised pecking order theory believes that equity financing is more conducive to growing companies than internal financing and bank borrowing (Myers S. C.,1977).

The following questions are raised based on the above case analysis:

- How to choose between bank loans and equity financing for capital-constrained enterprises?
- What is the difference between the optimal decisions of retailers and manufacturers under different financing models?
- What impact does consumers’ green preference on the optimal decision-making and financing strategy selection of each participant in the supply chain?
- What impact does the equity transfer ratio of the combined financing (bank lending and equity financing) on the optimal decision-making and financing strategy selection of each participant in the supply chain?

In order to answer these questions, a green supply chain is composed of a retailer and a capital-constrained manufacturer, the green supply chain is taken as the research object, and the income model of the participants in the supply chain is established without capital constraints or with capital constraints (bank lending and equity financing). The pricing and green production input decisions of the company are analyzed under various models, and the decision variables are optimized and
compared under different financing modes. The relevant parameters’ influence is analyzed on the optimal decision variables and the choice of financing mode. Under combined financing (bank lending and equity financing), the optimal decision-making, income and equity transfer ratio of each participant are analyzed in the green supply chain, and their impact are studied on optimal decision-making and financing and participants’ strategic choices.

2. RELATED RESEARCH

2.1 Operation and Management in Green Supply Chain

With the increase of consumers’ green preference, the greenness of products not only affects the market demand for products, but also affects the pricing of products by enterprises, which in turn affects the decision-making of other enterprises in the supply chain. Currently, scholars have studied the impact of consumers’ green preferences on the operation and management of green supply chains from different perspectives. In the case of competition for multiple supply chains, a comparative study of the influence for consumers’ low-carbon preferences is made on the optimal decision-making of the supply chain (Liu Z. G., Anderson T. D., & Cruz J. M., 2012). In the green supply chain, the influence of consumers’ green preference has been studied on operational decision-making (Gao P., Nie J. J., & Xie Z. Q., 2013), and it is believed that consumers’ green preference has a significant influence on the operational decision-making of the supply chain. Under centralized and decentralized decision-making, the influence of consumers’ low-carbon preference is analyzed on carbon emission reduction decisions and supply chain performance of the supply chain (Du S. F., Zhu J. A., Jiao H. F., et al., 2015), and the conditions for supply chain coordination are studied under revenue sharing and quantity discount contracts. In a perfectly competitive market and different dominance modes, the influence of the optimal decision-making of the supply chain and consumers’ low-carbon preference is researched on the optimal decision-making, the profit and emission reduction level of the supply chain (Wang Q. P., Zhao D. Z., & He L. F., 2016). In the closed-loop supply chain, the impact of consumers’ environmental awareness is studied on product market demand (Xu Y. M., & Xie H. Z., 2016), and on this basis, the conditions are analyzed for the coordination of revenue sharing contracts. In the case that consumers’ low-carbon preference and sales efforts jointly affect market demand, the optimal decision-making of the dual-channel supply chain and the influence of consumers’ low-carbon preference are analyzed on the optimal decision (Ji J. N., Zhang Z. Y., & Yang L., 2017). In the above research, the impact of consumers’ green preferences is analyzed on the operational decisions of the green supply chain, but the financial constraints are not considered in the supply chain.

2.2 Supply Chain Operations and Financing

The financing methods of SMEs mainly include bank loans, trade credit and equity financing. The existing literature mainly studies the operation and financing decisions of the supply chain under bank lending and trade credit financing. For example, the related literature under bank lending methods discusses the importance of bank credit to solve the problem of supply chain funding constraints from different perspectives, as well as the necessity of interactive decision-making between operations and financing (Xu X. D., & Birge J. R., 2020; Buzacott J. A., & Zhang R. Q., 2004; Dada M., & Hu Q. J., 2008; Kouvelis P., & Zhao W., 2009; Chod J., & Zhou J., 2014; Luo W., & Shang K. J., 2015).

Most of the relevant literature under the trade credit method are based on the EOQ (Economic Order Quantity Model) model to study the optimal credit period and inventory strategy in trade credit (Babitch V., et al., 2007; Lai G., Debo L. G., & Sycara K., 2009; Gupta D., & Wang L., 2009; Yang S. A., & Birge J., 2011; Jing B., Chen X., & Cai G., 2012). However, there is less literature on supply chain operation and financing under equity financing. In the case of complete information and incomplete information, the impact of invisible equity under accounts receivable financing is analyzed on the decision-making and income of financing companies, core companies and banks.
(Wang Z. R., et al., 2015), equity companies have lower financing costs. In the absence of competition and competition in the market, a comparative analysis of retailers’ equity financing strategies is made (Wang Y., & Yu H., 2018), market competition is not conducive to retailers’ equity financing, but it can increase the shareholding ratio and profits of original shareholders.

When a financing enterprise can choose a variety of financing methods, how to choose it, and how to determine the operation and financing decisions of its related participants are also one of the issues that must be considered by all participants in the capital-constrained supply chain. The existing related literature mainly focuses on the comparative study of bank lending and trade credit. For example, based on the newsboy model, a comparative analysis of bank lending and supplier lending patterns is carried out (Kouvelis P., & Zhao W. H., 2012), and the selection boundary of the two financing options is given. Under the condition of the supplier’s financial constraints, the supplier’s production decision is analyzed by comparing the retailer’s advance payment and bank borrowing financing schemes (Wang W. L., & Luo J. W., 2013). Under the bank financing and trade credit model, when all supply chain participants have financial constraints, it is analyzed that price discounts, two-part pricing, repurchase, and revenue sharing can only coordinate the supply chain under bank lending (Lee C. H., & Rhee B. D., 2010), but cannot coordinate the supply chain of the trade credit. There are few comparative studies on bank lending and equity financing.

When financially constrained retailers conduct bank loans and equity financing, the decisions and benefits of participating entities have been studied (Fang L., Xia Y., & Yang Y. M., 2018), and the initial capital affects the retailer’s choice of financing methods. Under the condition of retailer’s financial constraints, when considering cooperation and non-cooperation, the choice of retailer’s debt financing and equity financing is researched (Yu H., & Wang Y., 2018). Supply chain cooperation, enterprise growth and valuation level will affect the choice of financing methods of enterprises. Under the retailer’s investment-loan linkage strategy, the choice of revenue sharing contract and wholesale price contract is studied (Li X., & Yu H., 2020). The choice of supply chain contract structure depends on coordination benefits and coordination costs.

With the development of the market economy and the deepening of financial reforms, the combined financing based on a single financing method is gradually being carried out in corporate practice. Under the financial constraints, the selection is researched between retailer’s bank lending and trade credit portfolio financing strategy (Jin W., & Luo J. W., 2018), the supplier’s risk aversion degree affects the degree to which they provide transaction credit. In the dual-channel fresh agricultural product supply chain, the bank borrowing, deferred payment and their combined financing of capital-constrained retailers have been studied (Tang R. H., & Yang L., 2020). The deferred payment and the combined financing are more beneficial to retailers. In view of this, the combined financing of bank lending and equity financing is introduced into the green supply chain operation and financing delivery decision, and it is compared with the interactive decision of single bank lending and pure equity financing.

On the one hand, the financing and operation research of the supply chain mainly focuses on bank lending and trade credit. Moreover, the comparative research on its financing methods is also concentrated between bank loans and trade credit. However, the credit threshold of bank lending is relatively high, while trade credit is relatively high. Credit requires well-funded companies in the supply chain. Therefore, it is difficult for the vast majority of SMEs to obtain financing. With the introduction of national financial service policies, equity financing has gradually become the main financing channel for small and medium-sized enterprises, especially start-ups and growth enterprises. However, there are few researches on introducing equity financing into capital constraints of the operation and financing decision-making of the green supply chain. On the other hand, as consumers’ awareness of green consumption increases, manufacturers’ green production input levels can improve the market demand and market competitiveness of enterprises. Therefore, the impact of green production input levels and consumers’ green preferences on market demand are more in line with the research. actual.
2.3 Problem and Hypothesis

In this paper, a green supply chain is taken as the research object, it is composed of a single retailer and a single manufacturer. The manufacturer has financial constraints, and Stackelberg game is played with the retailer. The manufacturer is the leader. First, the optimal green investment level, and the wholesale price are determined, the retailer is the follower, and then the optimal retail price is determined according to the manufacturer’s optimal green input level and the optimal wholesale price. According to references (Liu Z. L., et al., 2012; Ghosh D., & Shah J., 2012; Liu P., & Yi S., 2017), the market demand for a product is assumed for \( Q = a-bp + \beta \eta \), where \( a \) is the potential maximum market demand for the product, \( b \) is the product price elasticity coefficient, \( \beta \) is the consumer’s green preference, and \( \eta \) is the input level of the manufacturer’s green production, \( p \) is the manufacturer’s retail price, and \( 0 < \beta < 1 \).

The retailer and the manufacturer are information symmetrical. Manufacturers use bank borrowing, equity financing, and portfolio financing. In the bank lending model, the bank first determines the interest rate \( r \), and then the manufacturer and the retailer use the Stackelberg game to determine the optimal decision. At the end of the period, the manufacturer repaid the bank’s loan principal and interest with sales proceeds. In the equity financing model, the venture capital institution is the fund provider and does not participate in the Stackelberg game between the manufacturer and the retailer, and only distributes dividends based on the equity ratio \( \theta \) which is determined in advance with the manufacturer, and does not require repayment of principal and interest. Under the combined financing model, the manufacturer first obtains partial financing from venture capital institutions with a financing scale of \( \tau L \), and then borrows \((1-\tau)L\) from the bank, where \( L \) is the manufacturer’s borrowing scale, and \( \tau \) is the equity financing ratio. After the manufacturer’s production is realized, the income which is obtained from the retailer will first return the principal and interest to the bank, and then dividends will be distributed to the venture capital institution according to the pre-agreed equity transfer ratio \( \theta \).

Other assumptions of the model:

- Assume that the manufacturer’s own funds are \( B \).
- The input cost of the manufacturer to produce green products is \( \frac{1}{2} k \eta^3 \) (Zhu W., & He Y., 2017), and \( k \) is the green investment coefficient.
- The capital market is perfectly competitive, and the ability of banks to provide funds for manufacturers is unlimited, and \( r_0 \) is the risk-free interest rate of the capital market.
- \( \pi_r, \pi_m (i = 0,1,2,3,4) \) represent the profits of retailers and suppliers under various financing modes.

3. DECISION-MAKING EQUILIBRIUM OF GREEN SUPPLY CHAIN WITHOUT FINANCING

The Stackelberg model is a production leadership model proposed by the German economist H. Von Stackelberg in the 1930s (1934). The model reflects the asymmetric competition between enterprises. The Stackelberg model is a production leadership model, and there is a difference in the order of action between manufacturers. The output is determined according to the following sequence: the leading manufacturer decides an output, and then the follower manufacturer can observe this output, and then decide his own output based on the output of the leading manufacturer. It should be noted that when leading manufacturers are deciding their own output, they fully understand how the follower will act - this means that the leading manufacturer can know the response function of the follower. Therefore, leading manufacturers will naturally anticipate the impact of their own decisions on the follower manufacturers. It is precisely when this effect is taken into account that the output determined by the leading firm will be a profit-maximizing output constrained by the response function of the
following firm. In the Stackelberg model, the decision of the leading firm no longer needs its own reaction function.

When there is no financing service, a Stackelberg game model is built between the manufacturer and the retailer. Based on the previous assumptions, the revenue model of the retailer and the manufacturer is constructed and the reverse induction method is used to analyze the optimal decision. The profit function of the manufacturer is formula (1):

\[ \pi_m = (w - c)Q - \frac{1}{2}k\eta^2, \quad \text{s.t. } cQ < B \]  

(1)

The retailer’s profit function is equation (2):

\[ \pi_r = (p - w)Q \]

(2)

Proposition 1: (1) When \( B > B^*, \) \( B^* = \frac{2bck(a - bc)}{8bk - \beta^2}, \) the manufacturer has no capital constraints, and the optimal decision of the manufacturer and retailer is formula (3):

\[ p_0^* = \frac{c(2bk - \beta^2) + 2ak}{8bk - \beta^2}, \quad w_0^* = \frac{c(4bk - \beta^2) + 4ak}{8bk - \beta^2}, \quad \eta_0^* = \frac{\beta(a - bc)}{8bk - \beta^2} \]

(3)

When \( B < B^*, \) the manufacturer has capital constraints but no financing, and the optimal decision of the manufacturer and retailer is formula (4):

\[ p_1^* = \frac{B^2 + 2bk(ac - B)}{2b^2ck}, \quad w_1^* = \frac{B^2 + 2bk(ac - 2B)}{2b^2ck}, \quad \eta_1^* = \frac{B\beta}{2bck} \]

(4)

Corollary 1: When \( B > B^*, \) the manufacturer has no capital constraints, the market demand of the product is \( Q^*_m = \frac{2bk(a - bc)}{8bk - \beta^2}, \) and the profit of the manufacturer and retailer are \( \pi^*_m = \frac{k(a - bc)^2}{8bk - \beta^2}, \)

\[ \pi^*_r = \frac{4bk^2(a - bc)^2}{(8bk - \beta^2)^2} \]

respectively and they increase with the increase of consumers’ green preference. When \( B < B^*, \) the manufacturer has capital constraints but no financing, the market demand of the product is \( Q^*_1 = \frac{B}{c}, \) and the profit of the retailer and the manufacturer are

\[ \pi^*_r = \frac{B^2}{bc^2}, \quad \pi^*_m = \frac{B(4kbk(a - bc) - B(8kb - \beta^2))}{4b^2c^2k} \] respectively.
4. DECISION-MAKING EQUILIBRIUM OF THE GREEN SUPPLY CHAIN WHEN FINANCING IS AVAILABLE

4.1 Optimal Decision Equilibrium in Bank Borrowing

When the manufacturer adopts the bank loan method, the bank loan financing service interest rate is \( r \) and higher than the risk-free interest rate \( r_0 \), that is, \( r > r_0 \), assuming that the capital market is in a state of perfect competition, \( r_0 = 0 \). A game model is established between the manufacturer and the retailer, and the manufacturer’s profit function is formula (5):

\[
\pi_{m2} = (w - c)Q - \frac{1}{2} k\eta^2 - r(cQ - B), \quad \text{s.t.} \quad cQ > B
\]  

(5)

The retailer’s profit function is formula (6):

\[
\pi_{r2} = (p - w)Q
\]  

(6)

The bank’s profit function is formula (7):

\[
\pi_b = r(cQ - B)
\]  

(7)

Proposition 2: (1) When \( BM < B \leq BN \), the manufacturer has capital constraints but does not finance through bank loans, the optimal decision of the manufacturer and retailer is the optimal decision of the proposition 1 when \( B < BN \).

When \( B < B_M \), \( B_M = \frac{2bck(a - bc(1 + r))}{8bk - \beta^2} \), the manufacturer has capital constraints and carries out bank loan financing. The optimal decision of the manufacturer and retailer is formula (8):

\[
p_2^* = \frac{c(2bk - \beta^2)(1 + r) + 6ak}{8bk - \beta^2}, \quad w_2^* = \frac{4bk^2(a - bc(1 + r)^2)}{8bk - \beta^2}, \quad \eta_2^* = \frac{\beta(a - bc(1 + r))}{8bk - \beta^2}
\]  

(8)

Corollary 2: When \( B < B_M \), the manufacturer has capital constraints and bank loan financing, the market demand of the product is \( Q_2^* = \frac{2bk(a - bc(1 + r))}{8bk - \beta^2} \), the profit of the retailer and the manufacturer are \( \pi_{r2}^* = \frac{4bk^2(a - bc(1 + r)^2)}{8bk - \beta^2}, \quad \pi_{m2}^* = \frac{k(a - bc(1 + r)^2) + Br(8bk - \beta^2)}{8bk - \beta^2} \) respectively, and they increase with the increase of consumers’ green preference.

Corollary 3: When \( B < B_N \), the manufacturer’s initial capital is negatively correlated with the wholesale price and the retailer’s retail price, and it is positively correlated with the manufacturer’s green production input level; when \( B_M < B \leq B_N \) or \( B < B_M \), The manufacturer’s wholesale price, the level
of green production input and the retailer’s retail price have nothing to do with the manufacturer’s initial capital.

From Propositions 1, 2 and Corollary 1, it can be seen that the optimal decision-making and financing strategies of manufacturers and retailers are affected by the initial capital level. When the initial capital is severely insufficient, the manufacturer will use all the initial capital and external financing to organize production. When the initial capital of the manufacturer reaches a certain level, the manufacturer will not carry out external financing, because the financing cost is greater than the increase in financing.

4.2 Optimal Decision Equilibrium in Equity Financing

Under the equity financing model, venture capital institutions do not participate in the Stackelberg game between retailers and manufacturers. Dividends will only be distributed to the manufacturer until the end, and the manufacturer does not need to repay the principal and interest. Therefore, in this financing mode, manufacturers can obtain optimal decisions without capital constraints. Assuming that the manufacturer’s capital need is \( L = cQ-B \), the dividend ratio of venture capital institutions is \( \theta \). Then, the manufacturer’s profit is formula (9):

\[
\pi_m = \left( (w - c)Q - \frac{1}{2} k\eta^2 + B + L \right) (1 - \theta) - B
\]  

(9)

Retailer’s profit is formula (10):

\[
\pi_r = (p - w)Q
\]  

(10)

Venture capital institution profit is formula (11):

\[
\pi_s = \left( (w - c)Q - \frac{1}{2} k\eta^2 + B + L \right) \theta - L
\]  

(11)

Proposition 3: Under the equity financing model, the optimal decision of manufacturers and retailers is \( \eta_3^* = \eta_0^* \), \( w_3^* = w_0^* \), and \( p_3^* = p_0^* \).

Proposition 3 shows that under the equity financing model, venture capital institutions provide manufacturers with all capital services and do not require financing interest, so that manufacturers can achieve a state of no capital constraints. Therefore, the optimal decision of the supply chain under the equity financing model is equal to the optimal decision without capital constraints. Management inspiration is that from the perspective of the supply chain as a whole, equity financing is the best choice, and the key lies in the negotiation of the equity transfer ratio. Especially for start-up companies, equity financing can enable companies to achieve leapfrog development.

At this time, the profits of retailers, suppliers and venture capital institutions are respectively \( \pi_r(p_3^*, w_3^*, \eta_3^*) \), \( \pi_m(p_3^*, w_3^*, \eta_3^*) \), \( \pi_s(p_3^*, w_3^*) \).
4.3 Comparative Analysis of Optimal Decision Variables under Different Financing Modes

In the bank lending and equity financing model, the optimal decision-making of the supply chain is compared and analyzed, and the following corollary 4 can be obtained:

**Corollary 4:** The optimal retail price and wholesale price under the bank loan financing model are larger than those under equity financing, while the green production input level and market demand are smaller than those under equity financing.

Corollary 4 shows that the market competitiveness of products under equity financing is stronger than that under bank loan financing, and the market demand and green production input level are higher. The main reason is that the capital which is obtained by the manufacturer through equity financing is equivalent to an increase in its initial capital level, so it can achieve the optimal decision without capital constraints.

5. Choice of Two Financing Methods

Under the debt financing and equity financing methods, the choice key of financing methods for manufacturers is the size of the income under the two financing methods, and the interest rate of debt financing and the equity transfer ratio of equity financing are the main factors that determine the manufacturer’s income. Therefore, under the same conditions of other factors, and assuming that the bank’s interest rate is exogenous, which financing method the manufacturer chooses? it depends on the proportion of the manufacturer’s equity transfer.

**Proposition 4:** When the equity transfer ratio satisfies $\theta < \theta < \bar{\theta}$, both manufacturers and venture capital companies are willing to accept equity financing, where $\theta$ and $\bar{\theta}$ satisfy $\pi_m\left(p_1^*, w_1^*, \eta_3, \theta\right) - \pi_m\left(p_1^*, w_1^*, \eta_2, r_0\right) = 0$, $\pi_m\left(p_2^*, w_2^*, \eta_3, \bar{\theta}\right) - \pi_m\left(p_2^*, w_2^*, \eta_2\right) = 0$. That is,

$$\theta = \frac{2akbc(a - bc) - B(8k^2 - \beta^2)}{k\left(a^2 - b^2c^2\right)}, \quad \bar{\theta} = \frac{2akbc + B\beta^2 - 8BkBk(1 + r) - kb^2c^2r(r + 2)}{k\left(a^2 - b^2c^2\right)}.$$

When the manufacturer chooses debt financing and equity financing, the manufacturer’s equity financing income is not less than the bank’s loan financing income, that is, $\pi_{m3}\left(p_3^*, w_3^*, \eta_3, \theta\right) \geq \pi_{m2}\left(p_3^*, w_2^*, \eta_2\right)$, and the manufacturer may use equity financing, otherwise, choose debt financing. Therefore, there is an upper limit for manufacturers to use equity financing, that is, $\pi_{m3}\left(p_4^*, w_4^*, \eta_3, \bar{\theta}\right) = \pi_{m2}\left(p_4^*, w_2^*, \eta_2\right)$, so that the maximum acceptable shareholding ratio of manufacturers can meet $\pi_{m3}\left(p_3^*, w_3^*, \eta_3, \bar{\theta}\right) - \pi_{m2}\left(p_2^*, w_2^*, \eta_2\right) = 0$.

**Proposition 5:** (1) When $B^{\theta_1}LB^* < B^\theta$, if $\theta \leq \theta_1$, the manufacturer chooses equity financing, otherwise, the manufacturer chooses its own initial capital for production and emission reduction.

(2) When $B < B^{\theta_2}$, if $\theta \leq \theta_2$, it is more advantageous for the manufacturer to choose equity financing than bank loan financing; otherwise, it is more advantageous for the manufacturer to choose bank loan financing. Wherein, $\theta_1 \in (\theta, \bar{\theta})$, $\theta_2 \in (\theta, \bar{\theta})$ and $\theta_1, \theta_2$ satisfy $\pi_{m3}\left(p_3^*, w_3^*, \eta_3, \theta_1\right) \geq \pi_{m1}\left(p_1^*, w_1^*, \eta_1\right)$ and $\pi_{m3}\left(p_3^*, w_3^*, \eta_3, \theta_2\right) \geq \pi_{m2}\left(p_2^*, w_2^*, \eta_2\right)$.
6. PORTFOLIO FINANCING

Under the condition that capital constraints manufacturers can carry out bank loans and equity financing, manufacturers can also carry out a combination of bank loans and equity financing, that is, part of the green cost τL uses equity financing, and the remaining part (1-τ)L uses bank loans. At this time, the manufacturer’s profit function is formula (12):

$$\pi_{m1} = \left( w - c \right) Q - \frac{1}{2} k\eta^2 - \tau \left( cQ - B \right) (1 - \tau) \left( 1 - \theta \right)$$  (12)

Retailer’s profit function is formula (13):

$$\pi_{r1} = (p - w) Q$$  (13)

Venture capital institution profit is formula (14):

$$\pi_{ss} = \left( w - c \right) Q - \frac{1}{2} k\eta^2 + B + (1 - \tau) L \theta - (1 - \tau) L$$  (14)

Proposition 6: Under the combined financing model, the manufacturer’s optimal wholesale price and optimal green level and the retailer’s optimal retail price is formula (15):

$$w^*_1 = \frac{\beta \left( a - bc \left( 1 + r - r\tau \right) \right) + 4ak}{8bk - \beta^2}, \quad \eta^*_1 = \frac{\beta \left( a - bc \left( 1 + r - r\tau \right) \right)}{8bk - \beta^2}, \quad p^*_1 = \frac{\beta \left( 2bk - \beta^2 \right) \left( 1 + r - r\tau \right) + 6ak}{8bk - \beta^2}$$  (15)

At this time, the optimal expected profit of the retailer and the manufacturer is formula (16):

$$\pi^*_{r1} = \frac{4bk \left( a - bc \left( 1 + r - r\tau \right) \right)^2}{(8bk - \beta^2)^2}, \quad \pi^*_{m1} = \frac{k \left( a - bc \left( 1 + r - r\tau \right) \right)^2 + Br \left( 8bk - \beta^2 \right)}{8bk - \beta^2}$$  (16)

At least, the amount of funds is formula (17):

$$B^* = \frac{2bck \left( a - bc \left( 1 + r - r\tau \right) \right)}{8bk - \beta^2}$$  (17)

Corollary 5: In the combined financing model, the equity financing ratio is positively correlated with the wholesale price and retail price of the product, and it is positively correlated with the
green level of the product; $\frac{\partial \pi^*}{\partial \tau} > 0$; when $\tau \in [0, \tau^*]$, $\frac{\partial \pi^*}{\partial \tau} < 0$. When $\tau \in (\tau^*, 1]$, $\frac{\partial \pi^*}{\partial \tau} > 0$.

Wherein $\tau^* = \frac{2b^2c^2k(1+r) - B(\beta^2 - 8bk) - 2abck}{2b^2c^2kr}$.

Corollary 5 shows that under combined financing, as the proportion of equity financing increases, the wholesale price and retail price of products decrease, while the green level increases. Therefore, the market competitiveness of products is increased and the social benefits of the green supply chain are improved. This shows that the combined financing strategy of investment-loan linkage has realized the close integration of the participants in the supply chain, the synergy of upstream companies is activated in the supply chain, and the competitiveness of the supply chain is improved. Moreover, when the proportion of equity financing decreases, that is, $\tau \in [0, \tau^*]$, manufacturers are more willing to use bank loan financing. When the proportion of equity financing is large, that is, $\tau \in (\tau^*, 1]$, manufacturers are more prefer equity financing. However, the increase in the proportion of equity financing is beneficial to retailers.

**Corollary 6**: $p_1^* > p_4^* > p_0^*$, $w_2^* > w_1^*$, $\eta_0^* > \eta_1^* > \eta_2^*$.

Corollary 6 shows that under the pure equity financing model, the optimal decision for equity financing is equal to that without capital constraints. When comparing bank borrowing and portfolio financing, the product wholesale price and retail price of pure equity financing are the lowest, and the portfolio financing is inferior, and pure bank borrowing is the highest. Because pure equity financing is equivalent to increasing the manufacturer’s own funds to the level when the funds are sufficient, the optimal decision is the same as when there is no capital constraint. In the case of pure bank borrowing, it leads to an outflow of income. Retailer prices and wholesale prices of products are relatively high, and the green level is the lowest. Therefore, from the perspective of the supply chain system, reducing the outflow of revenue from the supply chain system is conducive to improving the overall competitiveness of the supply chain and the green level of products. In practice, for start-ups or growing companies, price wars are often used to seize the market.

**Corollary 7**: When $\tau > \tau_1$, $\pi_{m_4}^* > \pi_{m_2}^*$, otherwise $\pi_{m_4}^* < \pi_{m_2}^*$; when $0 > \theta_s$, $\pi_{m_4}^* > \pi_{m_3}^*$, otherwise, $\pi_{m_4}^* < \pi_{m_3}^*$. $\tau_1 = \frac{\sqrt{\overline{\overline{\overline{\tfrac{8Bbk - B^2 - 2abck}{1 - \theta}}} + 2b^2c^2k(1 - \theta)(1 + r)}}}{2b^2c^2kr(1 - \theta)}$, (Myers S. C., 1977)

Corollary 7 shows that when the proportion of portfolio equity financing (equity transfer ratio) is greater than a certain value, portfolio financing is more advantageous than pure bank borrowing and pure equity financing, because the portfolio financing reduces the scale of bank borrowing and reduces the outflow of income. As far as financing and pure equity financing are concerned, the key lies in the coordination between the scale of equity investment and the share of equity benefits. For both borrowers and lenders, how to determine interest rates, investment ratios, and income sharing ratios is essentially the bargaining of financing costs, investment costs, and income sharing ratios. Therefore, it also supports the revised pecking order theory that equity financing is more conducive to growing companies than internal financing and bank borrowing (Myers S. C., 1977).
7. NUMERICAL ANALYSIS

In this paper, the MatLab 2019 version is used, numerical analysis verifies the main conclusions in the article and the influence of consumers’ green preferences on the choice of optimal decision variables, profits and financing models. The basic parameter assumptions are $a=10000$, $c=300$, $b=2$, bank loan interest rate $r=0.15$, the risk-free interest rate of the capital market $r_0=0.05$, green investment coefficient $k=100$.

7.1 The Impact of Consumers’ Green Preference on Product Retail Prices, Wholesale Prices and Input Efforts

Figures 1~4 show the influence of consumers’ green preference $\beta$ on manufacturers’ green investment effort level $\eta$ and wholesale price $w$, as well as retailers’ retail price $p$ and market demand $Q$.

As consumers’ green preference increases, retail prices, wholesale prices, green investment efforts and market demand increase. Because of higher retail prices, consumers are willing to buy green

Figure 1. The impact of green preference $\beta$ on wholesale prices $w$

![Figure 1](image1)

Figure 2. The impact of green preference $\beta$ on retail prices $p$

![Figure 2](image2)
products at higher prices, so retailers are willing to wholesale green products from manufacturers at higher wholesale prices. At the same time, it is influenced by consumers’ green preference, the level of green production input increases linearly with the increase of consumers’ green preference. Manufacturers are more willing to increase the level of green production input, the increase of consumers’ green preference will increase the demand for green products and correspondingly increase the demand, the retailer shows to increase the order quantity. Under the equity financing model, the wholesale price of the manufacturer and the retail price of the retailer are lower than that under the debt financing, while the green production input level and product market demand are higher. It shows that equity financing is more conducive than debt financing to increasing the competitiveness of green products in the green supply chain, the green level of products is improved and the market demand is increased for green products. Therefore, equity financing is more beneficial to start-ups, which can quickly expand the market share of products through price wars.
7.2 The Impact of the Manufacturer’s Initial Capital on the Retail Price, Wholesale Price and Effort Level of the Product

In Figures 5 and 6, when \( B < B^c \) and the manufacturer has capital constraints but no financing, the manufacturer’s initial capital level \( B \) will affect the manufacturer’s green investment effort level \( \eta \), wholesale price \( w \) and the retailer’s retail price \( p \).

With the increase in the initial funding level of manufacturers, manufacturers can increase market demand and incentivize retailers to order and sell by improving the greenness of products and lowering wholesale prices, so that retailers can also reduce the retail prices of products and increase market competitiveness, it shows that with the increase of manufacturers’ initial capital level, green products are more competitive and market demand is higher.

Figure 5. The impact of initial funds B on wholesale price w and retail price p

![Figure 5: The impact of initial funds B on wholesale price w and retail price p](image)

Figure 6. Effect of initial funds B on green investment effort level \( \eta \)

![Figure 6: Effect of initial funds B on green investment effort level \( \eta \)](image)
7.3 The Influence of Manufacturers’ Initial Capital and Consumers’ Green Preferences on the Choice of Financing Mode

Figures 7 and 8 show the influence of consumers’ green preference and the manufacturer’s initial capital level on the manufacturer’s choice of financing models (equity financing and debt financing).

As the manufacturer’s initial capital level increases, the upper and lower limits of the proportion of equity financing decrease, the manufacturer’s initial capital level increases, the manufacturer’s capital gap is getting smaller and smaller, and the required financial services are getting less and less. It can be seen that when $B^M < B < B^N$ ($B^M < B^N$), when the manufacturer has capital constraints but does not finance through bank loans, in the range of $B^W < B_1$ ($B^M < B_1$), the manufacturer can also use equity financing, and as consumers’ green preferences increase, the upper and lower limits of the proportion of equity financing have increased. It shows that with the increase of consumers’ green preferences and the decrease of the manufacturer’s capital constraints, the manufacturer can choose a higher proportion of equity financing.

Figure 7. Initial capital B and green preference $\beta = 0.3$ impact on the choice of financing mode (Equity ratio $\theta$)

Figure 8. Initial capital B and green preference $\beta = 0.8$ impact on the choice of financing mode (Equity ratio $\theta$)
preference, the critical value of the lack of initial capital $B$ gradually increases, because consumers’ green preference increases, this promotes the increase of consumer demand for green products, so to meet the needs of green consumers, manufacturers need to prepare more funds for the production of green products. As can be seen from Figures 7 and 8, there is an intersection between the upper and lower limits of the equity ratio under different consumer green preference levels. Manufacturers can choose equity financing on the left of the intersection, manufacturers will not choose equity financing on the right of the intersection. On the left side of the intersection, when the manufacturer is extremely short of funds, in order to reduce the impact of the lack of funds on income, the amount of financing that the manufacturer needs to obtain will be greater, and the cost of its debt financing will also be greater, resulting in an increase in the manufacturer’s acceptable upper limit of equity. At this time, the higher the consumer’s green preference, the larger the acceptable shareholding ratio, because consumer demand increases and the manufacturer’s expected income increases. As the manufacturer’s initial capital $B$ increases, the acceptable shareholding ratio $\theta$ between the manufacturer and the venture capital institution decreases, mainly because the manufacturer’s capital needs decrease. However, the greater the consumer’s green preference, the higher the acceptable equity ratio $\theta$. This is mainly because as consumers’ green preference increases, consumers’ market demand for green products increases. Therefore, manufacturers need more capital to organize production, and its demand for capital increases.

7.4 The Influence of Manufacturer’s Initial Capital and Bank Borrowing Rate on the Choice of Financing Mode

Figures 9 and 10 show that with the increase in bank lending rates, the critical value of capital demand gradually increases, and the range increases for manufacturers to have capital constraints without financing.

There is a meeting point for the upper and lower limits of the equity ratio at different interest rates. Manufacturers can choose equity financing on the left of the meeting, manufacturers will not choose equity financing on the right of the meeting, and as the bank’s loan interest rate increases, the meeting point moves to the left. That is, the greater the financing cost, the higher the upper limit of the manufacturer’s acceptable equity financing ratio. Therefore, the lending interest rate in the financial market also has an impact on the equity investment market, thereby affecting the financing options of capital-constrained companies.

Figure 9. The impact of initial capital $B$ and bank loan interest rate $r = 0.1$ on the choice of financing mode (Equity ratio $\theta$)
7.5 Choice of Single Financing Mode and Combined Financing Mode

Figure 11 shows that in portfolio financing, as the proportion of equity financing increases, manufacturers' profits increase. When the proportion of equity financing is small, manufacturers are more willing to use bank loan financing. When the proportion of equity financing reaches a certain value, manufacturers are more willing to use portfolio financing. Figure 12 shows that as the proportion of equity transfer increases and the proportion of equity financing increases, the combined financing is more beneficial to manufacturers, in the comparison of pure equity financing and portfolio financing, it can be seen that pure equity financing is better than portfolio financing. The main reason is that pure equity financing aims at the overall profit of the supply chain and does not result in the transfer of financing interest. Therefore, equity financing is more favorable for growth companies.

Figure 11. The influence of equity financing ratio \( \tau \) on the choice of financing mode (Suppliers' profits \( \pi_m \))
Management enlightenment: For manufacturers, a reasonable choice of financing strategy is conducive to the benefits of all participants in the supply chain. Moreover, for the government to use financial leverage to guide the development of the green supply chain, and to introduce supportive policies for “green finance”, the government and financial institutions can use interest rate adjustments to guide both borrowers and lenders to achieve a win-win goal. This is conducive to the maximization of social welfare effects. The government’s subsidy mechanism is discussed for the green supply chain. Under the government’s strategy of bank interest rate subsidies and price subsidies to manufacturers and retailers, bank interest rate subsidies are the government’s optimal strategy (Huang S., et al., 2020). It can be seen that equity financing is particularly beneficial to start-ups, that is, companies with less self-owned funds. The “Development of Public Innovation Space to Promote Mass Innovation Policies such as “Guiding Opinions on Enterprises” and “Management Measures for Private Equity Crowdfunding Financing” are used to promote and guide the equity investment market. Therefore, the growth and reform of the equity investment market has gradually become a boost to the development of enterprises, especially new start-ups. The main financing channel for leapfrog development. Intensifying the reform of the financial market and institutions, and choosing a reasonable financing strategy is beneficial to both borrowers and lenders based on the capital status of the enterprise. The state can increase financial policy support from the macro level, and make rational use of financial leverage.

8. CONCLUSIONS AND OUTLOOK

General supply chain finance emphasizes the authenticity of trade and the strength of core enterprises. On this basis, green supply chain finance further pays attention to environmental protection, so as to realize the mutual development of enterprises and the ecological environment. At present, my country’s green supply chain finance is in its infancy. It is necessary to gradually integrate green supply chain, supply chain finance and green finance. Green supply chain finance is an organic integration of green finance, supply chain finance and green supply chain. From the perspective of international practice, BNP Paribas and International The financial company launched a green supply chain financing plan in 2016, which is similar to sustainable.
In this paper, on the basis of existing literature, considering that market demand is affected by product green production input levels and retail prices, the manufacturer’s financing and operational decisions are studied. Consumers’ green preference is positively correlated with retail prices, wholesale prices, green investment intensity, product market demand, and equity financing acceptable share transfer ratio; when the manufacturer’s capital constraint is not financing, the manufacturer’s initial capital level is positively correlated to the wholesale price of manufacturing, it is negatively correlated to the retail price of the retailer, but it is positively correlated with the level of green investment efforts. The greater the bank loan interest rate, the greater the percentage of equity transfer that the manufacturer can accept. When a manufacturer raises funds, if the initial capital level is extremely low, it should choose equity financing. As the initial funding level increases, retailers should choose bank loans for financing; when the proportion of equity financing reaches a certain value, portfolio financing is more conducive to manufacturing than bank loans; while pure equity financing is more conducive to portfolio financing.

In this article, financing decisions are only considered when the participants in the supply chain are risk-neutral. Future research can consider the risk aversion characteristics of the participants in the supply chain and the multiple preferences of consumers, as well as the comparison between other financing methods and equity financing, certain management guidance and reference value are provided for enterprise financing.

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