



Blockchain technology empowers the crowdfunding decision-making of marine ranching

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ABSTRACT

Marine ranching, as a new commercial form, the lack of construction and development funds has become its development constraint. Crowdfunding provides a new way to break through the financing bottleneck of marine ranching, and blockchain technology (BT) can effectively solve the problem of information asymmetry in crowdfunding progress. However, the choice of enterprise crowdfunding methods and the influence of consumer crowdfunding and pre-sale crowdfunding on supply chain value co-creation have not been deeply studied. Based on the theory of value co-creation, this paper uses multi-level programming and backward induction method to construct and solve the supply chain models of consumer crowdfunding and pre-sale crowdfunding under the traditional mode and BT mode, and obtains balanced results. Analyze the influence of the product green attributes, the degree of the enterprise's attention to crowdfunding consumer value and ordinary consumer value, consumer recognition of product attributes (quality attributes, green attributes) and other parameters on supply chain operation; Through the comparative analysis of different models and numerical simulation, the optimal decision results are further discussed. The research shows that: (1) The overall value of the supply chain is higher when the marine ranching leading enterprise adopts the consumer crowdfunding method than when the pre-sale crowdfunding method. Moreover, the introduction of BT can improve the value of each subject in the supply chain system. (2) The marine ranching leading enterprise pays attention to the value of crowdfunding consumers and ordinary consumers, which will reduce their own value and increase the value of other subjects in the supply chain. The improvement of crowdfunding consumers' recognition of product attributes will improve their consumer value. (3) When the green attributes of products increase, the values of the leading enterprise, the retailer, the crowdfunding platform and consumers all increase, and the overall value of supply chain is improved. (4) Increasing product sales is the unified goal of all subjects in crowdfunding supply chain system, thus promoting the economic value and environmental value of enterprises.

1. Introduction

With the deterioration of global environmental quality, the marine environmental pollution and other ecological problems worsening, the coastal fishery resources are increasingly exhausted (Ren, 2021). Marine ranching, as a new type of ecological fishery model, aims at realizing the sustainable utilization of marine fishery resources (Du & Wang, 2021) and the protection of marine environment (Du & Cao, 2022), has

brought huge economic and ecological benefits (Du & Li, 2022). However, marine ranching is a capital-intensive industry, its construction and development needs to consume a lot of capital. As the leading enterprise of marine ranching still in the initial stage, the lack of its own funds and the financing difficulties caused by the rupture of the capital chain have become a major constraint on the construction and development of marine ranching (Qin et al., 2022). Therefore, it is urgent to break through the development bottleneck of capital shortage of marine

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ranching leading enterprises and accelerate the building of a maritime power.

Enterprises can choose various ways and channels to carry out financing, so as to solve the dilemma of capital shortage (Tang et al., 2022). For example, equity financing (Fu et al., 2021), supply chain financing (Zhang et al., 2023), crowdfunding (Chen et al., 2022), etc. Comparing with other financing methods of enterprises, crowdfunding has obvious advantages, and it can fill the funding gap that is difficult to obtain funds through traditional financing channels (Chen et al., 2022). And, for small and medium-sized enterprises that are still in the initial stage, crowdfunding has become a valuable financing mode (Junge et al., 2022), which can enable cash-strapped manufacturers to raise initial funds from many investors (Chen et al., 2022). Crowdfunding has the advantages of easy access and low financing cost (Ghobadi, 2022). It can provide potential demand information of products and provide financing channels for projects that cannot obtain financing through other financing methods (Babich et al., 2020). Also, consumers have the high consumer preference for crowdfunding related products (Acar et al., 2021). Based on the above analysis, the crowdfunding method is applicable to the leading enterprises of marine ranching: When the leading enterprises of marine ranching choose crowdfunding method, it can alleviate the shortage of funds for marine ranching enterprises and then accelerate the construction and development of marine ranching. Also, it can disperse the financing risks of enterprises, solve the financing problems of marine ranching enterprises, and provide new financing channels for enterprises. Nevertheless, when enterprises conduct crowdfunding, they will also face many problems and challenges. In the background of crowdfunding, potential investors usually have incomplete information about the product quality of enterprises or the reputation of entrepreneurs (Sewaid et al., 2021). There is information asymmetry between crowdfunding sponsors and consumers, as well as adverse selection, moral hazard and trust due to information asymmetry (Chaney, 2019). Information asymmetry also limits the ability of entrepreneurs to finance projects (Belleflamme et al., 2014). Crowdfunding will also face the problem of delayed delivery (Xu et al., 2021).

Blockchain is a distributed database structure with the advantages of decentralization and information visualization (Centobelli et al., 2021). Zhang et al. (2022) applied blockchain to sustainable supply chain to explore the key success factors of BT, and thinks that BT can enhance the flexibility, security and transparency of supply chain. Zhu et al. (2022) has studied the frontier theory of explaining the application and implementation of BT in supply chain, and the application of BT in supply chain can alleviate the supply chain management problems. In addition, the application of BT to the crowdfunding supply chain can effectively solve the problems of information asymmetry and trust, ensure the data security in the crowdfunding process, and improve the efficiency of crowdfunding (Nguyen et al., 2021). Based on the effectiveness of BT in dealing with the problems of information asymmetry, delayed delivery and trust faced by crowdfunding supply chain, we introduce BT into the crowdfunding supply chain system, and provides information services for the main bodies in the crowdfunding supply chain system (marine ranching leading enterprises, crowdfunding platforms, retailers, etc.). The application of BT will also bring more consumer surplus and social welfare (Wan et al., 2022), which will contribute to the creation of social value to realize value co-creation. At present, the competition among enterprises has been transformed into the competition among supply chains, and value creation is a vital embodiment of supply chain competition. Value co-creation will have a beneficial impact on both participating enterprises and consumers, and promote the value of both sides (Boadi et al., 2022), and emphasizes the role of consumers in the value co-creation of the supply chain system. At the same time, in the process of value co-creation, information asymmetry and other problems will hinder its successful realization (Chih et al., 2019). BT can effectively alleviate this problem and promote the social value co-creation of crowdfunding supply chain (Nguyen et al., 2021). Motivated by this, this study adopts the perspective of value co-

creation, takes the consumer crowdfunding and pre-sale crowdfunding as the main research objects. And uses the multi-level planning and the backward induction method in Stackelberg game to construct and solve the crowdfunding supply chain value co-creation model under the empowerment of BT respectively. Also, this paper analyzes the influence of product green attributes, the attention of the enterprise on the crowdfunding consumer value and ordinary consumer value, and consumers' recognition of product attributes on the supply chain operation. Comparing the optimal decision-making results of the two crowdfunding methods with and without BT. Finally, it provides reference for the selection of effective crowdfunding methods and the introduction of BT for marine ranching leading enterprises.

Based on these, the contributions of this paper are:

- i) The application of crowdfunding in leading enterprises of marine ranching and the comparison of the impact of different crowdfunding methods on enterprises have expanded the research boundary of crowdfunding and provided suggestions for the choice of crowdfunding methods for enterprises.
- ii) Based on the crowdfunding supply chain model, the influence of introducing BT is considered, which provides a quantitative perspective for analyzing the role of BT in crowdfunding supply chain.
- iii) According to the comparative analysis and numerical simulation results, some management suggestions are given from the selection of crowdfunding methods, whether BT is introduced and the degree of attracting consumers to participate in value co-creation of marine ranching enterprises respectively.

After the introduction, the structure of this paper is as follows: Section 2 is the literature review. Section 3 is the problem description and basic assumptions. Section 4 is the model building. Section 5 is the model solving. Section 6 is the comparative analysis of the optimal decision-making results of two different crowdfunding methods. Section 7 is numerical analysis. Section 8 is the conclusion and implications of this research, and gives the corresponding management enlightenment.

2. Literature review

2.1. Crowdfunding

Crowdfunding is an activity that seeks financial support from many individual investors through the Internet (Kuppuswamy and Bayus, 2017). It connects creators who have innovative ideas with supporters who have funds to invest in these ideas (Groza et al., 2020), and promotes enterprises and individuals to support their chosen projects with funds (Lukkarinen and Schwienbacher, 2023). It can not only solve the problem of capital shortage of enterprises, but also solve the financing dilemma by dispersing financing risks. Crowdfunding has many forms (Jiang et al., 2022), including consumer crowdfunding and pre-sale crowdfunding. Consumer crowdfunding means that on the basis of existing products, producers show their products and services to potential consumers through crowdfunding platforms to appeal to potential consumers to participate in the crowdfunding activities and collect the scattered market demand (Chen et al., 2022). Pre-sale crowdfunding refers to entrepreneurs attracting consumers to pre-order the product to obtain the funds needed for the production of the product before producing it. After crowdfunding becomes successful, the enterprise will implement price discrimination between crowdfunding consumers and ordinary consumers (Belleflamme et al., 2014). Both of them aim at raising the funds needed for product production, but consumer crowdfunding focuses on crowdfunding activities on the basis of existing products. While pre-sale crowdfunding focuses on crowdfunding activities on the basis of no products to obtain all the funds needed for product production.

Crowdfunding, as an emerging financing method, complements the

traditional forms of financing (Kim & Hann, 2019), has obvious advantages in promoting sustainable development of enterprises (Testa et al., 2020), accelerating capital accumulation of enterprises (Li & Wang, 2019) and promoting enterprises to carry out innovative activities (Herd et al., 2022). At present, some scholars have incorporated crowdfunding into the related research of supply chain. For example, Reza-Gharehbagh et al. (2021) incorporated crowdfunding into supply chain finance to explore the role of crowdfunding in promoting independent innovation. Zhang et al. (2022) put the equity crowdfunding into the study of value co-creation in closed-loop supply chain, and put forward an effective path to achieve a win-win situation of economic value and environmental value in closed-loop supply chain. At the same time, crowdfunding is also facing many problems. For example, the problem of information asymmetry has always been a severe challenge that restricts the sustainable development of crowdfunding (Qi et al., 2022), and it will lead to issues such as lagging decision-making, adverse selection and low fund-raising performance (Ghobadi, 2022). Compared with consumer crowdfunding, the pre-sale crowdfunding raises funds from consumers before the products are officially put on the market, so enterprises and consumers will face more information asymmetry problems. In order to make crowdfunding have a sustainable development, Kim et al. (2022) found that disclosure policy can make crowdfunding market more sustainable by reducing information asymmetry and helping crowdfunding people make more wise choices. Moreover, the introduction of relevant digital technologies on the crowdfunding platform can promote the information exchange between fundraisers and funders (Wu et al., 2022), enhance the degree of information disclosure and reduce the negative impact of information asymmetry on the crowdfunding process.

The literature review shows that crowdfunding is a new financing method, which has many advantages compared with the traditional financing methods. It is compatible with the leading enterprises of marine ranching. However, there is still a lack of research on supply chain value co-creation, comparative analysis between different crowdfunding methods and crowdfunding under BT empowerment.

2.2. Blockchain technology

Blockchain has become one of the most promising and potentially revolutionary technologies at present. It has the characteristics of decentralization, invariance, data integrity and transparency (Hughes et al., 2019). As a digital technology, BT affects many aspects of the economy (Zhang et al., 2022). BT provides enterprises with a new way to create and acquire value and a new organizational form, which can enhance the innovation level of enterprises (Chin et al., 2021). The application of BT can improve the quality of products and services (Dehghani et al., 2022), reduce the transaction costs of enterprises (Pan et al., 2020), enhance the green innovation performance of enterprises (Chin et al., 2022), and accelerate the transformation of governance forms and business models (Denter et al., 2022; Di Vaio et al., 2022), thus enhancing the competitive advantage of enterprises.

BT plays an important role in the supply chain. In the traditional supply chain management, the financing difficulty of upstream and downstream enterprises in the supply chain is the bottleneck factor restricting the improvement of the overall operation efficiency of the supply chain. Using BT can improve the transparency, traceability and reliability of the supply chain, reduce the information asymmetry among suppliers, retailers and consumers (Hastig & Sodhi, 2020), and enhance the sustainability of the environment (Yousefi & Tosarkani, 2022), thus improving the efficiency level of the supply chain (Di Vaio & Varriale, 2020; Wang et al., 2023). Moreover, BT can speed up the process of data transmission, help enterprises strengthen inventory management, reduce related costs and unnecessary waste, and promote the sustainable development of the supply chain (Zhu et al., 2022; Cao & Shen, 2022). In addition, Zheng et al. (2022) put forward an enterprise credit information sharing model based on BT, and holds that BT can

improve the credit reporting ability in the supply chain financial system, optimize the supply chain financial credit system, and further improve the financing efficiency of the supply chain. Wang et al. (2022) developed an analysis model to study the optimal information disclosure and equilibrium blockchain adoption strategy of competitive platforms, and reached the conclusion that BT can not only benefit the platforms that use it, but also provide more real and reliable messages for the market. Aiming at the problem of information asymmetry in crowdfunding supply chain, the better performance of blockchain can solve this problem. BT can reduce transaction risks and intermediary costs of the crowdfunding platform through cryptocurrency transactions and improve data security in crowdfunding process, thus improving crowdfunding efficiency (Nguyen et al., 2021). In the combination of BT and crowdfunding for related research, based on the characteristics that BT can provide a transparent and cost-effective platform for different applications, Hassija et al. (2020) applied BT to crowdfunding platform and proposed a unique and secure crowdfunding platform on the basis of blockchain and Ethereum smart contract. Nguyen et al. (2021) used qualitative research methods to explore the role of BT in the social value creation of crowdfunding.

Literature shows that BT can effectively solve the problems such as information asymmetry in the crowdfunding supply chain with its characteristics of decentralization and data integrity. However, the research of BT application in the crowdfunding supply chain is still in its infancy, and the current research focuses on the qualitative research stage, with few quantitative studies.

2.3. Value co-creation

With the development of market practice, the role of consumers has changed significantly, from ordinary product consumers to creators of product values. Service dominant logic considers the value generated between customers and enterprises, that is, value co-creation (Anshu et al., 2022), in which consumers and enterprises jointly create value. Value co-creation is a value creation method on which enterprise competition depends (Best et al., 2022). This is a win-win cooperative relationship, emphasizing the important role of consumers in value creation (Zhang & Meng, 2021). Value co-creation is regarded as an innovative strategy to integrate consumer thoughts and meet consumer needs (Liu et al., 2022). Consumers are the co-creators of value, and effective interaction between customers and companies is the prerequisite for the co-creation of value. In addition, value co-creation is a new and vital organizational strategy, which has a crucial impact on improving enterprise performance (Chi et al., 2022). It is beneficial for middle managers to discover entrepreneurial behaviors and create service opportunities, and bring economic value to the company (Yang & Leposky, 2022).

There are certain problems in value co-creation. For instance, in this process, consumers don't actively contribute their own abilities because of their knowledge asymmetry with enterprises (Chih et al., 2019), thus hindering the realization of value co-creation. The current wave of digital technology is further shaping consumer behavior, and the development of BT, artificial intelligence and big data promotes the realization of value co-creation (Wan et al., 2022). BT, with its decentralized and transparent characteristics, reduces the problems that hinder the realization of value co-creation between consumers and enterprises due to asymmetric information, and promotes the realization of value co-creation. In addition, some scholars have studied how to realize the theme of value co-creation in crowdfunding. For example, Nucciarelli et al. (2017) combined the value chain logic with platform logic to study the influence of crowdfunding on the process of value co-creation of the digital game industry. Laffey et al. (2021) believes that the speed of raising funds during the crowdfunding process and avoiding control of financial monitoring are the key sources of value co-creation. On this basis, Nguyen et al. (2021) discussed the role of BT in promoting the social value creation of crowdfunding by studying the application of

Table 1
Comparison of our work with related literature.

Research paper	Crowdfunding	BT	Value co-creation	Supply chain	Decision making
Reza-Gharehbagh et al. (2021)	✓			✓	
Zhang et al. (2022)	✓		✓	✓	✓
Wu et al. (2022)	✓			✓	✓
Nguyen et al. (2021)	✓	✓	✓		
Hassija et al. (2020)	✓	✓			
Wan et al. (2022)		✓	✓	✓	✓
Nucciarelli et al. (2017)	✓		✓	✓	
Laffey et al. (2021)	✓		✓		
This paper	✓	✓	✓	✓	✓

BT on crowdfunding platforms, and believed that crowdfunding was in line with the overall goal of creating social value. Besides, by constructing a closed-loop supply chain value co-creation model considering equity crowdfunding, [Zhang et al. \(2022\)](#) concluded that manufacturers should attract consumers to participate in value co-creation, and introducing new technologies such as BT can improve the financing efficiency of enterprises.

The above research began to consider the problem of value co-creation of the crowdfunding supply chain, and some studies have begun to apply BT to the crowdfunding supply chain for value co-creation research. However, this kind of research still needs to be further deepened and expanded.

In summary, crowdfunding, as an emerging financing method, has gradually attracted the attention of scholars. The existing research has also gradually focused on the introduction of BT into the crowdfunding supply chain for value co-creation and other related research. However, there is still a lack of research on the choice of different crowdfunding methods and the application of crowdfunding to leading enterprises in marine ranching. Therefore, this paper constructs the decision research of marine ranching crowdfunding under the power of BT. On this basis, considering the impact of value co-creation, it hopes to deepen the related research on crowdfunding and supply chain. [Table 1](#) presents the research gap as well as our contribution by comparing with the main relevant studies above.

3. Background

3.1. Problem description

Considering that marine ranching leading enterprises in the initial stage will face financing and market development problems, this paper discusses the supply chain decision-making in the marine ranching crowdfunding stage based on the two ways of consumer crowdfunding and pre-sale crowdfunding respectively. When marine ranching leading enterprises in shortage of funds adopt the way of crowdfunding for

financing, a crowdfunding supply chain system consisting of a marine ranching leading enterprise, a crowdfunding platform, a retailer and many consumers will be formed. In addition, BT is introduced into the established crowdfunding supply chain system. As shown in Fig. 1, this paper establishes the B model, $B = \{N, N_0, I, I_0\}$, N and N_0 respectively represent the revenue models of consumer crowdfunding supply chain and pre-sale crowdfunding supply chain system without BT. I and I_0 respectively represent the revenue models of consumer crowdfunding supply chain and pre-sale crowdfunding supply chain system with BT.

Consumer crowdfunding is based on existing products. Enterprises show their products and services to potential consumers through the crowdfunding platform, and then attract potential consumers to participate in crowdfunding activities (Chen et al., 2022), and obtain the required funds. Pre-sale crowdfunding is to attract consumers to book products before enterprises produce products, and to obtain the required funds before products are produced. The main difference between the two crowdfunding methods is that the focus of consumer crowdfunding is based on existing products, while the focus of pre-sale crowdfunding is based on future products. What they have in common is that both aim at raising the funds needed for product production. Therefore, enterprises are faced with the choice of these two crowdfunding methods.

The own funds of the marine ranching leading enterprise is M . If the enterprise raises funds by means of consumer crowdfunding, in the first stage, the total investment of consumers in consumer crowdfunding is m . And consumers can share out the total income of the marine ranching leading enterprise in the proportion of $\frac{m}{M+m}$ (Courey et al., 2021; Tsafack & Guo, 2021). In order to avoid the loss of control right of the marine ranching leading enterprise and refer to the assumptions of the literature in Fu et al. (2018). The proportion of consumers share out the total income of the marine ranching, it should meet the conditions $0 < \frac{m}{M+m} \leq 0.5$. The marine ranching leading enterprise is responsible for the production of products, and the production cost per unit product is c . Assuming that the total investment of consumers in consumer crowdfunding can meet the capital demand of the marine ranching leading enterprise, that is, the consumer crowdfunding project is successful.

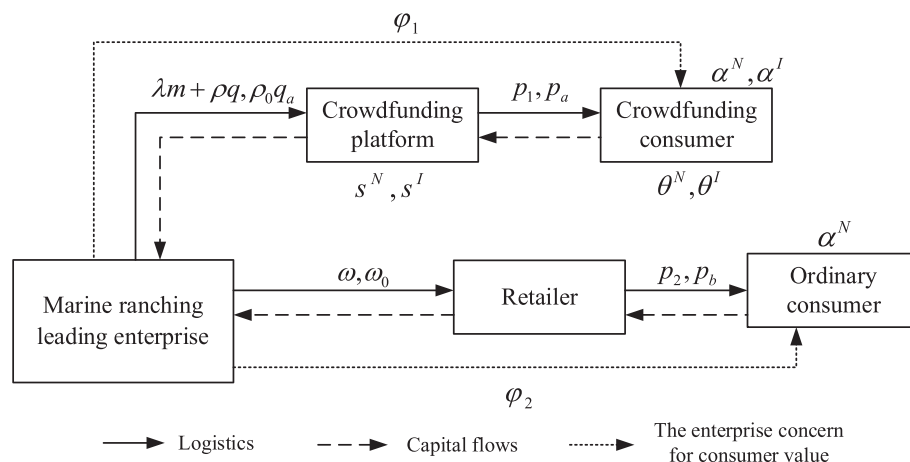
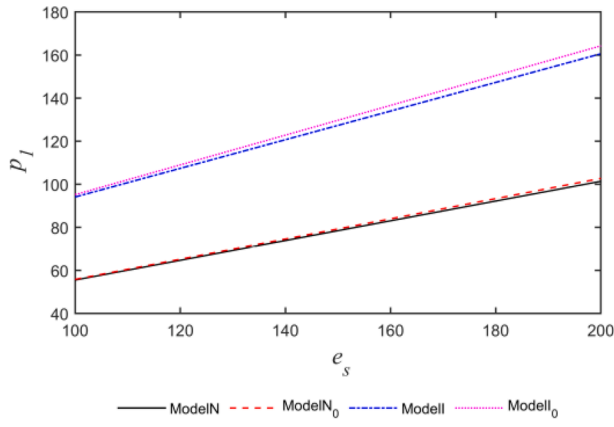
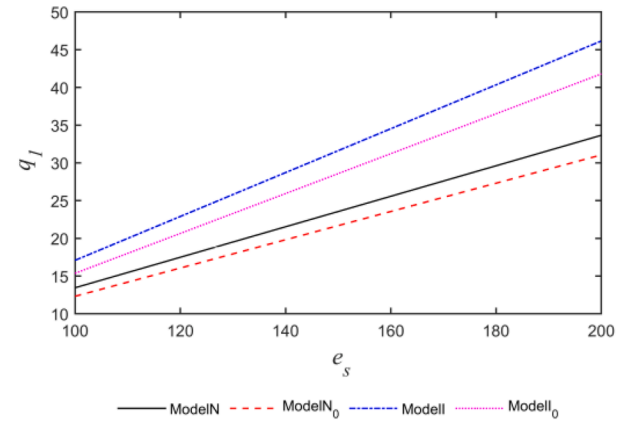


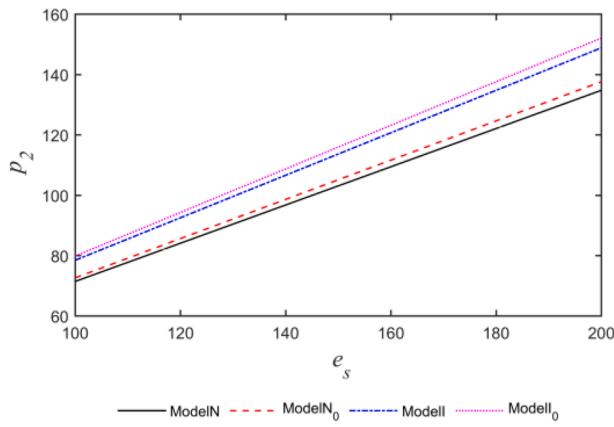
Fig. 1. The crowdfunding supply chain system model.



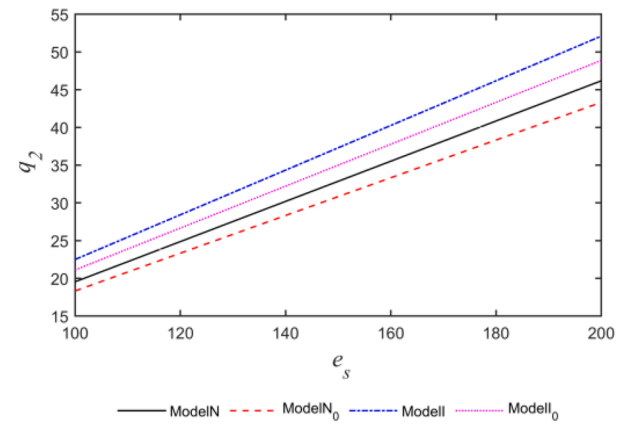
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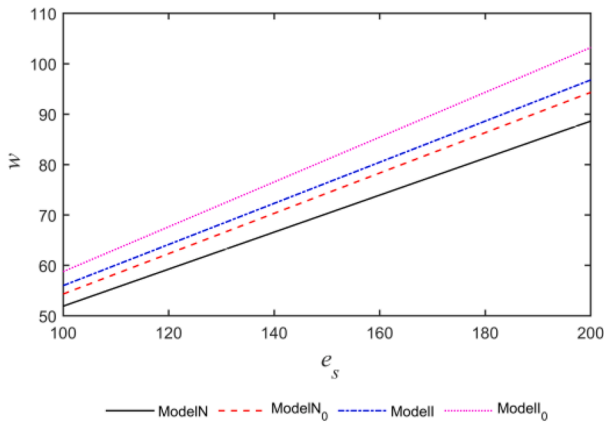
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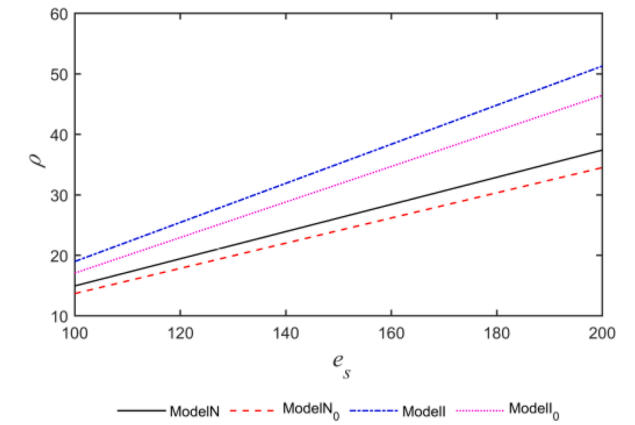
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(f)

Fig. 2. The relationship between product green attributes and the optimal decision-making variables.

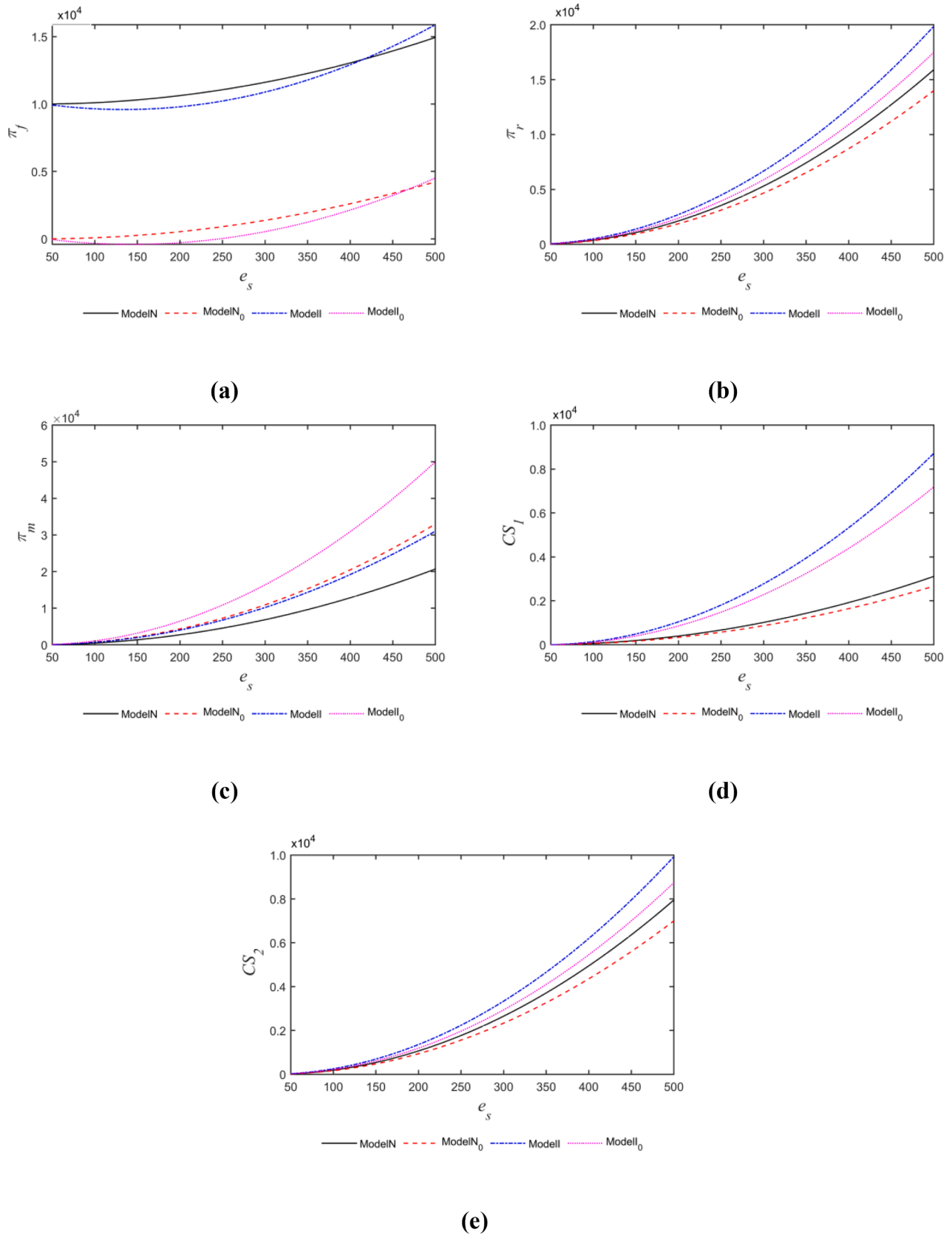
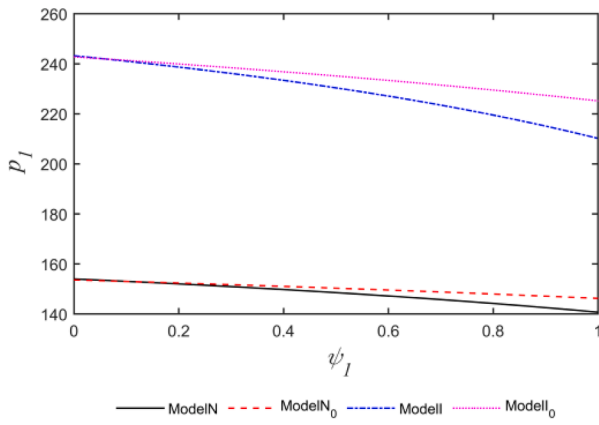
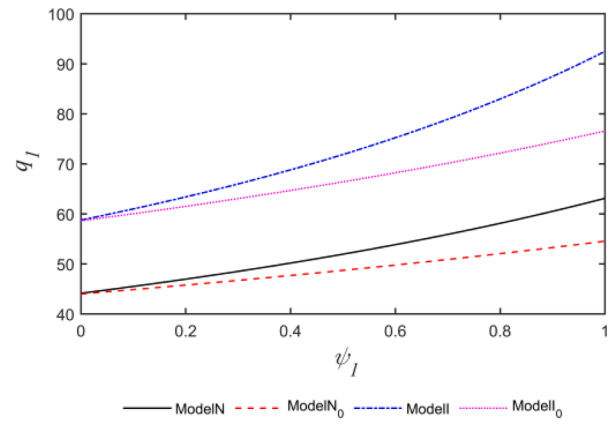


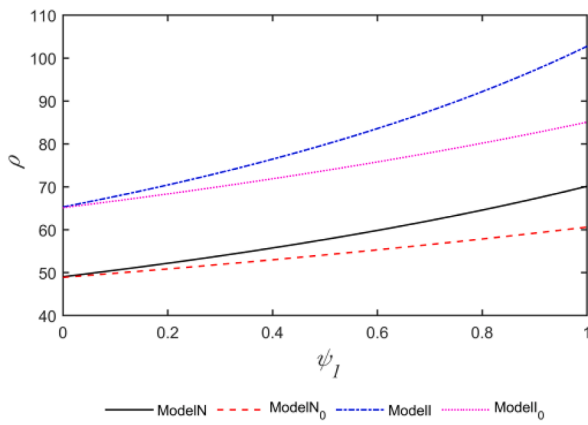
Fig. 3. The relationship between product green attributes and the optimal value of each subject.



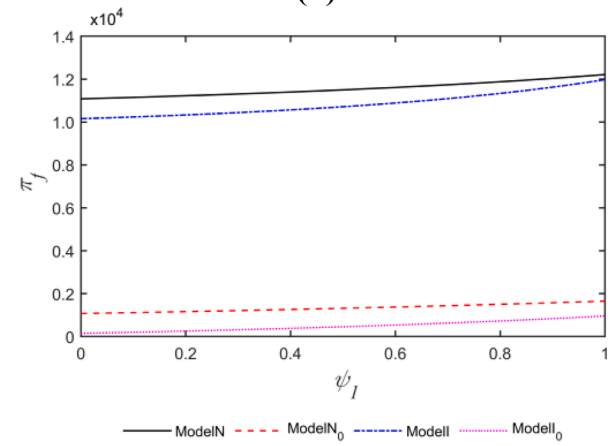
(a)



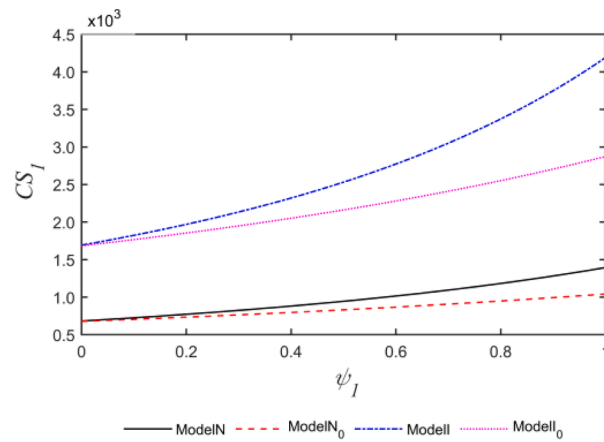
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(e)

Fig. 4. The relationship between the degree of attention to crowdfunding consumer value and the crowdfunding related parameters.

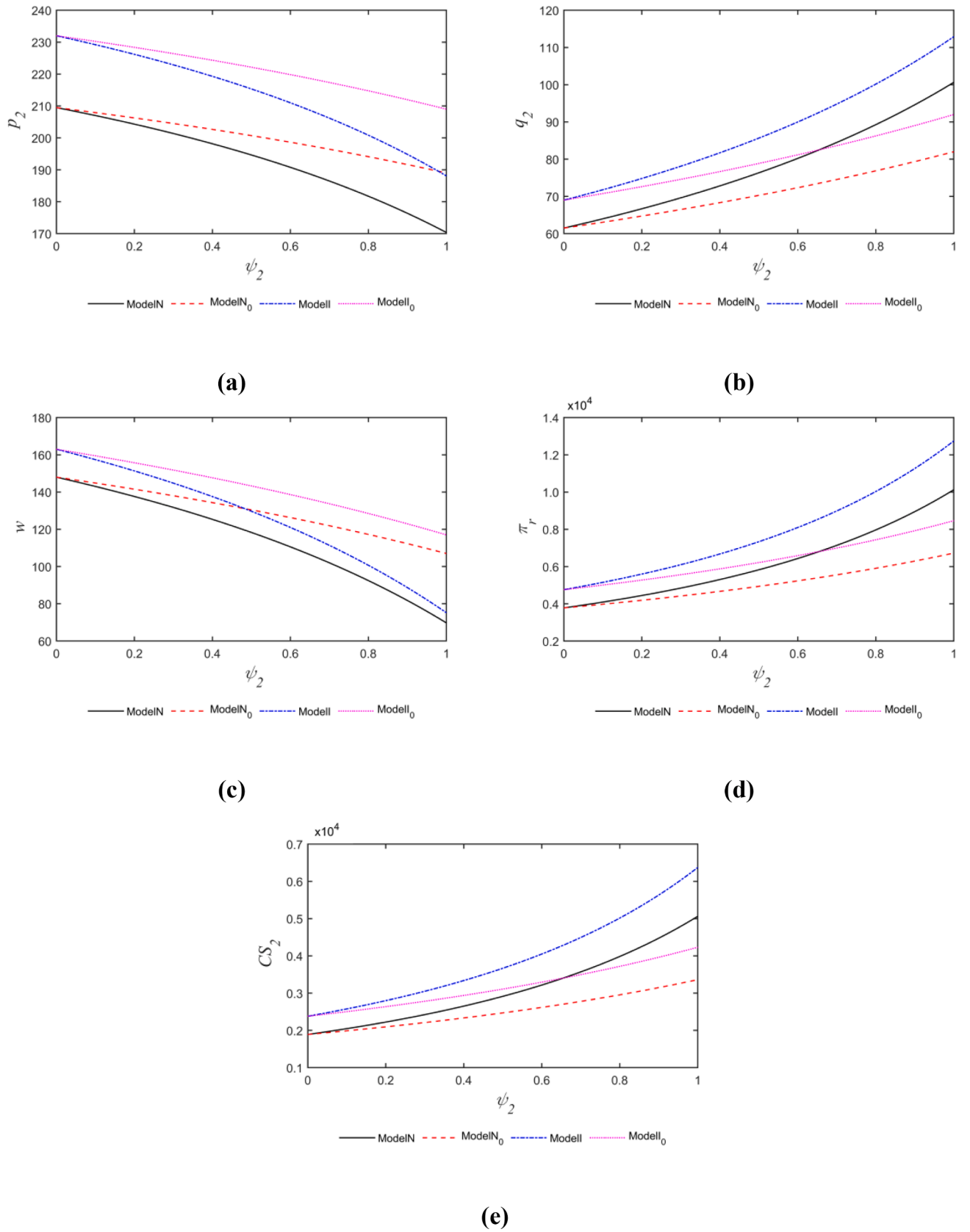


Fig. 5. The relationship between the degree of attention to ordinary consumer value and the crowdfunding related parameters.

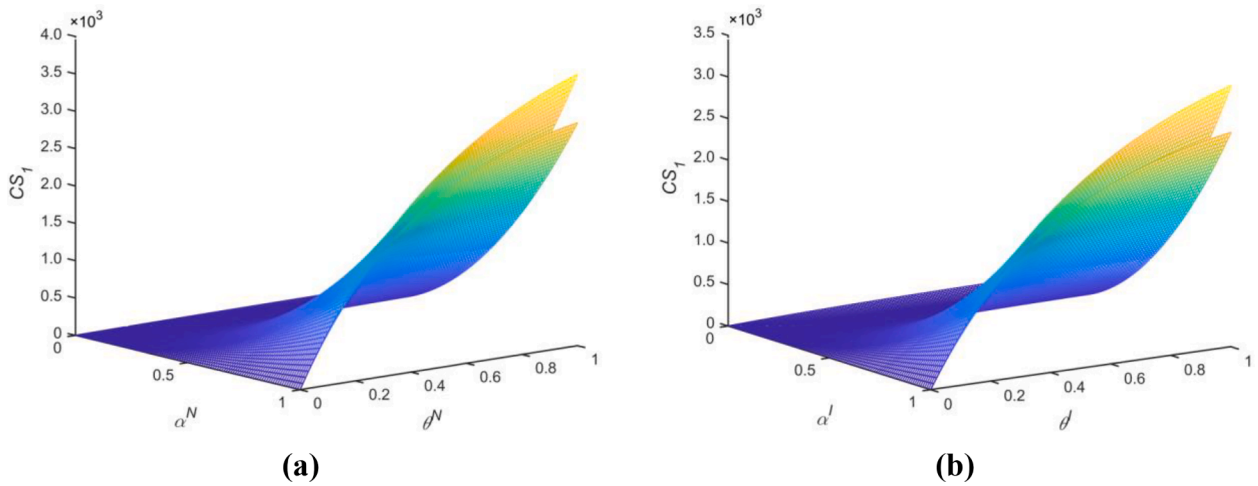


Fig. 6. The relationship between crowdfunding consumer value and product attributes.

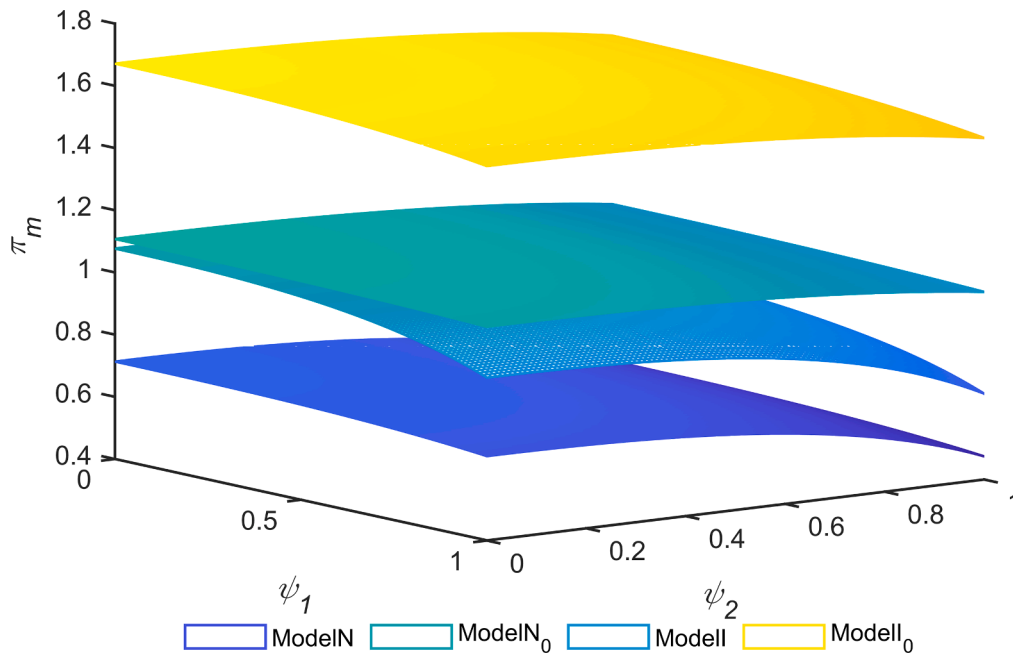


Fig. 7. The relationship between the marine ranching leading enterprise's value and the degree of attention.

Then, in the second stage, crowdfunding consumers can get q_1 quantity of products at the price p_1 , the marine ranching leading enterprise sells products to the retailer at wholesale price ω , and the ordinary consumers buy q_2 quantity of products at price p_2 in the retailer, meet the condition $p_1 < p_2$. After the completion of the sales stage, the enterprise needs to pay the commission of $\lambda m + \rho q_1$ to the crowdfunding platform, where ρ is the unit product commission in the case of consumer crowdfunding, and λ is the commission proportion coefficient of the total investment of crowdfunding consumers (Ma et al., 2022).

If the enterprise chooses the way of pre-sale crowdfunding for financing, in the first stage, the pre-sale crowdfunding consumers book q_a quantity of products with deposit o , and the final product price of the pre-sale crowdfunding consumers is p_a . Assuming that the pre-sale crowdfunding project is successful. Then, in the second stage, after the products are mature, the pre-sale crowdfunding consumers will pay the remaining money to take away the products, of which the remaining money is $p_a q_a - o$. At the same time, the marine ranching leading enterprise sells the products to the retailer at wholesale price ω_0 , and ordinary consumers finally buy q_b quantity of products at price p_b in the

retailer, meet the condition $p_a < p_b$. After the completion of the sales stage, the marine ranching leading enterprise needs to pay $\rho_0 q_a$ commission to the crowdfunding platform, and ρ_0 is the unit product commission in the case of pre-sale crowdfunding.

3.2. Basic assumptions

In order to solve the problem reasonably, this paper puts forward the following hypotheses:

Hypothesis 1. The final demand for marine ranching products will be affected by the product green attributes e_s , and satisfies the condition that $e_s \geq 0$ (Wan et al., 2021). Ordinary consumers' recognition of product green attributes is α ($0 < \alpha < 1$) without introducing BT (Yi et al., 2022). When BT is introduced, $\alpha = 1$. Crowdfunding consumers need to make decisions in advance. When BT is not introduced, their recognition of product green attributes is α^N , and when BT is introduced, it is α^I . Where $\alpha^N < \alpha^I$ and $0 < \alpha^N < \alpha^I < 1$.

Hypothesis 2. The marginal costs of introducing BT into the marine

ranching leading enterprise and the crowdfunding platform are c_{ls} and c_{lf} respectively.

Hypothesis 3. Referring to the hypothesis proposed by Wu (2012), assuming that the service level of the crowdfunding platform is s , and γ is the elasticity coefficient of the impact of platform service level on crowdfunding consumer demand. Without losing generality, meeting the condition $s^I > s^N$. Assuming that k represents the service cost coefficient of the crowdfunding platform, and satisfies $0 < k < 1$, the service cost of the consumer crowdfunding platform is $\frac{k\rho^2}{2}$, and the service cost of the pre-sale crowdfunding platform is $\frac{k\rho_0^2}{2}$ (Wan et al., 2022).

Hypothesis 4. Referring to the hypothesis in literature (Wan et al., 2022), this paper assumes that the quality attribute of unit product in two crowdfunding modes is v , v obeys the uniform distribution on $[0, 1]$. Its probability density function is $f(v)$, and its distribution function is $F(v)$. Assuming that consumers' willingness to pay is related to the quality attributes of unit products v . When BT is not introduced, crowdfunding consumers' recognition of product quality attributes is θ^N ($0 < \theta < 1$), because they fail to know product information. When BT is introduced, it can guarantee the final product quality of consumers. At this time, the product quality attributes becomes θ^I ($\theta^I > \theta^N$). Since ordinary consumers buy products after they are listed, whether BT is introduced or not, the ordinary consumers' recognition of product quality attributes is always equal to 1.

Hypothesis 5. When BT is introduced, consumer crowdfunding consumers can have a more detailed understanding of the subsequent operation and development of the enterprise, which enhance their investment confidence. At this time, consumers' valuation of unit product income is $v', v' \in (0, 1)$. When BT is not introduced, their valuation of product income becomes $\delta v'$, $0 < \delta < 1$, which δ is the valuation coefficient of consumers product income (Su & Zhang, 2022).

Hypothesis 6. Based on the theory of value co-creation, the degree of the enterprise's attention to consumer value is set as φ (Zhang et al., 2022), $0 \leq \varphi \leq 1$. φ_1 indicates the degree of the enterprise's attention to crowdfunding consumer value. φ_2 indicates the degree of the enterprise's attention to ordinary consumer value.

Based on the above hypotheses, the two types of consumer demand functions under different crowdfunding modes can be solved when BT is introduced or not. To simplify the model, this paper assumes that there are two types of consumers in the market, one is crowdfunding consumers and the other is ordinary consumers. Crowdfunding consumers buy products through consumer crowdfunding or pre-sale crowdfunding, while ordinary consumers buy products through the retailer. Superscript N and I represent BT not introduced and BT introduced respectively.

4. Model building

According to the above hypotheses, based on the utility function theory, when the real value of the product is higher than the perceived value of the consumer, the consumer will pay for this product (Liu et al., 2020).

The utility of crowdfunding consumers for the marine ranching leading enterprise's products is influenced by five factors. That includes product quality attributes, consumer recognition of product quality attributes, sales price, consumer valuation of product revenue, product green attributes, consumer recognition of product green attributes, and service level of the crowdfunding platform. Similarly, the utility of ordinary consumers for the marine ranching leading enterprise's products is affected by three factors, namely, product quality attributes, consumers' recognition of product quality attributes, sales price, product green attributes and consumer recognition of product green attributes. In addition, when purchasing the products, consumers will get consumer surplus, that is, consumer value (Liu et al., 2020).

4.1. Model N: Supply chain revenue model based on consumer crowdfunding without introducing BT

Without introducing BT, the utility of crowdfunding consumers can be expressed as: $U_1^N = \theta^N v - p_1^N + \delta v' + \alpha^N e_s + \gamma s^N$. When $U_1^N > 0$, crowdfunding consumers will choose to buy marine ranching products, and their willingness range to buy products is $\Theta_1^N = \{v : U_1^N > 0\}$, that is $\Theta_1^N = \{x_1^N = \frac{p_1^N - \delta v' - \alpha^N e_s - \gamma s^N}{\theta^N} < v \leq 1\}$. Thus, the demand function and consumer value function of crowdfunding consumers under the consumer crowdfunding model are respectively expressed as follows:

$$q_1^N = \int_{x_1^N}^1 f(v)dv = 1 - \frac{p_1^N - \delta v' - \alpha^N e_s - \gamma s^N}{\theta^N} \quad (1)$$

$$CS_1^N = \int_{x_1^N}^1 U_1^N dv = \frac{\theta^N (q_1^N)^2}{2} \quad (2)$$

The utility obtained by ordinary consumers can be expressed as: $U_2^N = v - p_2^N + \alpha e_s$. When $U_2^N > 0$, ordinary consumers will buy the product, and the willingness range of buying the product is $\Theta_2^N = \{v : U_2^N > 0\}$, that is $\Theta_2^N = \{x_2^N = p_2^N - \alpha e_s < v \leq 1\}$. Thus, the demand function and consumer value function of ordinary consumers under the consumer crowdfunding model are obtained as follows:

$$q_2^N = \int_{x_2^N}^1 f(v)dv = 1 - (p_2^N - \alpha e_s) \quad (3)$$

$$CS_2^N = \int_{x_2^N}^1 U_2^N dv = \frac{(q_2^N)^2}{2} \quad (4)$$

Based on the above analysis, the value functions of the crowdfunding platform, the retailer and the marine ranching leading enterprise under the consumer crowdfunding model without BT can be obtained as follows:

$$\Pi_f^N = \lambda m + \rho^N q_1^N - \frac{k(\rho^N)^2}{2} \quad (5)$$

$$\Pi_r^N = (p_2^N - \omega^N) q_2^N \quad (6)$$

$$\Pi_m^N = \frac{M}{M+m} [(p_1^N - \rho^N - c) q_1^N + (\omega^N - c) q_2^N] \quad (7)$$

Meanwhile, the objective function of decision-making of the marine ranching leading enterprise under this model is:

$$\begin{aligned} \Pi_m^N + \varphi CS^N = & \frac{M}{M+m} [(p_1^N - \rho^N - c) q_1^N \\ & + (\omega^N - c) q_2^N] + \varphi_1 \left(\frac{\theta^N (q_1^N)^2}{2} \right) + \varphi_2 \frac{(q_2^N)^2}{2} \end{aligned} \quad (8)$$

In this model, the marine ranching leading enterprise is the leader, followed by the retailer and the crowdfunding platform. Meet the Stackelberg game, a master-slave game model. The leading enterprise of marine ranching first decide the wholesale price of products and the price of products sold to crowdfunding consumers. Next, the retailer and the crowdfunding platform respectively determine the product prices and product commissions of ordinary consumers. Let the game model is Φ^N , including the marine ranching leading enterprise, the consumer crowdfunding platform and the retailer, then the hierarchical planning model of Φ^N is:

$$\begin{cases} \max_{p_1^N, \omega^N} \prod_m^N + \varphi CS^N \\ \text{s.t.} \begin{cases} \text{Where } p_1^N, p_2^N \text{ solve} \\ \max_{\rho^N} \prod_f^N \\ \max_{p_2^N} \prod_r^N \end{cases} \end{cases} \quad (9)$$

Therefore, Φ^N is a constrained two-level programming model. The value of enterprise alliance is $EVA = \prod_f^N + \prod_r^N + \prod_m^N$, supply chain value is $SCV = \prod_f^N + \prod_r^N + \prod_m^N + CS^N$. Finally, considering the consumer crowdfunding model without BT, the supply chain value co-creation model is as follows:

$$SCV \left(\arg \max_{\substack{p_1^N, \omega^N \\ \rho^N, p_2^N}} \Phi^N \right) \quad (10)$$

4.2. Model N_0 : Supply chain revenue model based on pre-sale crowdfunding without introducing BT

Under the pre-sale crowdfunding model without introducing BT, the utility of crowdfunding consumers can be expressed as: $U_a^N = \theta^N v - p_a^N + \alpha^N e_s + \gamma s_0^N$. When $U_a^N > 0$, crowdfunding consumers will choose to purchase the product, and their willingness range to buy the product is $\Theta_a^N = \{v : U_a^N > 0\}$, that is $\Theta_a^N = \left\{x_a^N = \frac{p_a^N - \alpha^N e_s - \gamma s_0^N}{\theta^N} < v \leq 1\right\}$. Thus, the demand function and consumer value function of crowdfunding consumers under the pre-sale crowdfunding model are respectively as follows:

$$q_a^N = \int_{x_a^N}^1 f(v) dv = 1 - \frac{p_a^N - \alpha^N e_s - \gamma s_0^N}{\theta^N} \quad (11)$$

$$CS_a^N = \int_{x_a^N}^1 U_a^N dv = \frac{\theta^N (q_a^N)^2}{2} \quad (12)$$

Similarly, the utility of ordinary consumers derived from marine ranching products can be expressed as: $U_b^N = v - p_b^N + \alpha e_s$. When $U_b^N > 0$, ordinary consumers will choose to buy the product, and the willingness range of buying the product is $\Theta_b^N = \{v : U_b^N > 0\}$, that is $\Theta_b^N = \{x_b^N = p_b^N - \alpha e_s < v \leq 1\}$. Thus, the demand function and consumer value function of ordinary consumers under the pre-sale crowdfunding model can be obtained as follows:

$$q_b^N = \int_{x_b^N}^1 f(v) dv = 1 - (p_b^N - \alpha e_s) \quad (13)$$

$$CS_b^N = \int_{x_b^N}^1 U_b^N dv = \frac{(q_b^N)^2}{2} \quad (14)$$

Based on the above analysis, the value functions of the crowdfunding platform, the retailer and the marine ranching leading enterprise under the pre-sale crowdfunding model without BT can be obtained as follows:

$$\prod_{f0}^N = \rho_0^N q_a^N - \frac{k(\rho_0^N)^2}{2} \quad (15)$$

$$\prod_{r0}^N = (p_b^N - \omega_0^N) q_b^N \quad (16)$$

$$\prod_{m0}^N = (p_a^N - \rho_0^N - c) q_a^N + (\omega_0^N - c) q_b^N \quad (17)$$

The objective function of decision-making of the marine ranching leading enterprise is:

$$\prod_{m0}^N + \varphi CS_0^N = (p_a^N - \rho_0^N - c) q_a^N + (\omega_0^N - c) q_b^N + \varphi_1 \left(\frac{\theta^N (q_a^N)^2}{2} \right) + \varphi_2 \frac{(q_b^N)^2}{2} \quad (18)$$

The game model is Φ_0^N , including the marine ranching leading enterprise, the pre-sale crowdfunding platform and the retailer. Then, the hierarchical planning model of Φ_0^N is:

$$\begin{cases} \max_{p_a^N, \omega_0^N} \prod_{m0}^N + \varphi CS_0^N \\ \text{s.t.} \begin{cases} \text{Where } \rho_0^N, p_b^N \text{ solve} \\ \max_{\rho_0^N} \prod_{f0}^N \\ \max_{p_b^N} \prod_{r0}^N \end{cases} \end{cases} \quad (19)$$

Therefore, Φ_0^N is a constrained two-level hierarchical programming model. The value of enterprise alliance is $EVA = \prod_{f0}^N + \prod_{r0}^N + \prod_{m0}^N$, supply chain value is $SCV = \prod_{f0}^N + \prod_{r0}^N + \prod_{m0}^N + CS_0^N$, and finally consider the supply chain value co-creation model without introducing BT under the pre-sale crowdfunding mode as follows:

$$SCV \left(\arg \max_{\substack{p_a^N, \omega_0^N \\ \rho_0^N, p_b^N}} \Phi_0^N \right) \quad (20)$$

4.3. Model I: Supply chain revenue model based on consumer crowdfunding when BT is introduced

Under the consumer crowdfunding model of introducing BT, the utility of crowdfunding consumers can be expressed as follows: $U_1^I = \theta^I v - p_1^I + v' + \alpha^I e_s + \gamma s^I$. When $U_1^I > 0$, crowdfunding consumers will purchase the product, and the willingness range to buy the product is $\Theta_1^I = \{v : U_1^I > 0\}$, that is $\Theta_1^I = \left\{x_1^I = \frac{p_1^I - v' - \alpha^I e_s - \gamma s^I}{\theta^I} < v \leq 1\right\}$. Thus, the demand function and consumer value function of crowdfunding consumers are as follows:

$$q_1^I = \int_{x_1^I}^1 f(v) dv = 1 - \frac{p_1^I - v' - \alpha^I e_s - \gamma s^I}{\theta^I} \quad (21)$$

$$CS_1^I = \int_{x_1^I}^1 U_1^I dv = \frac{\theta^I (q_1^I)^2}{2} \quad (22)$$

Similarly, the utility of the ordinary consumer can be expressed as: $U_2^I = v - p_2^I + e_s$. When $U_2^I > 0$, ordinary consumers will buy the product, and their willingness range to buy the product is $\Theta_2^I = \{v : U_2^I > 0\}$, that is $\Theta_2^I = \{x_2^I = p_2^I - e_s < v \leq 1\}$. Thus, the demand function and consumer value function of ordinary consumers under the consumer crowdfunding model are obtained as follows:

$$q_2^I = \int_{x_2^I}^1 f(v) dv = 1 - (p_2^I - e_s) \quad (23)$$

$$CS_2^I = \int_{x_2^I}^1 U_2^I dv = \frac{(q_2^I)^2}{2} \quad (24)$$

Based on the above analysis, the value functions of the crowdfunding platform, the retailer and the marine ranching leading enterprise under

the consumer crowdfunding model with BT can be obtained as follows:

$$\Pi_f^I = \lambda m + (p^I - c_{if})q_1^I - \frac{k(\rho^I)^2}{2} \quad (25)$$

$$\Pi_r^I = (p_2^I - \omega^I)q_2^I \quad (26)$$

$$\Pi_m^I = \frac{M}{M+m} [(p_1^I - \rho^I - c - c_{ls})q_1^I + (\omega^I - c)q_2^I] \quad (27)$$

The objective function of decision-making of the marine ranching leading enterprise is:

$$\begin{aligned} \Pi_m^I + \varphi CS^I = & \frac{M}{M+m} [(p_1^I - \rho^I - c - c_{ls})q_1^I \\ & + (\omega^I - c)q_2^I] + \varphi_1 \left(\frac{\theta^I (q_1^I)^2}{2} \right) + \varphi_2 \frac{(q_2^I)^2}{2} \end{aligned} \quad (28)$$

The game model is Φ^I , including the marine ranching leading enterprise, the consumer crowdfunding platform and the retailer, then the hierarchical planning model of Φ^I is:

$$\begin{cases} \max_{p_1^I, \omega^I} \Pi_m^I + \varphi CS^I \\ \text{s.t.} \left\{ \begin{array}{l} \text{Where } p_1^I, p_2^I \text{ solve} \\ \max_{\rho^I} \Pi_f^I \\ \max_{p_2^I} \Pi_r^I \end{array} \right. \end{cases} \quad (29)$$

Therefore, Φ^I is a constrained two-level hierarchical programming model. The enterprise alliance value is $EVA = \Pi_f^I + \Pi_r^I + \Pi_m^I$, supply chain value is $SCV = \Pi_f^I + \Pi_r^I + \Pi_m^I + CS^I$, and finally consider the supply chain value co-creation model without introducing BT under the consumer crowdfunding mode as follows:

$$SCV \left(\arg \max_{\substack{p_1^I, \omega^I, \\ \rho^I, p_2^I}} \Phi^I \right) \quad (30)$$

4.4. Model I_0 : Supply chain revenue model based on pre-sale crowdfunding when BT is introduced

The utility of pre-sale crowdfunding consumers gained from marine ranching products can be expressed as $U_a^I = \theta^I v - p_a^I + \alpha^I e_s + \gamma s_0^I$. When $U_a^I > 0$, crowdfunding consumers will buy marine ranching products, and their willingness range to buy products is $\Theta_a^I = \{v : U_a^I > 0\}$, that is $\Theta_a^I = \left\{x_a^I = \frac{p_a^I - \alpha^I e_s - \gamma s_0^I}{\theta^I} < v \leq 1\right\}$. Thus, the demand function and consumer value function of crowdfunding consumers under the pre-sale crowdfunding model are respectively as follows:

$$q_a^I = \int_{x_a^I}^1 f(v)dv = 1 - \frac{p_a^I - \alpha^I e_s - \gamma s_0^I}{\theta^I} \quad (31)$$

$$CS_a^I = \int_{x_a^I}^1 U_a^I dv = \frac{\theta^I (q_a^I)^2}{2} \quad (32)$$

The utility gained by the ordinary consumers can be expressed as: $U_b^I = v - p_b^I + e_s$. When $U_b^I > 0$, ordinary consumers will buy the product, and their willingness range to buy the product is $\Theta_b^I = \{v : U_b^I > 0\}$, that is $\Theta_b^I = \{x_b^I = p_b^I - e_s < v \leq 1\}$. Thus, the demand function and consumer value function of ordinary consumers under the pre-sale crowdfunding

model are respectively as follows:

$$q_b^I = \int_{x_b^I}^1 f(v)dv = 1 - (p_b^I - e_s) \quad (33)$$

$$CS_b^I = \int_{x_b^I}^1 U_b^I dv = \frac{(q_b^I)^2}{2} \quad (34)$$

Based on the above analysis, the value functions of the crowdfunding platform, the retailer and the marine ranching leading enterprise under the pre-sale crowdfunding model with BT can be obtained as follows:

$$\Pi_{f0}^I = (\rho_0^I - c_{if})q_a^I - \frac{k(\rho_0^I)^2}{2} \quad (35)$$

$$\Pi_{r0}^I = (p_b^I - \omega_0^I)q_b^I \quad (36)$$

$$\Pi_{m0}^I = (p_a^I - \rho_0^I - c - c_{ls})q_a^I + (\omega_0^I - c)q_b^I \quad (37)$$

The objective function of decision-making of the marine ranching leading enterprise is:

$$\begin{aligned} \Pi_{m0}^I + \varphi CS_0^I = & (p_a^I - \rho_0^I - c \\ & - c_{ls})q_a^I + (\omega_0^I - c)q_b^I + \varphi_1 \left(\frac{\theta^I (q_a^I)^2}{2} \right) + \varphi_2 \frac{(q_b^I)^2}{2} \end{aligned} \quad (38)$$

The game model is Φ_0^I , including the marine ranching leading enterprise, the pre-sale crowdfunding platform and the retailer, then the hierarchical planning model of Φ_0^I is:

$$\begin{cases} \max_{p_a^I, \omega_0^I} \Pi_{m0}^I + \varphi CS_0^I \\ \text{s.t.} \left\{ \begin{array}{l} \text{Where } p_0^I, p_b^I \text{ solve} \\ \max_{\rho_0^I} \Pi_{f0}^I \\ \max_{p_b^I} \Pi_{r0}^I \end{array} \right. \end{cases} \quad (39)$$

Therefore, Φ_0^I is a constrained two-level hierarchical programming model. The value of enterprise alliance is $EVA = \Pi_{f0}^I + \Pi_{r0}^I + \Pi_{m0}^I$, and the value of supply chain is $SCV = \Pi_{f0}^I + \Pi_{r0}^I + \Pi_{m0}^I + CS_0^I$, and finally consider the supply chain value co-creation model without introducing BT under the pre-sale crowdfunding mode as follows:

$$SCV \left(\arg \max_{\substack{p_a^I, \omega_0^I, \\ \rho_0^I, p_b^I}} \Phi_0^I \right) \quad (40)$$

5. Model solving

In this section, we use the backward induction method in Stackelberg game to solve the four models respectively, and the optimal decision of the marine ranching leading enterprise under this model is obtained.

5.1. Supply chain revenue model based on consumer crowdfunding without introducing BT

According to the Section 4.1 and decision order, the optimal decision result under the model N is solved. Firstly, on the basis of the consumer crowdfunding platform's value and the retailer's price maximization, the response functions of the crowdfunding platform commission ratio

ρ^N and the price of ordinary consumers' products p_2^N are solved respectively. Next, the two response functions are brought into the objective function of the marine ranching leading enterprise, which can solve p_1^N and ω . And, the optimal results of each decision variable are brought into the profit function of supply chain each main body. The optimal result under this model can be obtained, that is, Conclusion 1.

Conclusion 1 In the model N:

The optimal product purchase price of crowdfunding consumers is:

$$p_1^N = \left(\frac{2M\delta + M\delta k\theta^N - M\varphi_1\delta k\theta^N - \varphi_1\delta km\theta^N}{2M + 2Mk\theta^N - \varphi_1 km\theta^N - M\varphi_1 k\theta^N} \right) v' + \frac{Mk(\theta^N)^2 - M\varphi_1 k(\theta^N)^2 - \varphi_1 km(\theta^N)^2 + Mck\theta^N}{2M + 2Mk\theta^N - \varphi_1 km\theta^N - M\varphi_1 k\theta^N} \\ + \frac{2M\theta^N + 2M\alpha^N e_s + 2M\gamma s^N + M\alpha^N e_s k\theta^N + M\gamma ks^N \theta^N - M\alpha^N \varphi_1 e_s k\theta^N - M\varphi_1 \gamma ks^N \theta^N - \alpha^N \varphi_1 e_s km\theta^N - \varphi_1 \gamma kms^N \theta^N}{2M + 2Mk\theta^N - \varphi_1 km\theta^N - M\varphi_1 k\theta^N}$$

The optimal consumer value of crowdfunding consumers is: $CS_1^N = \frac{M^2 k^2 \theta^N (\theta^N - c + \alpha^N e_s + \gamma s^N + \delta v')^2}{2(2M + 2Mk\theta^N - \varphi_1 km\theta^N - M\varphi_1 k\theta^N)^2}$;

The optimal consumer value of ordinary consumers is: $CS_2^N = \frac{M^2 (\alpha e_s - c + 1)^2}{2(M\varphi_2 - 4M + \varphi_2 m)^2}$;

The optimal value of the enterprise alliance is:

$$EVA^N = \lambda m + \frac{M^2 k (\theta^N - c + \alpha^N e_s + \gamma s^N + \delta v')^2}{2(2M + 2Mk\theta^N - \varphi_1 km\theta^N - M\varphi_1 k\theta^N)^2} + \frac{M^2 (\alpha e_s - c + 1)^2}{(M\varphi_2 - 4M + \varphi_2 m)^2} \\ - \frac{M}{M+m} \left(\frac{M(\alpha e_s - c + 1)^2 (M\varphi_2 - 2M + \varphi_2 m)}{(M\varphi_2 - 4M + \varphi_2 m)^2} - \frac{Mk(M + Mk\theta^N - \varphi_1 km\theta^N - M\varphi_1 k\theta^N) (\theta^N - c + \alpha^N e_s + \gamma s^N + \delta v')^2}{(2M + 2Mk\theta^N - \varphi_1 km\theta^N - M\varphi_1 k\theta^N)^2} \right);$$

The optimal product order quantity of crowdfunding consumers is:

$$q_1^N = Mk(\theta^N - \frac{c + \alpha^N e_s + \gamma s^N + \delta v'}{2M + 2Mk\theta^N - \varphi_1 km\theta^N - M\varphi_1 k\theta^N});$$

The optimal unit product commission of the crowdfunding platform

The optimal value of the supply chain system is:

$$SCV^N = \lambda m + \frac{M^2 k (\theta^N - c + \alpha^N e_s + \gamma s^N + \delta v')^2}{2(2M + 2Mk\theta^N - \varphi_1 km\theta^N - M\varphi_1 k\theta^N)^2} + \frac{3M^2 (\alpha e_s - c + 1)^2}{2(M\varphi_2 - 4M + \varphi_2 m)^2} + \frac{M^2 k^2 \theta^N (\theta^N - c + \alpha^N e_s + \gamma s^N + \delta v')^2}{2(2M + 2Mk\theta^N - \varphi_1 km\theta^N - M\varphi_1 k\theta^N)^2} \\ - \frac{M}{M+m} \left(\frac{M(\alpha e_s - c + 1)^2 (M\varphi_2 - 2M + \varphi_2 m)}{(M\varphi_2 - 4M + \varphi_2 m)^2} - \frac{Mk(M + Mk\theta^N - \varphi_1 km\theta^N - M\varphi_1 k\theta^N) (\theta^N - c + \alpha^N e_s + \gamma s^N + \delta v')^2}{(2M + 2Mk\theta^N - \varphi_1 km\theta^N - M\varphi_1 k\theta^N)^2} \right).$$

$$\text{is: } \rho^N = \frac{M(\theta^N - c + \alpha^N e_s + \gamma s^N + \delta v')}{2M + 2Mk\theta^N - \varphi_1 km\theta^N - M\varphi_1 k\theta^N};$$

The optimal product purchase price of ordinary consumers is: $p_2^N =$

$$\frac{(\varphi_2 + \alpha\varphi_2 e_s)m + M(\varphi_2 - c + \alpha\varphi_2 e_s - 3 - 3\alpha e_s)}{\varphi_2 m + M\varphi_2 - 4M};$$

The optimal product purchase quantity of ordinary consumers is:

$$q_2^N = \frac{M(\alpha e_s - c + 1)}{4M - M\varphi_2 - \varphi_2 m};$$

The optimal product wholesale price is: $\omega^N =$

$$\frac{(\varphi_2 + \alpha\varphi_2 e_s)m + M(\varphi_2 - 2c - 2 - 2\alpha e_s + \alpha\varphi_2 e_s)}{\varphi_2 m + M\varphi_2 - 4M};$$

The optimal value of the crowdfunding platform is: $\Pi_f^N = \lambda m +$

$$\frac{M^2 k (\theta^N - c + \alpha^N e_s + \gamma s^N + \delta v')^2}{2(2M + 2Mk\theta^N - \varphi_1 km\theta^N - M\varphi_1 k\theta^N)^2};$$

The optimal value of the retailer is: $\Pi_r^N = \frac{M^2 (\alpha e_s - c + 1)^2}{(M\varphi_2 - 4M + \varphi_2 m)^2}$;

The optimal value of the marine ranching leading enterprise is:

$$\Pi_m^N = -\frac{M}{M+m} \left(\frac{M(\alpha e_s - c + 1)^2 (M\varphi_2 - 2M + \varphi_2 m)}{(M\varphi_2 - 4M + \varphi_2 m)^2} - \frac{Mk(M + Mk\theta^N - \varphi_1 km\theta^N - M\varphi_1 k\theta^N) (\theta^N - c + \alpha^N e_s + \gamma s^N + \delta v')^2}{(2M + 2Mk\theta^N - \varphi_1 km\theta^N - M\varphi_1 k\theta^N)^2} \right);$$

In order to ensure that the above optimal solution is meaningful, it is necessary to satisfy the condition $\theta^N - c + \alpha^N e_s + \gamma s^N + \delta v' \geq 0$ and $\alpha e_s - c + 1 \geq 0$.

Proof. See [Appendix A1](#).

5.2. Supply chain revenue model based on pre-sale crowdfunding without introducing BT

According to the Section 4.2 and decision order, the solution idea is similar to the Section 5.2, and then can get the optimal result under the model N_0 , named Conclusion 2.

Conclusion 2 In the model N_0 :

The optimal product purchase price of crowdfunding consumers is:

$$p_a^N = \frac{(\varphi_1 k - k)(\theta^N)^2 + (\varphi_1 \gamma ks^N - \alpha^N e_s k - \gamma ks^N - ck + \alpha^N \varphi_1 e_s k - 2)\theta^N - 2\alpha^N e_s - 2\gamma s^N}{(\varphi_1 k - 2k)\theta^N - 2};$$

The optimal product order quantity of crowdfunding consumers is:

$$q_a^N = \frac{k(\theta^N - c + \alpha^N e_s + \gamma s^N)}{2k\theta^N - \varphi_1 k\theta^N + 2};$$

The optimal unit product commission of the crowdfunding platform is: $\rho_0^N = \frac{\theta^N - c + \alpha^N e_s + \gamma s^N}{2k\theta^N - \varphi_1 k\theta^N + 2}$.

The optimal product purchase price of ordinary consumers is: $p_b^N = \frac{\varphi_2 \alpha e_s - 3\alpha e_s + \varphi_2 - 3 - c}{\varphi_2 - 4}$.

The optimal product purchase quantity of ordinary consumers is: $q_b^N = \frac{\alpha e_s - c + 1}{4 - \varphi_2}$.

The product optimal wholesale price is: $\omega_0^N = \frac{(\alpha \varphi_2 - 2\alpha) e_s - 2c + \varphi_2 - 2}{\varphi_2 - 4}$.

The optimal value of the crowdfunding platform is: $\Pi_{f0}^N = \frac{k(\theta^N - c + \alpha^N e_s + \gamma s^N)^2}{2(2k\theta^N - \varphi_1 k\theta^N + 2)^2}$.

The optimal value of the retailer is: $\Pi_{ra}^N = \left(\frac{\alpha e_s - c + 1}{\varphi_2 - 4} \right)^2$.

The optimal value of the marine ranching leading enterprise is: $\Pi_{ma}^N = \frac{k(k\theta^N - \varphi_1 k\theta^N + 1)(\theta^N - c + \alpha^N e_s + \gamma s^N)^2}{(2k\theta^N - \varphi_1 k\theta^N + 2)^2} - \frac{(\alpha e_s - c + 1)^2(\varphi_2 - 2)}{(\varphi_2 - 4)^2}$.

The optimal consumer value of crowdfunding consumers is: $CS_a^N = \frac{k^2 \theta^N (\theta^N - c + \alpha^N e_s + \gamma s^N)^2}{2(2k\theta^N - \varphi_1 k\theta^N + 2)^2}$.

The optimal consumer value of ordinary consumers is: $CS_b^N = \frac{1}{2} \left(\frac{\alpha e_s - c + 1}{\varphi_2 - 4} \right)^2$.

The optimal value of the enterprise alliance is:

$$EVA_0^N = \frac{k(\theta^N - c + \alpha^N e_s + \gamma s^N)^2}{2(2k\theta^N - \varphi_1 k\theta^N + 2)^2} + \left(\frac{\alpha e_s - c + 1}{\varphi_2 - 4} \right)^2 - \frac{(\alpha e_s - c + 1)^2(\varphi_2 - 2)}{(\varphi_2 - 4)^2} + \frac{k(k\theta^N - \varphi_1 k\theta^N + 1)(\theta^N - c + \alpha^N e_s + \gamma s^N)^2}{(2k\theta^N - \varphi_1 k\theta^N + 2)^2}$$

The optimal value of the supply chain system is:

$$SCV_0^N = EVA_0^N = \frac{k(\theta^N - c + \alpha^N e_s + \gamma s^N)^2}{2(2k\theta^N - \varphi_1 k\theta^N + 2)^2} + \left(\frac{\alpha e_s - c + 1}{\varphi_2 - 4} \right)^2 - \frac{(\alpha e_s - c + 1)^2(\varphi_2 - 2)}{(\varphi_2 - 4)^2} + \frac{k^2 \theta^N (\theta^N - c + \alpha^N e_s + \gamma s^N)^2}{2(2k\theta^N - \varphi_1 k\theta^N + 2)^2} + \frac{k(k\theta^N - \varphi_1 k\theta^N + 1)(\theta^N - c + \alpha^N e_s + \gamma s^N)^2}{(2k\theta^N - \varphi_1 k\theta^N + 2)^2} + \frac{1}{2} \left(\frac{\alpha e_s - c + 1}{\varphi_2 - 4} \right)^2.$$

Proof. See Appendix A2.

In order to ensure that the optimal solution mentioned above is meaningful, conditions $\theta^N - c + \alpha^N e_s + \gamma s^N \geq 0$ and $\alpha e_s - c + 1 \geq 0$ need to be met.

Next, this paper will mainly discuss the five variables of e_s , φ_1 , φ_2 , α^N and θ^N for the optimal decision results, and analyses the correlation between the optimal results and variables under each model. In view of the fact that the utility of crowdfunding consumers and ordinary consumers is related to the green attributes of products, the recognition of product quality attributes and the product green attributes. These three variables determine the demand of products, and then affect the whole marine ranching crowdfunding supply chain system. In addition, this paper analyzes the influence of enterprise's recognition of consumers on the optimal result of the model, so as to study the influence of value co-creation on the crowdfunding supply chain system of marine ranching. Proposition 1- Proposition 5 can be obtained according to Conclusion 1 and Conclusion 2.

Proposition 1. In the model of consumer crowdfunding and pre-sale crowdfunding without introducing BT, with the rise of product green attributes, the product purchase price and product order quantity of crowdfunding

consumers and ordinary consumers increase, and the product wholesale price increases. Also, the optimal product commission of the crowdfunding platform, the platform value, the retailer value and the value of the marine ranching leading enterprise increase, and the consumer value of crowdfunding consumers and ordinary consumers increases. On the contrary, they decrease.

Proof. See Appendix B1.

According to Proposition 1, the optimal product purchase price, product order quantity, consumer value, product wholesale price, product commission of the crowdfunding platform, the platform value, the retailer value and the value of the marine ranching leading enterprise all change in the same direction as the product green attributes. When the product green attributes increase, its environmental friendliness will also be improved accordingly. Both crowdfunding consumers and ordinary consumers in the market will prefer green consumption, which naturally increases the demand for products with high environmental friendliness. The rise of product demand will lead to the increase of product prices in a short time, and make the consumer value obtained by consumers show an increasing trend. In order to maximize its own value, the crowdfunding platform will increase the unit product commission. In addition, the promotion of product green attributes will also have a positive impact on the revenue of the whole supply chain system, making the value of the marine ranching leading enterprise, the retailer and the crowdfunding platform show an upward trend.

Proposition 2. In the model of consumer crowdfunding and pre-sale crowdfunding without introducing BT, with the increase of φ_1 , the marine ranching leading enterprise pays more attention to the value of crowdfunding consumers, the product purchase price of crowdfunding consumers decreases, the product order quantity and consumer value increase, and the optimal product commission of the crowdfunding platform and its value increase.

Proof. See Appendix B2.

According to Proposition 2, it can be concluded that when the marine ranching leading enterprise pays more attention to crowdfunding consumer value, the enterprise will appropriately reduce the price of the products they provide to crowdfunding consumers. Then, crowdfunding consumers will increase the product order quantity. Through the reduction of the product price, the satisfaction of crowdfunding consumers will be improved, and the consumer value from purchasing the products of the marine ranching enterprise will be increased. When the enterprise pays more attention to crowdfunding consumer value, the crowdfunding platform will increase the commission for unit products to maximize the value, and the value of the platform is on the rise.

Proposition 3. In the model of consumer crowdfunding and pre-sale crowdfunding without introducing BT, as the marine ranching leading enterprise pays more attention to ordinary consumer value, the product purchase price of ordinary consumers and optimal product wholesale price decrease, while the product purchase quantity, consumer value and the retailer's value increase.

Proof. See Appendix B3.

According to Proposition 3, it can be concluded that when the marine ranching leading enterprise pays more attention to ordinary consumer

value, the enterprise will reduce the price of the products they offer to ordinary consumers, which will lead ordinary consumers to buy more products, and increase consumers' satisfaction by lowering the price of products. Thus, increasing consumers' consumer value from purchasing marine ranching products. In addition, the optimal product wholesale price changes inversely with the degree of the enterprise's attention to ordinary consumer value, and the optimal value of the retailer also increases, that is, the more enterprise's attention to ordinary consumer value, the lower the product wholesale price, and the more value the retailer gets.

Proposition 4. In the model of consumer crowdfunding and pre-sale

$$p_1^I = \frac{2M + Mk\theta^I - \varphi_1 km\theta^I - M\varphi_1 k\theta^I}{2M + 2Mk\theta^I - \varphi_1 km\theta^I - M\varphi_1 k\theta^I} + \frac{Mk(\theta^I)^2 - M\varphi_1 k(\theta^I)^2 - \varphi_1 km(\theta^I)^2 + Mck\theta^I + 2M\theta^I}{2M + 2Mk\theta^I - \varphi_1 km\theta^I - M\varphi_1 k\theta^I};$$

$$+ \frac{M\gamma ks^I\theta^I - M\alpha^I\varphi_1 e_s k\theta^I - M\varphi_1 \gamma ks^I\theta^I - \alpha^I\varphi_1 e_s km\theta^I - \varphi_1 \gamma kms^I\theta^I + Mck\theta^I + 2M\alpha^I e_s + 2M\gamma s^I + M\alpha^I e_s k\theta^I}{2M + 2Mk\theta^I - \varphi_1 km\theta^I - M\varphi_1 k\theta^I};$$

crowdfunding without introducing BT, the value of crowdfunding consumers is positively correlated with the recognition of product green attributes α^N and the recognition of product quality attributes θ^N by crowdfunding consumers.

Proof. See Appendix B4.

Proposition 4 shows that crowdfunding consumer value is influenced by consumers' recognition of the product green attributes and the recognition of the product quality attributes. When consumers' recognition of the product green attributes and product quality attributes is improved, they will form a preference for the product, which will further enhance the consumer value from purchasing the products of the marine ranching leading enterprise.

Proposition 5. In the model of consumer crowdfunding and pre-sale crowdfunding without introducing BT, the value of the marine ranching leading enterprise shows a reverse trend with the degree of the enterprise's attention to crowdfunding consumer value φ_1 and the degree of the enterprise's attention to ordinary consumer value φ_2 .

Proof. See Appendix B5.

Proposition 5 shows that the marine ranching leading enterprise pays related costs to the attention of crowdfunding consumer value and ordinary consumer value, which reduces their own value. However, with the improvement of attention, the value of the enterprise alliance increases. From Proposition 2 and Proposition 3, it can be seen that the main reason for this phenomenon is that the marine ranching leading enterprise pays more attention to crowdfunding consumer value and ordinary consumer value, which makes consumers improve their satisfaction with products, increase sales, and increase the value of the retailer, the crowdfunding platform and consumers.

5.3. Supply chain revenue model based on consumer crowdfunding when BT is introduced

According to the Section 4.3 and decision order, the optimal decision

result under the model I is solved. Based on the maximization of the consumer crowdfunding platform's value and the retailer's value, the response functions of the commission ratio ρ^I and the optimal product price of ordinary consumers p_2^I are obtained respectively. Next, the two formulas are brought into the objective function of the marine ranching leading enterprise can solve p_1^I and ω^I . And, the optimal results of each decision variable are brought into the profit function of each main body in the supply chain, then can get the optimal result under model I, named Conclusion 3.

Conclusion 3 In the model I:

The optimal product purchase price of crowdfunding consumers is:

The optimal product order quantity of crowdfunding consumers is:

$$q_1^I = \frac{Mk(\theta^I - c_{ls} - c + v' + e_s \alpha^I + \gamma s^I)}{2M + 2Mk\theta^I - \varphi_1 km\theta^I - M\varphi_1 k\theta^I};$$

The optimal unit product commission of the crowdfunding platform is:

$$\rho^I = \frac{M(\theta^I - c_{ls} - c + v' + e_s \alpha^I + \gamma s^I)}{2M + 2Mk\theta^I - \varphi_1 km\theta^I - M\varphi_1 k\theta^I};$$

The optimal product purchase price of ordinary consumers is: $p_2^I = \frac{(\varphi_2 + \varphi_2 e_s)m + M(\varphi_2 - c - 3 - 3e_s + \varphi_2 e_s)}{\varphi_2 m + M\varphi_2 - 4M};$

The optimal product purchase quantity of ordinary consumers is:

$$q_2^I = \frac{M(e_s - c + 1)}{4M - M\varphi_2 - \varphi_2 m};$$

The optimal product wholesale price is: $\omega^I = \frac{(\varphi_2 + \varphi_2 e_s)m + M(\varphi_2 - 2c - 2 - 2e_s + \varphi_2 e_s)}{\varphi_2 m + M\varphi_2 - 4M};$

The optimal value of the crowdfunding platform is: $\Pi_f^I = \lambda m \frac{M^2 k(\theta^I - c_{ls} - c + v' + e_s \alpha^I + \gamma s^I)^2}{2(2M + 2Mk\theta^I - \varphi_1 km\theta^I - M\varphi_1 k\theta^I)^2} - \frac{Mkc_{ff}(\theta^I - c_{ls} - c + v' + e_s \alpha^I + \gamma s^I)}{2M + 2Mk\theta^I - \varphi_1 km\theta^I - M\varphi_1 k\theta^I} + M^2 k \left(\frac{\theta^I - c_{ls} - c + v' + e_s \alpha^I + \gamma s^I}{2M + 2Mk\theta^I - \varphi_1 km\theta^I - M\varphi_1 k\theta^I} \right)^2;$

The optimal value of the retailer is: $\Pi_r^I = \frac{M^2(e_s - c + 1)^2}{(M\varphi_2 - 4M + \varphi_2 m)^2};$

The optimal value of the marine ranching leading enterprise is: $\Pi_m^I = -\frac{M}{M+m} \left(\frac{M(M\varphi_2 - 2M + \varphi_2 m)(e_s - c + 1)^2}{(M\varphi_2 - 4M + \varphi_2 m)^2} - \frac{Mk(M + Mk\theta^I - \varphi_1 km\theta^I - M\varphi_1 k\theta^I)(\theta^I - c_{ls} - c + v' + e_s \alpha^I + \gamma s^I)^2}{(2M + 2Mk\theta^I - \varphi_1 km\theta^I - M\varphi_1 k\theta^I)^2} \right);$

The optimal consumer value of crowdfunding consumers is: $CS_1^I = \frac{M^2 k^2 \theta^I (\theta^I - c_{ls} - c + v' + e_s \alpha^I + \gamma s^I)^2}{2(2M + 2Mk\theta^I - \varphi_1 km\theta^I - M\varphi_1 k\theta^I)^2};$

The optimal consumer value of ordinary consumers is: $CS_2^I = \frac{M^2(e_s - c + 1)^2}{2(M\varphi_2 - 4M + \varphi_2 m)^2};$

The optimal value of the enterprise alliance is:

$$EVA^I = \lambda m - \frac{M^2 k (\theta^I - c_{Is} - c + v' + e_s \alpha^I + \gamma s^I)^2}{2(2M + 2Mk\theta^I - \varphi_1 k m \theta^I - M\varphi_1 k \theta^I)^2} - \frac{Mk c_{If} (\theta^I - c_{Is} - c + v' + e_s \alpha^I + \gamma s^I)}{2M + 2Mk\theta^I - \varphi_1 k m \theta^I - M\varphi_1 k \theta^I}$$

$$+ M^2 k \left(\frac{\theta^I - c_{Is} - c + v' + e_s \alpha^I + \gamma s^I}{2M + 2Mk\theta^I - \varphi_1 k m \theta^I - M\varphi_1 k \theta^I} \right)^2 - \frac{M}{M+m} \left(\frac{M(M\varphi_2 - 2M + \varphi_2 m)(e_s - c + 1)^2}{(M\varphi_2 - 4M + \varphi_2 m)^2} \right)$$

$$+ \frac{M}{M+m} \left(\frac{Mk(M + Mk\theta^I - \varphi_1 k m \theta^I - M\varphi_1 k \theta^I)(\theta^I - c_{Is} - c + v' + e_s \alpha^I + \gamma s^I)^2}{(2M + 2Mk\theta^I - \varphi_1 k m \theta^I - M\varphi_1 k \theta^I)^2} \right) + \frac{M^2 (e_s - c + 1)^2}{(M\varphi_2 - 4M + \varphi_2 m)^2};$$

The optimal value of the supply chain system is:

$$SCV^I = \lambda m - \frac{M^2 k (\theta^I - c_{Is} - c + v' + e_s \alpha^I + \gamma s^I)^2}{2(2M + 2Mk\theta^I - \varphi_1 k m \theta^I - M\varphi_1 k \theta^I)^2} - \frac{Mk c_{If} (\theta^I - c_{Is} - c + v' + e_s \alpha^I + \gamma s^I)}{2M + 2Mk\theta^I - \varphi_1 k m \theta^I - M\varphi_1 k \theta^I} + M^2 k \left(\frac{\theta^I - c_{Is} - c + v' + e_s \alpha^I + \gamma s^I}{2M + 2Mk\theta^I - \varphi_1 k m \theta^I - M\varphi_1 k \theta^I} \right)^2$$

$$+ \frac{M^2 k^2 \theta^I (\theta^I - c_{Is} - c + v' + e_s \alpha^I + \gamma s^I)^2}{2(2M + 2Mk\theta^I - \varphi_1 k m \theta^I - M\varphi_1 k \theta^I)^2} + \frac{M^2 (e_s - c + 1)^2}{2(M\varphi_2 - 4M + \varphi_2 m)^2} + \frac{M^2 (e_s - c + 1)^2}{(M\varphi_2 - 4M + \varphi_2 m)^2}$$

$$- \frac{M}{M+m} \left(\frac{M(M\varphi_2 - 2M + \varphi_2 m)(e_s - c + 1)^2}{(M\varphi_2 - 4M + \varphi_2 m)^2} - \frac{Mk(M + Mk\theta^I - \varphi_1 k m \theta^I - M\varphi_1 k \theta^I)(\theta^I - c_{Is} - c + v' + e_s \alpha^I + \gamma s^I)^2}{(2M + 2Mk\theta^I - \varphi_1 k m \theta^I - M\varphi_1 k \theta^I)^2} \right).$$

Proof. See Appendix A3.

In order to ensure that the above optimal solution is meaningful, it is necessary to satisfy the condition $\theta^I - c_{Is} - c + v' + e_s \alpha^I + \gamma s^I \geq 0, e_s - c + 1 \geq 0$.

5.4. Supply chain revenue model based on pre-sale crowdfunding when BT is introduced

According to the Section 4.4 and decision order, similar to the solution idea of Section 5.3, to solve the optimal decision result under the model I_0 , and then we can get the optimal result under this model, named Conclusion 4.

Conclusion 4 In the model I_0 :

The optimal product purchase price of crowdfunding consumers is:

$$p_a^I = \frac{(\varphi_1 k - k)(\theta^I)^2 + (\varphi_1 \gamma k s^I - \alpha^I e_s k - \gamma k s^I - c k + \alpha^I \varphi_1 e_s k - 2 - c_{Is} k) \theta^I - 2 \alpha^I e_s - 2 \gamma s^I}{(\varphi_1 k - 2k) \theta^I - 2};$$

The optimal product order quantity of crowdfunding consumers is:

$$q_a^I = \frac{k(\theta^I - c_{Is} - c + \alpha^I e_s + \gamma s^I)}{2k\theta^I - \varphi_1 k \theta^I + 2};$$

The optimal unit product commission of the crowdfunding platform

$$\text{is: } \rho_0^I = \frac{\theta^I - c_{Is} - c + \alpha^I e_s + \gamma s^I}{2k\theta^I - \varphi_1 k \theta^I + 2};$$

$$EVA_0^I = \frac{k(\theta^I - c_{Is} - c + \alpha^I e_s + \gamma s^I)(\alpha^I e_s + \gamma s^I - 4c_{If} k \theta^I + 2c_{If} \varphi_1 k \theta^I + \theta^I - c_{Is} - 4c_{If} - c)}{2(2k\theta^I - \varphi_1 k \theta^I + 2)^2}$$

$$+ \left(\frac{e_s - c + 1}{\varphi_2 - 4} \right)^2 + \frac{k(k\theta^I - \varphi_1 k \theta^I + 1)(\theta^I - c_{Is} - c + \alpha^I e_s + \gamma s^I)^2}{(2k\theta^I - \varphi_1 k \theta^I + 2)^2} - \frac{(\varphi_2 - 2)(e_s - c + 1)^2}{(\varphi_2 - 4)^2};$$

The optimal product purchase price of ordinary consumers is: $p_b^I = \frac{\varphi_2 e_s - 3e_s + \varphi_2 - 3 - c}{\varphi_2 - 4};$

The optimal product purchase quantity of ordinary consumers is:

$$q_b^I = \frac{e_s - c + 1}{4 - \varphi_2};$$

The optimal product wholesale price is: $\omega_0^I = \frac{(\varphi_2 - 2)e_s - 2c + \varphi_2 - 2}{\varphi_2 - 4};$

The optimal value of the crowdfunding platform is: $\Pi_{f0}^I =$

$$\frac{k(\theta^I - c_{Is} - c + \alpha^I e_s + \gamma s^I)(\alpha^I e_s + \gamma s^I - 4c_{If} k \theta^I + 2c_{If} \varphi_1 k \theta^I + \theta^I - c_{Is} - 4c_{If} - c)}{2(2k\theta^I - \varphi_1 k \theta^I + 2)^2};$$

The optimal value of the retailer is: $\Pi_{ra}^I = \left(\frac{e_s - c + 1}{\varphi_2 - 4} \right)^2;$

The optimal value of the marine ranching leading enterprise is:

$$\Pi_{ma}^I = \frac{k(k\theta^I - \varphi_1 k \theta^I + 1)(\theta^I - c_{Is} - c + \alpha^I e_s + \gamma s^I)^2}{(2k\theta^I - \varphi_1 k \theta^I + 2)^2} - \frac{(\varphi_2 - 2)(e_s - c + 1)^2}{(\varphi_2 - 4)^2};$$

The optimal consumer value of crowdfunding consumers is: $CS_a^I =$

$$\frac{k^2 \theta^I (\theta^I - c_{Is} - c + \alpha^I e_s + \gamma s^I)^2}{2(2k\theta^I - \varphi_1 k \theta^I + 2)^2};$$

The optimal consumer value of ordinary consumers is: $CS_b^I =$

$$\frac{(e_s - c + 1)^2}{2(\varphi_2 - 4)^2};$$

The optimal value of the enterprise alliance is:

The optimal value of the supply chain system is:

$$SCV_0^I = \frac{k(\theta^I - c_{Is} - c + \alpha^I e_s + \gamma s^I)(\alpha^I e_s + \gamma s^I - 4c_{If}k\theta^I + 2c_{If}\varphi_1 k\theta^I + \theta^I - c_{Is} - 4c_{If} - c)}{2(2k\theta^I - \varphi_1 k\theta^I + 2)^2} + \left(\frac{e_s - c + 1}{\varphi_2 - 4}\right)^2$$

$$+ \frac{k(k\theta^I - \varphi_1 k\theta^I + 1)(\theta^I - c_{Is} - c + \alpha^I e_s + \gamma s^I)^2}{(2k\theta^I - \varphi_1 k\theta^I + 2)^2} - \frac{(\varphi_2 - 2)(e_s - c + 1)^2}{(\varphi_2 - 4)^2} + \frac{(e_s - c + 1)^2}{2(\varphi_2 - 4)^2} + \frac{k^2\theta^I(\theta^I - c_{Is} - c + \alpha^I e_s + \gamma s^I)^2}{2(2k\theta^I - \varphi_1 k\theta^I + 2)^2}.$$

In order to ensure that the optimal solution mentioned above is meaningful, conditions $\theta^I - c_{Is} - c + \alpha^I e_s + \gamma s^I \geq 0$ and $e_s - c + 1 \geq 0$ need to be met.

Proof. See [Appendix A4](#).

Proposition 6 - Proposition 10 can be obtained according to Conclusion 3 and Conclusion 4.

Proposition 6. In the model of consumer crowdfunding and pre-sale crowdfunding with introducing BT, with the rise of product green attributes, the product purchase price and product order quantity of crowdfunding consumers and ordinary consumers increase, the product wholesale price increases, the optimal product commission of the crowdfunding platform increases, the value of the retailer and the marine ranching leading enterprise increases, the consumer value of crowdfunding and ordinary consumers increases, and the value of the crowdfunding platform decreases first and then increases.

Proof. See [Appendix B6](#).

According to Proposition 6, the product purchase price, product order quantity, product wholesale price, product commission of the crowdfunding platform, the retailer value, the marine ranching leading enterprise and consumer value of crowdfunding consumers change in the same direction as the product green attributes. Moreover, the influence of the change of product green attributes on the value of the crowdfunding platform tends to decrease first and then increase. When the product green attributes are lower than a certain threshold, the increase of product green attributes will bring a larger cost, which makes the value of the crowdfunding platform change inversely. When the product green attributes are higher than a certain threshold, the value of the crowdfunding platform changes with it in the same direction.

Proposition 7. In the model of consumer crowdfunding and pre-sale crowdfunding with the introduction of BT, as the marine ranching leading enterprise pays more attention to crowdfunding consumers, the product purchase price of crowdfunding consumers' decreases, the product order quantity and consumer value increase, the optimal product commission of crowdfunding platform increases, and the value of the crowdfunding platform decreases first and then increases.

Proof. See [Appendix B7](#).

According to Proposition 7, the product order quantity of crowdfunding consumers, the value of crowdfunding consumers, and the product commission of the crowdfunding platform are positively related to the degree of the enterprise's attention to crowdfunding consumer value. The product purchase price of crowdfunding consumers is negatively related to the degree of the enterprise's attention to crowdfunding consumer value. The value of the crowdfunding platform shows a trend of decreasing first and then increasing by the degree of the enterprise's attention to crowdfunding consumer value, that is, when the degree of the enterprise's attention to crowdfunding consumer value is lower than a certain threshold, the increase of the enterprises' attention will lead to the increase of costs, which makes the value of the crowdfunding platform show a downward trend. When the enterprise pays more attention

to crowdfunding consumer value than a certain threshold, the value of the crowdfunding platform shows an increasing trend with the increase of the enterprise's attention.

Proposition 8. In the model of consumer crowdfunding and pre-sale crowdfunding with the introduction of BT, as the marine ranching leading enterprise pays more attention to ordinary consumer value, the product purchase price and product wholesale price decrease, while the product purchase quantity of ordinary consumers, ordinary consumer value and the retailer value increase.

Proof. See [Appendix B8](#).

According to Proposition 8, it can be concluded that in the model of consumer crowdfunding and pre-sale crowdfunding with the introduction of BT, when the enterprise pays more attention to the value of ordinary consumers, they will appropriately reduce the product price they provide to ordinary consumers and increase consumers' purchase of the products. By lowering the price to improve consumers' satisfaction and increase consumers' value from purchasing products. In addition, as the enterprise pays more attention to ordinary consumer value, the product wholesale price that is the cost of the retailer will decrease, thus increasing the retailer's value.

Proposition 9. In the model of consumer crowdfunding and pre-sale crowdfunding with the introduction of BT, the value of crowdfunding consumers is positively related to the recognition of product green attributes α^N and the recognition of product quality attributes θ^N by crowdfunding consumers.

Proof. See [Appendix B9](#).

According to Proposition 9, it can be concluded that in the case of introducing BT, crowdfunding consumer value is influenced by its recognition of product green attributes and its recognition of product quality attributes. When rising consumers' recognition of product green attributes and product quality attributes, they will have a preference for such products, which will increase the consumer value obtained by crowdfunding consumers from purchasing the products of the marine ranching leading enterprise.

Proposition 10. In the model of consumer crowdfunding and pre-sale crowdfunding with the introduction of BT, the value of the marine ranching leading enterprise shows a reverse trend with the degree of the enterprise's attention to crowdfunding consumer value φ_1 and the degree of the enterprise's attention to ordinary consumer value φ_2 .

Proof. See [Appendix B10](#).

According to Proposition 10, it can be concluded that the attention paid by the marine ranching leading enterprise to crowdfunding consumer value and ordinary consumer value brings higher costs and reduces their own value. However, with the increasing attention, it can be seen from Proposition 7 and Proposition 8 that with the increasing attention of the marine ranching leading enterprise to crowdfunding consumer value and ordinary consumer value, consumers have improved their satisfaction with products and increased their purchase quantity, and the value of the retailer, the crowdfunding platform and consumers in the supply chain system have been improved.

6. Comparison of different crowdfunding methods

The optimal decision-making results obtained by adopting two different crowdfunding methods by the marine ranching leading enterprise (Conclusion 1 and Conclusion 2; Conclusion 3 and Conclusion 4) make comparative analysis, and Proposition 11- Proposition 13 can be obtained.

Proposition 11. *In different models, the product purchase price and product wholesale price satisfy the following relationship:*

The product purchase price of crowdfunding consumers: When $e_s > \zeta_1$, $p_1^N < p_a^N$; When $e_s > \zeta_2$, $p_1^I < p_a^I$.

The product purchase price of ordinary consumers: When $e_s > \zeta_3$ and the condition ψ_1 is satisfied, $p_2^N < p_b^N$; $p_2^I < p_b^I$.

The product wholesale price: When $e_s > \zeta_4$ and the condition ψ_2 is satisfied, $\omega^N < \omega_0^N$; $\omega^I < \omega_0^I$.

Proof. See Appendix B11.

It can be seen from Proposition 11 that under different crowdfunding models, the relationship between the optimal product purchase price for consumers and the optimal product wholesale price is non constant.

For crowdfunding consumers, when BT is not introduced and $e_s > \zeta_1$, the product purchase price under consumer crowdfunding is less than that under pre-sale crowdfunding. With the introduction of BT, when $e_s > \zeta_2$, the above relationship is also satisfied. On the contrary, the above relationship will be reversed, that is, with the change of product green attributes, the above relationship will also change accordingly.

For ordinary consumers, when BT is not introduced, $e_s > \zeta_3$ and condition ψ_1 is met, the product purchase price under consumer crowdfunding is lower than that under pre-sale crowdfunding, and the relationship between them will change with the change of product green attributes e_s . After the introduction of BT, there is a constant relationship: the product purchase price under consumer crowdfunding is less than that under pre-sale crowdfunding.

For the product wholesale price of the marine ranching leading enterprise, when $e_s > \zeta_4$ and condition ψ_2 are met without introducing BT, the product wholesale price under consumer crowdfunding is less than that under pre-sale crowdfunding. On the contrary, the relationship between the two is reversed. However, with the introduction of BT, there is a constant relationship: the product wholesale price under consumer crowdfunding is smaller than that under pre-sale crowdfunding.

The main reason for this phenomenon is that the products produced by marine ranching leading enterprises are more environmentally friendly than ordinary products. When the produced product environmentally friendly is higher, that is, the above conditions are met, because consumer crowdfunding is an activity after the products have been produced, the environmental friendliness of the products has a great impact on consumers' behavior at this time. In order to promote the success of crowdfunding activities, marine ranching leading enterprises will reduce the product prices of crowdfunding consumers to quickly raise the required funds. After the success of crowdfunding, in order to maintain stable development, the wholesale price sold to retailers is small, and the purchase price of ordinary consumers' products is also small.

For pre-sale crowdfunding, because it is an activity before the enterprise produces products, there will be problems such as information asymmetry between enterprises and consumers. Enterprises predict the order quantity of crowdfunding consumers by their product environmental friendliness, and then set the price, so the purchase price of their products is higher. After successfully raising and producing products in public, high environmental friendliness brings high wholesale prices and

high retail prices.

Proposition 12. *In different models, the product purchase quantity of consumers and the unit product commission satisfy the following relationship:*

The unit product commission of the crowdfunding platform: $\rho^N > \rho_0^N$; $\rho^I > \rho_a^I$.

The product order quantity of crowdfunding consumers: $q_1^N > q_a^N$; $q_1^I > q_a^I$.

The product purchase quantity of ordinary consumers: When $e_s > \zeta_5$, and meet the condition ψ_3 , $q_2^N > q_b^N$; $q_2^I > q_b^I$.

Proof. See Appendix B12.

It can be seen from Proposition 12 that, in different crowdfunding models, the relationship between the unit product commission of the crowdfunding platform and the product order of crowdfunding consumers is constant, while the relationship between the product purchase of ordinary consumers is non constant.

For the unit product commission fee charged by the crowdfunding platform, whether BT is introduced or not, the unit product commission under consumer crowdfunding is greater than the commission charged by the crowdfunding platform under pre-sale crowdfunding. This shows that for the same crowdfunding platform, compared with the way enterprises choose to raise funds by pre-sale crowdfunding, when the enterprise chooses the way of consumer crowdfunding, the crowdfunding platform will charge higher commission for unit products.

For crowdfunding consumers, whether BT is introduced or not, there is a relationship that the product order quantity under consumer crowdfunding is greater than that under pre-sale crowdfunding. The main reason for this phenomenon is that crowdfunding consumers will get a lower product purchase price in consumer crowdfunding (Proposition 11 can be known), which leads consumers to increase their purchase of the product.

For ordinary consumers, when BT is not introduced, $e_s > \zeta_5$ and condition ψ_3 is met, the product purchase quantity under consumer crowdfunding is greater than that under pre-sale crowdfunding. On the contrary, the relationship between them will be reversed. However, after the introduction of BT, the above-mentioned size relationship will always exist and will not change with the change of e_s .

In the consumer crowdfunding model, when the environmental friendliness of marine products is high, on the one hand, crowdfunding consumers and ordinary consumers get higher consumer utility from purchasing products, which will lead to higher purchases. On the other hand, crowdfunding consumers and ordinary consumers have lower product prices, which will stimulate them to increase their purchases. In this case, in order to obtain higher value, the crowdfunding platform will increase the commission charged to the enterprise accordingly. However, under the pre-sale crowdfunding model, higher product environmental friendliness will lead to higher product purchase price, which will make consumers reduce their purchases. At this time, in order to promote the success of crowdfunding, the crowdfunding platform will reduce the commission charged accordingly.

Proposition 13. *In different models, the value of the crowdfunding platform, the value of the retailer and the consumer value satisfy the following relationships:*

The value of the crowdfunding platform: $\Pi_f^N > \Pi_{f0}^N$; $\Pi_f^I > \Pi_{f0}^I$.

The value of the retailer: $\Pi_r^N > \Pi_{ra}^N$; $\Pi_r^I > \Pi_{ra}^I$.

The consumer value of crowdfunding consumers: $CS_1^N > CS_a^N$; $CS_1^I > CS_a^I$.

The consumer value of ordinary consumers: $CS_2^N < CS_b^N$; $CS_2^I < CS_b^I$.

Proof. See Appendix B13.

It can be seen from Proposition 13 that under different crowdfunding models, the relationship between the value of the crowdfunding platform, the value of the retailer and the consumer value is constant.

For the value of the crowdfunding platform and the value of the retailer, whether BT is introduced or not, the value obtained by consumer crowdfunding is higher than that obtained by pre-sale crowdfunding. The crowdfunding platform will charge higher commission for unit products under consumer crowdfunding, and crowdfunding consumers will order more products, thus making the crowdfunding platform get higher value. Also, under the consumer crowdfunding, the product wholesale price that is the cost of the retailer is lower, and ordinary consumers will buy more products under the consumer crowdfunding, thus making the value gained by the retailer higher.

For crowdfunding consumers, whether BT is introduced or not, the consumer value under consumer crowdfunding is greater than that under pre-sale crowdfunding. For ordinary consumers, whether BT is introduced or not, it will gain higher consumer value under the way of pre-sale crowdfunding. That is mainly because in the consumer crowdfunding model, for crowdfunding consumers, their utility from purchasing products increases, so their consumer value is higher. In the pre-sale crowdfunding model, ordinary consumers choose whether to buy or not after the products begin to appear. So, when the products are more environmentally friendly, they get higher consumer value.

From the above analysis, it can be seen that no matter whether the marine ranching leading enterprises introduce BT or not, when enterprises choose crowdfunding for financing, they will prefer to choose consumer crowdfunding. In the consumer crowdfunding, enterprises have a certain amount of self-owned funds as the basis to produce products, and crowdfunding consumers make investment choices on the basis of a better understanding of marine ranching products. In the pre-sale crowdfunding, crowdfunding consumers need to bear all the funds produced by enterprises, which leads to the low value of supply chain members. Moreover, because pre-sale crowdfunding is an activity before the production of products, there will be problems such as information asymmetry between enterprises and consumers. To sum up, the marine ranching leading enterprises will give priority to consumer crowdfunding to carry out crowdfunding activities.

In addition, due to the complexity of models and comparison results, it is difficult to compare and analyze the optimal decision variables of two crowdfunding methods without BT and those with BT by derivative and proof. Therefore, in the sixth part, with the help of numerical simulation, on the basis of further verifying the accuracy of the above proposition, this paper makes the correlation analysis on the influence of introducing BT on the optimal decision results.

7. Numerical analysis

In view of the fact that there are many different variables in the four different models constructed in this paper, the optimal solution has certain complexity. In order to better show the model constructed in this paper, we simulated the processing of model results by Zhang et al. (2022). In this section, we use MATLAB R2022a application program to simulate the optimal decision-making behavior under different models. Moreover, without losing generality, the values of variables and parameters allocated in this paper are in line with the conditions set by the model construction part and the actual market situation.

Assuming that the self-owned funds of the marine ranching leading enterprise $M = 900$, the total investment of crowdfunding consumers $m = 500$, the unit product cost $c = 25$, the cost of introducing BT by the marine ranching leading enterprise $c_{ls} = 30$, the cost of introducing BT by the crowdfunding platform $c_{ff} = 30$, the service cost coefficient of the

crowdfunding platform $k = 0.9$, the elasticity coefficient of the crowdfunding platform service level on the demand of crowdfunding consumers $\gamma = 15$, and the commission proportion coefficient of total investment of crowdfunding consumers $\lambda = 20$. For crowdfunding consumers, when BT is not introduced, their recognition of product quality attributes $\theta^N = 0.7$ and their recognition of product green attributes $\alpha^N = 0.6$. When BT is introduced, the relevant parameters become $\theta^I = 0.98$ and $\alpha^I = 0.95$. For ordinary consumers, when BT is not introduced, their recognition of product green attributes $\alpha = 0.9$. In addition, $v' = 0.6$, $\delta = 0.8$. Let the degree of the enterprise's attention to crowdfunding consumer value $\varphi_1 = 0.6$, and the degree of the enterprise's attention to ordinary consumer value $\varphi_2 = 0.4$. Take the product green attributes e_s of the marine ranching leading enterprise as the independent variable, and change it in the interval $[100, 200]$. Make the relationship diagram of the optimal decision-making variables change with the independent variable e_s in the four models, as shown in Fig. 2.

It can be seen from Fig. 2(a), Fig. 2(c) and Fig. 2(e) that, in different models, the product purchase price and product wholesale price of crowdfunding consumers and ordinary consumers are positively correlated with the product green attributes of the marine ranching leading enterprise. That is to say, with the enhancement of the products' environmental friendliness, the price of consumers buying such products will increase, and the product wholesale price of the marine ranching leading enterprise to the retailer will also increase accordingly. This is consistent with Proposition 1. Without introducing BT, satisfy the relationship: $p_1^N < p_a^N$, $p_2^N < p_b^N$, $\omega^N < \omega_0^N$. In the case of introducing BT, satisfy the relationship: $p_1^I < p_a^I$, $p_2^I < p_b^I$, $\omega^I < \omega_0^I$. This shows that under the pre-sale crowdfunding model, the product purchase price and product wholesale price are both higher, which is consistent with Proposition 11. In addition, the figure also reflects the influence of whether BT is introduced or not on each optimal decision variable. In the four models, the product purchase price of crowdfunding consumers satisfies the relationship: $p_a^I > p_1^I > p_a^N > p_1^N$, the product purchase price of ordinary consumers satisfies the relationship: $p_b^I > p_2^I > p_b^N > p_2^N$, and the product wholesale price satisfies the relationship: $\omega_0^I > \omega^I > \omega_0^N > \omega^N$. Then, Proposition 14 can be derived from this.

Proposition 14. When BT is introduced, the product purchase price of crowdfunding consumers and ordinary consumers and the product wholesale price are higher than the corresponding prices when BT is not introduced.

This Proposition shows that BT has increased the product purchase price of consumers and the product wholesale price. This is mainly because the introduction of BT by the enterprise will bring higher marginal costs. In order to ensure the optimization of their own value, the marine ranching leading enterprise will increase the product purchase price sold to crowdfunding consumers and the product wholesale price sold to the retailer. When the product wholesale price increases, the cost of the retailer increases. At this point, the retailer will increase the prices of products sold to ordinary consumers to maximize their own value.

It can be seen from Fig. 2(b), Fig. 2(d) and Fig. 2(f) that, in the four models, the product unit commission of the crowdfunding platform, the product order quantity of crowdfunding consumers and ordinary consumers rise with the rise of product green attributes of the marine ranching leading enterprise. This phenomenon shows that consumers will increase their product purchase quantity with high environmental friendliness. Moreover, the crowdfunding platform will charge more commissions for products with high product green attributes. This is consistent with Proposition 1. Under the two models without introducing BT, there have relationships: $\rho^N > \rho_0^N$, $q_1^N > q_a^N$, $q_2^N > q_b^N$. Under the two models of introducing BT, there have relationships: $\rho^I > \rho_a^I$, $q_1^I > q_a^I$, $q_2^I > q_b^I$. This shows that consumers will buy more marine ranching products under the model of consumer crowdfunding, mainly because the product purchase price is lower under this model of consumer

crowdfunding. Moreover, the commission charged by the crowdfunding platform for unit products is also low. This is consistent with Proposition 12. In addition, the figure also reflects the influence of whether BT is introduced or not on each optimal decision variable. In the four models, unit product commission satisfies the relationship: $\rho^I > \rho_a^I > \rho^N > \rho_0^N$, product purchase of crowdfunding consumers satisfies the relationship: $q_1^I > q_a^I > q_1^N > q_a^N$, product purchase of ordinary consumers satisfies the relationship: $q_2^I > q_b^I > q_2^N > q_b^N$, and thus Proposition 15 can be obtained.

Proposition 15. *When BT is introduced, the unit product commission, the product purchase of crowdfunding consumers and ordinary consumers are higher than those without introducing BT.*

Proposition 15 shows that when BT is introduced, the commission charged by the crowdfunding platform for unit products will increase, and the product purchase quantity of crowdfunding consumers and ordinary consumers will also increase. This phenomenon is caused by the following reasons: On the one hand, the introduction of BT by the crowdfunding platform will generate higher marginal cost, and in order to maximize its own value, the platform will increase the commission of unit products. On the other hand, because BT has the advantages of information visualization, when it is introduced, consumers will recognize the product green attributes and the product quality attributes more, thus increasing the purchase of products.

In order to make the simulation results more obvious and more conducive to analysis, the image of variable e_s changing in the interval [50, 500], other parameters remaining unchanged, and the change of other decision parameters and independent variable e_s are made. The relationship between product green attributes e_s and the optimal value of each subject in the supply chain system is shown in Fig. 3.

It can be seen from Fig. 3(a), Fig. 3(b), Fig. 3(c), Fig. 3(d), Fig. 3(e) that in the model N and model N_0 , the value of the crowdfunding platform, the value of the retailer and the consumer value of consumers are positively correlated with the product green attributes, and satisfy the relationship: $\Pi_f^N > \Pi_{f0}^N$, $\Pi_r^N > \Pi_{r0}^N$, $CS_1^N > CS_a^N$, $CS_2^N < CS_b^N$. That is, with the improvement of product environmental friendliness, the value gained by each subject in the supply chain system increases. In the model I and model I_0 , the value of the retailer and the consumer value of consumers are positively correlated with e_s . with the increase of e_s , the value of the crowdfunding platform shows a trend of decreasing first and then rising, and satisfying the relationship: $\Pi_f^I > \Pi_{f0}^I$, $\Pi_r^I > \Pi_{r0}^I$, $CS_1^I > CS_a^I$, $CS_2^I < CS_b^I$. This shows that at the beginning of the introduction of BT, the value of the crowdfunding platform will incur higher costs due to the introduction of BT, and it will show a downward trend and reach the lowest point with the improvement of product green attributes. With the continuous increase of e_s , the value of the crowdfunding platform is mainly affected by product green attributes, showing a trend of change in the same direction as e_s . This is consistent with Proposition 6 and Proposition 13. In addition, Fig. 3(a), Fig. 3(b), Fig. 3(c), Fig. 3(d), Fig. 3(e) also reflects the impact of BT on the value of each subject. Then, Proposition 16 can be deduced from this.

Proposition 16. *When BT is introduced, the value obtained by supply chain members is higher than that obtained when BT is not introduced.*

Proposition 16 shows that after the introduction of BT, the value gained by each subject in the supply chain system has increased. The main reason is the advantages of BT, because BT has the advantages of decentralization and information visualization. After the introduction of BT, the credibility of information obtained by the marine ranching leading enterprise, the crowdfunding platform, the retailer, crowdfunding consumers and ordinary consumers is enhanced, and the degree of trust among each subject is enhanced, which increases the value of each subject.

Make the product green attributes $e_s = 300$, and make the degree of the enterprise's attention to crowdfunding consumer value φ_1 as the

independent variable, change in the interval [0, 1]. The relationship between the degree of the enterprise's attention to crowdfunding consumer value and the changes of crowdfunding related parameters is shown in Fig. 4.

From Fig. 4(a), Fig. 4(b), Fig. 4(c), Fig. 4(e), it can be seen that the degree of the enterprise's attention to crowdfunding consumer value φ_1 is inversely correlated to the product purchase price of thus consumers, and has a positive correlation with the product order quantity of thus consumers. Similarly, the commission charged by the crowdfunding platform for unit products and the consumer value of crowdfunding consumers rise with the increase of φ_1 . When the enterprise attaches importance to crowdfunding consumers, the enterprise will pay more attention to the consumer value, so as to realize value co-creation, thus the product purchase price of consumers will be reduced. The decrease of consumers' product purchase price will positively promote consumers' order quantity, increase the product purchase quantity, and finally increase the value of crowdfunding consumers. In addition, when the marine ranching leading enterprise pays attention to crowdfunding consumer value, in terms of the crowdfunding platform, in order to maximize their own value, they will increase the commission charged for unit products.

As can be seen from Fig. 4(d), under the two models without introducing BT, the value of the crowdfunding platform increases with the rise of the enterprise's attention to crowdfunding consumer value φ_1 . Under the two models of introducing BT, the value of the crowdfunding platform will decrease first and then increase with the increase of φ_1 . The reason is that the introduction of BT by the crowdfunding platform requires high cost, and its value will show a downward trend. As the enterprise pays more attention to crowdfunding consumer value, the value they bring will offset their introduction costs, so the value of the crowdfunding platform will increase. This is consistent with Proposition 2 and Proposition 7.

Let the degree of the enterprise's attention to ordinary consumer value φ_2 as the independent variable, and change in the interval [0, 1]. The relationship between the degree of the enterprise's attention to ordinary consumer value and the changes of crowdfunding related parameters is shown in Fig. 5.

From Fig. 5(a), Fig. 5(b), Fig. 5(e), it can be seen that whether BT is introduced or not, the attention of the enterprise to ordinary consumer value is inversely proportional to the product purchase price of ordinary consumers, directly proportional to their purchase quantity, and inversely proportional to the consumer value obtained by ordinary consumers. When the enterprise pays more attention to ordinary consumer value, it will lower the price of the products it provides to consumers, which will make consumers buy more products. The increase of purchase quantity will increase the consumer value that consumers get from the purchased products. It can be seen from Fig. 5(c), Fig. 5(d) that with the increase of φ_2 , the product wholesale price shows a downward trend, while the value of the retailer shows an upward trend. When the enterprise pays attention to ordinary consumer value, they will lower the product wholesale price to indirectly lower the product purchase price, and the reduction of the product wholesale price that is the cost of the retailer will increase the value of the retailer. This is consistent with Proposition 3 and Proposition 8.

Let crowdfunding consumers' recognition of product green attributes and crowdfunding consumers' recognition of product quality attributes as independent variables, and change within the interval [0, 1], so as to make a three-dimensional diagram to more stereoscopically and intuitively examine their influence on the consumer value of crowdfunding consumers. The relationship between crowdfunding consumer value and product attributes changes is shown in Fig. 6.

As can be seen from Fig. 6(a), Fig. 6(b), whether BT is introduced or not, the value of crowdfunding consumers is influenced by their recognition of product green attributes and their recognition of product quality attributes. Moreover, the consumer value of crowdfunding consumers is directly proportional to consumers' recognition of product

green attributes, and to consumers' recognition of product quality attributes. This is consistent with Proposition 4 and Proposition 9.

Make the degree of the enterprise's attention to crowdfunding consumer value φ_1 and the degree of the enterprise's attention to ordinary consumer value φ_2 as independent variables, and both of them change in the interval $[0, 1]$. Make a three-dimensional diagram to examine the influence of them on the marine ranching leading enterprise's value, as shown in Fig. 7.

It can be seen from Fig. 7 that the value of the marine ranching leading enterprise is affected by the degree of the enterprise's attention to crowdfunding consumer value and ordinary consumer value. When the enterprise pays more attention to crowdfunding consumers and ordinary consumers, the value of the enterprise shows a downward trend. This is mainly because when the enterprise pays more attention to consumers, they will incur higher costs, thus making their own value tend to decline. This is consistent with Proposition 5 and Proposition 10.

These numerical analysis results are consistent with the propositions obtained by the model, which further proves the accuracy of the propositions obtained in this paper.

8. Conclusions

This paper studied the crowdfunding supply chain system, which is composed of the marine ranching leading enterprise, the crowdfunding platform, the retailer, crowdfunding consumers and ordinary consumers. Considering the differences of crowdfunding methods and whether BT is introduced, we have constructed four models, including N , N_0 , I , I_0 . Then, we describe the impact of two crowdfunding methods (consumer crowdfunding, pre-sale crowdfunding) and BT on the optimal decision-making of supply chain members through comparative analysis and numerical analysis. The main conclusions and management implications are as follows:

(1) When the marine ranching leading enterprise carries out crowdfunding, different crowdfunding methods will have different optimal decision results. The value of each subject in the supply chain system is higher when the enterprise adopts consumer crowdfunding, but lower when the enterprise adopts pre-sale crowdfunding. In addition, the introduction of BT in the marine ranching leading enterprise can significantly enhance the value of each subject in the supply chain system.

When faced with the choice of crowdfunding methods, the marine ranching leading enterprises with capital shortage should be more inclined to choose the method of consumer crowdfunding. Before consumer crowdfunding, enterprises should show the product information related to the consumers for crowdfunding, including the quality attributes of the products, the environmental friendliness of the products and so on. Crowdfunding consumers invest in enterprise products based on the more transparent information provided by enterprises. Corporate crowdfunding activities are highly likely to succeed. However, when enterprises choose the pre-sale crowdfunding method, crowdfunding consumers need to bear the most funds produced by the enterprise, which is a high risk, and then leads to the low value of the whole supply chain. What's more, since crowdfunding is an activity before the product is fully produced, information asymmetry problems will occur in the process, which will hinder the success of crowdfunding activities (Qi et al., 2022). The application of BT will enhance the transparency and credibility of the product information of marine ranching leading enterprises and the information related to the crowdfunding platform. It can promote cooperation among all parties in the supply chain system, and then form a benign strategic alliance to optimize the value of the supply chain system.

(2) Although the marine ranching leading enterprise pays attention to the value of crowdfunding consumers and ordinary consumers and then its own values are lost, value of the consumers, retailer, crowdfunding platform and supply chain system will be increased. In addition, the increased recognition of product attributes (quality attributes,

green attributes) by crowdfunding consumers will also increase their consumer value.

The marine ranching leading enterprises' attention to consumer value is of great significance to realize value co-creation. The leading enterprises pay proper attention to crowdfunding consumers and ordinary consumers in the market, which increases the value of crowdfunding supply chain system and supply chain members. Also, the recognition degree of crowdfunding consumer value to products is an important factor affecting the promotion of its consumer value. Therefore, in the actual market activities, marine ranching leading enterprises not only can set up a good corporate social responsibility image by taking active social welfare activities, increase consumers' willingness to participate in value co-creation (Liu et al., 2022). But also, enterprises can make full use of the online and offline sales channels of the crowdfunding platform, understanding the consumption preferences of crowdfunding consumers and ordinary consumers. And, it can continuously provide high-quality pre-sales, in-sales and after-sales services to enhance consumers' recognition of product attributes, increase consumer value and realize the overall value of the supply chain system.

(3) No matter what crowdfunding method the enterprise adopts and whether BT is introduced, the value of each subject in the supply chain is related to the green attribute of the product. The improvement of green attributes of products of the marine ranching leading enterprises will increase the value of the supply chain. Enterprises should actively take measures to improve the green attributes of their products.

The marine ranching leading enterprises can introduce green technology equipment, green production materials and more environmentally-friendly production processes throughout the whole process of product production lines, in order to enhance the concept of product green attributes. Also, enterprises can also effectively combine digital technology such as BT and big data with green development to improve the management level of green operation, and promote the upgrading of industrial structure and green development.

(4) The retailer and the crowdfunding platform should pay attention to increasing the sales volume of products, in order to promote the realization of economic value.

Increasing the sales volume of products is the unified goal of all subjects in the crowdfunding supply chain system. Retailers can use brand marketing, improve services and other ways to attract consumers to buy and increase the purchase volume. Crowdfunding platforms can improve the accessibility and reliability of platform information by optimizing their service level and using digital technology, in order to realize their economic value.

However, this study has certain limitations in addition to valuable results and implications. Firstly, this paper artificially divides consumers in the market into crowdfunding consumers and ordinary consumers. Consumers have the right to choose whether they are crowdfunding consumers or ordinary consumers, and it would be better if we consider this situation. Secondly, consumer crowdfunding and pre-sale crowdfunding are selected in this study, which cannot cover all the choices when enterprises face crowdfunding financing. In the future, the research can expand the scope of expanding the range of corporate crowdfunding methods and increasing the richness of research.

For future direction, we would apply our model to other fields and consider the choice of consumers in the market. In addition, valuable parameters can be introduced into the model to increase or reduce the model assumptions. Then, expand the boundaries of the established model.

CRedit authorship contribution statement

Xiaole Wan: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization, Supervision, Project administration, Funding acquisition. **Zhengwei Teng:** Methodology, Software, Validation, Formal analysis, Data curation, Writing – original draft, Writing –

review & editing, Visualization. **Qianqian Li:** Methodology, Software, Data curation, Writing – original draft, Writing – review & editing. **Muhammet Deveci:** Writing – original draft, Writing – review & editing, Visualization, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

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Appendix A. Supplementary data

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