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Research Article

Optimization and Coordination of Crowdsourcing Supply Chain in Fast Fashion Industry

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Due to inadequate designers in fast fashion industry and the development of the Internet, small-and-medium-sized garment makers have gradually turned to external talents to enhance their new product design efficiency via crowdsourcing initiative. This paper presents a new framework of crowdsourcing supply chain for fast fashion industry. First, a basic multiperiod order model is established in a crowdsourcing supply chain system, where a garment maker chooses the best one among available solutions submitted by online designers (i.e., crowdsources) in each period, then transforms it into finished product, and sells to consumers through a retailer. Second, we extend this model by integrating the factors of capital turnover, the retailer's risk-aversion, and the garment maker's minimum production quantity. Moreover, utilizing wholesale price, buyback, and profit-sharing scheme designs a mixed contract for coordinating crowdsourcees, retailer, and garment maker of crowdsourcing supply chain for achieving Pareto optimality. The models help the garment maker determining the optimal production quantities of crowdsourcing designed products and enable the retailer placing the optimum orders and setting the reasonable risk level. In addition, we also find that the incentive policy for crowdsourcing designers can be fulfilled by using a profit-sharing scheme with a piecewise function of order quantity instead of a linear function.

1. Introduction

Product innovation is a top business priority in the fast fashion industry and a key issue in academic research [1]. Nowadays, it is becoming a common rule that consumers prefer buying the products designed by their own to passively receiving firm's offerings [2]. As a result, personalized preference, tailored design, and customized production are dominant in the fast fashion industry, hence driving firms to engage innovation activities for sharping their edges. Meanwhile, on one hand, fierce competitions in fashion markets require producers to quickly respond to market demand with a reasonable price and without sacrificing speed of processing and delivery. On the other hand, a majority of fast fashion firms belong to small and medium-sized enterprises (SMEs) and usually lack enough designers or sufficient capital to meet the needs of customers. Despite their great efforts in innovation activities conducted by internal expertise in product design, these SMEs are still unsatisfied with their innovation outcomes [3]. Therefore, it has been widely recognized that SMEs need to introduce external talents to supplement their internal innovation capacities and to improve new product design efficiency. As such, there is an emerging focus on 'crowdsourcing' with a goal of offering SEMs with the desired innovation solutions [4].

The term 'crowdsourcing' coined by Howe first appeared in the magazine *Wireless*. Crowdsourcing refers to the behavior of an organization taking a certain task once conducted by the interfirm staff, instead, now turning to seek for help from a mass of online participants by the mean of an open call [5]. It carries the opportunity to change traditional business models with innovation thoughts. Allowing broadening the boundaries of an organization to fully capitalize on the creative solutions of external sources, this model has become a strategic act of sharpening competitive edge for the organization in various sectors [5]. Crowdsourcing,

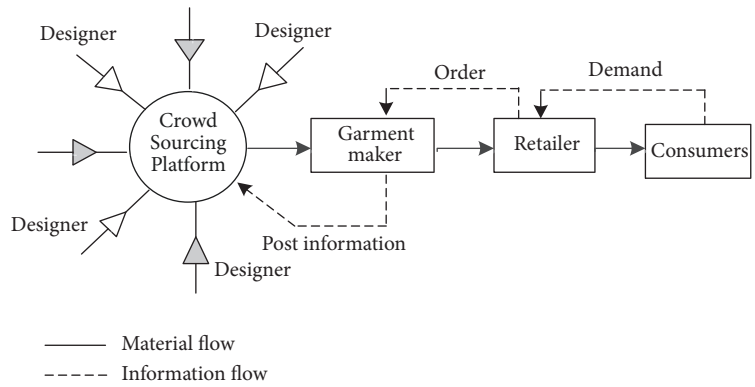

Figure 1: Crowdsourcing supply chain platform framework.

acted as a unique online model, is attracting a creative, enthusiastic crowd of people capable of submitting better solutions in quantity and quality than those available from the conventional patterns. It offers firms, by establishing open R&D platform, to gain values from an increasingly mass amount of online voluntary experts, who can provide firms the newer ideas and more valuable thoughts in an active and efficient way than what may be done by the interfirm experts. What is most important, crowdsourcing allows firms, particularly small-and-medium sized enterprises (SMEs), to generate extra competencies, which generally may not be obtained or possessed due to the lack of high-quality human resources or investment. This allows SMEs to have potential chances to compete against big companies and to tap new markets as well [6].

Although the application of crowdsourcing has powerful potentials and growing practices in many sectors (e.g., idea competition, global IT outsourcing, and knowledge contribution), yet implementation of crowdsourcing is nonetheless relatively complex and arises the corresponding problems. Firstly, in a real world, to highlight consumer's specific preference and personalized choices, crowdsourcees are more prone to offer the solutions with relatively high production cost, which are unaffordable to consumers, thus leading to crowdsourcing ineffectiveness. Secondly, SMEs are more likely to see crowdsourcing as a separate, efficient initiative, ignoring the importance of seamless interconnection between the crowdsourcing sector and the downstream supply chain system, causing the failure to quick response to market demand. Thirdly, to efficiently incentivize crowdsourcees is a key issue to facilitate the sustainable, long-term development of CSC, but there are few researches focusing on it. Based on the above challenges, there are three related research questions addressed in this paper, namely, (1) how does the fast fashion maker determine the best crowdsourcing design and optimal order quantity in the setting of crowdsourcing supply chain? (2) whether and how extant do the factors of the retailer's risk-aversion and garment maker's minimum production quantity influence the optimal outcomes? (3) could wholesale price, buyback contract, and profit-sharing scheme fully coordinate the garment maker, the retailer and online crowdsourcing designers, if not, how to devise the efficient contract?

To address three questions, we develop an analytical framework in which the crowdsourcing is integrated into a traditional fast fashion supply chain system. This new system is called a crowdsourcing supply chain (short for CSC). Based on this framework (Figure 1), we first establish a basic multiperiod order model of CSC system, where a retailer orders from a fast fashion garment maker, who possesses an online crowdsourcing platform, connected to n designers (i.e., crowdsourcees). On basis of this model, we further develop a model considering the factor of capital turnover, which is one of the crucial attributes for the fast fashion sector, as well as retailer's risk-aversion and garment maker's minimum production quantity in the CSC environment. Finally, using wholesale price, profit-sharing scheme, and buyback contract, we devise a multiparty incentive mechanism to coordinate crowdsourcees, the retailer, and garment maker in crowdsourcing supply chain.

A fast fashion crowdsourcing supply chain is different from the conventional one. It is an Internet-oriented, fast design-oriented, and consumer-oriented supply chain. Therefore, dynamic selection of the best designer meeting various requirements of the consumers on different collections of products is a key issue. Hence, there are three main contributions in this paper. Firstly, we contribute to creating a novel framework of crowdsourcing supply chain. Crowdsourcing design is embedded into the supply chain system and fully evaluated. The firms, especially SMEs, use crowdsourcing supply chains as an important business strategy for realizing R&D or design activities, hence reducing the risk of order loss. Secondly, we expand some knowledge in fast fashion supply chain management. Two important attributes, namely, online design, and offline production and sales, are taken into account simultaneously in the crowdsourcing supply chain system model. Thirdly, we devise a mixed contract covering all members of the crowdsourcing supply chain. This mixed contract coordinates not only between the garment maker and retailer, but also between the crowdsourcees and its downstream members as well. This measure will allow the crowdsourcing supply

chain to operate, in a sustainable and efficient manner, as a whole.

This paper is configurated as follows. In Section 2 the relevant existing work is given. Followed by the fact that three different crowdsourcing supply chain order models are presented in Section 3, Section 4 proposes the crowdsourcing supply chain's coordination mechanism among all members. Section 5 conducts a comparative and sensitivity analysis by using several illustrative examples. A conclusion and the perspectives on the future research work are provided in Section 6.

2. Literature Review

The related research of this paper can be categorized into three main streams: crowdsourcing, fast fashion supply chain management, and supply chain coordination.

2.1. Crowdsourcing. The first stream focuses on the literature about crowdsourcing. Although crowdsourcing has attracted the attention from many business and industrial companies, yet the published academic research results are rather limited. This work on crowdsourcing mainly focuses on R&D or innovation concerning motivation and incentive policy [7].

Crowdsourcing is an efficient way to solicit new product design idea from external partners, particularly from consumers [8]. This new initiative can be grouped into two categories. In the first category, the generation of new design ideas relies on customer's contributions. Threadless is such a company of implementing crowdsourcing of this category; after customers design T-shirt pattern to Threadless online, Threadless will select the best one to produce. Due to the customers competing with one another for an amount of money, this category of crowdsourcing is also regarded as a contest [9]. In the second category, the crowdsourcing is an ever-lasting open call for the innovations, which is not confined to the particularly-designated tasks just for only one time [10]. Amazon's Mechanical Turk belongs to this type. In this category of crowdsourcing, costumers usually develop and upload the diversified solutions via online platform. But whether these solutions are ultimately transformed into real physical products, it depends on company' finial decision. Except for the aforementioned taxonomy, crowdsourcing can also be classified into selective and integrative categories [11]. In the selective crowdsourcing, a pool of solutions from the online crowdsourcees will compete against each other, and the suitable solutions are only selected by the firm. On the contrary, integrative crowdsourcing is about collecting complementary ideas from the online masses. Unlike selective crowdsourcing, the contributors work together to accomplish the same task.

In addition, from the perspective of crowdsourcing motivation, Perera [12] analyzed the nation-wide crowdsourcing abilities by comparison between the China's manufacturing sector and India's service sector, implying China has more advantages over India in implementing crowdsourcing. This, mainly resulting by China, as a world-class manufacturing center, has fully possessed each tier of supply chain, while India just embraces the limited ones. On the other hand, Zhao and Zhu [13], from the firm lens, identified four main motivations for adopting crowdsourcing, namely, product quality, risk reduction, problem solving, and core competencies. What is more, Kosonen and Gan [14] further analyzed the influence of intrinsic/extrinsic motivations on crowdsourcing in terms of satisfaction theory, finding that there are three main drivers (i.e., social gains, learning gains, and peer recognition), which the firms generally concern.

The incentive is a key and important issue in a crowdsourcing system. Research into the incentive issues of crowdsourcing can encourage the potential mass participants to derive more and better solutions. Therefore, firms should ensure that an incentive policy is appropriate and proportionate [15]. Yang et al. [16] found that the crowdsourcing participants are prone to choose less popular and higher reward tasks and why they are most likely to behave as such is encountering fewer rivals and increasing the probability of winning. However, in a real world, the probability of winning may decrease in some types of tasks. Dipalantino and Vojnovic (2009) used a two-stage game model to establish the correlation between incentive and the crowdsourcees in the system where the strategic crowdsourcees are rewarded only, while the myopic crowdsources are filtered out. Moreover, Jain [17] identified appropriate incentive and governance mechanism to push crowdsourcees forward finishing the assigned missions without losing target. They developed an analytical model to explore the incentive and governance policy in three various crowdsourcing scenarios, providing insights into how incentive and governance policies have effect on the implementing crowdsourcing initiative. Unfortunately, although a crowdsourcing initiative plays a crucial role in the customized design, quick response, and cost-saving for garment industry, there is very little literature on crowdsourcing dealing with fast fashion, from the perspective of whole supply chain.

2.2. Fast Fashion Supply Chain Management. The second stream is about fast fashion supply chain management. Under the intensified worldwide competitions, the fast fashion industry generally faces the challenges of short product life cycle and high uncertainty in consumer demand [18]. With aim of quick responses to ever-changing market condition, fast fashion firms must effectively and efficiently configurate his/her supply chain system.

For dealing with these challenges, Kim [19] investigated several fashion companies such as ZARA and UNIQLO for case studies, discovering that the competitive advantages are directly related to the company's selection of its market segmentation, which influences its sourcing and distribution channel to a large degree. Castelli and Brun [20] adopted a qualitative approach to assess the channel alignment between garment maker and retailers, exploring that there exists a correlation between the associated factors (lifecycle stage and channel type) and the degree of alignment in Italian fashion retailers. Li et al. [21] examined the impact of corporate social responsibility act on channel integration in fast fashion supply chain through a case of H&M, finding that internal integration of a company can be enhanced from its own governance, while stakeholder integration can obtain the

win-win outcome from external coordination. Moreover, Nagurney and Yu [22] established a Nash equilibrium model in two fast fashion supply chains under the circumstances of conflicting or competing channels, using a differential inequality method, to solve the model.

2.3. Supply Chain Coordination. The other body of literature is concerning the supply chain's coordination, which avoids the double marginalization effect. Markdown/revenue-sharing/buyback is normally adopted in supply chain management with an aim to obtain a win-win outcome [23]. Elmaghraby et al. [24] examined the optimal markdown policy for the rational market with a short life cycle product. Most recently, Shen et al. [25] developed the supply chain's profit model, by utilizing the markdown policy in the fast fashion sector. Furthermore, Liu et al. [26] employed the markdown and return policy to design a hybrid contract to obtain the pareto optimality in a supply chain.

For revenue-sharing contract, Raza [27] used a revenue sharing contract to develop a model with the price and social responsibility investment dependent demand. Hu et al. [28] extended the coordination model of a three echelons supply chain via revenue sharing contracts, providing the two players' optimal policies, and coordination conditions. Additionally, Hu et al. [29] investigated the supplier's optimal decision under a wholesale-price and revenue-sharing contracts; finding coordination mechanism can allocate the optimal channel profit between the retailer and the supplier. To dampen negative effects of a long lead time, Heydari [30] formulated a per-order extra payment and revenue-sharing contract to convince the supplier for increasing its reorder point.

As for buyback contract, Wu [31] examined the impact of buyback policy in two competing supply chains, showing that the profit of the entire supply chain profit increase as the chain competition increases. And, Heydari et al. [32, 33] examined a supply chain system model under dual-buyback for consumer returned item and unsold item. In addition, Heydari and Norouzinasab [34] proposed a discount model to coordinate pricing and ordering decisions in a two-echelon supply chain. Also, Modak et al. [35] explored channel coordination in a three-echelon supply chain, using all unit quantity discount with franchise fee to resolve channel conflict.

Unlike the above contracts, Nosoohi and Nookabadi [36] utilized an option to coordinate a customer-oriented production system, with a long lead-time and stochastic demand. Furthermore, Zhao et al. [37] developed a bidirectional option contract, deriving closed-form expressions for the retailer's optimal initial order strategy and the option purchasing strategy to attain supply chain coordination. In addition, Heydari et al. [32, 33] proposed an incentive scheme based on delay in payments to globally optimise reorder point and order quantity in a supply chain. Yan et al. [38] design a partial credit guarantee (PCG) contract for supply chain finance system.

In contrast with the above-mentioned literature, in this paper, we consider a mixed contract, including wholesale price, buyback, and profit-sharing to coordinate crowdsourcees, garment maker, and retailer in a fast fashion crowdsourcing supply chain system; this mixed contract has been not seen before.

3. Crowdsourcing Supply Chain Order Models

3.1. Basic Multiperiod Order Model (BM). The notations used in the proposed mathematical models are shown in Notations section.

We assume that a fast fashion crowdsourcing supply chain consists of a retailer, a garment maker, and n crowdsourcing fashion designers, connected to a crowdsourcing platform. The supply chain services consumers with a kind of high fashion products (e.g., Dresses, Caps, and Bags). However, the garment maker does not possess its own fashion design capabilities; he/she must draw on crowdsourcing to serve consumer's customized needs.

The procedure for operating the fast fashion crowdsourcing supply chain includes four steps. Firstly, the garment maker collects information with feedback from the downstream retailer and consumers; then the aggregate demands are properly handled. Secondly, the garment maker posts the reasonable requirements to the crowdsourcing platform to call for design solutions from online crowdsourcing designers. Thirdly, the garment maker cooperates with the retailer, by selecting the best design, among all the solutions presented, with respect to the expected profit level and risk. Fourthly, the best design is immediately put into production and the crowdsourcing designer providing the best solution is rewarded in accordance with preannouncement (Figure 1).

As a fast fashion product is usually with a short life cycle, its sales window cannot last long; i.e., a fast fashion product will be sold for a very short time period only. Formally, we assume that one fashion product X_i is sold within a period i only; there are k different fast fashion products produced and sold to the consumers over the horizon of k-short periods, i.e., one product per period. Thus, rapid shift of new product in the fast fashion market requires crowdsourcees to speed up the pace of design, thus aligning to market demands.

At the beginning of each period i, the garment maker will produce and deliver the product X_i, ordered by the retailer in advance, to sales sites; then the retailer only allows the fast fashion product to be sold within the sales window i. When approaching the end of the sales window i, any unsold product will be off the shelf and cleared as salvage value s. It is assumed that the demand function D_i of product X_i is a cumulative distribution (D_i), where D_i follows the independent and identical distribution (idd). Due to the fast fashion products belonging to the similar product line, their revenue-cost structure possesses the same features. The garment maker rewards the crowdsourcing designer j with a financial incentive c_{cr}^{ji} if his/her design is selected. c_{cr}^{ji} also implies the crowdsourcing design payment for the designer j in period i. Moreover, we suppose that the garment maker produces the fashion product quantity q_i in period i, and wholesales to the retailer, who finally offers them to the

consumers. The unit production cost, unit wholesale price, and unit retail selling price are denoted by c_m, p_w, and p, respectively; it is worth noting that the inequality $s < c_m + c_{cr}^{ji} < p_w < p$ holds throughout the whole paper. Denote the profit of the retailer and of the crowdsourcing supply chain for retailing quantity q_i of fast fashion X_i within the sales window i as $\pi_{R,i}(q_i)$ and $\pi_{SC,i}(q_i)$, respectively.

For the crowdsourcing supply chain system, to obtain the optional order quantity q_i and select the corresponding crowdsourcee j, the k-periodic basic model can be expressed as

$$\begin{aligned} \max_{(q_i, z_j^i)} \quad & \sum_{i=1}^{k} E\left[\pi_{SC,i}\left(q_i, z_j^i\right)\right] \\ \text{s.t.} \quad & \sum_{j=1}^{n} z_j^i = 1 \\ & \sum_{i=1}^{k}\sum_{j=1}^{n} z_j^i = k \quad \forall k, i = 1, 2, \ldots, k \\ & z_j^i \in \{0, 1\}, \quad j = 1, 2, \ldots, n \end{aligned} \tag{1}$$

where $\sum_{i=1}^{k} E[\pi_{SC,i}(q_i, z_j^i)]$ is the expected total profit of the whole CSC (crowdsourcing supply chain) system over the horizon of k periods and z_j^i is a binary variable, taking the value of 1 if a fashion product i designed by the crowdsourcee j is accepted in period i, otherwise, taking the value of 0. The whole crowdsourcing supply chain's profit contains two parts (i.e., the retailer and garment maker's one). Notice that the crowdsourcing payment for the designer is illustrated as a form of cost in the formulated model. The first constraint of the model guarantees that only one crowdsourcing designer j is selected among n participating designers in period i via a competitive contest. The second constraint guarantees k design solutions are selected over the horizon of k periods. The third constraint shows that z_j^i is a binary variable.

To fully illustrate the above-mentioned crowdsourcing supply chain basic multiperiodic order model (BM) problem, the order quantity model for the retailer should be first introduced. Due to the fast pace of product renewal, it generally requires the retailer to offer different fashion products in different periods. In this way, the retailer order quantity model over the k-periods horizon can be expressed as

$$\max_{(q_i)} E\left[\sum_{i=1}^{k} \pi_{R,i}\left(q_i\right)\right] \tag{2}$$

where $E[\sum_{i=1}^{k} \pi_{R,i}(q_i)]$ is the expected overall profit of the retailer over the k-periods horizon. q_i represents the order quantity by the retailer in period i.

Since each fast fashion product demand follows an independent and identical distribution function with the same cost-revenue structure; hence, $E[\pi_{R,1}(q_1)] = E[\pi_{R,2}(q_2)] = \cdots = E[\pi_{R,k}(q_k)]$. As a result, to simplify the notation, we denote $E[\pi_{R,i}(q_i)] = E[\pi_R(q)], \forall i = 1, 2, \ldots, k$. We can further revise expression (2) as follows:

$$\max_{(q)} k\left(E\left[\pi_R\left(q\right)\right]\right) \tag{3}$$

$$\max_{(q)} k\left(E\left[\pi_R\left(q\right)\right]\right) \Longleftrightarrow \max_{(q)} E\left[\pi_R\left(q\right)\right] \tag{4}$$

We can easily observe that the optimal solution on the left of (4) is the same as the one on the right of (4). To be specific, the crowdsourcing supply chain retailer's multiperiods profit expression can be written as follows:

$$\begin{aligned} & \max_{(q)} E\left[\pi_R\left(q\right)\right] \\ & \quad = \max_{(q)} E\left(\left[\left(p - p_w\right) q - \left(p - s\right)\left(q - x\right)^+\right]\right) \end{aligned} \tag{5}$$

where x is the actual demand, $\pi_R(q) = (p - p_w)q - (p - s)(q - x)^+$, $(A)^+ = \max(A, 0)$.

$$E\left[\pi_R\left(q\right)\right] = \left(p - p_w\right) q - \left(p - s\right) \int_0^q F\left(x\right) dx \tag{6}$$

since

$$\begin{aligned} \frac{\partial\left[\pi_R\left(q\right)\right]}{\partial q} &= \left(p - p_w\right) - \left(p - s\right) F\left(q\right), \\ \frac{\partial^2\left[\pi_R\left(q\right)\right]}{\partial q^2} &= -\left(p - s\right) f\left(q\right) \end{aligned} \tag{7}$$

due to

$$\begin{aligned} & p - s > 0, \\ & f\left(q\right) > 0 \end{aligned} \tag{8}$$

So,

$$\frac{\partial^2\left[\pi_R\left(q\right)\right]}{\partial q^2} = -\left(p - s\right) f\left(q\right) < 0 \tag{9}$$

We can deduce $E[\pi_R(q)]$ is a concave in q, meaning the optimal solution of $\max_{(q)} E[\pi_R(q)]$ exists. Denote $q_{R,E^*}^b = F^{-1}[(p - p_w)/(p - s)]$. Hence, the optimum quantity ordered by retailer is q_{R,E^*}^b.

For obtaining the whole CSC system's optimum solution, we just use the previous treatment by changing (5) into (10) as follows.

$$\begin{aligned} & \max_{(q, z_j^i)} E\left[\pi_{SC}\left(q, z_j^i\right)\right] \\ & \quad = \max_{(q, z_j^i)} E\left[\left(p - c_m - c_{cr}^{ji} \cdot \sum_{j=1}^{n} z_j^i\right) q \right. \\ & \qquad \left. - \left(p - s\right)\left(q - x\right)^+\right]\Bigg) \end{aligned} \tag{10}$$

Since $E[\pi_{SC}(q, z_j^i)] = [p - c_m - c_{cr}^{ji} \cdot (\sum_{j=1}^n z_j^i)]q - (p - s)\int_0^q F(x)dx$ and $E[\pi_{SC}(q, z_j^i)]$ is a concave function, following the same way, we define $q_{SC,E^*}^b = F^{-1}[(p-c_m-c_{cr})/(p-s)]$, where $c_{cr} = c_{cr}^{ji} \cdot (\sum_{j=1}^n z_j^i)$; the optimal order quantity q_{SC,E^*}^b and the crowdsourcing designer (crowdsourcee) z_j^i can be obtained by maximizing the expected profit of the whole CSC system.

3.2. Model with Time Value of Capital (CM). For a crowdsourcing-designed fast fashion product, it is characterized by two factors, namely, high-frequent shift of new product and quick capital turnover. The two factors are quite different from ones in nonfast fashion products. Moreover, quick turnover of goods/capital can be used to assess the crowdsourcing supply chain performance; this, in turn, facilitates to increase the efficiency of capital utilization and reduce operational risks in crowdsourcing supply chain. Also, fast-in-fast-out capital operations can make the crowdsourcing platform more dynamic, in turn, motivating the crowdsourcing designers' continuous engagement.

Therefore, based on the above proposed multiperiod order model, we employ the factor, namely, time value of capital to quantify the capital utilization efficiency by a given market compound interest rate r and present value. Therefore, we incorporate it into the above basic model with an aim to determine the optimum order quantity q in each period through maximizing the whole crowdsourcing system's profit.

With the above problem description, we have the model in the presence of time value of capital:

$$\begin{aligned} \max_{(q_i, z_j^i)} \quad & E\left[\sum_{i=1}^k \frac{\pi_{SC,i}\left(q_i, z_j^i\right)}{(1+r)^i}\right] \\ s.t. \quad & \sum_{j=1}^n z_j^i = 1 \\ & \sum_{i=1}^k \sum_{j=1}^n z_j^i = k \quad \forall k, i = 1, 2, \ldots, k \\ & z_j^i \in \{0, 1\}, \quad j = 1, 2, \ldots, n \end{aligned} \tag{11}$$

Like the way of solving problem (2), for the CSC system's retailer, the order quantity model in the presence of time value of capital can be depicted by

$$\max_{(q_i)} E\left[\sum_{i=1}^k \frac{\pi_{R,i}\left(q_i\right)}{(1+r)^i}\right] \tag{12}$$

where $E[\sum_{i=1}^k (\pi_{R,i}(q_i)/(1+r)^i)]$ is the crowdsourcing supply chain retailer's expected total profit considering time value of capital over the horizon of k periods. r is the compound interest rate, while $E[\sum_{i=1}^k (\pi_{SC,i}(q_i, z_j^i)/(1+r)^i)]$ is the expected total profit of crowdsourcing supply chain when considering time value of capital over the horizon of k periods.

Theorem 1. *The whole CSC system's optimum order quantity q_{SC,E^*}^b in BM model is the same as that of the crowdsourcing supply chain q_{SC,E^*}^c in CM model, namely, $q_{SC,E^*}^b = q_{SC,E^*}^c$.*

Proof of Theorem 1. Observe that

$$\max_{(q_i)} E\left[\sum_{i=1}^k \frac{\pi_{R,i}\left(q_i\right)}{(1+r)^i}\right] = \max_{(q)} E\left[\sum_{i=1}^k \frac{\pi_R\left(q\right)}{(1+r)^i}\right] \tag{13}$$

Define

$$\sum_{i=1}^k \frac{1}{(1+r)^i} = \frac{(1+r)^k - 1}{r(1+r)^k} = A(r, k) \tag{14}$$

Therefore, we have the following formula:

$$\max_{(q)} E\left[\sum_{i=1}^k \frac{\pi_R\left(q\right)}{(1+r)^i}\right] = \max_{(q)} A(r, k)\left(E\left[\pi_R\left(q\right)\right]\right) \tag{15}$$

It is straightforward that the following equation holds.

$$\max_{(q)} A(r, k)\left(E\left[\pi_R\left(q\right)\right]\right) \Longleftrightarrow \max_{(q)} E\left[\pi_R\left(q\right)\right] \tag{16}$$

We can easily observe the optimal solution on the left of (16) is equivalent to one on the right of (16), since the optimal solution to the formula (15) is equal to the optimal solution on the left of (16), while the optimal solution to formula (5) is equal to the optimal solution on the right of (16).

Therefore, it is obvious that formula (15) has the same optimal solution as formula (5). The optimum quantity ordered by the retailer q_{R,E^*}^c in CM model is the same as the optimum order number q_{R,E^*}^b in BM model; namely,

$$q_{R,E^*} = q_{R,E^*}^b = q_{R,E^*}^c. \tag{17}$$

Thus, we can further derive that both formulas (11) and (18) are equivalent in terms of whole CSC system's optimum order quantity; namely,

$$\max_{(q)} E\left[\pi_{SC}\left(q, z_j^i\right)\right] \Longleftrightarrow \max_{(q_i, z_j^i)} E\left[\sum_{i=1}^k \frac{\pi_{SC,i}\left(q_i, z_j^i\right)}{(1+r)^i}\right] \tag{18}$$

Therefore, the optimum order number q_{SC,E^*}^c for the crowdsourcing supply chain in CM model is the same as the CSC optimum order quantity q_{SC,E^*}^b in BM model, denoted by $q_{SC,E^*} = q_{SC,E^*}^b = q_{SC,E^*}^c$. □

Proposition 2. *Under Theorem 1, when the optimum quantity ordered by the retailer is q_{R,E^*} while the whole CSC system's optimum order quantity is q_{SC,E^*}, the crowdsourcing supply chain's members cannot coordinate efficiently and effectively.*

Proof of Proposition 2. Under the wholesale price contract set by the garment maker, it is assumed that the wholesale price could coordinate all members of the whole CSC system; it implies that the optimum quantity ordered by the retailer

q_{R,E^*} is the same as the whole CSC system's optimum order quantity q_{SC,E^*}; namely,

$$F^{-1}\left[\frac{(p-p_w)}{(p-s)}\right] = F^{-1}\left[\frac{(p-c_m-c_{cr})}{(p-s)}\right] \tag{19}$$

Thus,

$$p_w = c_m + c_{cr} \tag{20}$$

The derived outcome contradicts with the previous hypothesis:

$$p_w > c_m + c_{cr} \tag{21}$$

Consequently, it proves the whole CSC system's members cannot coordinate by using wholesale price contract. Therefore, it is necessary to further investigate other efficient coordination mechanism for crowdsourcing supply chain. □

3.3. Model with Minimum Production Quantity and Risk-Aversion (MRM). In the fast fashion industry, due to demand uncertainty and short sales season, members of a crowdsourcing supply chain usually tend to make decisions with risk-aversion attitude for reducing risks. Here, we consider that the retailer is risk-averse while the other members of CSC are risk-neutral. Hence, we introduce the mean-variance, to evaluate the retailer's risk by using the 'variance of profit'. In addition, the garment maker usually has its own production quantity even-break point; it means over the threshold will bring profit-generating and below it causes loss. As such, the garment maker usually set a rule of the minimum production quantity to achieve the effect of economy of scale (Sen, 2008). So, we add the minimum production quantity denoted by q_{MOQ} as an additional constraint in the extended model.

Based on the above assumption and analysis, we have the revised model with minimum production quantity and risk-aversion (MRM) stated as follows by adding two additional constraints.

$$\begin{aligned}
\max_{(q_i,z_j^i)} \quad & E\left[\sum_{i=1}^{k}\frac{\pi_{SC,i}\left(q_i,z_j^i\right)}{(1+r)^i}\right] \\
s.t. \quad & \sum_{j=1}^{n} z_j^i = 1 \\
& \sum_{i=1}^{k}\sum_{j=1}^{n} z_j^i = k \quad \forall k, i = 1,2,\ldots,k \\
& V\left[\sum_{i=1}^{k}\frac{\pi_{SC,i}\left(q_i,z_j^i\right)}{(1+r)^i}\right] \le C^2 \\
& q_i > q_{MOQ} \\
& z_j^i \in \{0,1\}, \quad j = 1,2,\ldots,n
\end{aligned} \tag{22}$$

Define the minimum production quantity for crowdsourcing supply chain as q_{MOQ}. $V[\sum_{i=1}^{k}(\pi_{SC,i}(q_i,z_j^i)/(1+r)^i)]$ representing the crowdsourcing supply chain's variance of overall profit with time value of capital over the horizon of k periods. C^2 is the level of risk the crowdsourcing supply chain has a tendency to take.

Proposition 3. *(1) If $q_{R,E^*} < q_{NOQ} < q_{R,EV^*}$, the optimum quantity ordered by the retailer is q_{MOQ}; (2) if $q_{MOQ} < q_{R,E^*}(q_{SC,E^*}) < q_{R,EV^*}(q_{SC,EV^*})$, the optimum number ordered by the retailer (crowdsourcing supply chain) is $q_{R,E^*}(q_{SC,E^*})$; (3) if $q_{MOQ} < q_{SC,EV^*} < q_{SC,E^*}$, the optimum order quantity of the whole CSC system is q_{SC,EV^*}; (4) if $q_{R,E^*}(q_{SC,E^*}) < q_{R,EV^*}(q_{SC,EV^*}) < q_{MOQ}$, $q_{R,EV^*}(q_{SC,EV^*}) < q_{R,E^*}(q_{SC,E^*}) < q_{MOQ}$, and $q_{R,EV^*}(q_{SC,EV^*}) < q_{MOQ} < q_{R,E^*}(q_{SC,E^*})$, there is no optimum quantities ordered by the retailer and the whole CSC system as well.*

Proof of Proposition 3. Since $\max_{(q_i)} E[\sum_{i=1}^{k}(\pi_{R,i}(q_i)/(1+r)^i)] = \max_{(q)} E[\sum_{i=1}^{k}(\pi_R(q)/(1+r)^i)]$, $\sum_{i=1}^{k}(1/(1+r)^i) = ((1+r)^k-1)/r(1+r)^k = A(r,k)$, and $V[\sum_{i=1}^{k}(1/(1+r)^i)] = ((1+r)^{2k}-1)/(1+r)^{2k}[(1+r)^2-1] = B(r,k)$, we can derive formula (22) as formula (23) as follows:

$$\begin{aligned}
\max_{(q)} \quad & E\left[\pi_R(q)\right] \\
s.t. \quad & V\left[\pi_R(q)\right] \le \frac{L^2}{B(r,k)} \\
& q > q_{MOQ}
\end{aligned} \tag{23}$$

To be detailed, the retailer's profit can be depicted as $\pi_R(q) = (p-p_w)q - (p-s)(q-x)^+$; it is easy to observe that the retailer's variance of profit can be derived by $V[\pi_R(q)] = (p-s)^2\xi(q)$, where

$$\begin{aligned}
\xi(q) = {} & 2q\int_0^q F(x)\,dx - 2\int_0^q xF(x)\,dx \\
& -\left(\int_0^q F(x)\,dx\right)^2
\end{aligned} \tag{24}$$

Notice that $\xi(q)$ is an increasing function with respect to q, which means that $V[\pi_R(q)]$ is also an increasing function. Define the following notation: $q_{R,EV*} = \arg_q\{V[\pi_R(q)] - L^2/B(r,k) = 0\}$. □

Since $V[\pi_R(q)]$ is an increasing function with respect to q; hence, if the retailer can tolerate the risk, then $V[\pi_R(q_{R,E*})] - L^2/B(r,k) > 0$; we have $q_{R,EV*} < q_{R,E*}$; in this way, we can rewrite $q_{R,EV*}$ by $q_{R,EV*} = q_{R,E*} - \Delta_R$, where $\Delta_R > 0$. Δ_R represents the difference of the optimum order quantity between the setting of the retailer's risk-neutral ($q_{R,E*}$) and risk-aversion ($q_{R,EV*}$); Δ_R implies that the greater the difference is, the more tendency the retailer has to avoid risk.

Similarly, considering the different fashion product demands distributed independently and identically within

multiple periods, we find the same solution in three different formulas, which are represented as follows.

$$\begin{aligned}
&\max_{(q_i)} \quad E\left[\sum_{i=1}^{k} \frac{\pi_{SC,i}\left(q_i, z_j^i\right)}{(1+r)^i}\right] \\
&s.t. \quad \sum_{j=1}^{n} z_j^i = 1 \\
&\qquad \sum_{i=1}^{k}\sum_{j=1}^{n} z_j^i = k \quad \forall k, i = 1, 2, \ldots, k \\
&\qquad V\left[\sum_{i=1}^{k} \frac{\pi_{SC,i}\left(q_i, z_j^i\right)}{(1+r)^i}\right] \le C^2 \\
&\qquad q_i > q_{MOQ} \\
&\qquad z_j^i \in \{0,1\}, \quad j = 1, 2, \ldots, n \\
&\Updownarrow \\
&\max_{(q)} \quad A(r,k)\, E\left[\pi_{SC}\left(q, z_j^i\right)\right] \\
&s.t. \quad \sum_{j=1}^{n} z_j^i = 1 \\
&\qquad \sum_{i=1}^{k}\sum_{j=1}^{n} z_j^i = k \quad \forall k, i = 1, 2, \ldots, k \\
&\qquad B(r,k)\, V\left[\pi_{SC}\left(q, z_j^i\right)\right] \le C^2 \\
&\qquad q > q_{MOQ} \\
&\qquad z_j^i \in \{0,1\}, \quad j = 1, 2, \ldots, n \\
&\Updownarrow \\
&\max_{(q)} \quad E\left[\pi_{SC}\left(q, z_j^i\right)\right] \\
&s.t. \quad \sum_{j=1}^{n} z_j^i = 1 \\
&\qquad \sum_{i=1}^{k}\sum_{j=1}^{n} z_j^i = k \quad \forall k, i = 1, 2, \ldots, k \\
&\qquad V\left[\pi_{SC}\left(q, z_j^i\right)\right] \le \frac{C^2}{B(r,k)} \\
&\qquad q > q_{MOQ} \\
&\qquad z_j^i \in \{0,1\}, \quad j = 1, 2, \ldots, n
\end{aligned} \tag{25}$$

To be detailed, the crowdsourcing supply chain's profit can be written as $\pi_{SC}(q, z_j^i) = (p - c_m - c_{cr})q - (p - s)(q - x)^+$; for the variance of CSC's profit, we have $V[\pi_{SC}(q, z_j^i)] = (p - s)^2\xi(q)$, where $\xi(q) = 2q\int_0^q F(x)dx - 2\int_0^q xF(x)dx - (\int_0^q F(x)dx)^2$.

Since $\xi(q)$ is an increasing function of q, it is straightforward that $V[\pi_{SC}(q, z_j^i)]$ is also an increasing function of q. Defined by the following notation $q_{SC,EV*} = \arg_q\{V[\pi_{SC}(q, z_j^i)] - C^2/B(r,k) = 0\}$. As $V[\pi_{SC}(q, z_j^i)]$ is an increasing function of q, we can conclude that if $V[\pi_{SC}(q_{SC,E*})] - C^2/B(r,k) > 0$, then $q_{SC,EV*} < q_{SC,E*}$. We can rewrite $q_{SC,EV*}$ as $q_{SC,EV*} = q_{SC,E*} - \Delta_{SC}$, where $\Delta_{SC} > 0$.

We discover that if there are no restrictions, the optimum quantity ordered by the retailer should be $q_{R,E*}$. Considering that $V[\pi_R(q)]$ is an increasing function of q. On one hand, to hold the risk-aversion condition, the optimum quantity ordered by the retailer cannot exceed $q_{R,EV*}$. On the other hand, considering a rule of the garment maker's minimum production quantity, the optimum quantity ordered by the retailer should be greater than q_{MOQ}. As such, we have the retailer's optimum order quantity stated as follows.

(1) If $q_{R,E*} < q_{MOQ} < q_{R,EV*}$, the optimum order number of product $q_{R,E*} = q_{MOQ}$; (2) if $q_{MOQ} < q_{R,E*} < q_{R,EV*}$, the optimum order number of product $q_{R,E*} = q_{R,E*}$; (3) if $q_{MOQ} < q_{R,EV*} < q_{R,E*}$, the optimum number $q_{R,E*} = q_{R,EV*}$; (4) if $q_{R,E*} < q_{R,EV*} < q_{MOQ}$, $q_{R,EV*} < q_{R,E*} < q_{MOQ}$, and $q_{R,EV*} < q_{MOQ} < q_{R,E*}$, there is no optimum order quantity for the retailer.

Similarly, we can determine the whole CSC system's optimum ordering number in the same way. Furthermore, to reach coordination of the whole crowdsourcing supply chain, it is usual for the garment maker to offer a suitable wholesale price to the downstream retailer and hence try to achieve the Pareto optimality. According to this idea, the following proposition is shown as follows.

Proposition 4. *(a.1) When the optimum quantity ordered by the whole crowdsourcing system is $q_{SC,EV*}$, and the optimum quantity ordered by the retailer is $q_{R,EV*}$, the crowdsourcing supply chain can achieve coordination only when $p_w = p - (p - s)F(F^{-1}[(p - c_m - c_{cr})/(p - s)] - \Delta_{SC} + \Delta_R)$ and $\Delta_{SC} > \Delta_R$.*

(a.2) When the optimum quantity ordered by the whole crowdsourcing system is $q_{SC,EV*}$, and the optimum quantity ordered by the retailer is $q_{R,E*}$, the crowdsourcing supply chain can achieve coordination only when $p_w = p - (p - s)F(F^{-1}[(p - c_m - c_{cr})/(p - s)] - \Delta_{SC})$.

(b) When the optimum quantity ordered by the whole crowdsourcing system is q_{MOQ}, the whole crowdsourcing system can achieve coordination only when the order quantity by the retailer is q_{MOQ}.

(c) When the optimum quantity ordered by the whole crowdsourcing system is $q_{SC,E*}$, the whole crowdsourcing system cannot achieve the coordination.

Proof of Proposition 4. (a) To achieve coordination, the optimum quantity ordered by the retailer must be the same as the whole crowdsourcing system.

Considering that the optimum quantity ordered by the retailer is $q_{R,EV*}$, we have $q_{SC,EV*} = q_{R,EV*} \Longleftrightarrow q_{SC,E*} - \Delta_{SC} = q_{R,E*} - \Delta_R$, since $q_{R,E*} = F^{-1}[(p - p_w)/(p - s)]$ and $q_{SC,E*} = F^{-1}[(p - c_m - c_{cr})/(p - s)]$.

We obtain $p_w = p - (p - s)F(F^{-1}[(p - c_m - c_{cr})/(p - s)] - \Delta_{SC} + \Delta_R)$ and $\Delta_{SC} > \Delta_R$; when the optimum quantity ordered by the retailer is $q_{R,E*}$, we have $q_{SC,EV*} = q_{R,E*} \Longleftrightarrow q_{SC,E*} - \Delta_{SC} = q_{R,E*}$.

Therefore, $p_w = p - (p - s)F(F^{-1}[(p - c_m - c_{cr})/(p - s)] - \Delta_{SC})$.

(b) Similar to the proof of Proposition (a), in order to achieve coordination, the optimum quantity ordered by the retailer and crowdsourcing supply chain must be equal. Considering that the whole CSC system's optimum order quantity is q_{MOQ}, it is straightforward that the optimum quantity ordered by the retailer is q_{MOQ}.

(c) From the proof of Propositions (a) and (b), since the optimum quantity ordered by the retailer is $q_{R,E*}$, we have $q_{SC,E*} = q_{R,E*}$, and $p_w = c_m + c_{cr}$. This outcome conflicts with our previous assumption $p_w > c_m + c_{cr}$, then the whole CSC system cannot be coordinated. When the optimum quantity ordered by the retailer is $q_{R,EV*}$, we have $q_{SC,E*} = q_{R,EV*} \Longleftrightarrow q_{SC,E*} = q_{R,E*} - \Delta_R$. As $\Delta_R > 0$, we have $q_{R,E*} > q_{SC,E*}$. As we can deduce $p_w < c_m + c_{cr}$, the assumption $p_w > c_m + c_{cr}$ cannot hold, meaning that the whole CSC system cannot be coordinated at all. □

Proposition 4 reveals that wholesale price contract can partially and conditionally realize coordination in the whole CSC system. Comparing between Propositions 2 and 4, we find that the implementation of wholesale price contract in CM model is better than that in BM model.

4. Crowdsourcing Supply Chain Coordination

Now two problems still remain unsolved in the whole CSC system's coordination. Firstly, the wholesale price contract partially coordinates the CSC. Secondly, the wholesale price contract only focuses on the downstream members of CSC rather than all members including the crowdsourcing designer, garment maker, and retailer. It means that this contract just partly covers the crowdsourcing supply chain. As such, we should develop a multiparty contract to coordinate all CSC members by using the wholesale price, buyback contract, and a profit-sharing scheme; we call this contract a mixed contract.

To devise a mixed contract, for the downstream of the crowdsourcing supply chain, the garment maker is willing to provide a repurchase price p_b for some part of product which has not been sold out by the retailer at the end of each sales window, while the other products will be cleared at a clearance price s by the retailer. Assuming that the proportion of repurchase part is θ, thus the proportion of the clearance part is $1 - \theta$.

For the upstream of the whole CSC system, the garment maker offers the retailer with a wholesale price contract. Meanwhile, both the garment maker and the retailer provide crowdsourcing designers with a profit-sharing scheme, in which a reward c_{cr} relies on the retailer's sales profit. As the retailer selling price is fixed, thus the reward c_{cr} can be determined by the order quantity q, meaning that the more the retailer sells, the more reward the crowdsourcing designer can receive. In this way, the profit-sharing scheme inspires and encourages online designers to submit high quality, innovative solutions. Concretely, the crowdsourcing designer's unit design reward c_{cr} is directly proportion to order quantity q; namely, $c_{cr} = \alpha q \cdot \sum_{j=1}^{n}(c_{cr}^{ji} z_j^i)(\alpha > 0)$ and $\sum_{j=1}^{n} z_j^i = 1, z_j^i \in \{0, 1\},\ i = 1, 2, \ldots, k$.

As a result, the mixed contract (i.e., wholesale price, buyback contract, and profit-sharing scheme) covers all members of the whole crowdsourcing supply chain system; hence, the proposed corresponding model (BBM) involves three kinds of contracts and all members. Therefore, the profit, the expected profit, and variance of the profit function for the crowdsourcing supply chain can be written, respectively.

$$\begin{aligned} \pi_{SC}^{(BB)}(q) &= (p - c_m - \alpha q)\, q \\ &\quad - (p - s)(1 - \theta)(q - x)^+ \\ E\left[\pi_{SC}^{(BB)}(q)\right] &= (p - c_m - \alpha q)\, q \\ &\quad - (1 - \theta)(p - s)\int_0^q F(x)\, dx \\ V\left[\pi_{SC}^{(BB)}(q)\right] &= (1 - \theta)^2 (p - s)^2 \xi(q) \end{aligned} \tag{26}$$

From the above formulas, we can deduce the following outcomes:

$$\begin{aligned} q_{SC,E*}^{(BB)} &= \frac{[p - c_m - b(1 - \theta)(p - s)]}{[2\alpha + a(1 - \theta)(p - s)]} \\ q_{SC,EV*}^{(BB)} &= \arg_{q}\left\{V\left[\pi_{SC}^{(BB)}(q) - \frac{C^2}{B(r, k)}\right] = 0\right\} \end{aligned} \tag{27}$$

$q_{SC,E*}^{(BB)}$ is the optimum order quantity of the CSC system in the presence of mixed contract. In addition, to facilitate the analysis, the demand function is defined as $F(x) = ax + b$.

Since $V[\pi_{SC}^{(BB)}(q)]$ is an increasing function, if $V[\pi_{SC}^{(BB)}(q_{SC,E*}^{(BB)})] - C^2/B(r, k) > 0$ holds, then $q_{SC,EV*}^{(BB)} < q_{SC,E*}^{(BB)}$; we rewrite $q_{SC,EV*}^{(BB)}$ as $q_{SC,EV*}^{(BB)} = q_{SC,E*}^{(BB)} - \Delta_{SC}^{(BB)}$, where $\Delta_{SC}^{(BB)} > 0$.

Under the mixed contract, the retailer's profit is

$$\begin{aligned} \pi_R^{(BB)}(q) &= (p - p_w)\, q - (p - p_b)\, \theta (q - x)^+ \\ &\quad - (p - s)(1 - \theta)(q - x)^+ \end{aligned} \tag{28}$$

Similar to the way of deriving the crowdsourcing system's expected profit and variance of profit, we have the retailer's expected profit and variance of profit under the mixed contract shown below

$$E\left[\pi_R^{(BB)}(q)\right] = (p-p_w)q - \theta(p-p_b)\int_0^q F(x)\,dx - (1-\theta)(p-s)\int_0^q F(x)\,dx \tag{29}$$
$$V\left[\pi_R^{(BB)}(q)\right] = \left[\theta^2(p-p_b)^2 + (1-\theta)^2(p-s)^2\right]\xi(q)$$

Through the previous analysis, it is not difficult to obtain the optimum quantity ordered by the retailer in the setting of risk-aversion and risk-neutral.

$$q_{R,E*}^{(BB)} = \frac{(p-p_w)}{a\left[\theta(p-p_b)+(1-\theta)(p-s)\right]} - \frac{b}{a}$$
$$q_{R,EV*}^{(BB)} = \arg_{q}\left\{V\left[\pi_R^{(BB)}(q) - \frac{L^2}{B(r,k)}\right] = 0\right\} \tag{30}$$

Since $V[\pi_R^{(BB)}(q)]$ is an increasing function, considering that if $V[\pi_R^{(BB)}(q_{R,E*}^{(BB)})] - L^2/B(r,k) > 0$ holds, thus $q_{R,EV*}^{(BB)} < q_{R,E*}^{(BB)}$, we can rewrite $q_{R,EV*}^{(BB)}$ as $q_{R,EV*}^{(BB)} = q_{R,E*}^{(BB)} - \Delta_R^{(BB)}$, where $\Delta_R^{(BB)} > 0$.

Under the mixed contract, to fully coordinate all members of the CSC, including crowdsourcing designers, garment maker, and retailer, thus we have Proposition 5.

Proposition 5. *(a1) When the whole CSC system's optimal order quantity is $q_{SC,EV*}^{(BB)}$, and the optimum quantity ordered by the retailer is $q_{R,EV*}^{(BB)}$, the crowdsourcing supply chain can achieve coordination only when $p_b = p - (p-p_w)/a\theta(\delta - \Delta_{SC}^{(BB)} + \Delta_R^{(BB)} + b/a) - \gamma$.*

(a2) When the whole CSC system's optimal order quantity is $q_{SC,EV*}^{(BB)}$, and the optimum quantity ordered by the retailer is $q_{R,E*}^{(BB)}$, the crowdsourcing supply chain can achieve coordination only when $p_b = p-(p-p_w)/a\theta\{[p-c_m-b(1-\theta)(p-s)]/[2\alpha + a(1-\theta)(p-s)] - \Delta_{SC}^{(BB)} + b/a\} - (1-\theta)(p-s)/\theta$.

(b) When the whole CSC system's optimum order quantity is q_{MOQ}, the crowdsourcing system can achieve coordination only when the optimum quantity ordered by the retailer is also q_{MOQ}.

(c1) When the whole CSC system's optimum order quantity is $q_{SC,E*}^{(BB)}$, and the optimum quantity ordered by the retailer is $q_{R,EV*}^{(BB)}$, the crowdsourcing supply chain can achieve coordination only when $p_b = p-(p-p_w)/a\theta\{[p-c_m-b(1-\theta)(p-s)]/[2\alpha + a(1-\theta)(p-s)] + \Delta_R^{(BB)} + b/a\} - (1-\theta)(p-s)/\theta$.

(c2) When the whole CSC system's optimum order quantity is $q_{SC,E*}^{(BB)}$, and the optimum quantity ordered by the retailer is $q_{R,E*}^{(BB)}$, the crowdsourcing supply chain can achieve coordination only when $p_b = p-(p-p_w)/a\theta\{[p-c_m-b(1-\theta)(p-s)]/[2\alpha + a(1-\theta)(p-s)] + b/a\} - (1-\theta)(p-s)/\theta$.

Proof of Proposition 5. (a) To achieve coordination, the optimum quantity ordered by the retailer and whole CSC system must be the same. When the optimum quantity ordered by the retailer is $q_{R,EV*}^{(BB)}$, we have

$$q_{SC,EV*}^{(BB)} = q_{R,EV*}^{(BB)} \Longleftrightarrow q_{SC,E*}^{(BB)} - \Delta_{SC}^{(BB)} = q_{R,E*}^{(BB)} - \Delta_R^{(BB)} \tag{31}$$

Since

$$q_{SC,E*}^{(BB)} = \frac{\left[p-c_m-b(1-\theta)(p-s)\right]}{\left[2\alpha + a(1-\theta)(p-s)\right]}$$
$$q_{R,E*}^{(BB)} = \frac{(p-p_w)}{a\left[\theta(p-p_b)+(1-\theta)(p-s)\right]} - \frac{b}{a} \tag{32}$$

Then,

$$p_b = p - \frac{(p-p_w)}{a\theta\left\{\left[p-c_m-b(1-\theta)(p-s)\right]/\left[2\alpha + a(1-\theta)(p-s)\right] - \Delta_{SC}^{(BB)} + \Delta_R^{(BB)} + b/a\right\}} - \frac{(1-\theta)(p-s)}{\theta} \tag{33}$$

When the optimum quantity ordered by the retailer is $q_{R,E*}^{(BB)}$, thus,

$$q_{SC,EV*}^{(BB)} = q_{R,E*}^{(BB)} \Longleftrightarrow q_{SC,E*}^{(BB)} - \Delta_{SC}^{(BB)} = q_{R,E*}^{(BB)} \tag{34}$$

So, we obtain

$$p_b = p - \frac{(p-p_w)}{a\theta\left\{\left[p-c_m-b(1-\theta)(p-s)\right]/\left[2\alpha + a(1-\theta)(p-s)\right] - \Delta_{SC}^{(BB)} + b/a\right\}} - \frac{(1-\theta)(p-s)}{\theta} \tag{35}$$

(b) To achieve coordination, the optimum quantity ordered by the crowdsourcing supply chain and retailer must be equal. So, when the whole CSC system's optimum order quantity is q_{MOQ}, the optimum quantity ordered by the retailer is q_{MOQ}.

(c) Similar to the principle of proofs (a) and (b), to achieve coordinate the crowdsourcing supply chain, the optimum quantity ordered by the retailer must be the same as the crowdsourcing supply chain. When both optimum quantities ordered by the retailer and crowdsourcing supply chain are $q_{R,EV*}^{(BB)}$, we have

$$\begin{aligned} q_{SC,E*}^{(BB)} &= q_{R,EV*}^{(BB)} \Longleftrightarrow \\ q_{SC,E*}^{(BB)} &= q_{R,E*}^{(BB)} - \Delta_R^{(BB)} \end{aligned} \tag{36}$$

Hence,

$$p_b = p - \frac{(p - p_w)}{a\theta\left\{\left[p - c_m - b(1-\theta)(p-s)\right] / \left[2\alpha + a(1-\theta)(p-s)\right] + \Delta_R^{(BB)} + b/a\right\}} - \frac{(1-\theta)(p-s)}{\theta} \tag{37}$$

When the retailer's order quantity is $q_{R,E*}^{(BB)}$, we have

$$q_{SC,E*}^{(BB)} = q_{R,E*}^{(BB)} \tag{38}$$

Then, we obtain

$$p_b = p - \frac{(p - p_w)}{a\theta\left\{\left[p - c_m - b(1-\theta)(p-s)\right] / \left[2\alpha + a(1-\theta)(p-s)\right] + b/a\right\}} - \frac{(1-\theta)(p-s)}{\theta} \tag{39}$$

We summarize the coordination conditions of MRM and BBM models in Table 1. □

5. Numerical Analysis

5.1. Comparative Analysis. We take the case of Hailan Home (short for HLA) to conduct the numerical analysis. HLA is one of the most famous China's fast fashion garment makers for men with more than 60 billion RMB of market value in the year of 2016. It owns over 4200 chain stores all over the country, and offering 17 product series covers more than 400 varieties of fast fashion including T-shirts, shirts, lounge pants, Jacket, coat, casual suit, sweater, and windbreaker. All fast fashions are consumer-oriented. The shelf life of each variety is less than four weeks; thus, HLA is required to use crowdsourcing policy for customized design with the goal of quick response to market changes. So far, about 3% of HLA custom designs come from crowdsourcing initiative. But crowdsourcing design has become an inseparable part of HLA's innovation capabilities. In addition, HLA also specifies a minimum production quantity for each crowdsourcing designed product to avoid risk.

Without losing any generality, suppose that the HLA's fast fashion product demand function and crowdsourcing payment function are defined as $F(x) = ax + b$, and $c_{cr}^{ji} =$ rand(.), respectively. The random function generator will generate 12 crowdsourcing reward values, distributed in the range of [1.5, 2.5]. The other related parameters are shown in Table 2.

By computing with the Matlab software, we obtain the optimal profit, optimal order quantity of the garment maker, retailer, and crowdsourcing supply chain in the above four models, i.e., the multiperiod basic order model (BM), the model with time value of capital (CM), the model with minimum production quantity and risk-aversion (MRM), and the model with mixed contract (BBM), respectively, shown in Table 3.

Table 3 shows the figures of 10 and 13, which are the optimum quantities ordered by the crowdsourcing supply chain and retailer in BM and CM model, respectively. For MRM model, we obtain the crowdsourcing supply chain's and retailer's order quantities; i.e., $q_{SC,EV*} \approx 15$ and $q_{R,EV*} \approx 12$. As $q_{MOQ} < q_{R,EV*} < q_{R,E*}$ and $q_{MOQ} < q_{SC,E*} < q_{SC,EV*}$, according to Proposition 3, the optimum quantities ordered by the retailer and whole CSC system are 12 and 10, respectively. For BBM model, we have $q_{R,E*}^{(BB)} = 13$, $q_{SC,E*}^{(BB)} = 3$, $q_{R,EV*}^{(BB)} \approx 35$, $q_{SC,EV*}^{(BB)} \approx 24$, since $q_{MOQ} < q_{R,E*}^{(BB)} < q_{R,EV*}^{(BB)}$, $q_{SC,E*}^{(BB)} < q_{MOQ} < q_{SC,EV*}^{(BB)}$. Similarly, according to Proposition 3, the optimum quantities ordered by the retailer and whole CSC system are 13 and 8.

In summary, the profits and the quantities ordered by the crowdsourcing supply chain and the retailer in BM, CM, MRM, and BBM model are shown in Table 3 and Figure 2.

From Figure 2, we find that the optimum quantity ordered by the retailer is higher than that in the crowdsourcing supply chain under BM, CM, MRM, and BBM model. Specifically, the difference between the optimum quantities ordered by the crowdsourcing supply chain and the retailer is the smallest

Table 1: Conditions for achieving coordination in MRM and BBM models.

Order quantity (q)	Wholesale price without crowdsourcing incentive	Wholesale price, buyback contract with crowdsourcing incentive
$q_{SC} = q_R = q_{SC,EV*} = q_{R,EV*}$	$p_w = p - (p - s)F(\eta - \Delta_{SC} + \Delta_R)$	$p_b = p - \dfrac{(p - p_w)}{a\theta(\delta - \Delta_{SC}^{(BB)} + \Delta_R^{(BB)} + b/a)} - \gamma$
$q_{SC} = q_R = q_{SC,EV*} = q_{R,E*}$	$p_w = p - (p - s)F(\eta - \Delta_{SC})$	$p_b = p - \dfrac{(p - p_w)}{a\theta(\delta - \Delta_{SC}^{(BB)} + b/a)} - \gamma$
$q_{SC} = q_R = q_{MOQ}$	$q_R = q_{MOQ}$	$q_R = q_{MOQ}$
$q_{SC} = q_R = q_{SC,E*} = q_{R,E*}$	----	$p_b = p - \dfrac{(p - p_w)}{a\theta(\delta + b/a)} - \gamma$
$q_{SC} = q_R = q_{SC,E*} = q_{R,EV*}$	----	$p_b = p - \dfrac{(p - p_w)}{a\theta(\delta + \Delta_R^{(BB)} + b/a)} - \gamma$

Notice: $\eta = F^{-1}[(p - c_m - c_{cr})/(p - s)]$, $\delta = [p - c_m - b(1 - \theta)(p - s)]/[2\alpha + a(1 - \theta)(p - s)]$, $\gamma = (1 - \theta)(p - s)/\theta$.

Table 2: Related parameters.

a	b	p	p_w	s	c_m	r	k	L	C	q_{MOQ}	α	θ	p_b	n
-1/7	2	10	9	3	4	0.1%	4	59	137	8	2/13	7/13	4	12

Table 3: Actual demand, profit, and optimal order quantities in the four models.

Model	π_{R*}		π_{SC*}t		q_{R*}	q_{SC*}
BM	24|x=12	52|x=18	132|x=9	160|x=15	13	10
CM	23.94|x=12	51.87|x=18	131.67|x=9	159.6|x=15	13	10
MRM	19.95|x=11	47.88|x=18	131.67|x=9	159.6|x=15	12	10
BBM	26.07|x=12	51.87|x-=16	139.34|x=7	152.23|x=11	13	8

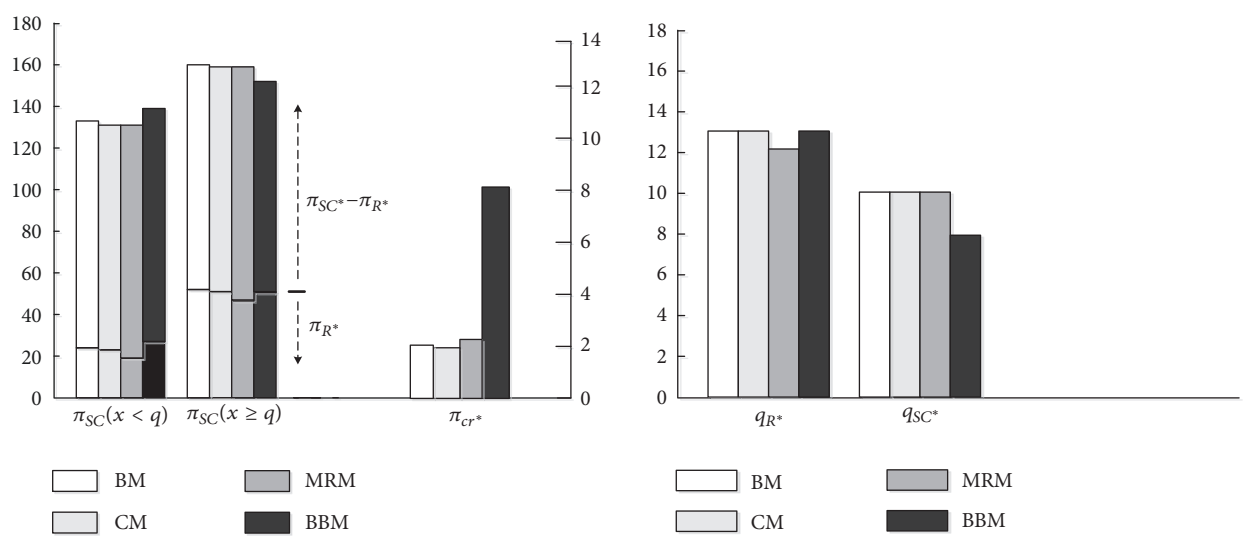

Figure 2: Profits and optimal order quantities in four models.

in MRM model, while it is the largest in BBM model. These differences are related to the existence of 'bullwhip effect' in the crowdsourcing supply chain under different decision-making scenarios. In the case of decentralized system, each member of the supply chain makes the decision individually by maximizing its own profit. The bullwhip effect is more obvious than the scenario of centralized decision-making, in which the members of the whole CSC system jointly make decisions. In addition, compared to the other three models, the optimum quantity ordered by the crowdsourcing supply chain in BBM model is the smallest. It implies that the mixed contract can effectively and efficiently coordinate companies in the crowdsourcing supply chain while maintaining inventory at the lowest level.

From the perspective of profit, the garment maker's profit is higher than those of the retailer and crowdsourcing

designer in four models, especially when the actual demand is lower than the optimal order quantity. On the other hand, as the actual demand is higher than the optimal order quantity, the proportion of the retailer's profits to the overall profit increases, hence showing that the optimal order quantity is important to the garment maker as well as the retailer. In addition, by considering the factor of time value of capital, the crowdsourcing supply chain's and retailer's profits in CM model are smaller than those in BM model. For the CM and MRM model, both the whole CSC system's optimum order quantity and profit remain unchanged. The optimum quantity ordered by the retailer in MRM model decreases compared to CM model. As a result, the profit in MRM model relatively reduces, implying that a decrease in the optimal order quantity leads to a loss of profit after integrating the constraint of the retailer's risk-aversion and the garment maker's minimum production quantity.

In CM and BBM model, under the mixed contract, when the actual demand is lower than the order number, it means the garment maker needs to buy back part of unsold products from the retailer, hence reducing the retailer's loss. If the order number is not higher than the actual demand, the garment maker does not need repurchasing and the retailer's profit remains unchanged. Similarly, when the actual demand is lower than the order number, the whole CSC system's profit in BBM model will increase, and vice versa. Thus, we can conclude that the use of a mixed contract is beneficial to both the retailer and the whole CSC system and can help the crowdsourcing supply chain to coordinate with the aim to increase the profit of each member.

5.2. Sensitivity Analysis. To explore the effect of the relevant elements on the crowdsourcing designers and supply chain's profits, we conduct a sensitivity analysis with respect to related factors: order quantity q, the proportion of crowdsourcing designers' payoff to the overall profit α ($\alpha = c_{cr}/q$, due to $q \propto \pi_{SC}$, thus, $\alpha \propto \pi_{SC}$), and clearance price s. The analysis is mainly based on BBM model, as the factors of clearance price s and interest rate r are involved. Meanwhile, the MRM model is also introduced to perform a comparative analysis.

(1) The Effect of Order Quantity q on the Crowdsourcing Designers and Supply Chain's Profit. As shown in Figure 3, the crowdsourcing designers' profit increases in order quantity q; namely, the retailer orders more products and the crowdsourcing designers receive more rewards. Additionally, the crowdsourcing supply chain's profit first increases and reaches a peak point at the profit of 35, then decreasing with q. In fact, when the quantity ordered by the retailer q is relatively smaller, it means the ordered products are in short supply, and the profit will naturally increase in q until the profit reaches the highest level. However, after this highest level, the supplies of fast fashion product exceed the demand. As a result, a number of products should be cleared out at a low price and profits begin to decrease with q.

Most importantly, Figure 3 shows that the crowdsourcing designers and supply chain's profit intersect at the point of 23, indicating that, when the order quantity is 23, the

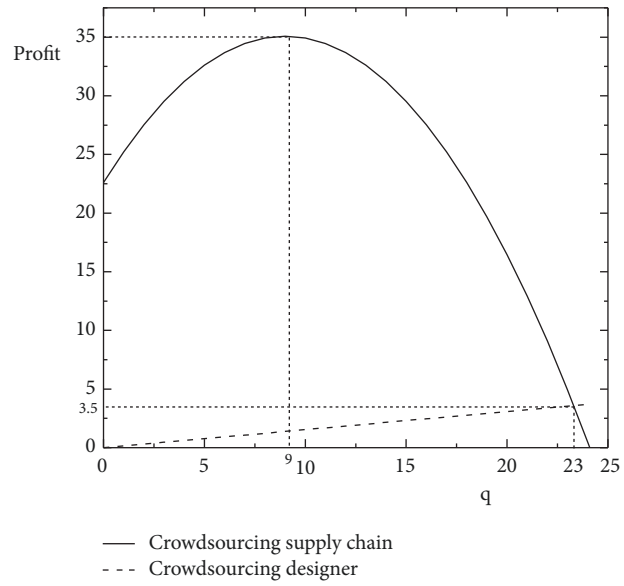

Figure 3: Effect of q on profit.

crowdsourcees will obtain the whole supply chain's profit exclusively. Furthermore, exceeding the order quantity of 23 implies the CSC system's loss, yet the crowdsourcees continuously receive the increasing payoff; the result of this phenomenon cannot motivate the garment maker and the retailer, except the crowdsourcees. Therefore, the profit-sharing scheme should be modified in this way, when the order quantity belongs to the interval [0, 9], and the crowdsourcees' payoff increases with α, when the order quantity is larger than 9, and the crowdsourcees' rewards decreases with q; it means implementing the profit-sharing scheme with a piecewise function of order quantity, rather than a linear function, thus motivating all members of the CSC. And the risks can be largely reduced or avoided.

(2) The Effect of α on the Crowdsourcing Designers and Supply Chain's Profit. From Figure 4, we can easily observe that the crowdsourcing designers' profit increases in α, when the proportion of α increases, and the crowdsourcing design cost will also increase. Conversely, the profit of the whole CSC system decreases with α. The two lines with respect to the crowdsourcing supply chain's and designer's profits intersect at the point of 0.62.

More interestingly, it can be seen from Figure 4 that the solid line is steeper than the dotted line, showing that the effect of the proportion on crowdsourcing supply chain's profit (α) is far higher than on the crowdsourcing designers. Therefore, it deduces that the value of α is a more efficient way of incentivizing the garment manufacturer and the retailer than crowdsourcing designers. It also indicates that it is better for the crowdsourcing supply chain manager to provide base payment and sales commission to incentivize crowdsourcing designers when the retailer's selling price is volatile and the demand is fluctuating.

(3) The Effect of Clearance Price s on the Total Profit of the Whole CSC System. From Figure 5, we can see that the

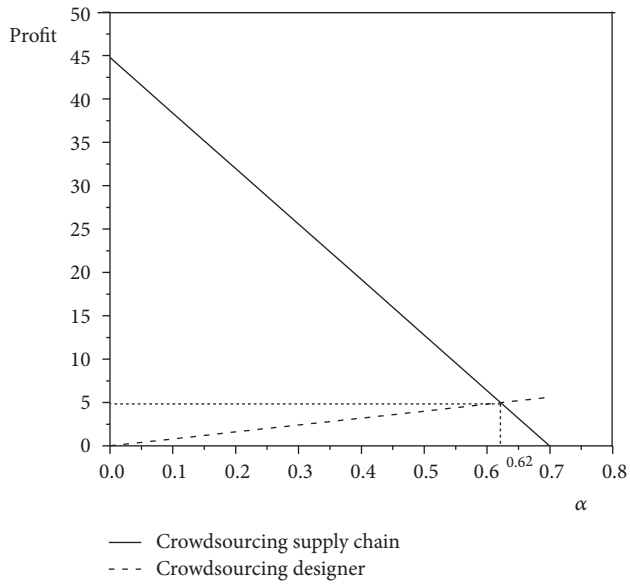

Figure 4: Effect of α on profit.

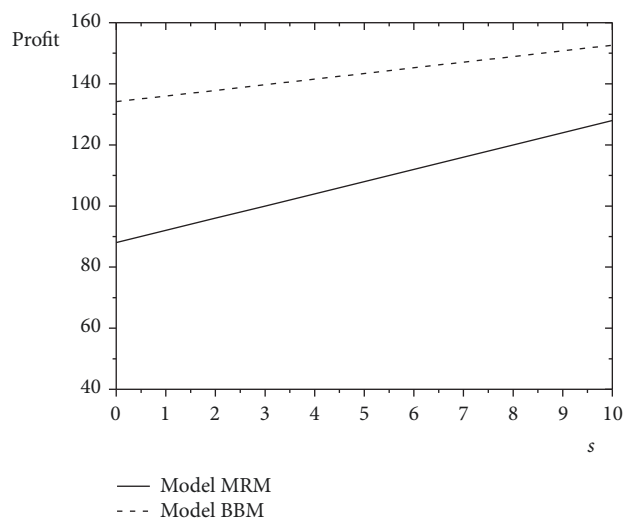

Figure 5: Effect of clearance price.

whole CSC system's total profits in MRM and BBM model increase in the clearance price s. The higher the clearance price, the lower the loss causes. Similarly, from Figure 5, the line representing the profit in BBM model is above the line representing profit of MRM model; meanwhile, the line representing profit in BBM model is steeper than in MRM model. This implies that the profit in BBM model is always higher than in MRM model. It further proves that the mixed contract is efficient and effective coordination for the whole CSC system, and the BBM model is more stable than the MRM model by considering the clearance price.

6. Conclusion

In this paper, the crowdsourcing innovation sector is embedded into a conventional fast fashion supply chain; on this basis, multiperiod basic order models of the retailer and crowdsourcing supply chain are established, respectively. Considering that the crowdsourcing platform has the features of multifrequent and rapid design, we integrate the factor of time value of capital into the basic model to assess the CSC performance. Then, in presence of the garment maker's production economy of scale and the retailer's risk-aversion, we extend to the crowdsourcing supply chain order model with minimum production quantity and risk-aversion. Through the optimization, the optimal order quantities and the implementation conditions in four settings are obtained. Followed by that, all members including the crowdsourcing designers, garment maker, and retailer are coordinated by devising a mixed contract to achieve the whole crowdsourcing supply chain Pareto optimality. Finally, a comparative and sensitivity analysis is conducted for further confirming the feasibility and practical values of the crowdsourcing model.

The main findings of this paper are summarized below. (1) The mixed contract can effectively and efficiently coordinate all members of the crowdsourcing supply chain while keeping inventory at the lowest level in BBM model. (2) From the perspective of profit, the garment maker's profit is higher than the retailer's and crowdsourcing designer's one in four models, especially when the actual demand is lower than the optimum ordering size. Moreover, as the actual demand is higher than the optimum ordering size, the retailer's profit in proportion to the overall profit increase, showing that the small order quantity is beneficial to the garment maker as well as the retailer. (3) Adjusting the proportion of crowdsourcing designers' payoff to the overall profit is a more efficient way to incentivize the garment maker and the retailer than the crowdsourcing designer. (4) In the policy for incentive to crowdsourcing designers, implementing the profit-sharing scheme with a piecewise function of order quantity is better than one with a linear function. Meanwhile, the decision-maker should offer a base payment and sales commission to incentivize the crowdsourcing designers when the retailing price is volatile and demand fluctuates.

For future research, several instructions can be focused on. Firstly, it is worth investigating the order quantity considering both the garment maker and the retailer's risk aversion; this will make the problem more realistic. Secondly, auction theory can be introduced to analyze crowdsourcing price. Thirdly, apart from online crowdsourcing design, dual-channel design (online/offline design) can also be introduced to explore crowdsourcing supply chain's performance.

Notations

X_i:	The set of fast fashion products in period i, $i = 1, 2, \ldots, k$
s:	The salvage value per unit unsold fast fashion product
D_i:	The demand function of fast fashion product X_i
$f(D_i), F(D_i)$:	pdf and cdf of fast fashion product demand D_i
c_{cr}^{ji}:	The reward for the crowdsourcee j designing the product in period i

q_i:	The fast fashion product quantity ordered by the retailer in period i (decision variable)
c_m:	Unit production cost
p_w:	Unit wholesale price
p:	Unit retail selling price
$\pi_{R,i}(q_i)$, $\pi_{SC,i}(q_i)$:	The profit of the retailer, and of the CSC ordering quantity q_i of fast fashion product X_i in period i
z_j^i:	Binary variable, representing if the fashion product designed by the crowdsourcee j is accepted in period i. (decision variable)
α:	The proportion of crowdsourcing designers' payoff to the overall profit.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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References

[1] J. Hauser, G. J. Tellis, and A. Griffin, "Research on innovation: A review and agenda for marketing science," *Marketing Science*, vol. 25, no. 6, pp. 687–717, 2006.

[2] D. Mahr and A. Lievens, "Virtual lead user communities: Drivers of knowledge creation for innovation," *Research Policy*, vol. 41, no. 1, pp. 167–177, 2012.

[3] P. G. Audia and J. A. Goncalo, "Past success and creativity over time: A study of inventors in the hard disk drive industry," *Management Science*, vol. 53, no. 1, pp. 1–15, 2007.

[4] F. M. Schweitzer, W. Buchinger, O. Gassmann, and M. Obrist, "Crowdsourcing: Leveraging Innovation through Online Idea Competitions," *Research-Technology Management*, vol. 55, no. 3, pp. 32–38, 2012.

[5] D. C. Brabham, "Moving the crowd at threadless: motivations for participation in a crowdsourcing application," *Information Communication & Society*, vol. 13, no. 8, pp. 1122–1145, 2010.

[6] R. Maiolini and R. Naggi, "Crowdsourcing and SMEs: Opportunities and challenges," in *Proceedings of ITATS*, 2010.

[7] J. Pénin and T. Burger-Helmchen, "Crowdsourcing of inventive activities: Definition and limits," *International Journal of Innovation and Sustainable Development*, vol. 5, no. 2-3, pp. 246–263, 2011.

[8] J. Albors, J. C. Ramos, and J. L. Hervas, "New learning network paradigms: Communities of objectives, crowdsourcing, wikis and open source," *International Journal of Information Management*, vol. 28, no. 3, pp. 194–202, 2008.

[9] K. J. Boudreau, N. Lacetera, and K. R. Lakhani, "Incentives and problem uncertainty in innovation contests: An empirical analysis," *Management Science*, vol. 57, no. 5, pp. 843–863, 2011.

[10] B. L. Bayus, "Crowdsourcing new product ideas over time: an analysis of the Dell IdeaStorm community," *Management Science*, vol. 59, no. 1, pp. 226–244, 2013.

[11] M. Kosonen and K. Henttonen, "Cheer the crowd? Facilitating user participation in idea crowdsourcing," *International Journal of Technology Marketing*, vol. 10, no. 1, pp. 95–110, 2015.

[12] I. Perera and P. A. Perera, "Developments and leanings of crowdsourcing industry: Implications of China and India," *Industrial and Commercial Training*, vol. 46, no. 2, pp. 92–99, 2014.

[13] Y. Zhao and Q. Zhu, "Evaluation on crowdsourcing research: Current status and future direction," *Information Systems Frontiers*, vol. 16, no. 3, pp. 417–434, 2014.

[14] M. Kosonen and C. Gan, "User motivation and knowledge sharing in idea crowdsourcing," *International Journal of Innovation Management*, vol. 18, no. 05, Article ID 1450031(23), 2014.

[15] J. M. Leimeister, M. Huber, U. Bretschneider, and H. Krcmar, "Leveraging crowdsourcing: activation-supporting components for IT-based ideas competition," *Journal of Management Information Systems*, vol. 26, no. 1, pp. 197–224, 2009.

[16] J. Yang, L. A. Adamic, and M. S. Ackerman, "Crowdsourcing and knowledge sharing: Strategic user behavior on Taskcn," in *Proceedings of the 2008 ACM Conference on Electronic Commerce, EC'08*, pp. 246–255, USA, July 2008.

[17] R. Jain, "Investigation of governance mechanism for crowdsourcing initiatives," in *Proceedings of America conference on information systems*, pp. 557–563, 2010.

[18] R. Masson, L. Iosif, G. Mackerron, and J. Fernie, "Managing complexity in agile global fashion industry supply chains," *The International Journal of Logistics Management*, vol. 18, no. 2, pp. 238–254, 2007.

[19] B. Kim, "Competitive priorities and supply chain strategy in the fashion industry," *Qualitative Market Research*, vol. 16, no. 2, pp. 214–242, 2013.

[20] C. M. Castelli and A. Brun, "Alignment of retail channels in the fashion supply chain: An empirical study of Italian fashion retailers," *International Journal of Retail & Distribution Management*, vol. 38, no. 1, pp. 24–44, 2010.

[21] Y. Li, X. Zhao, D. Shi, and X. Li, "Governance of sustainable supply chains in the fast fashion industry," *European Management Journal*, vol. 32, no. 5, pp. 823–836, 2014.

[22] A. Nagurney and M. Yu, "Sustainable fashion supply chain management under oligopolistic competition and brand differentiation," *International Journal of Production Economics*, vol. 135, no. 2, pp. 532–540, 2012.

[23] Q. Pang, Y. Hou, and Y. Lv, "Coordinating Three-Level Supply Chain under Disruptions Using Revenue-Sharing Contract with Effort Dependent Demand," *Mathematical Problems in Engineering*, vol. 2016, Article ID 9167864, 10 pages, 2016.

[24] W. Elmaghraby, A. Gülcü, and P. Keskinocak, "Designing optimal preannounced markdowns in the presence of rational customers with multiunit demands," *Manufacturing and Service Operations Management*, vol. 10, no. 1, pp. 126–148, 2008.

[25] B. Shen, T.-M. Choi, Y. Wang, and C. K. Y. Lo, "The coordination of fashion supply chains with a risk-averse supplier under the markdown money policy," *IEEE Transactions on Systems, Man, and Cybernetics: Systems*, vol. 43, no. 2, pp. 266–276, 2013.

[26] B. Liu, J. Chen, S. F. Liu, and R. Zhang, "Supply-chain coordination with combined contract for a short-life-cycle product," *IEEE Transactions on Systems, Man, and Cybernetics: Systems*, vol. 36, no. 1, pp. 53–61, 2006.

[27] S. A. Raza, "Supply chain coordination under a revenue-sharing contract with corporate social responsibility and partial demand information," *International Journal of Production Economics*, vol. 205, pp. 1–14, 2018.

[28] B. Hu, C. Meng, D. Xu, and Y.-J. Son, "Three-echelon supply chain coordination with a loss-averse retailer and revenue sharing contracts," *International Journal of Production Economics*, vol. 179, pp. 192–202, 2016.

[29] B. Hu, Y. Feng, and X. Chen, "Optimization and coordination of supply chains under the retailer's profit margin constraint," *Computers & Industrial Engineering*, vol. 126, pp. 569–577, 2018.

[30] J. Heydari, "Coordinating supplier's reorder point: A coordination mechanism for supply chains with long supplier lead time," *Computers & Operations Research*, vol. 48, pp. 89–101, 2014.

[31] D. Wu, "Coordination of competing supply chains with newsvendor and buyback contract," *International Journal of Production Economics*, vol. 144, no. 1, pp. 1–13, 2013.

[32] J. Heydari, T.-M. Choi, and S. Radkhah, "Pareto improving supply chain coordination under a money-back guarantee service program," *Service Science*, vol. 9, no. 2, pp. 91–105, 2017.

[33] J. Heydari, M. Rastegar, and C. H. Glock, "A two-level delay in payments contract for supply chain coordination: The case of credit-dependent demand," *International Journal of Production Economics*, vol. 191, pp. 26–36, 2017.

[34] J. Heydari and Y. Norouzinasab, "A two-level discount model for coordinating a decentralized supply chain considering stochastic price-sensitive demand," *Journal of Industrial Engineering International*, vol. 11, no. 4, pp. 531–542, 2015.

[35] N. M. Modak, S. Panda, and S. S. Sana, "Three-echelon supply chain coordination considering duopolistic retailers with perfect quality products," *International Journal of Production Economics*, vol. 182, pp. 564–578, 2016.

[36] I. Nosoohi and A. S. Nookabadi, "Designing a supply contract to coordinate supplier's production, considering customer oriented production," *Computers & Industrial Engineering*, vol. 74, no. 1, pp. 26–36, 2014.

[37] Y. Zhao, L. Ma, G. Xie, and T. C. E. Cheng, "Coordination of supply chains with bidirectional option contracts," *European Journal of Operational Research*, vol. 229, no. 2, pp. 375–381, 2013.

[38] N. Yan, B. Sun, H. Zhang, and C. Liu, "A partial credit guarantee contract in a capital-constrained supply chain: financing equilibrium and coordinating strategy," *International Journal of Production Economics*, vol. 173, pp. 122–133, 2016.