Commercial Used Apparel Collection Operations in Retail Supply Chains

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Highlights

- Comprehensively explore the commercial used apparel collection (UAC) programs.
- Analytically derive the optimal promotion effort and study "profit" coordination.
- Show that the results are robust with extensive extensions.
- UAC is better for all members if there're more environmental conscious consumers.
- Collecting own branded products will reduce market demand.
- Propose a novel and robust effort cost sharing contract to improve UAC.

Commercial Used Apparel Collection Operations in Retail Supply Chains[1]

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Abstract: Motivated by the commonly observed commercial used apparel collection (UAC) programs in the fashion retail supply chain operations, this paper analytically explores the associated operational challenges that firms face. First, in the basic model, we consider the case when a fashion retail brand promotes its UAC program and collects the used apparel from consumers. Depending on the conditions of the collected apparel products, the fashion retail brand will classify and either donate them for charity or send them to remanufacturing. For either case, the fashion retail brand gains a benefit. We analytically derive in closed-form the optimal promotion effort and study the mechanism for "profit" coordination. Our results indicate that many traditional supply chain contracts fail to achieve "profit" coordination. Thus, the effort cost sharing (ECS) contract is proposed and proven to be effective for "profit" coordination. Finally, to check the robustness of findings from the basic model, we examine various UAC practice related extended models, such as i) consumer coupon offering, ii) "no remanufacturing" model, iii) consumer heterogeneity in environmental consciousness, iv) own-brand collection *vs* any-brand collection. Our findings show that the qualitative insights continue to hold in the extended scenarios. Some novel scenario-dependent findings are also obtained. Insights derived in this paper not only contribute to the literature but also provide scientifically sound managerial guidance and insights to practitioners on how UAC programs can be best operated.

Keywords: Supply chain management, used apparel collection, socially responsible operations; promotion effort.

1. Introduction

1.1. Industrial Background

In fashion retail supply chains, the commercial used apparel collection (UAC) program has been widely implemented over the past few years. H&M, a renowned fast fashion brand and retailer, has implemented its UAC program since 2013[3]. In fact, H&M was one of the first large scale fast fashion brands which launched a commercial UAC program. Under H&M's UAC program, consumers can bring properly cleaned used apparel to H&M's retail stores. H&M collects the used apparel for commercial recycling as well as charity donation. H&M issues coupons (e.g., 10% off) to each small bag of collected used apparel. In 2019, H&M collected 29,005 tons of used garments through its UAC program[4]. Another fashion brand, Uniqlo, focuses on collecting its own "Uniqlo-branded" products which are in good shape. Uniqlo 100% donates its collected clothes to support children, refugees and others. In particular, through a special organization named UNHCR (Uniqlo and the United Nations High Commissioner for Refugees), Uniqlo provides emergent assistance to refugees, like those in Myanmar, South Sudan, Rwanda, Uganda, etc. Marks and Spencer (M&S)[5], a Britain's biggest fashion retailer, launched a "shwopping" scheme in 2012 to take back the old or unwanted apparel from customers. M&S cooperates with its charity partner Oxfam to arrange the donation, reuse, and recycling of the collected clothes. The "shwopping" scheme is one of M&S' "Plan A" sustainability program. Over the past five years, "Plan A" achieves a very profitable outcome with £185 million in net benefits (Brokaw 2012). In 2017, another fast fashion giant ZARA[6] initiated its "Join Life" program which aims at collecting used clothes and donating the collected apparel directly to charity organizations like Caritas, the Red Cross, Salvation Army, CEPF, Redress, and Oxfam. More industrial practices on UAC in fashion brands are shown in Table 1.1 (with full details in Appendix (A1)).

Table 1.1. UAC Practices of the Fashion Retail Brands (Yes: √; No: /).

		H&M	M&S	Uniqlo	Zara
Collection	Own brands' products	√	√	√	√
	Any brands	√	√	/	√
Usage	Remanufacturing or other commercial activities	√	√	/	√
	Donation (DO)	√	√	√	√
Incentive	Coupon for consumers	√	√	/	/
Facility	Collection box	√	√	√	√

As we can see from Table 1.1, despite having some slight differences (collecting its own products, or any brands; with or without coupons; solely for charity or with remanufacturing and commercial elements, etc.), UAC programs are very popular in the fashion industry. To a certain extent, fashion brands (especially fast

[3] https://www2.hm.com/en_gb/ladies/shop-by-feature/16r-garment-collecting.html [assessed 30 September 2019]
[4] https://sustainabilityreport.hmgroup.com/wp-content/uploads/2020/04/HM-Group-SR19-Highlights.pdf [assessed 21 July 2020]
[5] http://www.marksandspencer.com/s/plan-a-shwopping [assessed 30 September 2019]
[6] https://www.zara.com/hk/en/sustainability-collection-program-l1452.html?v1=967749 [assessed 30 September 2019]

fashion brands) establish these programs to change their traditionally unsustainable image (such as disposable fashion clothing, and "dirty" to the environment.) and gain a kind of intangible benefit in brand image improvement (Caro and Martínez-de-Albéniz, 2015).

From the literature, there is a considerable amount of research on the problems of electronic wastes and vehicles, involving collection, take-back, and remanufacturing (Bakal and Akcali, 2006; Bulmus et al., 2014; Govindan and Popiuc, 2014; Atasu et al., 2008; Calmon and Graves, 2017; Ponte et al., 2019; Kleber et al., 2020; Cai and Choi, 2021). However, few prior studies have analytically examined the problem of UAC in the fashion industry. Thus, it is important and interesting to investigate the problem of UAC, which contributes to both the extant literature and management of real-world practices. Due to the different features of electronic wastes (and vehicles) and used apparel, our modeling is also different from the literature on waste electronic products or vehicles. For example, waste electronic products or vehicles usually have a higher salvage value than the casual used fashion apparel. Therefore, either compulsory or voluntary remanufacturing may be profitable for electronic wastes or vehicles, but it is not true for used fashion apparel. In addition, apparel donation is a distinctive feature of UAC, which differentiates this paper from others and makes the modeling in this paper unique.

1.2. Research Objectives, Questions and Major Findings

Motivated by the observed real-world practices, this paper attempts to explore how commercial UAC operations enhance the profitability and social reputation of a fashion brand. We set up two research objectives: i) To explore the real practice based used apparel collection (UAC) program, which helps to close the loop in the textile and apparel supply chain; ii) To derive possible guidelines for fashion retail companies to efficiently implement UAC so as to achieve socially responsible, yet profitable operations.

To achieve these goals, we come up with three main research questions: i) What is the optimal promotion effort of the fashion brand for UAC? ii) How could the UAC supply chain be coordinated? iii) How robust are the results when different real-world relevant extended scenarios are examined?

To address these questions, we consider a supply chain with a fashion retail brand, a remanufacturer and a charity organization, and construct a stylized analytical model to identify the optimal operations of the fashion retail brand and the supply chain. To be specific, in our basic model, we consider the case when a fashion retail brand collects the used apparel from consumers in the market by exerting promotion effort. Some of the collected used apparel are in a good shape, which can be directly donated for charity for re-use. However, some of the collected used apparel can only be used for re-manufacturing or recycling. Regarding the benefits for these two different outlets for the collected used apparel, we consider the situation when the re-manufacturer will pay the fashion retail brand some money for each unit of used apparel sent for re-manufacturing. For the donation to charity, even though the charity organization will not "pay the fashion retail brand", the fashion retail brand actually enjoys a gain in reputation and good name as an ethical company, which in fact should be one important incentive for many of them to engage in UAC. We also

explore the supply chain coordination problem in this paper. As the supply chain in this paper contains a charity organization, the coordination problem is different from the traditional supply chain problem (Cachon and Lariviere, 2005; Ha and Tong, 2008; Govindan and Popiuc, 2014). Therefore, we present the "profit" coordination[7] definition as follows. Finally, to check the robustness of managerial findings from the basic model, various UAC practice related extended models, such as i) consumer coupon offering, ii) "no remanufacturing" model, iii) consumer heterogeneity in environmental consciousness, iv) own-brand collection *vs* any-brand collection, are examined.

Definition (Profit Coordination). *In the supply chain with UAC, it is said to be profit-coordinated if the retailer's optimal promotion effort is the same as the promotion effort that maximizes the supply chain's expected benefit.*

This paper derives several main results as summarized in the following. First, we analytically derive in closed-form the optimal promotion efforts in both decentralized and centralized settings. We find that the promotion effort in the decentralized setting fails to coordinate the channel. We propose an effort cost sharing (ECS) contract to help, in which the charity organization is required to share partial promotion cost of the fashion retail brand, e.g., by using its team of volunteers to help. Surprisingly, we uncover that traditional contracts like two-part tariff, revenue sharing, and rebates all fail to achieve coordination. Second, to check the robustness of managerial findings from the basic model and also examine various real world related scenarios, we have considered five extensions. Considering consumer coupon offering, we find that the fashion retail brand will exert more promotion effort in collecting the used apparel in the presence of coupon. In the centralized setting, with the enhanced promotion effort, the supply chain profit becomes better off. When there is no remanufacturing for used apparel, we find that taking back used apparel and solely used for charity donation (e.g., in Uniqlo) is not always a good strategy for the fashion retail brand to make more profits. When consumers are heterogenous in environmental consciousness, we find that a higher proportion of environmental conscious consumers will contribute to more profits to both the fashion retail brand and the remanufacturer. When the fashion retail brand only collects its own branded products under UAC, the market demand will decline due to a reduced promotion effort. The supply chain players' profits become worse off, when comparing with the any-brand collection model. Finally, we find that the effectiveness of ECS contract for supply chain coordination is robust across all extended models.

1.3. Contribution Statements and Paper Organization

The contributions of this paper are three-fold: i) This paper contributes to the extant literature on sustainable operations management, particularly, socially responsible operations, by exploring the commonly observed UAC programs. ii) This paper provides effective management strategies for fashion retail brands which are operating UAC programs, and lets them know theoretically when the UAC program will be especially significant. iii) Our findings provide valuable guidelines for the industrial practitioners to make effective

[7] As a remark, the term "profit coordination" is equivalent to the term "supply chain coordination" in this paper.

decisions (e.g., whether to offer coupon, or to collect only own brand's product) under UAC to achieve sustainable and socially responsible operations in the dynamic and challengeable fashion retail supply chain.

This paper proceeds as follows. Section 2 concisely reviews the relevant literature. Section 3 establishes the basic model and Section 4 presents equilibrium decisions[8] under both the decentralized setting and the centralized setting. Section 5 explores the supply chain coordination challenge with UAC. Section 6 investigates how robust the results are when different extended scenarios are examined. Section 7 concludes this paper and discusses managerial implications and future research.

2. Related Literature

This paper is related to two streams of operational research (OR) studies, namely socially responsible operations and remanufacturing. We review them as follows concisely.

2.1 Socially Responsible Operations

Profitability is not the only attribute of a successful firm nowadays. In OR, corporate social responsibility (CSR) is treated as much more important than ever before (Flammer 2015). This also gives rise to a lot of related studies in recent years. For instance, Servaes and Tamayo (2013) analytically study the impact of CSR on the corporate value. The authors explore the problem from the customer awareness perspective. They show that CSR activities can add value to the firm under some tricky conditions. Sodhi and Tang (2014) discuss socially responsible operations in supply chains. They focus on the case when the suppliers or distributors are from developing countries. The authors highlight that CSR remains an untapped OR research area. Besiou and Van Wassenhove (2015) address the challenge of modeling for decision-making in socially responsible operations. The authors present a novel umbrella approach which combines different methodologies to address CSR related operational issues. Plambeck and Taylor (2016) theoretically investigate how buyers can tactfully motivate suppliers to fulfill social and environmental responsibilities via setting contracts. The authors argue that the backfiring condition is likely to happen. Chen et al. (2017) analytically study the mutual dependence among supply chain agents for CSR. The authors explore a stylized two-party supply chain analytical model. They demonstrate that a win–win situation will be achieved if and only if the mutual commitments are "reciprocally similar".

Donation for charity is one form of CSR activities. In the literature, Arya and Mittendorf (2015) analytically study the role played by government subsidies for CSR in a supply chain. The authors argue that under government subsidies, firms will be incentivized to achieve certain pre-determined social goals like donation quantity, and this may result in an increase of the retail market price. Later on, Arya and Mittendorf (2016) indicate that the charity organization has to carry out an effective donation operation. The authors argue that the nonprofit accounting measures play an important role on the optimal use of resources. As a remark, similar to Arya and Mittendorf (2015, 2016), this paper also explores the issue of an effective

[8] In this paper, we use the term "optimal decision" and "equilibrium decision" interchangeably as they both refer to the best decision.

donation operation. However, this paper is different from Arya and Mittendorf (2015, 2016) in the problem domain, scope, focal point as well as the core findings.

2.2 Acquisition and Remanufacturing

Reverse supply chain management receives a lot of attention from the academia (Kleindorfer et al. 2005; Ilgin and Gupta 2010; Agrawal et al. 2019; Atasu et al. 2020). The reverse supply chain includes activities such as product returns, used product take-back, reuse, and remanufacturing (Brandenburg et al. 2014; Govindan et al. 2015; Feng et al. 2017). Used product acquisition and remanufacturing are widely explored in reverse supply chain management (Daniel et al. 2001; Savaskan and Van Wassenhove 2006; Tsiliyannis 2018).

On used product acquisition, Daniel et al. (2001) study the impact of product returns management and the profitability of remanufacturing. The authors find that product returns management is critical for firm's profitability. Savaskan et al. (2004) examine the reverse channel design for collecting the used products from customers. The authors reveal that the scenario with the retailer undertaking the collection task is the most efficient one. Savaskan and Van Wassenhove (2006) study two product collection systems, namely the manufacturer-led and the retailers-led systems. The authors reveal that the supply chain profits are affected by the promotion effort under the manufacturer-led collection system, while under the retailers-led collection system, the supply chain profits are affected by the retail competition. Karakayali et al. (2007) study the end-of-life product collection in two decentralized supply chain settings: one is the remanufacturer-driven channel, and the other is the collector-driven channel. The authors find that the choice of collection channel is affected by the collection rate as well as the environmental regulation. Choi et al. (2018) study the used intimate apparel collection programs and reveal that the collection approach and the retail competition level affect the used intimate apparel collection program significantly. Most recently, Kleber et al. (2020) investigate the competition between two remanufacturers in the collection of used products and the sales of remanufactured products. The authors find that a remanufacturer with market advantage outperforms the one with acquisition advantage. In this paper, following the industrial practice, we consider the case when the fashion retailer is in charge of collecting the used apparel for the respective reverse supply chain. This is a commonly seen industrial practice but not yet examined in the existent OR literature.

On remanufacturing, Majumder and Groenevelt (2001) investigate the competition of remanufacturing between an original equipment manufacturer and a local remanufacturer. The authors suggest that the social planner should give incentives to the original equipment manufacturer or decrease the remanufacturing cost in order to encourage more remanufacturing activities. Atasu et al. (2008) study the remanufacturing problem and conclude that remanufacturing can be effective for marketing. The authors propose that price differentiation of remanufactured products is critical for the manufacturer to keep its market share. Teunter and Flapper (2011) consider the core quality related issues in remanufacturing. The authors focus on uncovering the impacts brought by the uncertainty of "core quality fractions". Wang et al. (2017) analytically study remanufacturing operations considering both profitability and environmental impacts. The authors find that although there is a conflict between profitability and environmental benefits, carefully meeting conditions

on bargaining power and fixed cost of in-house remanufacturing may help align the two goals together. Kovach et al. (2018) investigate the impact of salesforce incentives on remanufacturing activities. The authors reveal that offering differentiated commissions for new and remanufactured products would help support remanufacturing and improve profit. Tsiliyannis (2018) adopts the Markov chain based method in conducting real-time forecasting of product returns in remanufacturing. Li et al. (2019) study trade-in remanufacturing and find that customers' willingness to pay for the remanufactured product and production cost play an important role in the trade-in program. For more research on remanufacturing, please refer to Debo et al. (2005), Bakal and Akcali (2006), Galbreth and Blackburn (2010), Kim et al. (2013); Bulmus et al. (2014); Cai et al. (2014); Flapper et al. (2014); Wu and Zhou (2016), Calmon and Graves (2017), Yan et al. (2017), and Ponte et al. (2019).

We summarize the relevant literature in Table 2.1 and identify the potential research gap in the domain of socially responsible operations, used product acquisition and remanufacturing. Different from the reviewed literature in reverse supply chain management, this paper considers both remanufacturing activities and donation of collected used apparel, and examines how promotion effort for UAC affects the profitability of the fashion retail brand. In our model, remanufacturing can create economic values and donation can enhance the fashion retail brand's social responsibility and hence ethical image and reputation. To the best of our knowledge, this paper is the first one which analytically explores the UAC operations with the consideration of charity donation and remanufacturing. The analytical model is neat and novel. All results are theoretically derived in closed-form.

As a remark, remanufacturing is commonly seen in the "circular economy (CE)" (Prosman et al. 2017; Elodie et al. 2020). The concept of "CE" originates, when the concept of "industrial ecosystem" was proposed for optimizing the energy and resource consumption. Nowadays, CE is perceived as an eco-efficient production and consumption system with the ideal goal of "zero waste" by "3R" or beyond: reduce, reuse and recycling (Yuan et al. 2006; Haupt et al. 2017). CE is a big scope, which is not the focus of this paper. Therefore, this paper can be linked to CE, but demarcated from it.

Table 2.1. Summary and comparison of reviewed literature.

Papers[9]	*Research Scope*		
	Socially Responsible Operations	*Acquisition*	*Remanufacturing*
Arya and Mittendorf (2015)	√		
Arya and Mittendorf (2016)	√		
Atasu et al. (2008)			√
Besiou and Van Wassenhove (2015)	√		
Bulmus et al. (2014)			√
Cai et al. (2014)		√	√
Chen et al. (2017)	√		
Choi et al. (2018)		√	
Daniel et al. (2001)		√	√
Flapper et al. (2014)			√

[9] The paper list follows the order of surname.

Karakayali et al. (2007)		√	
Kim et al. (2013)			√
Kleber et al. (2020)		√	√
Kovach et al. (2018)			√
Li et al. (2019)			√
Majumder and Groenevelt (2001)			√
Mittendorf (2015)	√		
Ni et al. (2010)	√		
Plambeck and Taylor (2016)	√		
Ponte et al. 2019		√	√
Savaskan et al. (2004)		√	
Savaskan and Van Wassenhove (2006)		√	
Servaes and Tamayo (2013)	√		
Sodhi and Tang (2014)	√		
Teunter and Flapper (2011)			√
Tsiliyannis (2018)			√
Wang et al. (2017)			√
This paper	√	√	√

3. Basic Model

We consider a fashion retail supply chain consisting of a fashion retail brand, a remanufacturer, a charity organization, and consumers. The fashion retail brand sells fashion products to the consumers and earns an average profit $\bar{p}$ per customer. With the UAC program, the fashion retail brand collects the used apparel for both remanufacturing and donation (P.S.: This is the common case for fashion retail brands such as H&M, Marks and Spencer, and Zara). To be specific, some of the collected used apparel may appear in a good shape, which can be directly donated for charity for re-use. However, some of the collected used apparel are not in a good shape and can only be used for re-manufacturing or recycling. The collected used apparel products are remanufactured or recycled by the third party for other purposes, e.g., carpet production, and spinning yarns. Therefore, the remanufactured products do not compete with the originally manufactured fashion product in the fashion brand's retail store. Therefore, they do not affect the market demand. Regarding the benefits for these two different outlets for the collected used apparel, we consider the situation when the re-manufacturer will pay the fashion retail brand for each unit of used apparel sent for remanufacturing. For the donation to charity, even though the charity organization will not "pay the fashion retail brand", the fashion retail brand actually enjoys a gain in reputation as an ethical company and we also quantify this gain by an intangible benefit. Figure 3.1 depicts the whole picture of the basic model.

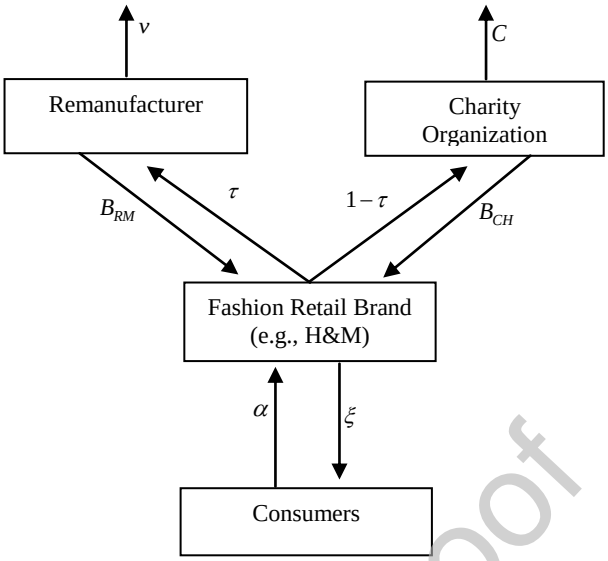


Figure 3.1. Model development in the basic model.

The potential market size for the fashion retail brand is denoted by N. Suppose that if the fashion retail brand offers the UAC program, it will attract an increased market demand to the store (i.e., it is not the total demand faced by the fashion retail brand, but the increased demand derived from UAC)[10]. Thus, the market demand can be expressed as follows:

$$D = a + b\xi, \tag{3.1}$$

where ξ is the promotion effort of the UAC program, $a > 0$ is the base market demand, and $b > 0$ is the coefficient of promotion effort towards the total market demand.

Note that the linear effort dependent demand function is commonly adopted in the OR literature (see Cachon and Lariviere 2005; Caldieraro and Coughlan 2007; Kovach et al. 2018). It is also in line with the consumer valuation/utility function which is uniformly distributed (such as the "Uniform (0,1) distribution"). The promotion effort of UAC program in this paper includes investments in advertisement, the public relations, the training of front-line sellers, and educating consumers, etc. The total market demand on the fashion products has a linear relationship with the promotion effort. We assume exerting the promotion effort incurs a quadratic cost $K(\xi)$, which is defined by: $K(\xi) = k\xi^2/2$. The quadratic cost function is widely adopted in modelling the cost of promotion effort (Jørgensen et al. 2003; Heese and Swaminathan, 2010; Karray 2011; Jørgensen and Zaccour, 2014; Liu et al. 2014; Lu and Navas, 2021). We also investigate the linear promotion cost case in Appendix (A2) to generate more insights for the fashion retail brand in the UAC program.

[10] In our model, we take this increase as deterministic. In fact, even if we include the randomness, it will not affect our qualitative result if we focus on exploring the expected benefit.

Suppose that from the UAC driven increased demand *D*, only some (i.e., $0 < \alpha < 1$) but not all consumers will take the used apparel back. In the basic model, we assume that the return rate α to be exogenous in our model. The reason why we consider the return rate α to be exogenous is to generate tracible analytical results. We relax this assumption by considering the return rate α to be endogenous in an extended model and find the main results in the endogenous return rate still hold[11].

We denote the collected quantity under the UAC program by *Q*, and it is defined below:

$Q = \alpha D$, where $0 < \alpha < 1$. (3.2)

Some of the collected used apparel may be in a very good shape, which can be directly donated to charity (e.g., Red Cross, Oxfam, etc.) for re-use. However, some of the collected used apparel may be too old or damaged that need to be re-manufactured or recycled. We denote the proportions of collected used apparel that need to be remanufactured by τ, and the ones which can be directly reused and donated for charity by $1-\tau$ (where $0 < \tau < 1$), respectively. Regarding the benefits for these two different outlets for the collected used apparel, we consider the situation when the re-manufacturer will pay the fashion retail brand B_{RM} for each unit of used apparel sent for re-manufacturing. Thus, the fashion retail brand[12] will gain a benefit of B_{RM} for each unit of collected used apparel for re-manufacturing. For the re-manufacturer, each unit of remanufactured used apparel will yield a value of *v*. For the donation to charity, even though the charity organization will not "pay the fashion retail brand", the fashion retail brand actually enjoys a gain in reputation as an ethical company. We represent the fashion retail brand's unit gain for this kind of donation to charity by B_{CH} (called the *unit good-name benefit from donation*), and the charity organization can generate a value of *C* (called the *moral benefit*) from each unit of donated used apparel, where B_{CH} and *C* are exogenous. As a remark, we do not consider the processing cost associated with classifying the collected used apparel, as considering such a cost will not affect any managerial insights while will make the model more complex.

We now consider the game sequence under UAC. First, the re-manufacturer decides the payment to the fashion retail brand for each unit of used apparel B_{RM}. Second, with given B_{RM}, the fashion retail brand reacts by deciding the optimal promotion effort ξ for the UAC program. As the charity organization only acts as a recipient of the used apparel, its presence only provides a way for the fashion retail brand to gain B_{CH}, and also generate a value of *C* for itself.

The notation list is shown in Appendix (A3). All technical proofs are placed in the Online Appendix II.

4. Equilibrium Decisions and Performance

4.1 Decentralized Setting

[11] The analysis for the case with an endogenous return rate is placed in Online Appendix I.

[12] Unless otherwise specified, the term "fashion retail brand" is equivalent to the term "fashion retailer" in this paper.

We start the analysis by exploring the decentralized supply chain. In the decentralized setting, both the fashion retail brand and remanufacturer aim to maximize their profits. The remanufacturer will determine the optimal payment B_{RM} for each unit of used apparel. The fashion retail brand will determine the optimal promotion effort ξ.

For a notational purpose, define:

$\bar{B} = \tau B_{RM} + (1-\tau) B_{CH}$,

$\Omega(B_{RM}) = \bar{p} + \alpha \bar{B}$, and

$\Delta = \frac{ak}{b^2} + \bar{p} + \alpha(1-\tau) B_{CH}$.

From the model in Section 3, we can express the fashion retail brand's profit as follows:

$$\pi_R(\xi) = \bar{p}D + B_{RM}\tau Q + B_{CH}(1-\tau)Q - K(\xi)$$
$$= (\bar{p} + \alpha \bar{B})\, D - K(\xi) \quad . \tag{4.1}$$

It is easy to show that $\pi_R(\xi)$ is a concave function of ξ. Thus, solving the first order condition yields the optimal promotion effort for a given B_{RM}:

$$\hat{\xi}_R = \arg_{\xi}\{\frac{\partial \pi_R(\xi)}{\partial \xi} = 0\} = \frac{(\bar{p} + \alpha \bar{B})b}{k}. \tag{4.2}$$

For the remanufacturer, its profit function when $\xi = \hat{\xi}_R$ is given below:

$$\pi_{RM}(B_{RM}; \xi = \hat{\xi}_R) = (v - B_{RM})\tau Q(\hat{\xi}_R) = (v - B_{RM})\tau\alpha\left(a + \frac{b^2 \Omega(B_{RM})}{k}\right). \tag{4.3}$$

Checking the structural properties of $\pi_{RM}(B_{RM}; \xi = \hat{\xi}_R)$ gives Lemma 4.1.

Lemma 4.1. *(a)* $\pi_{RM}(B_{RM}; \xi = \hat{\xi}_R)$ *is concave in* B_{RM}. *(b) The equilibrium* B_{RM} *and* ξ *under the decentralized basic model are given by:* $B_{RM}^* = \frac{v}{2} - \frac{\Delta}{2\alpha\tau}$, *and* $\xi_R^* = \frac{b}{k}\left(\bar{p} + \alpha \bar{B}_R^*\right)$, where $\bar{B}_R^* = (\tau B_{RM}^* + (1-\tau) B_{CH})$. *(c)* $B_{RM}^* < v$, *is always true.*

From Lemma 4.1, we can observe several interesting findings. First, Lemma 4.1(b) indicates that if v is sufficiently big, we have $B_{RM}^* > 0$, which means the remanufacturer has to pay the retailer for the used apparel. If v is sufficiently small so that $B_{RM}^* \le 0$, the remanufacturer does not need to pay the retailer, but the retailer may even need to sponsor the remanufacturer for remanufacturing the collected used apparel. Since the term Δ increases in *a*, $\bar{p}$, and B_{CH}, but decreases in *b*, we can learn how *a*, $\bar{p}$, B_{CH} and *b* affect B_{RM}^* from the closed-form expression in Lemma 4.1(b). Second, from the expression of the optimal promotion effort ξ_R^*, note that $\bar{B}_R^*$ represents the expected benefit of the collected used apparel for the retailer, and it plays a crucial role in determining the optimal promotion effort. To be specific, when $\bar{B}_R^*$ is

larger, the optimal promotion effort exerted by the fashion retail brand will increase. Furthermore, if the used apparel return rate α is higher, the optimal promotion effort also becomes larger. Lemma 4.1 (c) shows that at the equilibrium, it is always possible for the remanufacturer to make profits by remanufacturing the collected apparel from the fashion retail brand because the value of remanufacturing is always larger than the fees paid to the fashion retail brand. For more discussions, we conclude them in Table 4.1, which shows sensitivity analyses of B_{RM}^* and ξ_R^* with respect to various parameters. Please refer to Appendix (A4).

4.2 Centralized Setting

In the centralized setting, the total expected benefit of the supply chain is expressed as follows: $\pi_{SC}(\xi) = \pi_R(\xi) + \pi_{RM}(\xi) + \pi_C(\xi)$, where $\pi_R(\xi)$, $\pi_{RM}(\xi)$ and $\pi_C(\xi)$ represent the profits (or benefits) of the fashion retail brand, the remanufacturer, and the charity organization, respectively.

The benefit gained by the charity organization is expressed below:

$$\pi_C(\xi) = C(1-\tau)Q. \tag{4.4}$$

Thus, we have:

$$\pi_{SC}(\xi) = \bar{p}D + v\tau Q + (B_{CH} + C)(1-\tau)Q - K(\xi). \tag{4.5}$$

Checking the structural properties of $\pi_{SC}(\xi)$, we have Lemma 4.2.

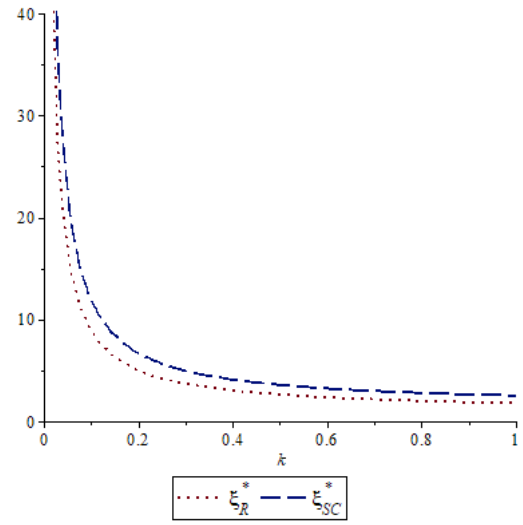
Lemma 4.2. *In the centralized setting, we have (a) $\pi_{SC}(\xi)$ is concave in ξ; (b) The optimal ξ that maximizes the supply chain's expected benefit is given by:* $\xi_{SC}^* = \frac{b}{k}\left[\bar{p} + \alpha\tau v + \alpha(1-\tau)(B_{CH} + C)\right]$.

From Lemma 4.2, we can see that the optimal promotion effort for the whole supply chain follows a similar format as the optimal promotion effort for the fashion retail brand. Combining Lemmas 4.1 and 4.2, we have Proposition 4.1.

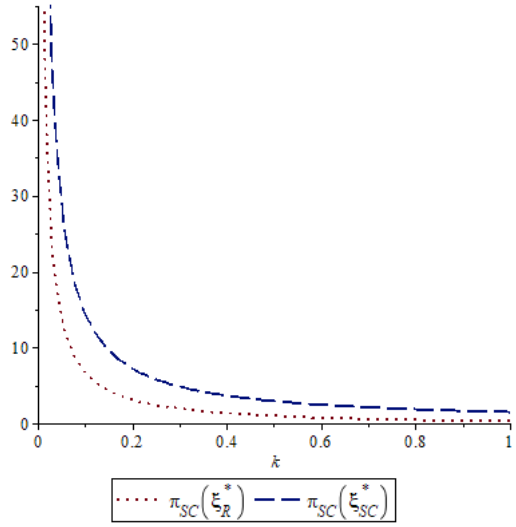
Proposition 4.1. *(a) $\xi_R^* < \xi_{SC}^*$, for any $B_{RM} \le v$. (b) $\pi_{SC}(\xi_R^*) < \pi_{SC}(\xi_{SC}^*)$.*

Proposition 4.1(a) shows that the fashion retail brand's optimal promotion effort is below the supply chain's optimal promotion effort for any $B_{RM} \le v$. A bit surprisingly, observe that this also means that even when the remanufacturer supplies at cost ($B_{RM} = v$), the supply chain is still not coordinated in terms of supply chain profitability. The reason is that, in the supply chain, each donated quantity only gives a value of B_{CH} to the fashion retail brand, but it gives $B_{CH} + C$ to the supply chain (with a unit value C generated for the charity organization). By itself, the decentralized UAC supply chain is hence inefficient and there are rooms for improvement. Proposition 4.1(b) further shows that from the perspective of supply chain, the achieved level of supply chain under the decentralized supply chain setting is lower than the one under the centralized supply chain setting. Figure 4.1 shows the results in Proposition 4.1.

Therefore, is there any approach to coordinate the supply chain? We will explore the coordination problem in Section 5.



(a) The equilibrium promotion efforts.



(b) The equilibrium supply chain profits.

Figure 4.1. Comparison of the decentralized and centralized supply chains (depicted with $v = a = b = 1$, $B_{CH} = \alpha = 0.5$, and $t = 0.8$).

5. Coordination

In Section 4, we find that compared to the centralized supply chain, the decentralized supply chain with UAC is inefficient in achieving the profit and social welfare. In real world, the supply chain with UAC involves the charity organization, remanufacturer, and fashion retail brand. It is basically impossible for them to be controlled in a centralized manner as they are so different and none of them can naturally be the coordinator. In this section, we examine how a novel effort cost sharing (ECS) contract can overcome this supply chain coordination challenge.

From Section 4, we note that the supply chain with UAC cannot be coordinated even if we set $B_{RM} = v$ to overcome the double marginalization effect. In this sub-section, we propose an innovative measure to help coordinate the supply chain, which requires the help from the charity organization. To be specific, the charity organization may help support the UAC program's promotion by assigning some volunteers and workers to help the fashion retail brand. By doing so, the charity organization shares a part of the promotion effort cost. Suppose that the charity organization can help by partially sharing the fashion retailer's promotion effort, with a proportion of $1-\beta$, where $0 < \beta \le 1$. The promotion effort of the fashion retail brand in this scenario is denoted as $\xi_{R,\beta}$.

The sequence of the event under the ECS contract is given as follows. First, the remanufacturer decides the payment $B_{RM,\beta}$ to the fashion retail brand for each unit of used apparel, and the charity organization determines to share $1-\beta$ of the promotion cost. Then, with given $B_{RM,\beta}$ and β, the fashion retail brand decides the optimal promotion effort $\xi_{R,\beta}$ to maximize its profit.

The fashion retail brand's profit under the effort cost sharing (ECS) contract is as follows:

$$\pi_R(\xi_{R,\beta}) = \bar{p}D + B_{RM}\tau Q + B_{CH}(1-\tau)Q - \beta\frac{k(\xi_{R,\beta})^2}{2}. \quad (5.1)$$

Following the same step in Section 4.1, we define $\Delta_\beta = \frac{ak\beta}{b^2} + \bar{p} + \alpha(1-\tau)B_{CH}$ and present Lemma 5.1.

Lemma 5.1. *Under the basic model with the ECS contract: (a) The equilibrium* B_{RM} *and* ξ *under the decentralized supply chain are given by:* $B^*_{RM,\beta} = \frac{v}{2} - \frac{\Delta_\beta}{2\alpha\tau}$ *, and* $\xi^*_{R,\beta} = \frac{b}{k\beta}\left(\bar{p} + \alpha\bar{B}^*_{R,\beta}\right)$ *, where* $\bar{B}^*_{R,\beta} = B^*_{RM,\beta}\tau + B_{CH}(1-\tau)$. *(b)* $B^*_{RM,\beta} \geq B^*_{RM}$. *(c)* $\xi^*_{R,\beta} \geq \xi^*_R$.

Lemma 5.1 indicates that in the presence of the ECS contract, the equilibrium payment of the remanufacturer and promotion effort the fashion retail brand are affected and can be larger than those in the case without ECS. Using the result in Lemma 5.1, we can find the proper way to set the ECS contract to achieve $\xi^*_{R,\beta} = \xi^*_{SC}$, i.e., coordinate the supply chain. We summarize the results in Proposition 5.1.

Proposition 5.1. *Under the ECS contract, setting* $\beta_{SC} = \frac{\bar{p} + \alpha\tau v + \alpha(1-\tau)B_{CH}}{2\left[\bar{p} + \alpha\tau v + \alpha(1-\tau)(B_{CH}+C)\right] + akb^{-2}}$ *can achieve profit-coordination, where the charity organization has to share* $1-\beta_{SC}$ *proportion of the total UAC promotion cost (e.g., by contributing its team of volunteers).*

Proposition 5.1 indicates that by using the ECS contract, profit-coordination can be achieved which means the supply chain's profitability is maximized. One important and interesting remark is that, many traditional supply chain contracts, including the "powerful" two-part tariff, and revenue sharing contracts, all fail to achieve the supply chain coordination. The reason is due to the presence of the charity organization and the benefit earned through it appears to be different from the revenue derived from conventional business transactions. Finally, we choose the ECS contract, particularly for the coordination problem in this paper. Note that in this paper, we do not model the manufacturer-retailer channel which means the traditional buyback mechanism does not apply here. In fact, for "buyback" scheme, it may be suitable to the reverse logistics problems when the remanufacturer is the original manufacturer. However, in this paper, the remanufacturer acts as a third-party role for remanufacturing or recycling the collected used apparel into carpet, new yarns, etc.

6. Extended Models and Analyses

In this section, we extend the basic model analysis by considering various real UAC practice related scenarios. The purpose is to illustrate the robustness of findings derived from the basic model as well as uncover additional insights. As a remark, for each extension, we focus on revealing the respective impacts on supply chain profit under the centralized setting, because we could always achieve SC-coordination by using the properly set ECS contract (P.S.: We have shown in Section 5 and will not analyze it in each case).

6.1. Consumer Coupon Offering

In the basic model, we consider the scenario when the consumers only donate the used apparel without any extra incentive offered (e.g., in Uniqlo, and Zara). While in the real world, we have witnessed that some fashion brands (e.g., H&M, Marks and Spencer) offer incentives, such as discount coupons, to entice consumers to return used apparel. In this extended model, we explore the situation when the fashion retail brand grants a discount coupon (with the discount rate of "*S* off", where *S* is a percentage) to the consumers who return the old or unwanted clothes. As in general not all consumers will use the coupon, we denote the coupon redeem rate as η, where $0 \le \eta \le 1$. With the coupon, the same amount of promotion effort will yield a higher impact on demand because there some consumers are attracted by coupons. Through modeling and analysis, we conclude the results in Propositions 6.1 and 6.2, which are shown in Online Appendix II.

We find that with the consumer coupon offering, the optimal fee that the manufacturer pays to the fashion retail brand is sensitive to the coupon value *S*. When *S* is large, the remanufacturer pays more to the fashion retail brand; while when S is small, the remanufacturer pays less to the fashion retail brand. The reason is as follows. In the presence of coupon, the fashion retail brand spends more on the promotion (coupon offering is absent in the basic model). Therefore, it is natural for the fashion retail brand to get more payment from the remanufacturer. Moreover, with coupon offering, the optimal promotion effort of the fashion retail brand will become larger than that in the case without coupon offering. This is an interesting result because one might predict that with the coupon, the fashion retail brand might not need to work harder to exert a higher effort to collect the used apparel. Our result shows the opposite. In fact, the use of coupon can not only increase the amount of used apparel collation from the market, but also generate a higher revenue to the fashion retail brand, which directly explains why the fashion retail brand will increase its promotion effort. Finally, offering coupons is a wise measure for the fashion retail brand because it leads to more profits. This finding partially explains why most fashion retail brands which offer UAC would also grant a discount coupon to consumers (see Table 1.1) as it is beneficial to do so.

In the centralized setting, the optimal promotion effort for the supply chain profit maximization is higher when coupons are offered. With the enhanced promotion effort, the resulting supply chain profit is improved. Therefore, offering "consumer coupons" is a beneficial measure to the supply chain.

6.2. "No RM" Model

In the existing UAC programs, regarding the quality requirements of the collected apparel, we observe that there exist two phenomena. For example, H&M collects used apparel in both good and bad shapes and send them for charity donation and commercial remanufacturing, respectively. However, another international fashion brand Uniqlo only takes back used apparel in a good shape purely for charity donation. Thus, there is no remanufacturing part for Uniqlo's UAC program and we call it the "No RM" model. In this extended model, we explore the performances of the fashion retail brand, supply chain profit and social welfare under the "No RM" model, as seen in real world by companies such as Uniqlo.

In the basic model, we learn from Lemma 4.1 that if v is sufficiently small, we may have $B_{RM}^{*} \le 0$, which implies that the remanufacturer does not need to pay the retailer, but the retailer may even need to sponsor the remanufacturer for getting and remanufacturing the used apparel. To this end, it may be wise to for the fashion retail brand to give up RM totally and impose a measure to filter the collected used apparel, all for charity (e.g., the case of Uniqlo). Through modeling and analysis, we conclude the results in Propositions 6.3 and 6.4, which are shown in Online Appendix II.

Define: $v_{\overline{RM}} = \frac{1}{\alpha\tau}\left[\frac{ak}{b^2} + \bar{p} + \alpha(1-\tau)B_{CH}\right]$, where $v_{\overline{RM}}$ is the threshold for $B_{RM}^{*} = 0$. We find that $v \le v_{\overline{RM}}$ is equivalent to $B_{RM}^{*} \le 0$.

Our results reveal that in the decentralized setting, it is wise for the fashion retail brand to give up RM when v is sufficiently small (i.e., $v \le v_{\overline{RM}}$), and the fashion retail brand will generate more profits than before. Meanwhile, the fashion retail brand needs to exert a higher promotion effort under the "No RM" model.

In the centralized setting, the supply chain profit becomes worse off in the "No RM" model. This result is important because we note that the "No RM" model can be optimal for the fashion retail brand, but it is always harmful to the whole supply chain. As such, there is an inherent conflict between the choice to go for "No RM" between the fashion retail brand and supply chain (as well as the social welfare perspective). Thus, for truly socially responsible fashion retail brands, the "No RM" model seems to be insufficient.

6.3. Consumer Heterogeneity in Environmental Consciousness

In the basic model, consumers are assumed to be homogeneous in terms of their environmental consciousness. In this sub-section, we consider the case when among the consumers, γ portion of them are environmental conscious (E), and the remaining (i.e., $1-\gamma$) are non-environmental conscious (NE). To be specific, they are heterogeneous in the following two dimensions. First, environmental conscious consumers are more sensitive to the UAC promotion effort than non-environmental conscious ones. Denote the sensitivity coefficients of environmental and non-environmental conscious consumers by b_E and b_{NE}, respectively. We have $b_E > b_{NE} \ge 0$. Second, the environmental conscious consumers have a higher used apparel donation rate than that of the non-environmental conscious consumers, which are denoted by α_E and α_{NE}, respectively, and $1 \ge \alpha_E > \alpha_{NE} \ge 0$. In particular, if $b_E = b_{NE} = b$ and $\alpha_E = \alpha_{NE} = \alpha$, this model degenerates to the basic one. Let $\bar{\alpha} = \gamma\alpha_E + (1-\gamma)\alpha_{NE}$ and $\bar{b} = \gamma b_E + (1-\gamma)b_{NE}$ denote the average consumer return rate (equal to the average collection rate) and the average sensitivity coefficient, respectively. Exploring the equilibrium with consumer heterogeneity in environmental consciousness, we have Propositions 6.5 and 6.6, which are shown in Online Appendix II.

We derive the equilibrium results with the consideration of consumer heterogeneity in environmental consciousness in the decentralized supply chain. As the proportion of environmental conscious consumers (γ) increases, the retailer invests more in the UAC promotion effort and the remanufacturer pays more for the collected apparel. These may not increase the demand, but will definitely increase the amount of collected used apparel, which is environmentally friendlier. Comparing the equilibrium results with that in the basic model, we find that the interaction effect of the two dimensions of environmental consciousness (sensitivity coefficient and used apparel collection rate) plays a crucial role. As the degree of heterogeneity in consumer environmental consciousness increases, the interaction effect becomes higher. This induces the retailer to invest more in the UAC promotion effort and encourages the remanufacturer to pay more for the used apparel. Both the retailer and the remanufacturer can achieve higher profits.

In the centralized supply chain, we find profit-coordinating promotion effort increases in the proportion of environmental conscious consumers. Our findings in this extended model prove the robustness of the results in Proposition 4.1: (i) the collecting effort in the decentralized supply chain is lower than those in the centralized supply chain due to the "double marginalization effect" and (ii) the SC-coordinating promotion effort should be higher than that in the decentralized supply chain. Moreover, the consumer heterogeneities in the two dimensions of environmental consciousness, i.e. the sensitivity coefficient and the used apparel collection rate, would amplify their interaction effect ($\bar{\alpha} \cdot \bar{b} > a \cdot b$). This makes the UAC collection effort more effective, and enhances the retailer's promotion effort and supply chain's profit.

6.4. Own-Brand Collection Versus Any-Brand Collection

The real-world practices reveal that some fashion retail brands only collect their own brands' used apparel, e.g., Uniqlo, while some other fashion retail brands, such as H&M and Zara, collect used apparel from any brands. Obviously, the any-brand collection (ABC) scheme will collect more used apparel, while the own-brand collection (OBC) scheme will obtain less. Through modeling and analysis, we conclude the results in Propositions 6.7 and 6.8, which are shown in Online Appendix II.

We find both the optimal B_{RM} and ξ_R in the OBC model are smaller than the ABC model, which means that the fashion retail brand will exert less effort in promoting its own UAC program under OBC, and the remanufacturer will also pay less to get the used apparel for remanufacturing. With the reduced optimal B_{RM} and ξ_R in the OBC model, profits of all supply chain players are reduced. These findings imply that in the OBC model, the market demand will decline with a reduced promotion effort. Worst of all, the supply chain players' profits also suffer a loss under the OBC model, when compared with the ABC model.

In the centralized setting, the optimal promotion effort which maximizes the supply chain's profit in the OBC model becomes smaller and the corresponding supply chain's profit is also reduced. This indicates that from the supply chain perspective, the OBC model is inferior to the ABC model (i.e., basic model).

6.5. Summary of Extensions

We summarize the findings from the extended models in Table 6.1. As a remark, all the findings are made under the assumptions (same with those in the basic model): exogenous price; and constant collection rate.

Table 6.1. The summary table of the results from extended models (for robustness checking)

Scenarios	*Coordination by ECS?*	*Effects on* ξ_R^* *and* B_{RM}^*	*Key insights*
Consumer Coupon Offering	Yes	With the consumer coupon offering, ξ_R^* increases and B_{RM}^* is affected by coupon value.	It is wise to offer consumer coupons, because the fashion retail brand, the supply chain and the social welfare benefit from the coupon offering.
"No RM" Model	Yes	In "No RM" model, ξ_R^* becomes larger and B_{RM}^* is zero.	It is wise for the fashion retail brand to give up RM when v is sufficiently small. Thus, the fashion retail brand will generate more profit than before. However, the supply chain benefit and the social welfare are reduced.
Consumer heterogeneity in environmental consciousness	Yes	A higher proportion of environmental conscious consumers will lead to higher B_{RM}^* and ξ_R^*.	The interaction effect of the two dimensions of environmental consciousness. If the degree of consumer heterogeneity in environmental consciousness increases, the UAC program will be more effective.
Own-brand collection VS Any-brand collection	Yes	"Own-brand collection" model reduces both the B_{RM}^* and ξ_R^*.	It is unwise to perform "own-brand collection", when the fashion retail brand aims to earn more money from UAC program.

7. Managerial Insights, Conclusion and Future Research

7.1. Concluding Remarks

The commercial used apparel collection (UAC) operations are commonly observed in the real world. In this paper, based on the observed real-world practices, we have analytically explored the UAC operations. First, in the basic model, we have considered the case when a fashion retail brand collects the used apparel from consumers in the market by exerting promotion effort. We have analytically derived in closed-form the optimal promotion efforts for UAC in both decentralized and centralized settings. We have developed a novel contractual mechanism, called effort cost sharing (ECS) contract, in which the charity organization helps the fashion retail brand's UAC operations by sharing partially the promotion cost, e.g., by contributing its team of volunteers to help. We have shown that the ECS contract can successfully achieve supply chain coordination. Finally, to check the robustness of managerial findings from the basic model and also examine various UAC practice related cases, we have examined various extended models and found that the qualitative results from the basic model continue to hold in the extended cases.

7.2. Managerial Implications

From the analytical findings, we have generated a series of important managerial insights and implications. We discuss them in the following.

i) How to maximize the supply chain profit with UAC? Analytical results reveal that in the decentralized setting, the fashion retail brand aims to maximize its own profit and exerts an optimal promotion effort accordingly. However, the decentralized promotion effort fails to coordinate the supply chain (containing the charity organization). Since the supply chain profit would not be maximized automatically, we propose an effort cost sharing (ECS) contract to help, in which the charity organization shares a part of the UAC promotion cost with the fashion retail brand. To implement the contract, the charity organizations can provide manpower such as volunteers to help promote UAC or engage in joint promotion programs. One important and interesting remark is, many traditional supply chain contracts, including the "powerful" two-part tariff, and revenue sharing contracts, all fail to achieve profit-coordination. This is caused by the presence of the charity organization: its earned benefit appears to be different from the revenue derived from conventional business transactions.

ii) Is "consumer coupon offering" better than without? Consumer coupon offering is another strategy adopted by some fashion retail brands in the UAC programs. However, not all fashion retail brands provide "coupon" to the consumers who donate the used apparel. For example, fashion retail brands like "H&M" and "Marks & Spencer" give discount coupons to consumers, while fashion retail brands like "Zara" and "Uniqlo" only collect the used clothes without coupon offering. Our analytical findings show that issuing consumer coupons is useful. With the coupon, under the assumption that a proportion of the coupon will be redeemed, it is interesting to note that the fashion retail brand will exert more promotion efforts to collect the used apparel and gain more profits from this strategy. In the centralized setting, with the enhanced promotion effort, the supply chain profit becomes better off. Therefore, offering "consumer coupons" is a beneficial and wise measure to the fashion retail brand, as well as the supply chain.

iii) Is "no remanufacturing" wise for the fashion retail brand? We have observed that in real world, some fashion retail brands only collect used apparel which are in good conditions for donation. They do not collect the severely damaged apparel which can only be used for remanufacturing. If we take a look at Table 1.1, we will find that Uniqlo is an example for this "No RM" model. When the value of remanufacturing is low, "No RM" model can increase the profit for the fashion retail brand to make more profits but decrease the profit for the supply chain. That is, the "No RM" model can be optimal for the fashion retail brand but it is always harmful to the whole supply chain. In terms of implementing "No RM" model, there is an inherent conflict between the fashion retail brand and the supply chain. Thus, truly socially responsible fashion retail brands should not adopt the "No RM" model.

iv) How to strategically deal with consumer heterogeneity in environmental consciousness? With the increase of consumers' environmental consciousness, the fashion retail brand has to reshape the business strategy to efficiently respond to the emerging demand of the environmental conscious consumers. Our

analytical results show that a higher proportion of environmental conscious consumers will contribute to more profits to both the fashion retail brand and the remanufacturer. As a result, the consumer heterogeneities in the two dimensions of environmental consciousness (sensitivity coefficient and the used apparel collection rate) make the promotion effort more effective and enhance the profits of both the retailer and the supply chain. If the degree of consumer heterogeneity in environmental consciousness increases, it could make the UAC program will be more effective.

v) Is own-brand collection (OBC) better than any-brand collection (ABC)? The results in our paper reveal that in the OBC model, the market demand will decline due to the reduced promotion effort. The fashion retail brand's profit hence becomes worse off in the OBC model, comparing with that in the ABC model. In the centralized setting, the optimal promotion effort which maximizes the supply chain profit in the OBC model becomes smaller and the supply chain profit is reduced. To achieve the profit coordination, note that the charity organization needs to share a higher proportion of the total UAC promotion costs, comparing with the ABC model. Our findings clearly reveal the weakness of OBC model, and it should be avoided if the fashion retail brand faithfully commits to the UAC program.

7.3. Future Research

This paper is not perfect and there are a few limitations. First, our modelling may not include all the operations scenarios of UAC. Thus, future research can be conducted to examine other probable configurations of UAC operations. Second, we assume the increased market demand derived from UAC is a linear function of the promotion effort of the fashion retail brand. There may exist other functional forms, which can be studied in the future. In our analysis, we do not consider the probable impacts brought by UAC on the apparel manufacturers, suppliers and other forward supply chain related operations such as sourcing (Calvo and Martínez-de-Albéniz, 2015) and supply contracting (Ha and Tong, 2008; Leng and Zhu, 2009; Govindan and Popiuc, 2014). Future research can be conducted to investigate them.

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Appendix (A1): UAC and Related Practices in the Real World.

Table A1. Details of UAC and related practices[13].

Details of UAC and Related Practices of the Fashion Retail Brands						
		H&M[14]	**M&S**[15]	**Uniqlo**[16]	**Zara**[17]	**Nike**[18]
Objectives	Environmental sustainability	Be climate smart	Reducing the impact of M&S operations on the environment	Environmental protection	Environmental commitment	Minimize environmental footprint
	CSR	Be ethical	Improving performance across a wide range of social issues	Improve the world through clothes	Social commitment	Embrace new technologies that can propel us to a low-carbon, closed-loop future.
	Sustainable business/profit	Reduce, Reuse and Recycle	Creating sustainable value: circular economy policy	Social business	Advancing the circular economy of the textile sector	Double the business with half the impact
Collection content	own products	√	√	√	√	√
	include others	√	√	/	√	√
Usage	% donation % remanufacturing % rewear or reuse	1.Cooperate with I:CO, which collects and sorts them into three categories:Rewear, Reuse, Recycle. 2.The surplus is donated to H&M Foundation and split between social projects, and recycling projects.	Shwopping Scheme: M&S collaborates with the non-profit making charity organization Oxfam in its UACP program for resell, reuse or recycling.	100% donation to people who need clothing all over the world	All clothing collected in the network of stores are 100% donated directly to Cáritas, the Red Cross, Salvation Army, CEPF, Redress and Oxfam	Over the past five years, 1. 47% waste recycled; 2.16%closed-loop reuse; 3. 28% incinerated for clean energy recovery.
Facility	In public area	√	√	/	√	√
	Collection box	√	√	√	√	√
Incentive	Coupon for consumers	√	√	/	/	√

[13] As a remark, apart from Nike, other sportswear brands like Adidas and Puma, also initiate the take-back program.
[14] https://hmgroup.com/content/dam/hmgroup/groupsite/documents/masterlanguage/CSR/reports/sustainability_reports/Conscious%20Actions%20Sustainability%20Report%202014_en.pdf [assessed 30 September 2019]
[15] http://annualreport.marksandspencer.com/ [assessed 30 September 2019]
[16] https://www.fastretailing.com/eng/sustainability/report/pdf/csr2009_e_06.pdf
[17] https://www.zara.com/hk/en/sustainability-collection-program-l1452.html?v1=967749 [assessed 30 September 2019]
[18] https://purpose.nike.com/reuse-a-shoe [assessed 30 September 2019]

Appendix (A2): The Case with Linear Promotion Cost.

In the limiting case, we consider a linear promotion cost which can be modeled as $k\xi/2$. We use $\Pi_R^l(\xi)$ to denote the profit of fashion retail brand in the decentralized setting. Then, it can be expressed as follows:

$$\Pi_R^l(\xi) = \bar{p}D + B_{RM}\tau Q + B_{CH}(1-\tau)Q - k\xi/2$$
$$= \left(\bar{p} + \alpha\tau B_{RM} + \alpha(1-\tau)B_{CH}\right)a + \left(\left(\bar{p} + \alpha\tau B_{RM} + \alpha(1-\tau)B_{CH}\right)b - k/2\right)\xi.$$

We can learn if $\left(\bar{p} + \alpha\tau B_{RM} + \alpha(1-\tau)B_{CH}\right)b - k/2 \le 0$, the fashion retail brand does not need to exert any promotion effort. Otherwise, the fashion retail brand will lose money in this UAC program. If $\left(\bar{p} + \alpha\tau B_{RM} + \alpha(1-\tau)B_{CH}\right)b - k/2 > 0$, the larger ξ, the more profit the fashion retail brand can make. By solving $\left(\bar{p} + \alpha\tau B_{RM} + \alpha(1-\tau)B_{CH}\right)b - k/2 \le 0$ and $\left(\bar{p} + \alpha\tau B_{RM} + \alpha(1-\tau)B_{CH}\right)b - k/2 > 0$, we have $k \ge 2\left(\bar{p} + \alpha\tau B_{RM} + \alpha(1-\tau)B_{CH}\right)b$ and $k < 2\left(\bar{p} + \alpha\tau B_{RM} + \alpha(1-\tau)B_{CH}\right)b$ respectively.

To conclude, in the decentralized setting, if the promotional cost parameter of the UAC program is large enough (i.e., $k \ge 2\left(\bar{p} + \alpha\tau B_{RM} + \alpha(1-\tau)B_{CH}\right)b$), the fashion retail brand does not benefit from this UAC program and thereby exert no promotion effort. However, if the promotional cost parameter of the program is sufficiently small (i.e., $k < 2\left(\bar{p} + \alpha\tau B_{RM} + \alpha(1-\tau)B_{CH}\right)b$), the fashion retail brand should adopt this UAC program and a larger promotion budgeting is better.

In the centralized setting, we use $\Pi_{SC}^l(\xi)$ to denote the profit of supply chain in the decentralized setting. Then, it can be expressed as follows:

$$\Pi_{SC}^l(\xi) = \bar{p}D + v\tau Q + (B_{CH} + C)(1-\tau)Q - K(\xi)$$
$$= \left(\bar{p} + \alpha\tau v + \alpha(1-\tau)(B_{CH} + C)\right)a + \left(\left(\bar{p} + \alpha\tau v + \alpha(1-\tau)(B_{CH} + C)\right)b - k/2\right)\xi.$$

We can learn if $\left(\bar{p} + \alpha\tau v + \alpha(1-\tau)(B_{CH} + C)\right)b - k/2 \le 0$, it is not good to exert any promotion effort for the supply chain. Otherwise, the supply chain will become worse off in this UAC program. If $\left(\bar{p} + \alpha\tau v + \alpha(1-\tau)(B_{CH} + C)\right)b - k/2 > 0$, a larger promotion effort will make more supply chain profits in this UAC program. By solving $\left(\bar{p} + \alpha\tau v + \alpha(1-\tau)(B_{CH} + C)\right)b - k/2 \le 0$ and

$\left(\bar{p}+\alpha\tau v+\alpha(1-\tau)(B_{CH}+C)\right)b-k/2>0$, we have $k\geq 2\left(\bar{p}+\alpha\tau v+\alpha(1-\tau)(B_{CH}+C)\right)b$ and $k<2\left(\bar{p}+\alpha\tau v+\alpha(1-\tau)(B_{CH}+C)\right)b$ respectively.

To conclude, in the centralized setting, if the promotional cost parameter of the UAC program is large enough (i.e., $k\geq 2\left(\bar{p}+\alpha\tau v+\alpha(1-\tau)(B_{CH}+C)\right)b$), the supply chain doesn't benefit from this UAC program and thereby doesn't need to exert any promotion effort. However, if the promotional cost parameter of the program is small enough (i.e., $k<2\left(\bar{p}+\alpha\tau v+\alpha(1-\tau)(B_{CH}+C)\right)b$), this UAC program is beneficial to the supply chain and a larger promotion budgeting is better.

Finally, when we compare both decentralized and centralized settings, it is interesting to find there is occasion that adopting UAC program is beneficial to the fashion retail brand, but not the supply chain. To be specific, when the promotional cost parameter is small enough, adopting UAC program is beneficial to both the fashion retail brand and the supply chain; when the promotional cost parameter is medium, adopting UAC program is only beneficial to the fashion retail brand; when the promotional cost parameter is large enough, adopting UAC program is harmful to both the fashion retail brand and the supply chain. The details are shown in the Table A2.

Table A2. Impact of promotional cost parameter k on the adoption of UAC program ("YES" represents "should adopt UAC program; "NO" represents "should not adopt UAC program).

The cost parameter	The fashion retail brand	The supply chain
$k<2\left(\bar{p}+\alpha\tau B_{RM}+\alpha(1-\tau)B_{CH}\right)b$	YES	YES
$2\left(\bar{p}+\alpha\tau B_{RM}+\alpha(1-\tau)B_{CH}\right)b\leq k<2\left(\bar{p}+\alpha\tau v+\alpha(1-\tau)(B_{CH}+C)\right)b$	YES	NO
$k\geq 2\left(\bar{p}+\alpha\tau v+\alpha(1-\tau)(B_{CH}+C)\right)b$	NO	NO

Note that: $\bar{p}+\alpha\tau B_{RM}+\alpha(1-\tau)B_{CH}<\bar{p}+\alpha\tau v+\alpha(1-\tau)(B_{CH}+C)$.

Appendix (A3): The Notation Table.

Table A3. Notation Table.

Notations	
a	Base market demand
b	Coefficient of the promotion effort towards demand
ξ	Promotion effort of the fashion retail brand
ξ_R	Promotion effort of the fashion retail brand in the decentralized setting
ξ_{SC}	Promotion effort of the fashion retail brand in the centralized setting
k	Coefficient of the promotion effort towards collection cost
α	Returned rate of used apparel
τ	Proportion of collected used apparel for remanufacturing
B_{RM}	Re-manufacturer's payment to the fashion retail brand for each unit of used apparel sent for re-manufacturing
v	Value generated form each unit of remanufactured used apparel
B_{CH}	Fashion retail brand's unit gain for donation to charity (called the unit good-name benefit from donation)
C	Moral benefit of the charity organization from each unit donation
Z	Social benefits of donation
D	Market demand
$K(\xi)$	Collection cost
Q	Amount of returned used apparel
$\pi_R(\xi)$	Fashion retail brand's profit
$\pi_{RM}(\xi)$	Remanufacturer's profit
$\pi_C(\xi)$	Charity organization's benefit
$\pi_{SC}(\xi)$	Supply chain profit
β	Fashion retail brand's sharing proportion of the promotion effort
ECS	Effort cost sharing
S	Discount coupon (percentage)
η	Coupon redeem rate
σ	Degree of competition in promotion efforts between the two competing fashion retail brands.
γ	Proportion of consumers who are environmental conscious
ρ	Proportion of own brand products among all the collected used apparel

Appendix (A4): Sensitivity Analyses

Based on Lemma 4.1, we have conducted sensitivity analyses of B_{RM}^* and ξ_R^* with respect to various parameters. The results are shown in Table 4.1.

Table 4.1. Sensitivity analyses of B_{RM}^* and ξ_R^* with respect to various parameters.

(Increase ↑; decrease ↓)

Parameter	Effect on B_{RM}^*	Effect on ξ_R^*
$v\uparrow$	↑	↑
$\overline{p}\uparrow$	↓	↑
$a\uparrow$	↓	↓
$B_{CH}\uparrow$	↓	↑
$\alpha\uparrow$	↑	↑
$\tau\uparrow$	↑	↑ if $v > B_{CH}$; ↓ if $v < B_{CH}$

From Table 4.1, we learn that B_{RM}^* will increase with the unit remanufactured value v or the used apparel return rate α, while it will decrease with the base demand a, the retail average profit on each unit $\overline{p}$, or the good-name benefit from donation B_{CH}. When the unit remanufactured value is large, the remanufacturer can make more revenue from remanufacturing each unit of the used apparel. As a result, the remanufacturer has the incentive to pay more to the fashion retail brand so as to entice it to collect more used apparel for remanufacturing. It is a bit surprising to note that when the return rate is higher, the remanufacturer needs to pay more to the fashion retail brand with an increased B_{RM}^*. The probable explanation for it is that, if the return rate α increases, then each unit of demand D can contribute a higher value of collected quantity Q (because $Q = \alpha D$). Alternatively, when the return rate is higher, the per unit investment in UAC promotion has a higher marginal benefit for the remanufacturer (the effect of the UAC promotion effort on the return quantity can be measured by αb). As a result, it is logical for the remanufacturer to increase B_{RM}^* to encourage the fashion retail brand to work even more diligently to increase demand D by increasing the promotion effort. When the base demand a increases, the remanufacturer will pay less (per unit of collected apparel for remanufacturing) to the fashion retail brand. This is a very natural result because a larger base demand means that relatively speaking, the effect of exerting effort by the fashion retail brand is less significant. The remanufacturer hence reduces the optimal promotion effort. Finally, for the effect brought by τ on the optimal promotion effort [which refers to the proportion of collected apparel for remanufacturing (and $1-\tau$ represents to the proportion of collected apparel for donation to charity)], we can see that it depends on the relative size of v and B_{CH}. This is intuitive because the fashion retail brand's promotion effort decision will need to increase its effort to collect more for remanufacturing if v is relatively large (compared to the benefited gained from donation to charity B_{CH}). The opposite happens when v is relatively small compared to B_{CH}.

When the average unit profit $\bar{p}$ increases, the remanufacturer will pay less to the fashion retail brand. If the good name benefit from donation B_{CH} increases, the payment from the remanufacturer to the fashion retail brand will decrease. Thus, there is in fact a "spillover effect" because the fashion retail brand can obtain relatively more benefits from donation (when B_{CH} increases), she already has an incentive to increase effort and hence the remanufacturer could take advantage and reduce B_{RM} (and still get the optimal amount of used apparel for remanufacturing). For the remanufacturer, it is important to note that an increase of (i) the base demand *a*, (ii) the unit profit $\bar{p}$ from retailing, or (iii) the good-name benefit from donation B_{CH} would all imply a reduced B_{RM}^{*} which means that the per unit payment to the remanufacturer by the fashion retail brand drops.

For the optimal promotion effort of the fashion retail brand ξ_R^{*}, it increases with the remanufactured value *v*, the return rate α, the retail average profit on each unit $\bar{p}$, and the good-name benefit from donation B_{CH}, while decreases with the base demand *a*. The findings imply that when the remanufactured value *v* increases, the fashion retail brand will enhance its promotion effort to enlarge the market demand. Accordingly, the fashion retail brand will collect more used apparel and distribute a larger amount for remanufacturing and get more money from the remanufacturer. When the return rate is high, the fashion retail brand will also get more used apparel by increasing the promotion effort and earn more money from the remanufacturer. When the unit retail profit $\bar{p}$ increases, the fashion retail brand would like to exert a higher promotion effort, which contributes to the increase of the fashion retail brand's profit. When the good-name benefit from donation B_{CH} increases, the fashion retail brand will increase the donation amount through a higher promotion effort, which also helps improve the fashion retail brand's profit and good reputation. For the fashion retail brand, it is important to notice that only when the base demand *a* increases, could she spend less promotion effort in the used apparel collection program. When other parameters (*v*, $\bar{p}$, B_{CH}, α) increase, the fashion retail brand has to exert more promotion effort.