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Research Article

No Refund or Full Refund: When Should a Fashion Brand Offer Full Refund Consumer Return Service for Mass Customization Products?

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We analytically explore in this paper the consumer return policy under fashion mass customization (MC) program. To be specific, we model the stochastic fashion MC program with the consideration of consumer demand uncertainty. If a consumer return policy is implemented, we further consider return uncertainty. By modeling the optimization objective of the risk averse MC fashion brand via a mean-variance approach, we derive the closed-form optimal solution under each case. We then conduct both analytical and numerical sensitivity analyses. For the scenario with full refund and return, we reveal the analytical conditions under which the optimal retail price and the optimal number of options available for customization (called the "optimal modularity level") vary monotonically with respect to the salvage value and the return service charge. For the scenario when there is no refund and return, we show that the optimal retail price and the optimal modularity level are decreasing in the MC fashion brand's degree of risk aversion, the demand uncertainty, and the price-demand sensitivity coefficient. In addition, our numerical analysis indicates that whether the risk averse MC fashion brand would prefer offering consumer return with full refund to no return depends heavily on the demand-return correlation (DRC) parameter.

1. Introduction

Mass customization (MC) is an industrial practice which helps to manufacture customized products to satisfy consumers' needs with a cost close to mass production [1–7] in a timely manner [8–10]. In the fashion industry, as driven by the consumer needs [11–13], the advances of production and information technology [14–21] and the increasingly competitive market situation [22–25], MC has developed to be a very popular industrial practice [17, 26] and a lot of fashion retail brands and fashion retailers are implementing it. In fact, we can find MC in nearly all kinds of well-established fashion brands, from high-end luxury brands (Hermes, LV, etc.) to mass-market labels (Adidas, Nike, Puma, Brooks Brothers, etc.) (see [8, 27] for more cases and empirical details). However, fashion brands offering MC services face some challenges, and it is known that big name retailers/brands like Levi's and Lands' End have already terminated their MC programs for different reasons.

In recent years, there are more and more analytical studies on fashion MC and some of them concern about consumer returns. In particular, Liu et al. [28] develop a three-dimensional optimization problem and analytically derive the optimal decisions on retail price [29], modularity level [30–32], and refund rate (under consumer return [33]). From both analytical and numerical analyses, they obtain several important findings and insights. Among others, they argue that the degree of risk aversion of the fashion MC service provider is an influential factor affecting the respective optimal decisions. In addition, Choi [34] studies the optimal return service charging policy for fashion retailers offering MC. He develops the closed-form analytical conditions under which it is optimal for the fashion MC service provider to provide free return service charge to consumers.

In the fashion industry, the adoption of consumer return under the MC service program is very polarized. Actually, we find that the fashion MC brands either simply do not allow any consumer return or they would allow full refund in the return policy. For example, the international brand Nike is implementing MC and it allows consumer return with full refund for its NIKEiD products. (p.s.: Nike makes it clear on its website that under its NIKEiD MC program, any consumer can return the MC products (with any reasons) within 30 days of purchase if they want to.) However, many other similar sporty fashion brands do not allow return for MC products (except for those with manufacturing defects or quality problems).

In light of the above industrial observation and based on the prior studies in the literature, we examine in this paper the optimal retail pricing and modularity level decisions for a risk averse MC fashion brand (p.s.: an MC fashion brand is a fashion brand which is offering MC.) for both scenarios with and without consumer return. We study the optimal pricing and modularity level decisions under each scenario. We analytically reveal that a linear relationship exists between the optimal price and the optimal level of modularity under both scenarios. We also show analytically how the optimal pricing and level of modularity decisions relate to some important model parameters. After that, we explore the factors which will affect the risk averse MC fashion brand's decision on when to offer consumer return with full refund. We find that whether it is optimal for the risk averse MC fashion brand to offer consumer return with full refund or no return depends critically on the demand return correlation coefficient.

The rest of this paper is organized as follows. We review the related literature concisely in Section 2. We present the analytical models in Section 3. We derive the optimal decisions in Section 4. We conduct numerical sensitivity analysis in Section 5. We conclude and discuss future research directions in Section 6.

2. Literature Review

MC is an important make-to-order/build-to-order [32, 35] business strategy widely adopted in fashion retailing. In fact, MC helps consumers to develop customized products [36] and participate in the codesign process [37] which is a known means of cocreating value [38, 39]. It is also a popular topic in operations management (see [40] for a relatively recent review) and both empirical and analytical studies are reported in recent years. For example, Peters and Saidin [16] explore via a case study approach the challenges of MC implementation. They study the critical factors which drive the service provider to adopt MC. They discuss the challenges behind the MC implementation in the service sector. They further propose a novel framework which can help the service provider to offer MC. Gu et al. [41] develop an optimization model to describe the implementation of MC as a gradual process. They derive two optimization methods to find the optimal customization quantity. They indicate that their proposed methods can successfully reduce the amount of customized items in every part of the overall production process and hence enhances the efficiency of MC. Helms et al. [42] examine e-commerce and knowledge management and identify how they can support MC. They find that e-commerce provides capabilities for the MC service provider to reach global market and helps in learning about customer preferences. They reveal that knowledge management can help manage the intellectual capital. They argue that both e-commerce and knowledge management can significantly improve the implementation of MC. Bock [43] studies the pros and cons on employing off-shore and near-shore production strategies under MC. He proposes a mixed-model assembly line balancing approach to provide a direct comparison of the estimated variable manufacturing costs by generating a location-based line layout for all competing locations. He runs several tests with various location configurations and identifies the factors which affect the optimal sourcing and production strategy for the MC company. Brun and Zorzini [44] investigate the relationships between postponement and modularization under MC. They examine the industrial cases in Italy with a case study approach. They reveal that product/process customization and product/process complexity are critical factors which affect the postponement and modularization relationship. Yao and Liu [45] study an interesting problem on how companies handle the probable contradiction between scale production effect and customized demand under MC. They develop a dynamic multiobjective optimization model and derive effective algorithm to solve it. They test their proposed algorithm by simulation and show that their proposed algorithm can enhance the scheduling efficiency under the MC program. Most recently, motivated by a typical MC production company that has an inefficient scheduling operations problem, Zhong et al. [46] examine the applicability of an RFID-enabled manufacturing execution system (MES) for MC. In their proposed MES, the RFID-based devices are deployed on the shop floor to keep track of the production data. As a result, they find that both operational planning and scheduling decisions become enhanced. They conduct a case study and conclude that their proposed MES is effective.

In the domain of fashion apparel, MC has also been extensively studied. For example, Dong et al. [1] discuss how MC can be implemented and integrated with the mass production line to achieve high quality and low price fashion products. Ulrich et al. [37] study the consumer-to-design scheme of fashion products under MC and generate a number of interesting insights. Yeung and Choi [27] explore the implementation of MC in the Hong Kong apparel industry. They identify a few barriers which hinder the development of fashion MC in markets like Hong Kong. Choi et al. [47] conduct a mean-variance analysis of the fashion MC program with consumer return. Based on the assumption that the consumer demand function is independent of the return service charging policy, they derive a couple of counter-intuitive findings. Liu et al. [28] study the optimal retail pricing, refund, and modularity decision making problem for a fashion mass customization system. They obtain several important insights via extensive sensitivity analysis.

Based on the above reviewed literature, this paper conducts an analytical research on MC program with a risk averse fashion brand under the mean-variance framework [48, 49]. This paper is related to [28, 32, 47] because they all consider optimal decisions related to retail pricing and modularity.

However, this paper is different from [28, 32] in which the demand and return uncertainty models are different and this paper focuses on examining the polarized strategic decisions on allowing consumer return with full refund or disallowing return at all whereas [28, 32] focus on the optimal operational decisions on price, modularity, and refund rate. This paper is also different from [47] because we argue that demand must relate to the return service charge whereas [47] assumes consumer demand independent of return service charge. Finally, this paper is also different from [34] because these two papers have totally different optimal decisions and the research objectives are also different.

3. Analytical Models

In this paper, we consider a risk averse MC fashion brand which sells an MC fashion product directly to consumers via an online platform (e.g., the MC retailing website). The whole process is a make-to-order type and the fashion brand will start producing the product after receiving the order from the consumer. In this paper, we consider the situation that the MC fashion brand makes a few important decisions, namely the retail price of the MC product (p), the number of options available for customization (we call it the level of modularity of the product (m)) (notice that this product modularity is different from the production process modularity concept commonly explored in the literature [50]), and whether to allow consumer return with full refund or no return. *Notice that the "consumer return scheme" here refers to the product return from consumers who are unhappy with the purchase with any reason (probably within some reasonable time, such as one month), but it is not related to the situations with manufacturing mistakes, defects, or other product quality problems*. As widely observed from the industrial practice in the fashion apparel industry, the MC fashion brands are adopting very polarized measure on consumer return: they either disallow return (i.e., no return, no refund) or accept return with full refund. Based on this industrial practice, we first represent the amount of refund under the consumer return policy by r. Thus, a full refund under the consumer return scheme implies $r = p$, and the no return scheme has $r = 0$.

Following [28, 32], we construct the following analytical models in two separate scenarios, namely *"full refund under consumer return"* and *"no consumer return."* The notation employed in this paper basically follows the literature [28, 32, 34].

3.1. Full Refund under Consumer Return

Demand function: $\widetilde{D}_1 = \alpha - \beta p + \gamma r + \delta m + \widetilde{\varepsilon}_D$, $(\beta > \gamma)$; (p.s.: notice that this price dependent function is very commonly employed in the literature, see, e.g., [25, 51].)

Return quantity function: $\widetilde{R} = \phi + \psi r + \widetilde{\varepsilon}_R$;

Salvage value: $S(m) = s + vm$;

Modularity cost: $C(m) = (1/2)\theta m^2$.

Since under the consumer return scheme, we assume a full refund will be granted for each return, we have the rate of refund $r = p$. Thus

$$\widetilde{D}_1 = \alpha - \beta p + \gamma (p - l) + \delta m + \widetilde{\varepsilon}_D, \quad (\beta > \gamma); \tag{1}$$

(p.s.: we use subscripts 1 and 2 to represent the scenarios "with consumer return and full refund" and "no return," respectively.) $\widetilde{R} = \phi + \psi(p - l) + \widetilde{\varepsilon}_R$, $l < p$ is the service charge.

The profit function is hence expressed as follows:

$$\begin{aligned} P_1 = {} & p\left(\alpha - \beta p + \gamma (p - l) + \delta m + \widetilde{\varepsilon}_D\right) \\ & + (S(m) - l)\left(\phi + \psi (p - l) + \widetilde{\varepsilon}_R\right) - \frac{1}{2}\theta m^2. \end{aligned} \tag{2}$$

We consider the scenario when the demand function and return quantity are correlated with a coefficient of correlation of ρ. Thus, the expected profit and the variance of profit are given as follows:

$$\begin{aligned} E[P_1] = {} & p\left[\alpha - \beta p + \gamma (p - l) + \delta m\right] \\ & + (s + vm - l)\left[\phi + \psi (p - l)\right] - \frac{1}{2}\theta m^2, \\ V[P_1] = {} & p^2\sigma_D^2 + (s + vm - l)^2\sigma_R^2 \\ & + 2\rho\sigma_R\sigma_D p (s + vm - l). \end{aligned} \tag{3}$$

Define in the following the mean-variance (MV) objective function [28, 52–57] of the MC fashion brand, where k represents the degree of risk aversion for the MC fashion brand:

$$U_1 = E[P_1] - kV[P_1]. \tag{4}$$

In order to examine whether U_1 is concave, we construct the Hessian matrix as follows:

$$\begin{aligned} H_{U_1} & = \begin{vmatrix} \dfrac{\partial^2 U_1}{\partial m^2} & \dfrac{\partial^2 U_1}{\partial m \partial p} \\ \dfrac{\partial^2 U_1}{\partial p \partial m} & \dfrac{\partial^2 U_1}{\partial p^2} \end{vmatrix} \\ & = \begin{vmatrix} -\theta - 2kv^2\sigma_R^2 & \delta + v\psi - 2kv\rho\sigma_D\sigma_R \\ \delta + v\psi - 2kv\rho\sigma_D\sigma_R & -2\beta + 2\gamma - 2k\sigma_D^2 \end{vmatrix} \\ & = \left(2\beta - 2\gamma + 2k\sigma_D^2\right)\left(\theta + 2kv^2\sigma_R^2\right) \\ & \quad - \left(\delta + v\psi - 2kv\rho\sigma_D\sigma_R\right)^2 \end{aligned}$$

Table 1

Parameter	α	β	γ	θ	δ	ϕ	φ	v	s	l	k	ρ	σ_D	σ_R
Value	2000	30	2	30	10	20	8	0.2	1	0.8	0.02	0.3	100	20

$$= 2\theta(\beta-\gamma) + 2k\theta\sigma_D^2 + 4k\rho\sigma_D\sigma_R(v\delta + v^2\psi) + 4kv^2\sigma_R^2(\beta-\gamma) + 4k^2v^2\sigma_D^2\sigma_R^2(1-\rho^2) - (\delta+v\psi)^2 > 0. \tag{5}$$

By checking the Hessian matrix, we can see that U_1 will be a concave function of p and m if and only if (5) holds.

3.2. No Consumer Return. For the scenario without consumer return, the model is much simpler because there will be no return and no salvage value of the returned product. As such, the demand function, the modularity cost, and the profit function are derived as follows.

Demand function: $\widetilde{D}_2 = \alpha - \beta p + \delta m + \widetilde{\varepsilon}_D$.

Modularity cost: $C = (1/2)\theta m^2$.

The profit function is:

$$P_2 = p(\alpha - \beta p + \delta m + \widetilde{\varepsilon}_D) - \frac{1}{2}\theta m^2. \tag{6}$$

The expected profit and variance of profit are hence given as follows:

$$E[P_2] = p(\alpha - \beta p + \delta m) - \frac{1}{2}\theta m^2; \quad V[P_2] = p^2\sigma_D^2. \tag{7}$$

Similarly, we construct the MV objective function as follows:

$$U_2 = E[P_2] - kV[P_2]. \tag{8}$$

By checking the Hessian matrix, we can see that U_2 is a concave function of p and m if and only if (9) is satisfied as follows:

$$H_{U_2} = \begin{vmatrix} \frac{\partial^2 U_2}{\partial m^2} & \frac{\partial^2 U_2}{\partial m \partial p} \\ \frac{\partial^2 U_2}{\partial p \partial m} & \frac{\partial^2 U_2}{\partial p^2} \end{vmatrix} = \begin{vmatrix} -\theta & \delta \\ \delta & -2\beta - 2k\sigma_D^2 \end{vmatrix} = 2\theta(\beta + k\sigma_D^2) - \delta^2 > 0. \tag{9}$$

4. Optimal Pricing and Modularity Level Decisions

For a notational purpose, we define the following:

$$\begin{aligned} A_1 &= \theta(\alpha - l\gamma) - \theta\psi(l-s) + v(\delta + v\psi)(\phi - l\psi), \\ B_1 &= 2\rho\sigma_D\sigma_R(l\theta - s\theta - v^2\phi + lv^2\psi) \\ &\quad + 2\sigma_R^2(v^2\alpha - lv^2\gamma + lv\delta - sv\delta), \\ G_1 &= (\delta + v\psi)(\alpha - l\gamma) - \psi(\delta + v\psi)(l-s) \\ &\quad + 2v(\phi - l\psi)(\beta - \gamma), \\ I_1 &= 2v\sigma_D^2(\phi - l\psi) + 4v\sigma_R^2(\beta-\gamma)(l-s) \\ &\quad - 2\rho\sigma_D\sigma_R(v(\alpha - l\gamma) - (\delta + 2v\psi)(l-s)), \\ J_1 &= 4v\sigma_D^2\sigma_R^2(l-s)(1-\rho^2), \\ K_1 &= 2\theta(\beta-\gamma) - (\delta + v\psi)^2, \\ L_1 &= 2\theta\sigma_D^2 + 4v\rho\sigma_D\sigma_R(\delta + v\psi) + 4v^2\sigma_R^2(\beta-\gamma), \\ F_1 &= 4v^2\sigma_D^2\sigma_R^2(1-\rho^2). \end{aligned} \tag{10}$$

In order to have more analytical closed-form results, we assume in the rest of this paper that (5) and (9) hold which implies that U_1 and U_2 are concave functions of p and m. Thus, we can easily derive Lemma 1.

Lemma 1. *Under the scenario with full refund under consumer return, (a) the optimal pricing and modularity level decisions are given as follows:*

$$p_1^* = \frac{A_1 + B_1 k}{K_1 + L_1 k + F_1 k^2}, \qquad m_1^* = \frac{G_1 + I_1 k + J_1 k^2}{K_1 + L_1 k + F_1 k^2}. \tag{11}$$

(b) The optimal pricing and modularity level decisions are linearly related to one another: $p_1^* = \xi m_1^*$, where $\xi = (A_1 + B_1 k)/(G_1 + I_1 k + J_1 k^2)$.

Lemma 1 shows the closed-form expression of the optimal decisions for the MC fashion brand when it offers full refund consumer return. Notice from Lemma 1(b) that it is very interesting to reveal analytically that the optimal pricing decision and the optimal modularity level decisions are directly proportional to one another if $\xi > 0$. Despite being complicated, we can further derive Theorem 2 by checking the respective first-order partial derivatives of the optimal decisions.

Theorem 2. *Under the consumer return policy with full refund, (a) the optimal retail price is a strictly decreasing*

Table 2: (a) Sensitivity analysis on the effect brought by k (with $\rho = -1$). (b) Sensitivity analysis on the effect brought by k (with $\rho = -0.3$). (c) Sensitivity analysis on the effect brought by k (with $\rho = 0$). (d) Sensitivity analysis on the effect brought by k (with $\rho = 0.3$). (e) Sensitivity analysis on the effect brought by k (with $\rho = 1$).

(a)

k	$\Delta U(\rho = -1)$	Optimal strategy
0	3573.464	Consumer return with full refund
0.0025	1346.646	Consumer return with full refund
0.005	828.6819	Consumer return with full refund
0.0075	618.2397	Consumer return with full refund
0.01	508.4378	Consumer return with full refund
0.0125	442.3226	Consumer return with full refund
0.015	398.6414	Consumer return with full refund
0.0175	367.8473	Consumer return with full refund
0.02	345.0745	Consumer return with full refund
0.0225	327.6048	Consumer return with full refund
0.025	313.8096	Consumer return with full refund
0.0275	302.6579	Consumer return with full refund
0.03	293.4675	Consumer return with full refund
0.0325	285.7699	Consumer return with full refund
0.035	279.2335	Consumer return with full refund
0.0375	273.617	Consumer return with full refund
0.04	268.7412	Consumer return with full refund
0.0425	264.4703	Consumer return with full refund
0.045	260.6994	Consumer return with full refund
0.0475	257.3464	Consumer return with full refund
0.05	254.3461	Consumer return with full refund

(b)

k	$\Delta U(\rho = -0.3)$	Optimal strategy
0	3573.464	Consumer return with full refund
0.0025	1077.694	Consumer return with full refund
0.005	550.2467	Consumer return with full refund
0.0075	351.1763	Consumer return with full refund
0.01	253.4773	Consumer return with full refund
0.0125	197.6467	Consumer return with full refund
0.015	162.3939	Consumer return with full refund
0.0175	138.5062	Consumer return with full refund
0.02	121.4449	Consumer return with full refund
0.0225	108.7525	Consumer return with full refund
0.025	98.99825	Consumer return with full refund
0.0275	91.30056	Consumer return with full refund
0.03	85.09028	Consumer return with full refund
0.0325	79.98568	Consumer return with full refund
0.035	75.72236	Consumer return with full refund
0.0375	72.11208	Consumer return with full refund
0.04	69.01759	Consumer return with full refund
0.0425	66.33674	Consumer return with full refund
0.045	63.99209	Consumer return with full refund
0.0475	61.924	Consumer return with full refund
0.05	60.08586	Consumer return with full refund

(c)

k	$\Delta U(\rho = 0)$	Optimal strategy
0	3573.464	Consumer return with full refund
0.0025	972.1282	Consumer return with full refund
0.005	447.7589	Consumer return with full refund
0.0075	257.8076	Consumer return with full refund
0.01	168.0751	Consumer return with full refund
0.0125	118.62	Consumer return with full refund
0.015	88.45607	Consumer return with full refund
0.0175	68.6862	Consumer return with full refund
0.02	55.01266	Consumer return with full refund
0.0225	45.15184	Consumer return with full refund
0.025	37.79863	Consumer return with full refund
0.0275	32.16292	Consumer return with full refund
0.03	27.74351	Consumer return with full refund
0.0325	24.2099	Consumer return with full refund
0.035	21.33693	Consumer return with full refund
0.0375	18.96689	Consumer return with full refund
0.04	16.98659	Consumer return with full refund
0.0425	15.31309	Consumer return with full refund
0.045	13.88447	Consumer return with full refund
0.0475	12.65375	Consumer return with full refund
0.05	11.58473	Consumer return with full refund

(d)

k	$\Delta U(\rho = 0.3)$	Optimal strategy
0	3573.464	Consumer return with full refund
0.0025	872.1531	Consumer return with full refund
0.005	354.8006	Consumer return with full refund
0.0075	176.2229	Consumer return with full refund
0.01	95.8788	Consumer return with full refund
0.0125	53.7666	Consumer return with full refund
0.015	29.38607	Consumer return with full refund
0.0175	14.25304	Consumer return with full refund
0.02	4.366616	Consumer return with full refund
0.0225	−2.34816	No return
0.025	−7.0484	No return
0.0275	−10.4174	No return
0.03	−12.8778	No return
0.0325	−14.7011	No return
0.035	−16.0677	No return
0.0375	−17.1003	No return
0.04	−17.8848	No return
0.0425	−18.4824	No return
0.045	−18.9374	No return
0.0475	−19.2824	No return
0.05	−19.542	No return

(e)

k	$\Delta U(\rho = 1)$	Optimal strategy
0	3573.464	Consumer return with full refund
0.0005	2374.058	Consumer return with full refund
0.001	1653.531	Consumer return with full refund
0.0015	1190.932	Consumer return with full refund
0.002	878.7702	Consumer return with full refund
0.0025	659.8301	Consumer return with full refund
0.003	501.4762	Consumer return with full refund
0.0035	384.0431	Consumer return with full refund
0.004	295.1391	Consumer return with full refund
0.0045	226.6607	Consumer return with full refund
0.005	173.1403	Consumer return with full refund

(e) Continued.

k	$\Delta U(\rho=1)$	Optimal strategy
0.0055	130.7888	Consumer return with full refund
0.006	96.91849	Consumer return with full refund
0.0065	69.58424	Consumer return with full refund
0.007	47.35295	Consumer return with full refund
0.0075	29.15195	Consumer return with full refund
0.008	14.16698	Consumer return with full refund
0.0085	1.772005	Consumer return with full refund
0.009	−8.51977	No return
0.0095	−17.0909	No return
0.01	−24.2446	No return
0.0105	−30.2239	No return
0.011	−35.2243	No return
0.0115	−39.4048	No return
0.012	−42.8955	No return
0.0125	−45.8034	No return
0.013	−48.217	No return
0.0135	−50.2098	No return
0.014	−51.8436	No return
0.0145	−53.17	No return
0.015	−54.2326	No return

(increasing) function of the service charge l if $-\gamma\theta - \nu\delta\psi + 2k\nu\sigma_R^2(\delta - \nu\gamma) + (2k\rho\sigma_D\sigma_R - \psi)(\theta + \nu^2\psi) < 0$ (sufficient conditions are $\delta - \nu\gamma < 0$ and $2k\rho\sigma_D\sigma_R - \psi < 0$). (b) The optimal retail price is a strictly increasing (increasing) function of the salvage value s if $\theta > 2k\nu\delta\sigma_R^2/(\psi - 2k\rho\sigma_D\sigma_R)$.

In parallel to the scenario with consumer return, we can derive Lemma 3 by the same logic.

Lemma 3. *Under the no consumer return scenario, (a) the optimal pricing and modularity level decisions are given as follows $p_2^* = \alpha\theta/(2\theta(\beta + k\sigma_D^2) - \delta^2)$ and $m_2^* = \alpha\delta/(2\theta(\beta + k\sigma_D^2) - \delta^2)$. (b) The relationship between the optimal pricing and the optimal modularity level is given by $p_2^* = (\theta/\delta)m_2^*$.*

Lemma 3 shows the closed-form expression of the optimal decisions for the MC fashion brand when there is no consumer return. Similar to the case with consumer return, it is very interesting to note that the resulting optimal retail price is directly proportional to the optimal modularity level. In other words, Lemmas 1(b) and 3(b) both reveal that *it is optimal for the MC fashion brand to charge a higher price if more options are available to consumers (as quantified by the level of modularity in the model) no matter whether the "consumer return with full refund"* (p.s.: for the case with consumer return and full refund, this result holds whenever ξ is positive) *or "no return" strategy is imposed.* This supplements the common belief that fashion brands can charge a premium by offering MC (compared to mass production) because of having more variety of options for consumers. With the result in Lemma 3, we can further derive Theorem 4.

Theorem 4. *Under the no consumer return scenario, (a) If k increases, both p_2^* and m_2^* will decrease. (b) If β or σ_D increases,*

Table 3: (a) Sensitivity analysis on the effect brought by σ_R (with $\rho = -1$). (b) Sensitivity analysis on the effect brought by σ_R (with $\rho = -0.3$). (c) Sensitivity analysis on the effect brought by σ_R (with $\rho = 0$). (d) Sensitivity analysis on the effect brought by σ_R (with $\rho = 0.3$). (e) Sensitivity analysis on the effect brought by σ_R (with $\rho = 1$).

(a)

σ_R	$\Delta U(\rho=-1)$	Optimal strategy
0	57.47614	Consumer return with full refund
5	112.6601	Consumer return with full refund
10	178.8924	Consumer return with full refund
15	256.321	Consumer return with full refund
20	345.0745	Consumer return with full refund
25	445.2616	Consumer return with full refund
30	556.9698	Consumer return with full refund
35	680.2648	Consumer return with full refund
40	815.1897	Consumer return with full refund
45	961.7641	Consumer return with full refund
50	1119.983	Consumer return with full refund
55	1289.818	Consumer return with full refund
60	1471.215	Consumer return with full refund
65	1664.095	Consumer return with full refund
70	1868.354	Consumer return with full refund
75	2083.861	Consumer return with full refund
80	2310.462	Consumer return with full refund
85	2547.977	Consumer return with full refund
90	2796.201	Consumer return with full refund
95	3054.907	Consumer return with full refund
100	3323.843	Consumer return with full refund

(b)

σ_R	$\Delta U(\rho=-0.3)$	Optimal strategy
0	57.47614	Consumer return with full refund
5	72.71861	Consumer return with full refund
10	88.54183	Consumer return with full refund
15	104.8257	Consumer return with full refund
20	121.4449	Consumer return with full refund
25	138.2716	Consumer return with full refund
30	155.1791	Consumer return with full refund
35	172.0444	Consumer return with full refund
40	188.7511	Consumer return with full refund
45	205.1917	Consumer return with full refund
50	221.269	Consumer return with full refund
55	236.8976	Consumer return with full refund
60	252.0048	Consumer return with full refund
65	266.5306	Consumer return with full refund
70	280.4274	Consumer return with full refund
75	293.6601	Consumer return with full refund
80	306.2044	Consumer return with full refund
85	318.0468	Consumer return with full refund
90	329.1825	Consumer return with full refund
95	339.615	Consumer return with full refund
100	349.3545	Consumer return with full refund

(c)

σ_R	$\Delta U(\rho=0)$	Optimal strategy
0	57.47614	Consumer return with full refund
5	57.31906	Consumer return with full refund

(c) Continued.

σ_R	$\Delta U(\rho = 0)$	Optimal strategy
10	56.85037	Consumer return with full refund
15	56.07753	Consumer return with full refund
20	55.01266	Consumer return with full refund
25	53.67209	Consumer return with full refund
30	52.0757	Consumer return with full refund
35	50.24625	Consumer return with full refund
40	48.20862	Consumer return with full refund
45	45.98904	Consumer return with full refund
50	43.61431	Consumer return with full refund
55	41.11118	Consumer return with full refund
60	38.5057	Consumer return with full refund
65	35.82278	Consumer return with full refund
70	33.08575	Consumer return with full refund
75	30.31611	Consumer return with full refund
80	27.53335	Consumer return with full refund
85	24.75483	Consumer return with full refund
90	21.99579	Consumer return with full refund
95	19.26937	Consumer return with full refund
100	16.58673	Consumer return with full refund

(d)

σ_R	$\Delta U(\rho = 0.3)$	Optimal strategy
0	57.47614	Consumer return with full refund
1	54.50733	Consumer return with full refund
2	51.56711	Consumer return with full refund
3	48.65629	Consumer return with full refund
4	45.77567	Consumer return with full refund
5	42.92605	Consumer return with full refund
6	40.10819	Consumer return with full refund
7	37.32283	Consumer return with full refund
8	34.57069	Consumer return with full refund
9	31.85248	Consumer return with full refund
10	29.16887	Consumer return with full refund
11	26.52051	Consumer return with full refund
12	23.90802	Consumer return with full refund
13	21.33201	Consumer return with full refund
14	18.79306	Consumer return with full refund
15	16.29172	Consumer return with full refund

(e)

σ_R	$\Delta U(\rho = 1)$	Optimal strategy
0	57.47614	Consumer return with full refund
1	47.75089	Consumer return with full refund
2	38.4596	Consumer return with full refund
3	29.60083	Consumer return with full refund
4	21.17313	Consumer return with full refund
5	13.175	Consumer return with full refund
6	5.604925	Consumer return with full refund
7	−1.53862	No return
8	−8.25721	No return
9	−14.5524	No return
10	−20.4259	No return
11	−25.8792	No return
12	−30.914	No return
13	−35.532	No return
14	−39.735	No return
15	−43.5246	No return

Table 4: (a) Sensitivity analysis on the effect brought by σ_D (with $\rho = -1$). (b) Sensitivity analysis on the effect brought by σ_D (with $\rho = -0.3$). (c) Sensitivity analysis on the effect brought by σ_D (with $\rho = 0$). (d) Sensitivity analysis on the effect brought by σ_D (with $\rho = 0.3$). (e) Sensitivity analysis on the effect brought by σ_D (with $\rho = 1$).

(a)

σ_D	$\Delta U(\rho = -1)$	Optimal strategy
20	3449.186	Consumer return with full refund
30	2594.183	Consumer return with full refund
40	1844.719	Consumer return with full refund
50	1307.854	Consumer return with full refund
60	946.619	Consumer return with full refund
70	705.1343	Consumer return with full refund
80	541.0528	Consumer return with full refund
90	426.7885	Consumer return with full refund
100	345.0745	Consumer return with full refund
110	285.1112	Consumer return with full refund
120	240.0424	Consumer return with full refund
130	205.4228	Consumer return with full refund
140	178.3037	Consumer return with full refund
150	156.6838	Consumer return with full refund
160	139.1748	Consumer return with full refund
170	124.7939	Consumer return with full refund
180	112.8319	Consumer return with full refund
190	102.7681	Consumer return with full refund
200	94.2139	Consumer return with full refund

(b)

σ_D	$\Delta U(\rho = -0.3)$	Optimal strategy
20	2450.895	Consumer return with full refund
30	1608.23	Consumer return with full refund
40	1016.281	Consumer return with full refund
50	650.045	Consumer return with full refund
60	430.0031	Consumer return with full refund
70	296.1204	Consumer return with full refund
80	212.2569	Consumer return with full refund
90	157.9012	Consumer return with full refund
100	121.4449	Consumer return with full refund
110	96.19273	Consumer return with full refund
120	78.1769	Consumer return with full refund
130	64.97559	Consumer return with full refund
140	55.06682	Consumer return with full refund
150	47.46713	Consumer return with full refund
160	41.52439	Consumer return with full refund
170	36.7957	Consumer return with full refund
180	32.9736	Consumer return with full refund
190	29.84028	Consumer return with full refund
200	27.23856	Consumer return with full refund

(c)

σ_D	$\Delta U(\rho = 0)$	Optimal strategy
20	2084.977	Consumer return with full refund
30	1266.59	Consumer return with full refund
40	741.2984	Consumer return with full refund
50	438.7885	Consumer return with full refund
60	268.2584	Consumer return with full refund
70	170.537	Consumer return with full refund

(c) Continued.

σ_D	$\Delta U(\rho = 0)$	Optimal strategy
80	112.777	Consumer return with full refund
90	77.41918	Consumer return with full refund
100	55.01266	Consumer return with full refund
110	40.34647	Consumer return with full refund
120	30.4589	Consumer return with full refund
130	23.61273	Consumer return with full refund
140	18.75729	Consumer return with full refund
150	15.23858	Consumer return with full refund
160	12.63853	Consumer return with full refund
170	10.68328	Consumer return with full refund
180	9.189367	Consumer return with full refund
190	8.031324	Consumer return with full refund
200	7.121739	Consumer return with full refund

(d)

σ_D	$\Delta U(\rho = 0.3)$	Optimal strategy
20	1752.936	Consumer return with full refund
30	968.2728	Consumer return with full refund
40	508.8139	Consumer return with full refund
50	264.978	Consumer return with full refund
60	138.1811	Consumer return with full refund
70	71.41194	Consumer return with full refund
80	35.41802	Consumer return with full refund
90	15.54633	Consumer return with full refund
100	4.366616	Consumer return with full refund
110	−1.98807	No return
120	−5.59179	No return
130	−7.59094	No return
140	−8.63718	No return
150	−9.1104	No return
160	−9.237	No return
170	−9.15444	No return
180	−8.9475	No return
190	−8.66903	No return
200	−8.35226	No return

(e)

σ_D	$\Delta U(\rho = 1)$	Optimal strategy
20	1099.709	Consumer return with full refund
25	704.3688	Consumer return with full refund
30	425.6345	Consumer return with full refund
35	238.2991	Consumer return with full refund
40	116.6536	Consumer return with full refund
45	39.76602	Consumer return with full refund
50	−7.6261	No return
55	−35.9901	No return
60	−52.2552	No return
65	−60.9155	No return
70	−64.8518	No return

both p_2^* and m_2^* will decrease. (c) If α increases, both p_2^* and m_2^* will increase. (d) If θ increases, m_2^* will decrease. (e) If δ increases, p_2^* will decrease.

From Theorem 2, we can see that, for the scenario when the MC fashion brand offers consumer return, the optimal decisions on retail price and modularity level depend highly on the salvage value and the return service charge. From Theorem 4, we can observe that for the scenario when the MC fashion brand does not offer consumer return, the optimal decisions on retail price and modularity level depend highly on different market parameters such as the primary demand, the price-demand sensitivity coefficient, the modularity-demand sensitivity coefficient, and the modularity cost sensitivity coefficient; the corresponding relationships are shown in closed-form as summarized by Theorem 4.

After we have analyzed the separate scenarios, we now examine a critical research question of this paper on whether the MC fashion brand should offer consumer return with full refund or no return. To address this question, we employ the analytical results above and define $\Delta U \equiv U_1(p_1^*, m_1^*) - U_2(p_2^*, m_2^*)$. Obviously, whenever ΔU is strictly positive, we have $U_1(p_1^*, m_1^*) > U_2(p_2^*, m_2^*)$ which means that it is better to implement the consumer return policy with full refund, compared to the strategy of offering no return. As such, ΔU represents the amount of benefit that can be brought by employing consumer return with full refund (as compared to the no return no refund scenario) in MV domain.

5. Numerical Sensitivity Analysis

Owing to the complexity of the analytical expression of ΔU, we have to employ extensive numerical analysis to reveal under what conditions the strategy of "implementing consumer return with full refund" will outperform the strategy of "no return and no refund." In determining the set of numerical values in conducting the analysis, we make reference to the data set as employed in [28, 32]. To be specific, we set the parameters as in Table 1.

We focus on analyzing how the degree of risk aversion k, the return uncertainty σ_R, and the demand uncertainty σ_D affect the value of ΔU (which in turn determines the optimal strategy) because they are the most critical parameters related to the consumer return policy under MC. We also explore the problem with "positive, zero, and negative ρ" because a different sign of ρ can significantly affect the finding. The results are shown in Tables 2 to 4 and also plotted in Figures 1 to 3, respectively. Notice that the numerical range of each parameter is set with reference to the conditions with which the mean-variance objective function remains concave and the optimal pricing and modularity level decisions are all feasible.

From Tables 2(a) to 2(e), it is interesting to note that the no return scenario would outperform the consumer return scenario with full refund only when ρ and k are both big enough. In other words, when $\rho \leq 0$, consumer return with full refund is more preferred to the MC fashion brand irrespective of the degree of risk aversion. Only under the case when $\rho \geq 0.3$, for a sufficiently risk averse MC fashion brand (i.e. with a sufficiently big k), having no return is better than the case with consumer return with full refund. This result is partially intuitive as it indicates that a sufficiently risk averse MC fashion brand will prefer no return to having consumer return because the corresponding risk from consumer return is too high to bear. However, our result also indicates the important role played by the "very strong mediating factor"

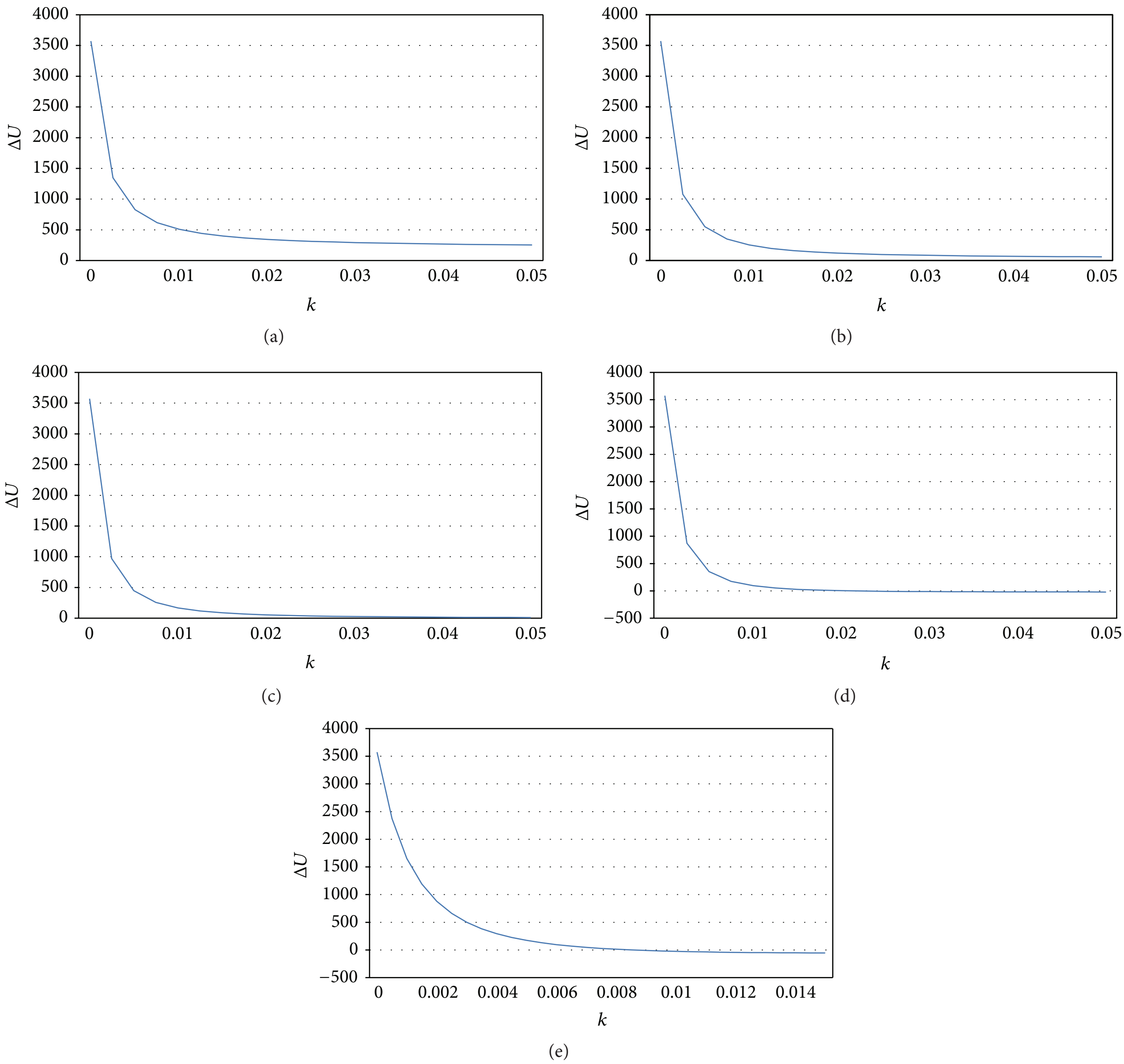

Figure 1: (a) Sensitivity analysis on the effect brought by k (with $\rho = -1$). (b) Sensitivity analysis on the effect brought by k (with $\rho = -0.3$). (c) Sensitivity analysis on the effect brought by k (with $\rho = 0$). (d) Sensitivity analysis on the effect brought by k (with $\rho = 0.3$). (e) Sensitivity analysis on the effect brought by k (with $\rho = 1$).

ρ which can affect the result very significantly. In addition, as observed from Figures 1(a) to 1(e), for all cases, when k increases, ΔU decreases which implies that the amount of benefit that can be brought by employing consumer return with full refund (as compared to the no return no refund scenario) in MV domain is decreasing with the MC fashion brand's degree of risk aversion.

From Tables 3(a) to 3(e), we can observe that when ρ is small (i.e., $\rho \leq 0.3$), the consumer return scenario with full refund is the preferred choice for all values of σ_R under study. When $\rho = 1$, (i) we observe that the consumer return scenario with full refund is still the preferred choice when σ_R is small. (ii) If σ_R is sufficiently high, then the no return scenario outperforms the full refund scenario. Again, similar to our prior findings, ρ is a very important "mediating factor" which can substantially affect the optimal choice of whether to adopt no return or return with full refund when the return uncertainty varies. From Figures 2(a) to 2(e), we can observe that, (i) for $\rho < 0$, when σ_R increases, ΔU increases which means that the respective amount of benefit that can be brought by employing consumer return with full refund (as compared to the no return no refund scenario) in MV domain is increasing with the return uncertainty. (ii) On the contrary, for $\rho \geq 0$, when σ_R increases, ΔU decreases which indicates that the effect as brought by increasing σ_R on ΔU is just reverted when $\rho \geq 0$ (compared to the case when $\rho < 0$).

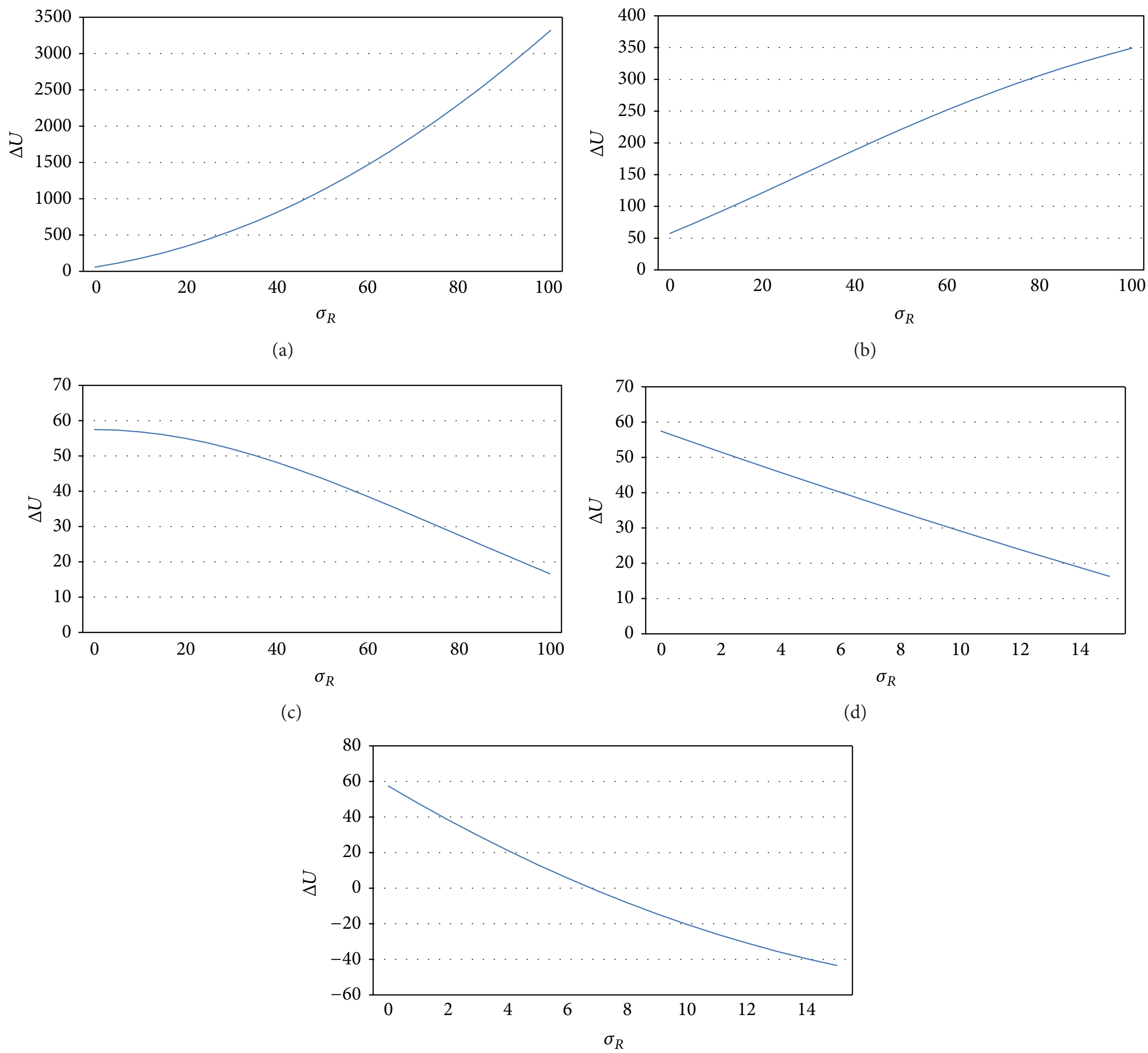

Figure 2: (a) Sensitivity analysis on the effect brought by σ_R (with $\rho = -1$). (b) Sensitivity analysis on the effect brought by σ_R (with $\rho = -0.3$). (c) Sensitivity analysis on the effect brought by σ_R (with $\rho = 0$). (d) Sensitivity analysis on the effect brought by σ_R (with $\rho = 0.3$). (e) Sensitivity analysis on the effect brought by σ_R (with $\rho = 1$).

From Tables 4(a) to 4(e), it is interesting to note that the impact on the optimal choice of return policy (no return versus return with full refund) as brought by the demand uncertainty is rather similar to the return uncertainty. The consumer return with full refund scenario is the preferred choice for all demand uncertainty (σ_D) values under study when $\rho \leq 0$. When $\rho \geq 0.3$, we find that, (i) the consumer return scenario with full refund is still the preferred choice when σ_D is small. (ii) If σ_D is sufficiently big, the no return scenario outperforms the full refund scenario. As observed from Figures 3(a) to 3(e), we notice that different from the case with σ_R, ΔU is always a decreasing function of σ_D irrespective of whether ρ is positive or negative. In other words, the amount of benefit that can be brought by employing consumer return with full refund (as compared to the no return no refund scenario) in MV domain is decreasing with the demand uncertainty for all ρ.

6. Conclusion

In this paper, we have explored the stochastic fashion MC service programme with the consideration of consumer demand uncertainty and risk aversion of the company. We have obtained a number of important findings and insights. For example, for the scenario with full refund and return, we have derived the closed-form analytical optimal decisions in retail pricing and modularity level. We have also

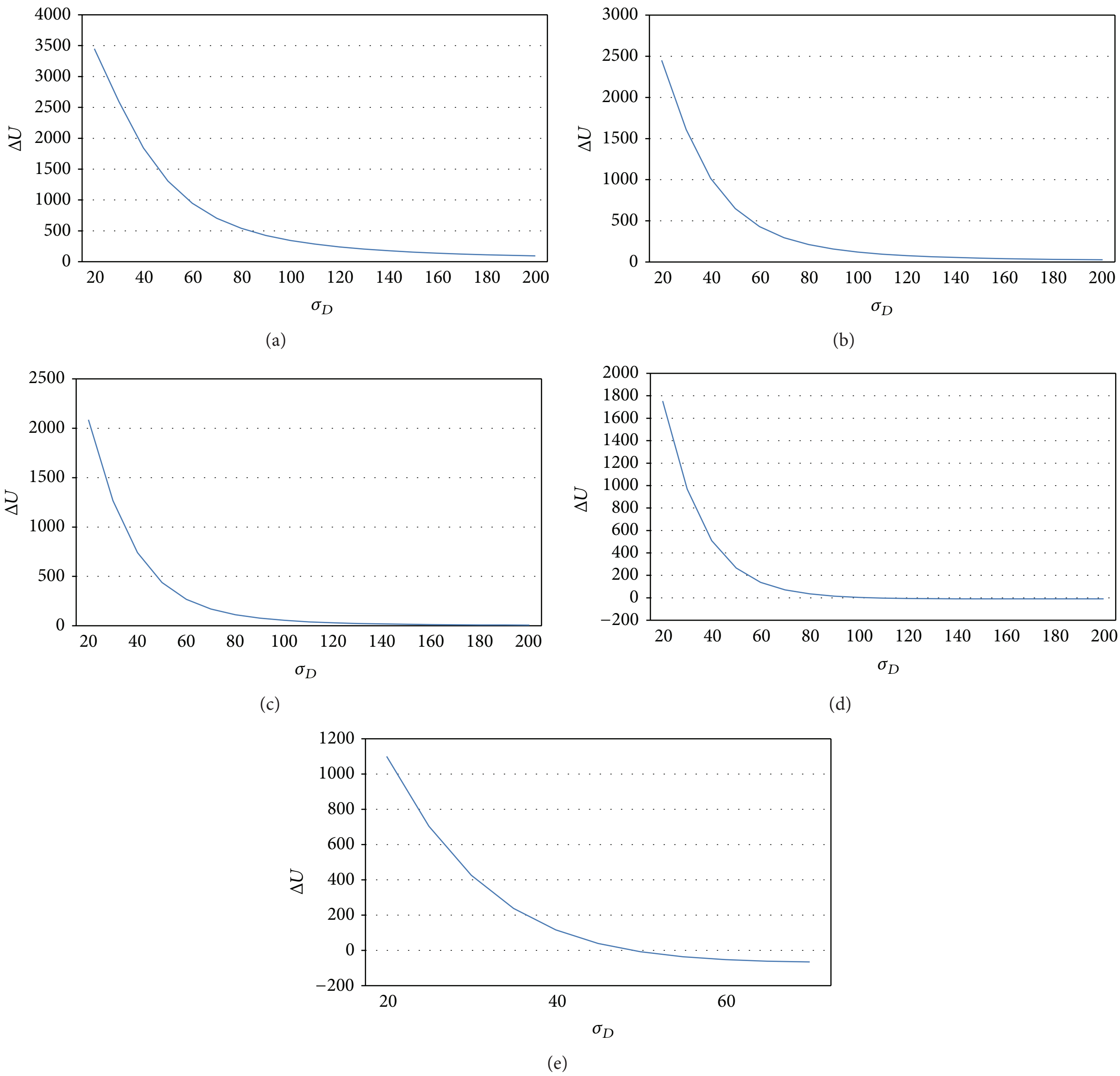

Figure 3: (a) Sensitivity analysis on the effect brought by σ_D (with $\rho = -1$). (b) Sensitivity analysis on the effect brought by σ_D (with $\rho = -0.3$). (c) Sensitivity analysis on the effect brought by σ_D (with $\rho = 0$). (d) Sensitivity analysis on the effect brought by σ_D (with $\rho = 0.3$). (e) Sensitivity analysis on the effect brought by σ_D (with $\rho = 1$).

revealed the analytical conditions under which the optimal retail price and the optimal modularity level would vary monotonically with respect to the return service charge and the salvage value. For the scenario when there is no refund and no return, we have obtained the neat closed-form expressions of the optimal pricing and modularity decisions. Our analysis has also indicated that the optimal retail price and the optimal modularity level are decreasing in the MC fashion brand's degree of risk aversion, the demand uncertainty, and the price-sensitivity coefficient. In addition, for both scenarios, we have interestingly found that the optimal retail pricing decision is linearly proportional to the optimal modularity decision. Finally, we have discovered that whether the risk averse MC fashion brand would prefer offering consumer return with full refund to no return depends critically on the demand-return correlation parameter ρ.

For future research, we believe that it can be done in a number of ways. First, it will be interesting to examine the MC schemes with multiple players under competition in a game-theoretic setting. Second, it will be promising to explore empirically more operational and marketing factors which may affect the demand of MC fashion products. After that, new analytical models based on the new empirical results can be constructed for further in-depth theoretical analysis.

Notation

p : The unit retail price
m : The level of modularity
$\widetilde{D}_1$: The market demand in the presence of consumer return with full refund
$\widetilde{D}_2$: The market demand in the absence of consumer return
l: The service charge per return
α: The primary demand which depends on factors such as product quality, brand image, and the general market factors, $\alpha > 0$
β: The price-demand sensitivity coefficient, $\beta > 0$
γ: The (consumer return) refund-rate-demand sensitivity coefficient, $\beta > \gamma > 0$
δ: The modularity-demand sensitivity coefficient, $\delta > 0$
ε_D: A bounded continuous random variable which represents the demand uncertainty with zero mean and variance σ_D^2
ϕ: The base return number which is independent of the refund rate, $\phi > 0$
ψ: The return number sensitivity coefficient, $\psi > 0$
$\widetilde{R}$: The return quantity
ε_R: A bounded continuous random variable which represents the uncertainty regarding the number of return with zero mean and variance σ_R^2
θ: The modularity-cost sensitivity coefficient, $\theta > 0$
v: The unit modularity level m dependent reusability value of the returned product which depends on $v > 0$
s: The unit reusability value of the returned product which is independent of m, $s > 0$
$S(\cdot)$: The salvage value function
$C(\cdot)$: The modularity cost function.

Conflict of Interests

In this paper, names of some real world companies are mentioned. The coauthors declare that there is no conflict of interests in citing these companies. The coauthors need to cite them because they are well-known examples to illustrate the real-world relevance of the analysis.

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