Coordination and Enhancement Schemes for Quick Response Mass Customization Supply Chains with Consumer Returns and Salvage Value Considerations**[[1]](#footnote-1)**

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### Abstract

Mass customization (MC) programs are commonly seen in the real world. Many companies offer consumer returns and quick delivery for their MC products to the market. Thus, the quick response strategy is crucial for MC supply chains. Prior studies in related areas only examine MC supply chains with limited features and topics such as measures for win-win coordination and profit risk analysis, but without a comprehensive consideration of these aspects together. Besides, the systems enhancement schemes are not yet explored. This paper aims to fill these gaps and generate novel insights. Among the findings, we show that a higher salvage value of the consumer returned items and a higher salvage value of the unused inventories both can reduce the value of quick response for the supplier. We illustrate how a simple two-part tariff contract and a sophisticated hybrid contract can achieve win-win coordination with different levels of flexibility. We uncover that the coordinated MC supply chain’s profit risk is basically decreasing in the consumer returns rate and the salvage value of unused inventories, but increasing in the salvage value of consumer returns. Finally, we demonstrate how three practical measures, namely technology investment, product design improvement, standardization of component, can further improve the MC supply chain system.

**Keywords:** Supply chain management, coordination, quick response, mass customization.

1. **INTRODUCTION**

***A. Background and Research Motivation***

Nowadays, mass customization (MC), as a strategy based on offering personalized products or service, has become famous for its high efficiency in satisfying the target consumers and thus it has attracted substantial attention from both practitioners and academicians. In practice, it is widely adopted by many brands from different industries with great success. For example, Dell, HP and IBM in the computer industry, BMW in the automobile industry, LEGO in the toy industry, as well as Adidas, Dorothy, and Nike in the fashion industry [46] are all well-known examples. In fact, a continuously increasing business significance has been shown in the MC market over the recent few years. For instance, Shoes of Prey, a US-based MC retailer, has shown to have a transaction volume of more than 6 million mass customized shoes by 2016 (from its 2016 end-of-year report). According to Owler’s estimation, the revenue of Shoes of Prey has hit $2.5 million in 2016. Cimpress N.V.[[3]](#footnote-3) has announced a 26% revenue increase in its third fiscal quarter of the fiscal year 2017 ($550.6 million) compared to $436.8 million in the same time period in 2016, which is available on its official website ir.cimpress.com. In the meantime, the "Global Footwear Market 2017-2021" report and Technavio’s latest market research report on the US furniture market (e.g., IKEA) all have indicated a similar emerging trend of the MC market. There is no doubt that MC is a critical and very significant practice in real world business operations.

To support MC operations requires careful planning of the respective supply chain systems [15], [48]. Some critical topics in supply chain systems include inventory planning, information sharing and risk management. In recent years, considering the great challenges posed by the high variability of the market demand, the quick response strategy[[4]](#footnote-4) has become an industrial trend that is widely emphasized in supply chain systems across industries. Quick response is a well-established strategy which aims at shortening the lead time and reducing the forecast error by combining the newly gathered market information into inventory decisions before the start of the selling season [1]. In the presence of quick response, the supply chain is believed to be more agile and competitive.

On the other hand, the salvage market, in which companies can sell the leftover inventories and defective or unwanted products (e.g., from the consumer returns), has emerged as a target for recent research [2][4] under the wave of “environmental sustainability”. In fact, these leftovers and returns can result from product recalls, warranty returns, damaged goods and over-stocked inventory. In particular, due to the fierce competition in the industry, companies tend to offer additional favourable agreements for returns to the consumers [45] [61], especially for some new programs like MC because consumer returns can positively influence the consumers and encourage them to buy more [62] [63]. As a result, an effective salvage management of the unused inventories and consumer returns is important, regardless of whether the company adopts quick response or not. In addition, since the value of a product can be reduced after use, the salvage value of the unused items should be different from the consumer returned items. This is a non-trivial topic which deserves detailed exploration of the relevant impacts. From another side, the supply chain systems are widely acknowledged to fail to be optimal by themselves under a decentralized mode of operations (i.e., it is not coordinated). This also leads us to explore what kind of supply chain contract can help achieve win-win coordination[[5]](#footnote-5) in the presence of consumer returns.

Given the popularity of MC in practice and the lack of related studies which simultaneously investigate consumer returns with salvage value considerations, mass customization and win-win coordination in the context of supply chain systems, this paper is developed. Essentially, this paper extends [5] by establishing a mass customization supply chain with consumer returns, and devoting to examining (i) the performance of supply chain contracts in coordinating the whole channel, (ii) the risk level induced by the MC program, (iii) the supply chain enhancement industrial measures such as technology investment and improved product design.[[6]](#footnote-6) Moreover, different impacts of consumer returns and unused products are specifically investigated from the perspective of the salvage values of unused and returned items. The findings in our paper not only can be a reference for future researchers that are interested in MC and consumer returns, but it also provides a guideline for managers of the MC brands when they make decisions for their MC supply chain systems.

***B. Literature Review and Positioning***

In the literature of supply chain systems operations, consumer returns, mass customization, and channel coordination as well as quick response are all important areas. We review some related studies follows.

In the field of the consumer returns related operations, Krumwiede and Sheu [6] examined the influence of the companies’ attitudes towards consumer returns on the loyalty level of their customers and the final business performance. Ramanathan [7] explored the performance of the companies in handling consumer returns by dividing the products into two categories, namely low-risk products and high-risk products. Chen and Bell [8] and Ghoreishi et al. [9] discussed the optimal decisions of the selling price and the inventory control policy with the consideration of the negative effects of customer returns. Zeballos et al. [10], Sheu et al. [11] and Guide et al. [12] individually analyzed the uncertainty of consumer returns.

For mass customization, related studies include [13], [14], [15], [16] and [17] and we introduce them as follows. First, Yao and Deng [13] proposed a multi-objective dynamic scheduling model to solve the scheduling problem in an MC program. Zhang et al. [14] conducted an empirical based study to explore the influence of the organizational structures and product modularity on the development of the MC program. Lai et al. [15] illustrated the interaction among the external conditions (e.g., external competition), the internal integration, and the capability of the MC program using a dataset collected from the industry. Liu et al. [16] constructed a conceptual MC model and conducted a survey to reveal the effects of functional integration on the performance of mass customization, with a focal point on customer satisfaction. Moon et al. [17] integrated the concept of service design into an MC system. The authors modeled the ever-changing external environment by using game theory to determine the equilibrium module-based product families design. In addition, there are some studies which focus on exploring the utilization of information in the MC program. For example, Zhang et al. [38] stated the significance of using information for manufacturer's design and production capabilities enhancement. Heradio et al. [39] revealed the limitations of existing approaches to provide information about feature dependencies and incompatibilities to support the MC program. The authors proposed a novel and new algorithm to solve this problem.

Channel coordination is a critical topic in supply chain management, especially for quick response supply chain with information sharing. Here, coordination means achieving the globally optimal supply chain system. In the literature, Kurata and Yue [18] studied the incentives to motivate the sharing of sales information between the manufacturer and the retailer so as to achieve a better performance of the whole supply chain system. Ha and Tong [19] analyzed supply contracting in two supply chain systems which compete with each other. The authors assumed that the channel members’ costs of investment in information sharing are different. Xu et al. [20] presented analytical results on the optimal coordinating contract design when both the manufacturer and the retailer are risk conservative and they uncovered the effects of risk tolerance. Choi et al. [21] investigated the coordination issue in a supply chain when the individual players are influenced by their own risk preferences under a mean-risk optimization model. Xu et al. [22] examined the effectiveness of both single supply chain contracts and a hybrid contract in coordination for a supply chain which includes a risk-neutral upstream manufacturer and a risk-averse downstream retailer. As a remark, how the high variability of market demand affects contract setting for coordination was also studied in the related literature [23][24].

The role played by information updating i.e., the quick response strategy, is also widely discussed in the literature[[7]](#footnote-7). For example, Cachon and Swinney [56] conducted an analysis on the value of the quick response system with the consideration of strategic consumers and Lin and Parlarturk [57] studied the influence of quick response together with retail competition. Besides, the determination of pricing and inventory decisions in a quick response environment was examined in [49] and [51] in the setting with heterogeneous and uncertain consumer valuations. In the meantime, there are also a number of studies considering the coordination issue under quick response such as [26] [44] [54] [55]. Among them, Yang et al. [26] explored the coordination mechanism in which the retailer is allowed to change the order quantities according to the updated market information and the two suppliers have different lead-times. Chow et al. [44] discussed the implementation of the supply chain contracts when a minimum order quantity is required and the order quantity of the retailer could be decided either before the update of new demand information or after. Zhou and Wang [54] established a supply chain system with two orderings opportunities as well as two selling periods. The authors investigated the performance of the supply chain with proposed coordination mechanisms. Yang et al. [55] compared the effects of strategic consumer behavior on the final value of information updating under different supply chain structures, and various supply chain contracts are proposed to enhance channel performance.

Although some studies highlighted above have explored both information updating and coordination challenges together, mass customization systems with consumer returns are not considered. While for the studies on MC and consumer returns, they mostly consider the two issues separately. An exception is [5]. In fact, the closest study which relates to this paper is [5] in which the authors considered consumer returns, mass customization program and information updating. However, the difference between the salvage values of unused inventories and consumer returns was not explored in [5]. Moreover, only Pareto improvement but not the optimization of the whole supply chain system was investigated in [5]. The level of risk associated with the MC program and different system enhancement measures were also not mentioned in [5]. As a consequence, we develop this paper which extends [5] and the current literature with the study of win-win coordination in the quick response MC supply chain. We consider the presence of two different salvage values. We conduct a risk analysis and also uncover how industrial measures, such as technology investment, product design enhancement, and standardization of component, can be used to further enhance the MC supply chain’s systems performance. These highlight the originality and major contributions of this paper. The specific literature positioning of this paper is presented in Table I. As shown in Table I, this paper is the first study to explore the win-win coordination in a mass customization program under the simultaneous consideration of the consumer returns, the quick response strategy with risk analysis, and the different salvage values of unused inventories and consumer returns.

**TABLE I. SPECIFIC COMPARISONS BETWEEN THIS PAPER AND OTHER RELATED LITERATURE**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Literature** | **Quick Response** | **Mass customization** | **Consumer returns** | **Pareto improvement / Win-Win[[8]](#footnote-8)** | **Coordination mechanisms[[9]](#footnote-9)** | **Different salvage values** | **Risk analysis** |
| [1] | ✓ | 🗶 | 🗶 | ✓ | ✓ | 🗶 | 🗶 |
| [5] | ✓ | ✓ | ✓ | ✓ | 🗶 | 🗶 | 🗶 |
| [7] | 🗶 | 🗶 | ✓ | 🗶 | 🗶 | 🗶 | ✓ |
| [8] | 🗶 | 🗶 | ✓ | 🗶 | 🗶 | 🗶 | 🗶 |
| [10] | 🗶 | 🗶 | ✓ | 🗶 | 🗶 | 🗶 | 🗶 |
| [13] | 🗶 | ✓ | 🗶 | 🗶 | 🗶 | 🗶 | 🗶 |
| [14] | 🗶 | ✓ | 🗶 | 🗶 | 🗶 | 🗶 | 🗶 |
| [19] | 🗶 | 🗶 | 🗶 | 🗶 | ✓ | 🗶 | 🗶 |
| [20] | 🗶 | 🗶 | 🗶 | ✓ | ✓ | 🗶 | ✓ |
| [21] | 🗶 | 🗶 | 🗶 | 🗶 | ✓ | 🗶 | ✓ |
| [22] | 🗶 | 🗶 | 🗶 | 🗶 | ✓ | 🗶 | ✓ |
| [23] | 🗶 | 🗶 | 🗶 | ✓ | ✓ | 🗶 | ✓ |
| [26] | ✓ | 🗶 | 🗶 | 🗶 | ✓ | 🗶 | 🗶 |
| [27] | ✓ | 🗶 | 🗶 | 🗶 | ✓ | 🗶 | 🗶 |
| This paper | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

***C. Paper’s Structure and Organization***

The rest of this paper is organized as follows. First of all, the basic model is formulated in Section II. Afterwards, both the centralized and decentralized models are analyzed in Section III. Then in Section IV, win-win coordination mechanisms are explored. Lastly, three systems enhancement practices which can improve the performance of the MC quick response supply chain are discussed in Section V. We conclude this paper in Section VI. Besides, we also present results of risk analysis on the MC program in Appendix A. To enhance presentation and exposition of findings, all technical proofs are relegated to Appendix B.

1. **MODEL FORMULATION**

In this paper, we conduct an analytical study on the use of quick response in a retail supply chain under an MC program. The supply chain system includes an upstream supplier and a downstream retailer (e.g., a retail brand) dealing with a single short-life seasonal product (i.e., a single selling period product). Under the MC program, the customers are allowed to make some reasonable and simple customization[[10]](#footnote-10) on the basic product (e.g., a handbag, and the customization refers to the addition of accessories or some personal printed messages), and the retail brand will then further tailor-make these items according to the requirements of the customers. Such MC programs can be observed from the real world like the soccer jersey MC programs in the fashion industry and MC schemes in electronic products (e.g. iPads in Apple). As a remark, both the supplier and the retail brand aim at maximizing their own expected profit.

For the decision making process, we consider a two-echelon MC supply chain in which the retail brand decides the ordering quantity of the basic product before the start of the selling season. This MC product is available for a short season. The sequence of events is summarized as follows. Firstly, before the start of the MC program, the retail brand determines the ordering quantity of the un-customized items and submits the order to the supplier either under slow response or quick response strategy. Then manufacturing activities start and the un-customized basic product is directly delivered to the retail brand, which will be further customized by the retail brand after receiving MC requests from the consumer. After that, demand for the MC products is realized and unsatisfied consumers can return the products back to the retail brand for full refund. Finally, the retail brand salvages the unused leftovers (i.e., un-customized ones) and consumer returns with different salvage values.

As a classical model for determining the optimal ordering quantity under the objective of maximizing the expected profit, the newsvendor model is adopted in this paper [31]. The respective revenue-cost parameters are as follows: The retail brand places an ordering quantity *q* of the un-customized basic product at a unit ordering cost of *c*. The mass customized items are sold at a unit retail price *p* and an unconditional consumer returns policy with a full refund is provided. From history, the retail brand estimates that the consumer return rate is a certain number, denoted by . Besides, reselling is not permitted and as a result, by the end of the selling season, the retail brand salvages the unused basic products at a unit value of and the consumer returned products with a unit value of , both of which can be further processed and some maybe remanufactured. From the supplier’s side, a unit production cost *m* for those un-customized products is incurred. As a remark, to avoid trivial cases, throughout this paper, we assume that [[11]](#footnote-11) and . In the meanwhile, is also constrained by the condition of in order to guarantee the profit margin of the MC product (under the consideration of consumer returns) is bigger than the unit ordering cost, which means a profitable business for the MC program. In addition, for ease of presentation, we let subscripts *b, s, sc, SR* and *QR* denote the retail brand, the upstream supplier, the MC supply chain, as well as the scenarios with “slow response” and “quick response”, respectively. Let superscript *\** denote the optimal solution of the corresponding decision variable and let superscripts *C, B, T,* and *H* represent the centralized model, the decentralized model led by the retail brand, the decentralized model under a two-part tariff contract, and the decentralized model coordinated by a hybrid contract, respectively. Notice that the above newsvendor based inventory model for MC supply chains is similar to the one in [5] except we consider the presence of two different salvage values. This is non-trivial because as we will see later on, these salvage values relate to different industrial measures and the supply chain can be improved by taking some new enhancement schemes.

The market demand in this paper follows the basic well-established mathematical model for demand uncertainty and Bayesian information updating[[12]](#footnote-13) in the literature [1][5]. In the following, we present it without further discussions because the model is well-known in the literature. Interested readers should refer to [1] for more details. Under this demand structure, if the retail brand orders under slow response with a long lead time, the forecasted demand in the consumer market is , and it follows a normal distribution . However, if the retail brand places an order under the quick response strategy, then according to the Bayesian normal conjugate pair theory, it can be derived that *,* and *.* Define and as the standard normal density function and the standard normal cumulative distribution function, respectively and let be the inverse function of Furthermore, we also represent the standard normal right linear loss function as, which can be expressed by: The notations used in this paper are listed in Table II (in Appendix C.).

Then on the basis of the model introduced above, we have the profits of the retail brand and the supplier as follows:

*(1) From the perspective of the* *retail brand:*

The profit of the retail brand with operational mode can be derived as:

,. (1)

Note that in (1), is the revenue generated from selling the mass customized products to the customers, is the ordering cost of the un-customized product,is the revenue attained from salvaging the unused basic items. As a consequence, the first three elements give the profit of the retail brand when there are no consumer returns. The last two elements are respectively the cost and salvage value from allowing unconditional consumer returns under the MC program. This profit function is different from the one in [5] in which there are two different salvage values in (1), and this paper focuses on examining them.

The expected profit of the retail brand is:

,.

For the retail brand, it aims to find an optimal ordering quantity to maximize its own expected profit, and the corresponding optimization problem can be written as:

,.

*(2) From the perspective of the upstream supplier:*

As the Stackelberg follower, the upstream supplier produces basic items according to the ordering quantity received from the retail brand with a negotiated wholesale price. It can be found that the expected profit of the supplier is:

.

1. **CENTRALIZED AND DECENTRALIZED SETTINGS: THE COMPARISONS**

*A. Decisions in the Centralized Setting*

In this section, we first explore the centralized setting to act as a benchmark so that we can develop the systems optimization scheme for supply chain coordination in the decentralized setting.

Under the centralized model, it is assumed that the upstream supplier and the retail brand are vertically integrated and perform as a central decision maker who determines all relevant decisions aiming at maximizing the total profit of the entire supply chain system. The profit functions of the whole channel can be derived based on the expected profits of the retail brand and the upstream supplier that we have discussed in Section II.

Since , it is straightforward to show that the following is the expected profit of the supply chain system:

, (2)

The optimization problem of the whole supply chain is hence shown as follows:

,.

Then, following the newsvendor model and using the first order condition, it can be observed that the optimal ordering quantity, which maximizes the expected profit of the whole supply chain, is:

; (3)

whereis the optimal inventory fill-rate under the centralized setting.

*B. Decisions in the Decentralized Setting*

In the decentralized system, the retail brand is the decision maker for the ordering quantity of the un-customized product, with either the slow response or quick response delivery option, under the supply contract offered by the supplier. The retail brand aims at maximizing his own profit rather than the whole supply chain system’s. Afterwards, the upstream supplier reacts and fulfills the order, taking the retail brand’s decisions into consideration.

*(1) The profit function of the retail brand:*

Based on the formulation and arguments in the previous sub-sections, we have the expected profit function of the retail brand in the decentralized supply chain setting as:

.

The corresponding optimal ordering quantity, which maximizes the expected profit of the retail brand, is given as[[13]](#footnote-14):

. (4)

The optimal expected profit function of the retail brand under optimal ordering quantity is:

,

whereis the optimal service level in the decentralized setting, which is under the leadership of the retail brand.

*(2) The profit function of the upstream supplier:*

Considering the leadership of the retail brand, when the retail brand’s ordering quantity equals to ,the expected profit of the upstream supplier can be listed as:

.

*C. Discussions*

*(1) Comparisons between the Centralized and Decentralized Systems*

According to the discussion in above, it can be seen that no matter under which response strategy, the optimal ordering quantity from the aspect of the retail brand is always different from the one from the supply chain’s[[14]](#footnote-15). This phenomenon reveals the existence of double marginalization in the decentralized setting, which decreases the performance of MC program and can also be observed from the models proposed in other studies like [1], [3] and [5]. Additionally, the empirical analyses in [14] and [52] also show the existence of this phenomenon when executing MC in the real world.

*(2) Win-Win Condition under the Consideration of Consumer Returns and Unused Inventories*

From the supply chain system’s perspective, the comparisons of the expected profits of the retail brand and the upstream supplier (in the decentralized model) between the two different ordering scenarios can help determine whether the QR strategy is beneficial to each individual, i.e., QR may not be necessarily a win-win strategy in all conditions. Therefore, we define the expected value of quick response (EVQR) for each supply chain member, and then we derive some findings as shown in Property 1 and Lemma 1.

For a notational purpose, we define the following:

, , ,, , ;

.

The condition of win-win scenario is explored in the following, which refers to the case when both the retail brand and the upstream supplier are benefited after adopting QR.

Define: , .

We first present Property 1 (which is found by directly checking the expressions of  and ) and then Lemma 1.

**Property 1.** and *are both positive if and only if the consumer returns rate*  *is bounded between*  and .

**Lemma 1.** *Under the adoption of quick response, the salvage value of unused inventories and the salvage value of consumer returns have opposite effects on the chance of achieving a win-win outcome for the whole supply chain system.*

Lemma 1 shows an interesting result regarding the impacts brought by the salvage values. If we look into the technical details, we can see that an increase in the salvage value of the unused items will lead to an increase in (the lower bound of consumer returns rate for win-win) while keep the upper bound the same, which consequently reduces the flexibility of consumer returns rate in achieving a win-win outcome. Similarly, when the salvage value of consumer returns decreases, the range also becomes smaller. Therefore, an increase of the salvage value of unused leftovers or a decrease of the salvage value of consumer returns will decrease the likelihood of achieving a win-win result.

*(3) Comparisons on the Effects of Consumer Returns and Unused Inventories*

From the analytical EVQR expressions of different members, it is possible that the consumer returns and unused inventories may have different effects on the EVQR of each supply chain member, and the difference is summarized in Corollary 1 and Corollary 2.

Corollary 1. *(a) is monotonically decreasing in ; (b) i) Necessary and sufficient condition: is increasing in if and only if ; is decreasing in if and only if ; ii) Sufficient condition: When ,[[15]](#footnote-16) is increasing in ; (c) Necessary and sufficient condition: is increasing in if and only if ; is decreasing in if and only if .*

Corollary 1 shows the fact that from the perspective of the supplier, a higher salvage value of consumer returns will reduce the benefits gained from QR. It is reasonable since a higher salvage value of consumer returns means a lower expected loss of offering the consumer returns policy for MC. The information collected from the time stage that is closer to the selling season, which is about the specific customer needs, also becomes not as crucial as in the case when the salvage value of consumer returns is low. Consequently, the expected value of quick response depresses. As for the retail brand, when the loss induced by the consumer returns rate is big enough, i.e.,, it will definitely benefit from an increased salvage value of consumer returns owing to the reduced overall loss. That is, the higher possibility of having consumer returns, the more important the salvage value of consumer returns becomes. It is also the case for the whole MC supply chain. Therefore, it is necessary to consider the consumer returns’ salvage value when investigating the performance of QR for MC.

Corollary 2. *(a) is monotonically decreasing in ; (b) i) Necessary and sufficient condition: is increasing in if and only if ; is decreasing in if and only if ; ii) Sufficient condition: When ,[[16]](#footnote-17) is decreasing in ; (c) i) Necessary and sufficient condition: is increasing in if and only if ; is decreasing in if and only if ; ii) Sufficient condition: When , is decreasing in .*

Corollary 2 indicates that the salvage value of unused inventories has a negative impact on the supplier’s EVQR. It is intuitive as a higher salvage value of unused inventories means a lower level of loss for holding leftover inventories, which substantially reduces the importance of information updating about the market demand (i.e. QR) when making quantity preparation for the basic items. Similarly, when the salvage value of unused inventories is sufficiently high, i.e., high enough to make the inventory service level larger than 0.5, both the retail brand and the MC supply chain will also reduce the EVQR if the salvage value of those unused items continues to increase. On the basis of the discussions above, the consideration of unused inventories’ salvage value is critical for efficiently managing the performance of QR in MC supply chains.

1. **WIN-WIN COORDINATION**

From Section III, we know that the supply chain system is not guaranteed to be coordinated and in fact, a win-win situation for the supply chain members need not appear after they have implemented QR. We hence explore in this section the contractual arrangement which can achieve win-win coordination. Here, we say that the win-win coordination after implementing QR is achieved when the supply chain members are all benefited by the implementation of QR and the supply chain system is also optimized at the same time [3].

To achieve win-win coordination, one would think about the use of a powerful yet simple supply contract. The candidate which appears naturally would be the two-part tariff contract which is capable of coordinating many supply chains in the presence of double marginalization problem. Under the two-part tariff contract (*, F*), the profit functions of the retail brand and the supplier can be listed as follows:

*;*

.

Correspondingly, the retail brand’s new optimization problem is:

.

At the same time, the objective of the supplier is to ensure and , given the negotiated wholesale price as well as the condition of (i.e. achieving coordination).

However, Lemma 2 shows the result that the two-part tariff contract has very limited flexibility in achieving win-win coordination.

**Lemma 2.** *When and , the win-win coordination be achieved by the two-part tariff supply contract (with wholesale price and fixed credit transfer F) if and only if , and in the range of*

Lemma 2 indicates that only when the upstream supplier agrees to set his wholesale price that is sufficient enough to cover his manufacturing cost, will win-win coordination be achieved by a two-part tariff contract, which reveals the limitation of a two-part tariff contract in achieving win-win coordination when the consumer returns are considered and the salvage values of consumer returns and leftovers are different. In fact, given this complex channel structure, the limitation also appears to other simple supply chain contracts. For instance, if the adopted contract is a buyback contract (or a markdown contract), adjusting the buyback price (or the markdown price) can only guarantee the ordering quantity chosen by the retail brand is optimal for the supply chain while either of the members may still suffer. As a consequence, a hybrid contract is needed to improve the performance of the MC supply chain even when the upstream supplier is not willing to charge such a low wholesale price since it is risky. In fact, the superiority of a hybrid contract is also proved by other literature such as [32], although the hybrid contract proposed in this paper is different from [32].

Considering the existence of double marginalization, a hybrid contract combining the decisions in a differentiated buyback contract and a two-part tariff contract is designed in this section. Under this contract, the upstream supplier agrees to buyback all of the leftover items and consumer returns from the retail brand at the end of the selling season on the basis of their respective salvage values. That is, the supplier will buyback the unused basic items with a buyback price of and the consumer returns with a buyback price of [[17]](#footnote-18) To eliminate arbitrage value of the products returned by the retail brand, it is assumed that and. Besides, to ensure a profitable business, is also bounded by. At the same time, the hybrid contract also contains other two parameters, referring to the unit wholesale cost *c* paid by the retail brand for ordering the basic items and a lump-sum fee *F* paid by the retail brand to the upstream supplier aiming at compensating the loss of the supplier. Notice that in this paper, we assume that the upstream supplier has a same salvage capability as the retail brand, which means the two salvage values of leftover items and consumer returns are exactly the same with the situation when salvaged by the retail brand[[18]](#footnote-19).

Under the hybrid contract (*c, , F*), the profit functions of the retail brand and the supplier become:

,

.

Then the retail brand’s new optimization problem is:

.

The supplier sets the contract parameters to achieve , , and .

Define:

,

.

**Proposition 1.** *When and , the MC supply chain can achieve win-win coordination under quick response by utilizing a differentiated buyback policy based two-part tariff contract, with , and the parameter F in the range of , where:*

; *.*

Proposition 1 indicates that a policy combines a differentiated buyback mechanism and a two-part tariff mechanism can help achieve win-win coordination for the MC supply chain with unconditional consumer returns in the presence of the quick response strategy. That is, the expected profit of the whole channel is maximized and in the meanwhile, both of the retail brand and the upstream supplier will choose the quick response strategy since none of them suffers.

Referring to Lemma 2 and Proposition 1, it can be seen that with the help of the two-part tariff contract and the hybrid contract, both of which relate to the side-payment contract, the QR strategy can always bring more profit than the initial SR case.[[19]](#footnote-20) Notice that, the side-payment contract consists of a major linear transfer function as well as an additional constant monetary transfer and is widely applied in practice for coordination like the consignment contract and the franchising contract. Similar cases with the arbitrary allocation of profit surplus can also be observed from companies like Amazon (e.g., the Pro-merchant program) and 7–11 [59].

At the same time, given the various challenges in the dynamic market environment, detailed comparison on the performance of these two contracts is also made in Table III, which provides a guideline for the selection between these two contracts when pursuing different objectives. As can be observed from Table III, the hybrid contract outperforms the two-part tariff contract in the flexibility of dividing the channel profit. However, the two-part tariff contract is more favorable in practice than the hybrid contract when the involved players pursue a coordination mechanism which is simpler to be implemented. In addition, under the two-part tariff contract, as the retail brand has to pay the supplier a guaranteed lumpsum of money, there is essentially no risk for the supplier. Thus, the two-part tariff contract also has its strength in the risk aspect. In short, there are strengths and weaknesses associated with the two contracts and hence we propose them for decision makers to choose.

**TABLE III. COMPARISONS BETWEEN THE TWO-PART TARIFF CONTRACT AND THE HYBRID CONTRACT**

|  |  |  |
| --- | --- | --- |
| **Category** | **The two-part tariff contract** | **The hybrid contract** |
| Profit risk | Lower | Higher |
| Flexibility of dividing profits | Lower | Higher |
| Simplicity in practice[[20]](#footnote-21) | Higher | Lower |

1. **SYSTEMS ENHANCEMENT MEASURES**

According to the supply chain risk analysis conducted in Appendix A and the discussion in previous sections, it can be observed that the consumer returns rate, the salvage value of the unsold inventories and consumer returns all can substantially influence the performance of the MC program, no matter from the perspective of the expected value of the quick response strategy (Part C in Section III) or the variance of the MC supply chain’s profit (the supply chain risk analysis in Appendix A). Therefore, in the following, we discuss the methods to improve the MC supply chain from these three aspects by using various industrial measures, namely technology investment, product design improvement, and standardization of component. Note that these measures all incur a certain sunk cost which is taken as a fixed cost (for a long time operation) and shared among products, etc. Thus, the cost per product per period is negligible and being ignored in the model.

*A. Technology Investment*

MC is a technology driven measure. It is understood that if the supply chain members are willing to enhance the MC process by investing in technologies, quality of the MC process and product will both be improved. For instance, the MC program may encounter some feature incompatibilities owing to the increased variability problem [39]. The investment in developing automated supporting tools to help identify those incompatible features can efficiently improve the quality of the mass customized products, which can consequently contribute to the decrease of consumer returns percentage. Apart from this, the MC supply chain can also enhance the MC process by following the multistage manufacturing systems emphasized in [60] or introducing some intelligent systems, such as the hybrid OLAP-association rule mining based quality management system[[21]](#footnote-22) [40].

In short, with proper technology investment, the quality of the MC products will be enhanced, and consequently the proportion of consumer returns will be reduced (). In this sub-section, we examine the impacts brought by this action.

Define:

, , , .

,

,

.

Then we have Lemma 4.

Lemma 4.

*(a) If these two consumer returns rates (i.e.,* , *) are in the range of , the expected profit of the entire chain is increased by increasing the technology investment in the MC process*; *(b) From the view of the whole channel, the expected value of quick response is increased if and only if both of these two can satisfy* ; *(c) Under the win-win coordination contact, the lower bound for win-win outcome is reduced if both of the new and updated satisfy , and the upper bound for win-win outcome is increased if these two satisfy* ; *(d) The risk of the entire chain is increased if* .

As indicated in Lemma 4, the investment in technology not only can increase the expected profit of the entire supply chain, but also increase the significance of quick response for the supply chain (by increasing the expected value of quick response). In the meantime, the difficulty in achieving win-win coordination can also be reduced if the respective conditions are satisfied. However, the profit variance is very likely increased, which means the level of risk is higher.

*B. Product Design Improvement*

From the perspective of improving the value of consumer returned products, it is important to consider from the product design perspective to see if the MC product can be, e.g., design in a modular format in which different components can be decomposed as “modules” that could be used for the production of other products, i.e., designs its products in a way that is easier to decompose [41][42]. If yes, then the salvage value of the consumer returned items will be higher (). From this perspective, we have Lemma 5.

Lemma 5.

*(a) If these two salvage values of consumer returns (i.e.,* , *) are in the range of , the expected profit of the whole channel is increased by designing the MC products in a way that is easier to decompose*; *(b) From the view of the whole channel, the expected value of quick response is increased if and only if both of these two can satisfy* ; *(c) Under the win-win coordination contact, the lower bound for win-win outcome is reduced if both of the new and updated satisfy , and the upper bound for win-win outcome is increased if these two satisfy* ; *(d) The risk of the entire chain is increased*.

Similar to the case of technology investment in the MC process, the improvement in product design is also shown to be effective in increasing the expected profit of the entire chain, as well as the expected values of quick response of the MC supply chain. It is also helpful in decreasing the difficulty in attaining win-win coordination. However, the level of risk faced by the supply chain system is higher.

*C. Standardization of Component*

In the MC supply chain that we investigated, the unused standard semi-finished (i.e. un-customized) product can actually be used to produce other products if the supply chain has considered it in its product development and planning processes. That is, if the unused standard semi-finished product can be created in a way that is easier to be used as a component of another product, the salvage value of them will be higher (). This leads us to derive Lemma 6.

Lemma 6.

*(a) If these two salvage values of the unsold inventories (i.e., , ) are in the range of , the expected profit of the whole channel is increased by designing the basic products in a way that is easier to be used as a component for another product*; *(b) From the view of the whole channel, the expected value of quick response is increased if and only if both of these two can satisfy* ; *(c) Under the win-win coordination contact, the lower bound for win-win outcome is reduced if both of the new and updated satisfy , and the upper bound for win-win outcome is increased if these two satisfy ; (d) The risk of the entire chain is reduced if* .

Lemma 6 presents the effects of the standardization of unused products as components for other production processes. Similar to the case of other measures, we identify the conditions under which this measure can improve supply chain profitability, value of quick response and reduce risk.

1. **INSIGHTS, CONCLUSION AND FUTUURE RESEARCH**

MC supply chain systems are commonly seen in the industry and many firms offer consumer returns for their MC programs. The use of quick response strategy is well-advocated and its application in MC supply chain systems is an important topic. Prior studies only explore MC supply chains and quick response from a decentralized setting and issues such as impacts of different salvage values, measures for win-win coordination, profit risk analysis, and systems enhancement schemes are not yet explored. This paper aims to fill these gaps by building models and conducting both analytical and numerical analyses.

To be specific, we have found a number of insights and some interesting ones are highlighted in the following. A brief summary of these insights is also listed in Table IV below.

1. **Impacts of salvage values:** For the supplier, a higher salvage value of the consumer returned items and a higher salvage value of the unused inventories both lead to a lower EVQR to the supplier. As a result, the expected value of quick response is in fact lower if either salvage value is higher. This shows an interesting finding which relates to the salvage values and the value of QR for the supplier in the MC supply chain system.
2. **Win-win coordination:** We have shown that win-win coordination can be achieved by a simple contract such as the two-part tariff contract. However, the simple two-part tariff contract only offers limited flexibility in parameter setting and the supplier has to supply at cost first. This is not a desirable situation. As such, we have proposed another contract, called the differentiated buyback policy based two-part tariff contract, which can achieve win-win coordination with a higher level of flexibility.
3. **Profit risk analysis:** When an MC supply chain achieves win-win coordination, its expected profit is maximized and both the supplier and the retail brand enjoy a positive expected payoff from implementing quick response. However, how about the associated level of risk? In this paper, we have modelled the coordinated supply chain system’s level of risk by using the MV theory. We have found that the coordinated supply chain system’s level of risk is basically (i) decreasing (quadratically) in the consumer returns rate, (ii) increasing (linearly) in the salvage value of consumer returns, and (iii) decreasing (linearly) in the salvage value of unused inventories. Notice that these findings are interesting, especially for the effects of consumer returns rate and the salvage value of consumer returns. The reason is when the consumer returns rate is reduced, the supply chain benefits from having a higher expected profit. However, the profit uncertainty and hence risk is also higher. For the salvage value of consumer returns, if it is larger, the supply chain has a higher expected profit but at the same time, the profit risk is also higher. We hence find the standard tradeoff between payoff-and-risk with respect to these two important parameters.
4. **Systems enhancement schemes:** Finally, we have examined three systems enhancement measures, namely the technology investment measure, the product design improvement measure, and the standardization of component measure. For each one of them, we have shown how they can improve the supply chain’s performance and the respective analytical conditions are found.

**TABLE IV. A SUMMARY OF THE MANAGERIAL INSIGHTS**

|  |  |
| --- | --- |
| **Managerial insights** | **Descriptions** |
| Impacts of salvage values | Although a higher salvage value can reduce the potential loss for the players, some players may not benefit from it under the quick response strategy. Therefore, MC companies should pay attention to the compensation provided to the suppliers so as to attain a sustainable relationship with them. |
| Win-win coordination | Different supply chain contracts have different advantages. When adopting coordination mechanism, MC managers should carefully choose it based on the priority of objectives and the characteristics of related players. |
| Profit risk analysis | It is crucial to find a suitable tradeoff between the final payoff and the related risks when designing the specific terms in the consumer returns policy for MC and making the preparation for the basic inventories such as the quality and materials. |
| Systems enhancement schemes | MC managers can improve the performance of the MC supply chain from various aspects of the MC products in different processing stages, e.g., through technology investment, product design improvement, and standardization of component. |

This paper considers an MC supply chain with a single supplier and a single retail brand and we check the reliability of our model from the aspects of consumer returns and quick response. First of all, similar to other studies on consumer returns, our model treats the consumer returns rate as a primary factor derived from history data and we have shown its influence on the channel performance, the results of which are consistent with other prior studies (e.g., its negative effect on the optimal ordering quantity) like [64]. Secondly, the full return policy assumption in our model is also widely adopted among MC studies in the literature and commonly observed in practice, and we have derived the same conclusion about the necessity of supply chain contracts in coordinating a full-refund system. Furthermore, by following the popular Bayesian information updating model, we also capture the impact of the updated information on inventories decisions (e.g., inventory service level) as the models proposed by others.

However, similar to other research works, this paper also has some limitations. For instance, since products can be returned at different time periods, the salvage value may differ and thus future research can further investigate coordination mechanisms with the objective of stimulating timely consumers returns. In the meantime, given the different qualities of returned products in practice, a quality-based partial refund amount also deserves further exploration in the future. Besides, in this paper, we haven’t considered the supply side uncertainty and if it is considered, new interesting results can be derived. Apart from the above, future research can be conducted by extending this supply chain structure to include, e.g., multiple suppliers or multiple retail brands. Important insights can be generated when the model includes the competition effect between the suppliers or the retail brands such as the price competition and service competition.

## REFERENCES

[1] A. V. Iyer, and M. E. Bergen, “Quick response in manufacturer-retailer channels,” Management Science, vol. 43, no. 4, pp. 559-570, 1997.

[2] X.M. Huang, J. W. Gu, W. K. Ching, and T. K. Siu, “Impact of secondary market on consumer return policies and supply chain coordination,” Omega, vol. 45, pp. 57-70, 2014.

[3] T.M. Choi, “Supply chain systems coordination with multiple risk sensitive retail buyers,” IEEE Transactions on Systems, Man, and Cybernetics: Systems, vol. 46, pp.636-645, 2016.

[4] G. P. Cachon, and A. G. Kök, “Implementation of the newsvendor model with clearance pricing: How to (and how not to) estimate a salvage value,” Manufacturing & Service Operations Management, vol. 9, no. 3, pp. 276-290, 2007.

[5] T. M. Choi, and S. Guo, “Responsive supply in fashion mass customisation systems with consumer returns,” International Journal of Production Research, in press, 2017.

[6] D. W. Krumwiede, and C. Sheu, “A model for reverse logistics entry by third-party providers,” Omega, vol. 30, no. 5, pp. 325-333, 2002.

[7] R. Ramanathan, “An empirical analysis on the influence of risk on relationships between handling of product returns and customer loyalty in e-commerce,” International Journal of Production Economics, vol. 130, no. 2, pp. 255-261, 2011.

[8] J. Chen, and P. C. Bell, “The impact of customer returns on pricing and order decisions,” European Journal of Operational Research, vol. 195, no. 1, pp. 280-295, 2009.

[9] M. Ghoreishi, A. Mirzazadeh, G. W. Weber, and I. Nakhai-Kamalabadi, “Joint pricing and replenishment decisions for non-instantaneous deteriorating items with partial backlogging, inflation-and selling price-dependent demand and customer returns,” Journal of Industrial and Management Optimization, vol. 11, no, 3, pp. 933-949, 2015.

[10] L. J. Zeballos, M. I. Gomes, A. P. Barbosa-Povoa, and A. Q. Novais, “Addressing the uncertain quality and quantity of returns in closed-loop supply chains,” Computers & Chemical Engineering, vol. 47, pp. 237-247, 2012.

[11] J. B. Sheu, Y. H. Chou, and C. C. Hu, “An integrated logistics operational model for green-supply chain management,” Transportation Research﹣Part E, vol. 41, no. 4, pp. 287-313, 2005.

[12] V. D. R. Guide Jr, V. Jayaraman, and J. D. Linton, “Building contingency planning for closed-loop supply chains with product recovery,” Journal of Operations Management, vol. 21, no. 3, pp. 259-279, 2003.

[13] J. M. Yao, and Z. L. Deng, “Scheduling optimization in the mass customization of global producer services,” IEEE Transactions on Engineering Management, vol. 62, no. 4, pp. 591-603, 2015.

[14] M. Zhang, X.D. Zhao, and Y.N. Qi, “The effects of organizational flatness, coordination, and product modularity on mass customization capability,” International Journal of Production Economics, vol. 158, pp. 145-155, 2014.

[15] F.J. Lai, M. Zhang, D. M. Lee, and X.D. Zhao, “The impact of supply chain integration on mass customization capability: An extended resource-based view,” IEEE Transactions on Engineering Management, vol. 59, no. 3, pp. 443-456, 2012.

[16] G.S. Liu, R. Shah, and R. G. Schroeder, “The relationships among functional integration, mass customisation, and firm performance,” International Journal of Production Research, vol. 50, no. 3, pp. 677-690, 2012.

[17] S. K. Moon, J. Shu, T. W. Simpson, and S. R. Kumara, “A module-based service model for mass customization: Service family design,” IIE Transactions, vol. 43, no. 3, pp. 153-163, 2010.

[18] H. Kurata, and X. Yue, “Trade promotion mode choice and information sharing in fashion retail supply chains,” International Journal of Production Economics, vol. 114, no. 2, pp. 507-519, 2008.

[19] A. Y. Ha, and S. Tong, “Contracting and information sharing under supply chain competition,” Management Science, vol. 54, no. 4, pp. 701-715, 2008.

[20] G.Y. Xu, B. Dan, X.M. Zhang, and C. Liu, “Coordinating a dual-channel supply chain with risk-averse under a two-way revenue sharing contract,” International Journal of Production Economics, vol. 147, pp. 171-179, 2014.

[21] T. M. Choi, D. Li, H. Yan, and C. H. Chiu, “Channel coordination in supply chains with agents having mean-variance objectives,” Omega, vol. 36, no. 4, pp. 565-576, 2008.

[22] M. Xu, Q. Wang, and L. Ouyang, “Coordinating contracts for two-stage fashion supply chain with risk-averse retailer and price-dependent demand,” Mathematical Problems in Engineering, 259164, 2013.

[23] Y. He, and X. Zhao, “Coordination in multi-echelon supply chain under supply and demand uncertainty,” International Journal of Production Economics, vol. 139, no. 1, pp. 106-115, 2012.

[24] W. G. Zhang, J.H. Fu, H.Y. Li, and W.J. Xu, “Coordination of supply chain with a revenue-sharing contract under demand disruptions when retailers compete,” International Journal of Production Economics, vol. 138, no. 1, pp. 68-75, 2012.

[25] K. L. Donohue, “Efficient supply contracts for fashion goods with forecast updating and two production modes,” Management Science, vol. 46, no. 11, pp. 1397-1411, 2000.

[26] D. Yang, T. M. Choi, T. Xiao, and T. C. E. Cheng, “Coordinating a two-supplier and one-retailer supply chain with forecast updating,” Automatica, vol. 47, no. 7, pp. 1317-1329, 2011.

[27] H.Y. Chen, J. Chen, and Y. H. Chen, “A coordination mechanism for a supply chain with demand information updating,” International Journal of Production Economics, vol. 103, no. 1, pp. 347-361, 2006.

[28] D. J. Thomas, D. P. Warsing, and X. Zhang, “Forecast updating and supplier coordination for complementary component purchases,” Production and Operations Management, vol. 18. no. 2, pp. 167-184, 2009.

[29] T. M. Choi, D. Li, and H. Yan, “Optimal two-stage ordering policy with Bayesian information updating,” Journal of the Operational Research Society, vol. 54, no. 8, pp. 846-85, 2003.

[30] T. M. Choi, and P. S. Chow, “Mean-variance analysis of quick response program,” International Journal of Production Economics, vol. 114, no. 2, pp. 456-475, 2008.

[31] H.S. Lau, “The newsboy problem under alternative optimization objectives,” Journal of the Operational Research Society, vol.31, no. 6, pp.525–535, 1980.

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

[33] S. Asian and X. Nie, “Coordination in supply chains with uncertain demand and disruption risks: existence, analysis, and insights,” IEEE Transactions on Systems, Man, and Cybernetics: Systems, vol. 44, no. 9, pp.1139-1154, 2014.

[34] Z. He, T.C.E. Cheng, J. Dong, and S. Wang, “Evolutionary location and pricing strategies in competitive hierarchical distribution systems: A spatial agent-based model,” IEEE Transactions on Systems, Man, and Cybernetics – Systems, vol. 44, no. 7, pp. 822-833, 2014.

[35] H.M. Markowitz, “Portfolio selection: Efficient diversification of investment,” John Wiley & Sons, New York, 1959.

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

[37] J. Li, T.M. Choi, and T.C.E. Cheng, “Mean variance analysis of fast fashion supply chains with returns policy,” IEEE Transactions on Systems, Man, and Cybernetics: Systems, vol. 44, no. 4, pp. 422 – 434, 2014.

[38] M. Zhang, H.F. Guo, B.F. Huo, X.D. Zhao, and J.B. Huang, “Linking supply chain quality integration with mass customization and product modularity,” International Journal of Production Economics, in press, 2017.

[39] R. Heradio, H. Perez-Morago, M. Alférez, D. Fernandez-Amoros, and G. H. Alférez, “Augmenting measure sensitivity to detect essential, dispensable and highly incompatible features in mass customization,” European Journal of Operational Research, vol. 248, no. 3, pp. 1066-1077, 2016.

[40] C. K. H. Lee, K. L. Choy, G. T. Ho, K. S. Chin, K. M. Y. Law, and Y. K. Tse, “A hybrid OLAP-association rule mining based quality management system for extracting defect patterns in the garment industry,” Expert Systems with Applications, vol. 40, no. 7, pp. 2435-2446, 2013.

[41] J. P. Schöggl, R. J. Baumgartner, and Hofer, D., “Improving sustainability performance in early phases of product design: A checklist for sustainable product development tested in the automotive industry,” Journal of Cleaner Production, vol. 140, pp. 1602-1617, 2017.

[42] S.R. Li, V. Jayaraman, A. Paulraj, and K. C. Shang, “Proactive environmental strategies and performance: Role of green supply chain processes and green product design in the Chinese high-tech industry,” International Journal of Production Research, vol. 54, no. 7, pp. 2136-2151, 2016.

[43] J. Chen, “The impact of sharing customer returns information in a supply chain with and without a buyback policy,” European Journal of Operational Research, vol. 213, no. 3, pp. 478-488, 2011.

[44] P. S. Chow, T. M. Choi, and T. C. E. Cheng, “Impacts of minimum order quantity on a quick response supply chain,” IEEE Transactions on Systems, Man, and Cybernetics-Part A: Systems and Humans, vol. 42, no. 4, pp. 868-879, 2012.

[45] J. Liu, B. Mantin, and H.Y. Wang, “Supply chain coordination with customer returns and refund-dependent demand,” International Journal of Production Economics, vol. 148, pp. 81-89, 2014.

[46] A. Alptekinoğlu, and C. J. Corbett, “Mass customization vs. mass production: Variety and price competition,” Manufacturing & Service Operations Management, vol. 10, no. 2, pp. 204-217, 2008.

[47] J.W. Pratt, H. Raiffa, and R. Schlaifer. *Introduction to Statistical Decision Theory*. MIT Press.

[48] P. G. Brabazon, B. MacCarthy, A. Woodcock, and R. W. Hawkins, “Mass customization in the automotive industry: Comparing interdealer trading and reconfiguration flexibilities in order fulfillment,” Production and Operations Management, vol. 19, no. 5, pp. 489-502, 2010.

[49] J.F. Dong, and D.D. Wu, “Two-period pricing and quick response with strategic customers,” International Journal of Production Economics, in press, 2017.

[50] D. Z. Yu, and C. Xiang, “A manufacturer’s production and pricing strategies with a salvage channel,” International Journal of Production Research, vol. 55, no. 2, pp. 347-357, 2017.

[51] J.F. Dong, L. Jiang, and Y. Jiao, “Pricing strategy and quick response adoption system with strategic customers,” Mathematical Problems in Engineering, 1287162, 2017.

[52] Y. K. Ro, J. K. Liker, and S. K. Fixson, “Modularity as a strategy for supply chain coordination: The case of US auto,” IEEE Transactions on Engineering Management, vol.54, no.1, pp.172-189, 2007.

[53] T. M. Choi, and S. Sethi, “Innovative quick response programs: A review,” International Journal of Production Economics, vol.127, no.1, pp.1-12, 2010.

[54] Y. W. Zhou, and S. D. Wang, “Supply chain coordination for newsvendor-type products with two ordering opportunities and demand information update,” Journal of the Operational Research Society, vol.63, no.12, pp.1655-1678, 2012.

[55] D.J. Yang, E.S. Qi, and Y.J. Li, “Quick response and supply chain structure with strategic consumers,” Omega, vol.52, pp.1-14, 2015.

[56] G. P. Cachon, and R. Swinney, “The value of fast fashion: Quick response, enhanced design, and strategic consumer behavior,” Management Science, vol.57, no.4, pp.778-795, 2011.

[57] Y. T. Lin, and A. Parlaktürk, “Quick response under competition,” Production and Operations Management, vol.21, no.3, pp.518-533, 2012.

[58] M.M. Leng, and A. Zhu, “Side-payment contracts in two-person nonzero-sum supply chain games: Review, discussion and applications,” European Journal of Operational Research, vol.196, no.2, pp.600-618, 2009.

[59] B. R. Sarker, “Consignment stocking policy models for supply chain systems: A critical review and comparative perspectives,” International Journal of Production Economics, vol.155, pp.52-67, 2014.

[60] S.C. Du, R. Xu, and L. Li, “Modeling and analysis of multiproduct multistage manufacturing system for quality improvement,” IEEE Transactions on Systems, Man, and Cybernetics: Systems, in press, 2016.

[61] A. Alptekinoğlu, and A. Grasas, “When to carry eccentric products? Optimal retail assortment under consumer returns,” Production and Operations Management, vol.23, no.5, pp.877-892, 2014.

[62] S. K. Mukhopadhyay, and R. Setoputro, “Optimal return policy and modular design for build-to-order products,” Journal of Operations Management, vol.23, no.5, pp.496-506, 2005.

[63] R. Batarfi, M. Y. Jaber, and S. M. Aljazzar, “A profit maximization for a reverse logistics dual-channel supply chain with a return policy,” Computers & Industrial Engineering, vol.106, pp.58-82, 2017.

[64] R. Ruiz-Benitez, and A. Muriel, “Consumer returns in a decentralized supply chain,” International Journal of Production Economics, vol.147, pp.573-592, 2014.

**Appendix A: Supply Chain Systems Risk Analysis**

Considering the high uncertainty in the consumer market, the supply chain inevitably suffers a high level of risk [33] [34]. Therefore, risk analysis for the coordinated supply chain system is conducted in this part. We employ the variance of profit of the whole channel under a centralized supply chain structure as a measure of risk. Notice that this approach follows the classic Nobel prize awarded mean-variance (MV) theory [35] and has been widely adopted by various supply chain optimization studies such as [3][30][36][37].

From the standpoint of the MC supply chain, the variance of profit at , is:

.

Define the following and we have Lemma 3.

, , , ,

Lemma 3. (*a) is decreasing in if and only if ; (b) is increasing in ; (c) is decreasing in if and only if .*

As shown in Lemma 3, when there is a change on the consumer returns rate, the salvage value of the consumer returns, or the salvage value of the leftover products, the variance of profit of the whole supply chain system under two ordering time stages will also change. In Lemma 3, even though the specific increasing/decreasing situation is associated with a condition, as we will see in Section B, the condition is basically satisfied.

In the following, the numerical analysis is conducted to better illustrate the impacts of consumer returns and unused inventories on the variance of profit of the MC supply chain system in the quick response scenario.[[22]](#footnote-23) We consider the input values of the related parameters are *p* = 37.5, *c* = 12.5, *m* = 5, =1.5, =0.8, =35, =100, =25, =0.38. As a remark, these numerical values are set by referring to other relevant papers such as [30], [43], [44] and [45], and they satisfy the basic assumptions of the model explored in this paper. For instance, for the salvage value of consumer returns and the unused basic products, we set the values within the ranges of and , as we have discussed in Section II. In addition, to ensure the reliability of our numerical analysis, we have explored various scenarios with different values for the parameters and we have also set the four scenarios with different salvage values of consumer returns and salvage values of unused items (see the online supplementary file). In order to specifically show the independent effects of these three aspects, we change the value of, and , respectively. As the results are all similar, to avoid duplication, we only show the case with one scenario.

**FIGURE I. The supply chain’s variance of profit plotted against the consumer returns rate.**

**FIGURE II. The supply chain’s variance of profit plotted against the salvage value of consumer returns.**

**FIGURE III. The supply chain’s variance of profit plotted against the salvage value of unused product.**

By referring to all tables that are provided in the online supplementary file, it can be found that the variance of profit is always much lower in the quick response case than the slow response counterpart. Besides, from Figure I, we can see that the supply chain’s profit variance is decreasing in the consumer returns rate. The drop is also very obvious and exhibit a quadratic pattern. It is reasonable that when the consumer returns rate is very low, it is difficult to forecast the final quantity of consumer returns, which consequently increases the uncertainty of the profit. However, if the consumer returns ratio is high, it becomes easier for the whole channel to estimate the final consumer returns quantity and make corresponding preparation for dealing with these returns so as to maximize the channel’s profit.[[23]](#footnote-24) From Figure II, when the salvage value of consumer returns increases, the supply chain’s profit variance increases. The rate of increase is linear. Finally, from Figure III, we find that when the salvage value of unused item increases, the supply chain’s profit variance decreases. The change is also linear. As a consequence, since the supply chain’s profit variance represents the level of supply chain risk, Figures I to III indicate various important findings. First, for the salvage values, a lower salvage value of consumer returns and a higher salvage value of unused item would lead to a lower level of supply chain risk. Second, counter-intuitively, if the consumer returns rate is higher, the profit uncertainty is actually lower which means the level of risk is lower. This is an interesting situation.

**Appendix B: All Proofs**

**B. 1. Proof of Lemma 1.**

It is straightforward to observe that ; while if and only if . Therefore, the occurrence of win-win situation is bounded by the condition of .

By taking the first order derivative, it can be concluded that the difference between two boundaries of is a decreasing function of but an increasing function of .

B. 2. Proof of Corollary 1.

Based on previous discussions, we have: Then by taking the first order derivation, it can be derived that:

(a) .

(b) if and only if ; if and only if ;

Besides, when , ,, , .

(c) Similarly, we have: if and only if ; if and only if .

B. 3. Proof of Corollary 2. Similar to the proof of Corollary 1.

**B. 4. Proof of Lemma 2.**

The optimal expected profits of the retail brand and the upstream supplier under a two-part tariff contract is 6, we utilize the ofas needed to improve the performance of the fashion supply chain. ile either one of them willupdated as:

*;*

; .

It is easy to find that if, the coordination of the MC supply chain can be attained. And by setting in the range of , the condition of can be ensured, which means a win-win outcome for the two members.

**B. 5. Proof of Proposition 1.**

The revised expected profits of the supplier and the retail brand under the hybrid contract are:

.

By differentiating once and twice with respect to *q*, we find that is concave and hence it can be derived that the optimal ordering quantity under the hybrid contract is:

*,* .

To achieve supply chain coordination, we need to find a value of *θ* that can make .

Thus, .

Apart from the above, in order to achieve win-win coordination, we need and

Then by substituting *, ,* into and simultaneously, we have

It can be found that:

,

. Then we have Proposition 1.

B. 6. Proof of Lemma 3.

Parts a) and c): According to , we have:

;

;

thus, it is obvious that:

if and only if ;

if and only if .

Part b) From the expression, it is straightforward to note that a larger salvage value of consumer returns would lead to a higher variance of supply chain profit.

B. 7. Proof of Lemma 4.

(a) This is based on the first order derivation of the expected profit of the entire chain.

(b) Based on the previous analysis, we have:

, Then by taking the first order derivation, it can be derived that:

.

Thus, we have: if and only if .

(c) Differentiating and with , we have:

if and only if.

if and only if **.**

(d) An observation of Lemma 3.

B. 8. Proof of Lemma 5. It is similar to the proof of Lemma 4.

B. 9. Proof of Lemma 6. It is similar to the proof of Lemma 4.

**Appendix C: Tables**

**TABLE II. NOTIONS IN THE ANALYTICAL MODEL**

|  |  |
| --- | --- |
| **Parameters** | **Description** |
| *p* | Unit retail price of mass customized product paid by the consumer to the retail brand |
| *q* | The order quantity decided by the retail brand |
| *c* | Unit ordering cost of un-customized products paid by the retail brand to the upstream supplier |
|  | Unit salvage value of the customer returns |
|  | Unit salvage value of the leftover products |
| *m* | Unit production cost of the un-customized products |
| *s* | The service level under certain ordering quantity |
| *λ* | Consumer return ratio based on the observation of history data |
| *x* | Market demand for the mass customized product |
| *ϕ(x)* | The standard normal density function of the market demand *x* |
| *Φ(x)* | The standard normal cumulative distribution function of the market demand *x* |
|  | The standard normal right linear loss function of the market demand *x* |
|  | The profit function of the retail brand |
|  | The profit function of the upstream supplier |
|  | The profit function of the entire chain |
|  | The expected profit of the retail brand |
|  | The expected profit of the upstream supplier |
|  | The expected profit of the entire chain |

**SHORT BIO**

|  |  |
| --- | --- |
| **Shu Guo** is currently a PhD student at The Hong Kong Polytechnic University. She has published in International Journal of Production Research, and Journal of Cleaner Production. Her current research interest is on quick response fashion mass customization supply chains with consumer returns. | **Eunice_201708.jpg** |
| **Tsan-Ming Choi** received his Ph.D. from The Chinese University of Hong Kong. He is currently a full professor at The Hong Kong Polytechnic University. His research interests mainly focus on supply chain systems optimization. He has authored/edited 16 books and published extensively in *ISI Web of Science* Indexed journals such as *IEEE Transactions on Systems, Man, and Cybernetics - Systems, IEEE Transactions on Automatic Control, IEEE Transactions on Cybernetics, IEEE Transactions on Engineering Management, IEEE Transactions on Industrial Informatics, Automatica, Naval Research Logistics, Production and Operations Management,* etc. He is currently a senior editor of *Production and Operations Management,* and *Decision Support Systems,* an associate editor of *IEEE Transactions on Systems, Man, and Cybernetics – Systems, Information Sciences*, and *Transportation Research – Part E,* and an editorial board member of *INFORMS Service Science,* and *International Journal of Production Research*. He is a member of IEEE, INFORMS, and POMS. | **CHOI** |
| **Bin Shen** is currently an associate professor and associate head in the business school at Donghua University. He received his PhD degree from The Hong Kong Polytechnic University. His papers have appeared in leading journals such as Annals of Operations Research, European Journal of Operational Research, IEEE Transactions on Systems, Man and Cybernetics - Systems, International Journal of Production Economics, International Journal of Production Research, Journal of Cleaner Production, Journal of the Operational Research Society, Omega, Supply Chain Management, etc. |  |
| **Sojin Jung** is an Assistant Professor of the Institute of Textiles and Clothing at the Hong Kong Polytechnic University. She earned her Ph.D. at the University of North Carolina at Greensboro, USA. Her research interests center on fashion retail and consumer studies and sustainability issues in the industry. She has published articles in refereed journals, including *Journal of Cleaner Production*, *Corporate Social Responsibility and Environmental Management* etc., and she has garnered external grants from Research Grants Council of the Hong Kong government. |  |

1. The authors sincerely thank the editor and reviewers for their helpful and important comments on this paper. [↑](#footnote-ref-1)
2. Corresponding author. [↑](#footnote-ref-2)
3. It is one of the worldwide leaders in the MC market with the ownership of over 20 brands such as Vistaprint and National Pen. It offers customization services of physical products to various industries like printed marketing materials, and it is reported to produce more than 46 million MC items a year. [↑](#footnote-ref-3)
4. Notice that the quick response strategy we explored in this paper is based on the Bayesian conjugate pair (BCP) theory. The BCP theory is based on the well-established Bayes’ Rule in conditional probability studies. The rationale behind the BCP theory is to identify some statistical processes in which an analytically tractable (and hence easily implementable) prior distribution can be updated to the corresponding posterior distribution which also exhibits a nice functional form. The respective prior-posterior distribution pair is called the “conjugate pair”. For example, we have the beta prior Bernoulli process BCP, as well as the normal prior normal process BCP. For more details, please refer to [47]. [↑](#footnote-ref-4)
5. In this study, win-win coordination refers to the situation when the expected profit of the entire chain is maximized and in the meantime, both of the involved players, e.g., the retail brand and the upstream supplier, are benefitted. [↑](#footnote-ref-5)
6. Since the objective of this paper it to identify measures to enhance the performance of the MC program, we aim to achieve it through the exploration on coordination mechanisms and profit variance as well as the systems enhancement schemes, with the major focus on consumer returns and unsold inventories. As a result, other aspects which are not related to this objective (e.g. reliability and sustainability measures) will not be explored in this paper. [↑](#footnote-ref-6)
7. Although there are many papers discussing quick response before 2010 like [25], [27] and [28], we mainly introduce those papers published after 2011 in the main content. For those works published before 2011, interested readers can refer to [53] for more details. [↑](#footnote-ref-7)
8. Pareto improvement refers to the scenario when none of the involved supply chain members would suffer a loss while at least one of them is strictly benefited after adopting QR, and a win-win outcome is the case when both supply chain members are benefited after adopting QR. Notice that, achieving Pareto improvement or win-win outcome does not necessarily guarantee the global optimization of the supply chain. [↑](#footnote-ref-8)
9. The term “coordination” means the global optimization of the whole supply chain system. [↑](#footnote-ref-9)
10. “Reasonable” here means the changes required by the consumers should not conflict with the design of the products as well as the characteristics of the brand, and it must be practical. [↑](#footnote-ref-10)
11. It is reasonable to assume that the salvage value of the unsold product is bigger than the salvage value of the consumer returned product since the value of a product should be reduced after use. Furthermore, since in practice the consumer returns under MC are always with customization, it is more difficult to be resold, which is not the case for those unsold products. [↑](#footnote-ref-11)
12. It is a theory frequently utilized to capture the demand uncertainty structure for those short-life products in an environment with information updating. Under this theory, the variance of the market demand consists of both the inherent demand uncertainty of the product (i.e., in this paper) as well as the deductible forecast variance (i.e., and ). The inherent demand uncertainty of the product is something that cannot be further reduced by QR, which means that even if the market information about the mean demand is perfect, the market demand is still a random variable. Besides, with the updated information, the forecast variance under QR is smaller than the one under the slow response strategy, i.e., [1][5][29]. [↑](#footnote-ref-13)
13. In this paper, the “B” in the optimal ordering quantity and the optimal service level refers to the situation when the whole supply chain channel is led by the retail brand. [↑](#footnote-ref-14)
14. This is observed based on the comparison between the optimal ordering quantity of the retail brand and the optimal ordering quantity of the whole supply chain that we have derived in Section III. [↑](#footnote-ref-15)
15. It is the case when the optimal inventory service level of the retail brand . [↑](#footnote-ref-16)
16. It is the case when the optimal inventory service level of the retail brand . [↑](#footnote-ref-17)
17. The supplier is supposed to have the capability to distinguish the consumer returns from unused basic products and to acquire enough information about the final salvage market. [↑](#footnote-ref-18)
18. It happens when there is a common salvage market or recycle channel. Typical examples are the Amelia’s chain, which is a salvage chain in Pennsylvania, and the Liquidity Service Inc. [50]. [↑](#footnote-ref-19)
19. The existence of the lump-sum fee *F* guarantees that, with the help of these two contracts, the QR strategy is always more preferable than SR for the supply chain. For more details, interested readers can refer to the definition of and on P.17 as well as the Proofs of Lemma 2 and Proposition 1 in Appendix B. [↑](#footnote-ref-20)
20. This is an observation from the perspective of the whole channel. [↑](#footnote-ref-21)
21. This is a data mining system which can help extract defect patterns from various products. [↑](#footnote-ref-22)
22. Readers interested in the numerical analysis of variance of profit of the MC supply chain in the slow response case can refer to the online supplementary file for more details. [↑](#footnote-ref-23)
23. Notice that the extreme case when the consumer returns rate is equal to 1 is not considered in this paper since it means a business collapse, which will not happen in practice. Thus, the profit uncertainty, i.e., the risk, can never be totally avoided. [↑](#footnote-ref-24)