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Pareto Improving Supply Chain Coordination Under a Money-Back Guarantee Service Program

Jafar Heydari,[a] **Tsan-Ming Choi,**[b] **Saghi Radkhah**[c]

[a]School of Industrial Engineering, College of Engineering, University of Tehran, Tehran, Iran; [b]Business Division, Institute of Textiles and Clothing, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong; [c]Department of Industrial Engineering, Alborz Campus, University of Tehran, Tehran, Iran

Contact: j.heydari@ut.ac.ir (JH); jason.choi@polyu.edu.hk (T-MC); saghiradkhah@yahoo.com (SR)

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Abstract. Money-back guarantee (MBG) is a well-known service offered by many retailers. Under the MBG policy, a purchased item by a consumer can be returned for a full refund. In this paper, we explore a supply chain (SC) system comprising of one retailer, which offers the money-back guarantee policy and faces a stochastic demand. With a given supply contract offered by the supplier, the retailer makes decisions on the order quantity and the market coverage of the money-back guarantee service. With reference to real-world practices, we examine three models, namely, (1) the traditional wholesale pricing model without the buyback contract, (2) the model with a buyback contract (between the supplier and the retailer) for unsold items, and (3) a dual-buyback (DB) contract model for both unsold and consumer returned items. We find that using the buyback contract alone for unsold items cannot achieve Pareto improving supply chain coordination, whereas the DB contract can. Numerical findings also indicate that the DB contract can lead to an expansion of the money-back guarantee service program to cover more customers. This paper's findings support the implementation of the DB contract, which is commonly seen in the industry, for efficient supply chain management in the presence of the money-back guarantee service program.

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Keywords: logistics • inventory • supply chain management • dual-buyback contract • money-back guarantee

1. Introduction

The money-back guarantee (MBG) service program is commonly seen in the real world. In fact, from the consumer perspective, it is highly desirable if the retailer offers the money-back guarantee service, which allows returning the goods with a full refund. Undoubtedly, the ability to return the purchased items with a money-back guarantee would attract more customers and stimulate demand. In particular, when the consumer cannot judge the quality of product prior to purchasing (e.g., in e-tailing), the money-back guarantee service can boost confidence, reduce risk (Heiman et al. 2001), and signal the guaranteed product quality (Moorthy and Srinivasan 1995). In fact, money-back guarantee is commonly recognized as the most important risk reliever in e-tailing, followed by offering a well-known brand and a price reduction (Van den Poel and Leunis 1999).

Money-back guarantee programs vary significantly from one firm to another in areas such as shipping and handling fees, and coverage duration. Notice that the money-back guarantee service may be proposed to consumers as an option where consumers are authorized to buy the product bundled with a money-back guarantee or without it[1] (Heiman et al. 2002).

From the retailer perspective, offering consumer returns policies such as money-back guarantee may cause a high amount of returned goods, which significantly affects the retailer's profitability (Ülkü et al. 2013). According to Stock et al. (2002), in the United States, returned goods have been estimated to exceed \$100 billion per year. Consumer return rate for some fashion goods is about 74% (Mostard and Teunter 2006). Some consumer returns are about defective items but most returns are related to a failure of meeting customer expectation. According to Lawton (2008) only 5% of customer returns are actually defective items. At Hewlett-Packard (HP), over 6% of inkjet printer sales are returned by customers and 80% of returns are not from defective items (Ferguson et al. 2006). Among all types of customer returns policies, money-back guarantee is an effective way to ensure customer satisfaction. According to an empirical analysis by McWilliams and Gerstner (2006), about 87% of stores offer a money-back guarantee to their customers. Guide et al. (2006) report that most of mass retailers in the European Union offer a money-back guarantee within a prespecified time after purchase. However, reselling retuned items directly by the retailer requires careful planning and is nontrivial. For instance, in some cases, it is not cost-effective to sell at a very low price by the retailer. In some other cases, reselling the returned items is not permitted by the manufacturer (e.g., HP and Bosch both request retailers to send back the returned products to their respective return centers (Ferguson et al. 2006)). Thus, in this situation, implementing a money-back guarantee service program together with a buyback contract between the retailer and the supplier makes very good sense.

As an example, the retail giant *Walmart* offers money-back guarantee services and it sends back the consumer returned items to one of its six regional return centers across the United States. For many items, the consumer returned items are being further returned to vendors for reprocessing. In addition, in many categories, unsold items are also sent back to vendors under a buyback arrangement.

Motivated by the popularity of money-back guarantee service programs and the presence of buyback contracts in the supply chain (SC), which offers money-back guarantee (e.g., the Walmart case), we conduct an analytical study on the channel coordination challenge in supply chains with money-back guarantee. To be specific, we consider the situation when market demand relates to the money-back guarantee service program (Davis et al. 1995, Wood 2001, Xiao et al. 2010). The inventory system is modeled as a single-period newsvendor problem, and the retailer is the decision maker on inventory quantity. We study the situation in which the retailer allows a certain number of customers to return the purchased items until the end of the period. This is related to the real-world practices in which companies can specify customers in specific groups (e.g., the registered members[2]), specific geographical locations, or specific sales channels (online or offline), to enjoy the money-back guarantee, and has been employed in Chen and Bell (2012). Thus, the portion of customers who are selected for implementing the money-back guarantee (MBG) service program, which is called *the market coverage for MBG*, is also the decision of the retailer. In this paper, our focal point is to examine the supply chain coordination challenge, which involves aligning both the inventory decision and the market coverage decision for MBG. With reference to real-world practices, we examine three different models with MBG, namely, (1) the traditional wholesale pricing model, (2) the model with a buyback policy for unsold items, and (3) a dual buyback (DB) contract for both unsold and returned items. As we will prove later on, we reveal that both the wholesale pricing contract and the buyback contract (for unsold items) cannot guarantee coordinating the supply chain with a Pareto improving situation. Only the DB contract can successfully achieve Pareto improving coordination.

To the best of our knowledge, this paper is different from most papers reviewed above because we consider the situation when the retailer makes a decision not only on order quantity, but also the market coverage. This is the first paper that explores the supply chain coordination challenge in the presence of an MBG service program. The analysis also reveals the fact that real-world practices of having the wholesale pricing contract or the buyback contract alone cannot achieve Pareto improving coordination. Finally, we propose the use of a DB contract to coordinate the supply chain and achieve Pareto improvement.

The rest of this paper is structured as follows. We concisely review the related literature in Section 2. We present the supply chain models (with the three separate contracting scenarios) and derive analytical insights in Section 3. We report the numerical analysis and the respective findings in Section 4. We conclude this paper with a discussion on managerial insights and future research directions in Section 5.

2. Literature Review

The current study is related to the literature of supply chain coordination, especially the buyback contract. Consumer returns policies and money-back guarantee are also other critical aspects related to this study. We review them as follows.

2.1. Money-Back Guarantee Service Programs

In retailing, when consumers cannot judge the quality of products, such as purchasing from a new brand, a new product line, or the online sales channel, they will hesitate to make the purchases. One very useful way of convincing consumers to feel comfortable to purchase is the MBG service program. In fact, Moorthy and Srinivasan (1995) indicate specifically that the money-back guarantee service helps signal the product quality. Van den Poel and Leunis (1999) propose that the money-back guarantee service is recognized as one of the most important risk relievers for the Internet retailing, followed by offering a well-known brand and a price reduction scheme. Heiman et al. (2001) argue that the money-back guarantee service and demonstrations are two primary risk reduction tools to reduce consumers' risk of prepurchase uncertainty. Heiman et al. (2002) further examine the money-back guarantee service program and mention that it can be offered to customers as an option where customers are authorized to buy the product bundled with money-back guarantee or without it, usually with a different price point. Other related studies on the money-back guarantee service program include a study on MBG service program quality (Posselt et al. 2008), the appeal of money-back guarantee services to positive consumer emotional responses (Suwelack et al. 2011), and the use of the money-back guarantee service to help the development of store brand (Jeng et al. 2014). Similar to the above studies, this paper examines the money-back guarantee service program. Different from all of them, we focus on exploring Pareto improving supply chain coordination with different commonly seen contracts.

2.2. Buyback Contracts

Buyback contracts, also known as the channel returns policies (Pasternack 1985, Becker-Peth et al. 2013), are widely explored in the supply chain management literature. Under a buyback contract, the retailer can return unsold products by the end of the selling season to the supplier for a partial refund (or full refund, depending on the scheme). In fact, it is shown by Pasternack (1985) that the buyback contract with a partial refund for all unsold quantities can achieve Pareto coordination on the quantity decision for a make-to-order supply chain selling a single newsvendor product. After that, various studies have extended the buyback contract analysis in different directions. For example, Emmons and Gilbert (1998) develop a buyback policy when the retailer has a prespecified order quantity commitment. Lee and Rhee (2007) investigate a buyback policy where both the supplier and the retailer have stochastic salvage capacities. Yue and Raghunathan (2007) consider the effect of information asymmetry in a supply chain with the buyback contract. Babich et al. (2012) explore the impact of asymmetric demand information on the implementation of a buyback contract where the retailer does not share demand information.

For the case with a price-dependent demand, Arcelus et al. (2008) develop a buyback contract-based supply chain model with a price-dependent uncertain demand and explore the optimal polices with and without a secondary market. He et al. (2009) investigate a supply chain with stochastic demand that depends on both sales effort and price and prove that a buyback policy cannot achieve coordination. Zhao et al. (2014) investigate the buyback contract with a stochastic price-dependent demand. They focus on uncovering the effect of demand uncertainty on the implementation of buyback. Other buyback contract related studies include Choi et al. (2008), Hsieh and Wu (2009), Gürler and Yılmaz (2010), Hou et al. (2010), Ryu and Yücesan (2010), Chen (2011), Ai et al. (2012), He and Zhao (2012), Shen and Willems (2012), Choi et al. (2013), Shen et al. (2013), Devangan et al. (2013), Lee et al. (2013), Wu (2013), Zhang et al. (2014), Ohmura and Matsuo (2016). This paper is related to the above reviewed studies on buyback contracts as we also explore the use of buyback in achieving coordination. However, different from all of them, we consider the presence of the MBG service program, and treat both retail ordering quantity and the market coverage of money-back guarantee service as decisions to be coordinated.

2.3. Coordination in the Presence of Consumer Returns

Consumer returns policy is an important service program. It has also been explored in the supply chain coordination context. For example, Xiao et al. (2010) explore a buyback policy under consumer returns with a partial refund policy. The authors find that the buyback policy is capable of coordinating the supply chain when the product demand is a function of the refund amount. Su (2009) examines the impact of both MBG service program and partial returns policies on SC performance and shows that common buyback contracts are ineffective under consumer returns policies. Chen (2011) examine, under an information asymmetric setting, the impacts of sharing consumer returns information. They uncover that the retailer prefers not to share information if the manufacturer underestimates the returns amount. Chen and Bell (2011) analyze buyback polices with a price-dependent demand in the presence of consumer returns. In their model, consumer returns are exogenously given and hence are not treated as a decision. In the presence of fraudulent returns, Ülkü et al. (2013) analytically explore the optimization problem on both the price and the allowable return period from the retailer perspective. Choi (2013) studies the service charging policies for consumer returns under the mass customization program in the fashion industry. The author identifies the conditions related to the level of risk in which offering a full refund for consumer returns is optimal. Liu et al. (2014) investigate buyback polices under consumer returns when demand depends on the refund amount. The authors find that the buyback policy is unable to coordinate the supply chain when the refund amount is endogenous. Ruiz-Benitez and Muriel (2014) analyze a buyback policy in the presence of an exogenously given consumer return program. Yoo (2014) explore the relationship between consumer returns policy and product quality decisions in which the retailer decides the optimal consumer returns policy and the supplier makes a decision on the product quality. Xu et al. (2015) examine consumer returns where the consumer valuation depends on both the refund amount and the return deadline. They derive the retailer's optimal decisions including pricing, ordering, refund amount, and return deadline. For more related studies on coordination contracts with consumer returns (including in the remanufacturing aspects), refer to the reviews in Govindan et al. (2013). Similar to the above studies, we examine in this paper the consumer returns and how the respective supply chain can be coordinated. However, different from those studies, we focus on consumer returns under the money-back guarantee service program. In addition, we explore the dual buyback contract, which is different from the ones examined in the above reviewed studies.

3. Modeling

We consider a two-level supply chain consisting of one retailer and one supplier. The retailer decides the order quantity and the market coverage of the MBG service program. In this model, demand is stochastic and relates to the market coverage of MBG. We consider the situation when a certain portion of customers who have purchased will return the items. Moreover, the unsold remaining items by the end of the season will be salvaged and we assume there is a common salvage market and hence salvage value. For the returned items, we consider the situation when they can only be used for remanufacturing purposes (Govindan et al. 2015) in the supplier site (i.e., following the case in Walmart). Before we present the models, we introduce several critical definitions and also the list of notation:

Definition 1 (Supply Chain Coordination)**.** In this paper, a supply chain is coordinated if the retailer makes its quantity and market coverage decisions to be the same as the ones that are optimal for the supply chain system.

Definition 2 (Pareto Improving)**.** In the supply chain, a contract is called "Pareto improving" if it can guarantee that after its implementation, the retailer and the supplier are either better off (in terms of profitability) or at least one of them is strictly better off and the other is not worse off.

Definition 3 (Pareto Improving Supply Chain Coordination)**.** In this paper, a contract can lead to the Pareto improving supply chain coordination when the supply chain is coordinated, and the Pareto improving situation is attained at the same time.

3.1. Notations

The following notations are used in this paper:

- m: production cost per unit product
- h_1: holding cost of remaining products per item
- h_2: holding cost of returned products per item
- v_0: salvage value of each remaining product (the same for the retailer and the supplier)
- v_r: salvage value of each returned product in the supplier site
- p: retail price
- w: wholesale price
- w_b: wholesale price under buyback policy
- β: market coverage of money-back guarantee (the portion of customers in the market who are selected for the money-back guarantee program), $0 \le \beta \le 1$
- α: real percentage of returns (out of all selected customers for the money-back guarantee program), $0 \le \alpha \le 1$
- γ: money-back-elasticity coefficient of demand, which is scaled to be bounded between 0 and 1 ($0 \le \gamma \le 1$)
- Q: retailer order quantity
- b_b: buyback price for remaining items
- b_r: buyback price for returned items
- x: a random variable representing customer demand
- $f(x)$: probability distribution function of demand that is continuous and differentiable
- $F(x)$: cumulative distribution function of demand
- Ω: relative bargaining power of the retailer with respect to the supplier ($0 \le \Omega \le 1$)

For the cost-revenue parameters, to have a meaningful situation, we have the following: $p > w > m$, $v_0 - h_1 < w$, $v_r - h_2 < w$, $b_b > v_0$, $b_r > v_r$, $b_b - h_1 < w$, $b_r - h_2 < w$.

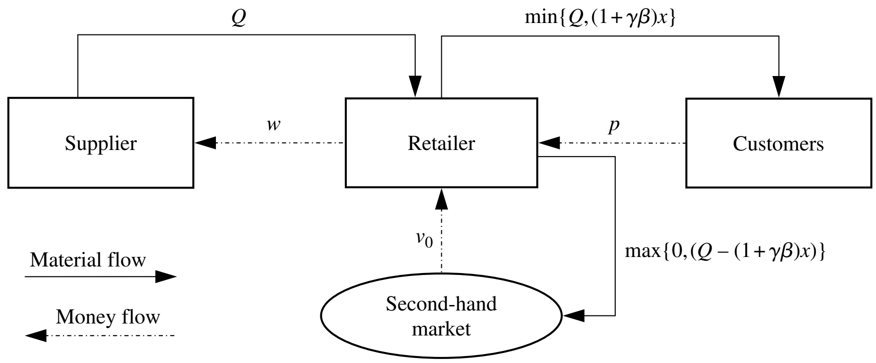
3.2. The Traditional Model with the Pure Wholesale Pricing Contract

Under the traditional model, the supplier offers a pure wholesale pricing contract to the retailer. The retailer makes decisions on Q and β individually based on its own expected profit. Figure 1 shows the sequence of events in the traditional model.

Based on Figure 1, remaining unsold items at the end of the selling season will be sold in a secondary market with a price v_0. The retailer's profit function is given as follows:

$$\Pi_T^r = \begin{cases} p(1+\gamma\beta)x - wQ - (h_1 - v_0)(Q - (1+\gamma\beta)x) - (p+h_2)\alpha\beta(1+\gamma\beta)x & Q > (1+\gamma\beta)x \\ (p-w)Q - (p+h_2)\alpha\beta Q & Q \le (1+\gamma\beta)x, \end{cases} \tag{1}$$

Figure 1. The Supply Chain Under the Traditional Wholesale Pricing Contract Model



where $(1+\gamma\beta)x$ represents the increased demand after offering a money-back guarantee to customers. Note that when the sales volume is equal to $(1+\gamma\beta)x$ then the real volume of returned items will be $\alpha\beta(1+\gamma\beta)x$; when the sales volume is equal to Q, then the real volume of returned items will be $\alpha\beta Q$. The expected profit of the retailer is expressed as follows:

$$E(\Pi_T^r) = [p(1+\gamma\beta)+(h_1-v_0)(1+\gamma\beta)-(p+h_2)\alpha\beta(1+\gamma\beta)]\int_0^{Q/(1+\gamma\beta)} x f(x)\,dx \\ - Q[p+(h_1-v_0)-(p+h_2)\alpha\beta]\int_0^{Q/(1+\gamma\beta)} f(x)\,dx + Q[(p-w)-(p+h_2)\alpha\beta]. \tag{2}$$

Theorem 1. *The retailer's expected profit under the pure wholesale pricing contract is concave in Q for a given β. The retailer's optimal order quantity is*

$$Q_T^r = (1+\gamma\beta)F^{-1}\left(\frac{(p-w)-\alpha\beta(p+h_2)}{(p+(h_1-v_0)-\alpha\beta(p+h_2))}\right). \tag{3}$$

Proof of Theorem 1. The second-order derivative of the expected profit of the retailer with respect to Q can be calculated as

$$\frac{\partial^2 E(\Pi_T^r)}{\partial Q^2} = -(p-(v_0-h_1)-(p+h_2)\alpha\beta)\frac{f(Q/(1+\gamma\beta))}{(1+\gamma\beta)}. \tag{3a}$$

Notice that in our model, in the presence of the MBG service program, the marginal profit of the retailer (from selling each item) is $p-w-(p+h_2)\alpha\beta$, which must be positive to ensure a profitable business:

$$p-w-(p+h_2)\alpha\beta > 0. \tag{3b}$$

Since the unit wholesale price is larger than the net leftover salvage product's value, we have

$$w > v_0 - h_1. \tag{3c}$$

Putting (3c) into (3b) yields

$$p-(v_0-h_1)-(p+h_2)\alpha\beta > 0. \tag{3d}$$

Thus, combining (3a) and (3d) implies that

$$\frac{\partial^2 E(\Pi_T^r)}{\partial Q^2} < 0,$$

and hence the retailer's expected profit function is concave in Q. To calculate the retailer's optimal order quantity, it is enough to make $\partial E(\Pi_T^r)/\partial Q = 0$, which yields Equation (3). □

Based on Theorem 1, to calculate optimal values of both decision variables, the following algorithm, Algorithm 1, is proposed:

Algorithm 1

Step 1. Set $\beta = 0$.
Step 2. Calculate Q related to the current value of β using Equation (3).
Step 3. Calculate $E(\Pi_T^r)$ using Equation (2) for current Q and β.
Step 4. Until $\beta = 1$, $\beta = \beta + \varepsilon$, go to step 2 where ε is a small enough positive number.
Step 5. A combination of Q and β that returns the maximum $E(\Pi_T^r)$ is the optimal solution under the traditional model with the wholesale pricing contract; i.e., Q_T^r and β_T^r.

Notice that in Algorithm 1, the concavity of the retailer's expected profit function in Q for a given β guarantees the optimal solution can be identified from the proposed algorithm. Under the traditional model with the wholesale pricing contract, the supplier's profit is given by $(w - m)Q$, and it depends on the decisions made by the retailer. It is well known that the pure wholesale pricing contract cannot achieve supply chain coordination (see Cachon 2003).

3.3. The Model with Buyback Contracts for Remaining Unsold Items

The proposed buyback contract has two parameters (w_b, b_b). Under this model, the supplier offers the retailer to return all remaining unsold products at the end of selling period for a buyback price b_b.

From Figure 2, under the buyback contract, the supplier buys back the remaining unsold items from the retailer and salvages them for a price v_0 in a secondary market. It is easy to note that the number of remaining unsold items at the end of the selling period is given by $\max\{0, (Q - (1 + \gamma\beta)x)\}$. The profit function of the retailer under the buyback contract model can be formulated as

$$\Pi_B^r = \begin{cases} (p(1+\gamma\beta)x - w_b Q - h_1(Q - (1+\gamma\beta)x) + b_b(Q - (1+\gamma\beta)x) - (p + h_2)\alpha\beta(1+\gamma\beta)x) & Q > (1+\gamma\beta)x \\ (p - w_b)Q - (p + h_2)\alpha\beta Q & Q \le (1+\gamma\beta)x. \end{cases} \quad (4)$$

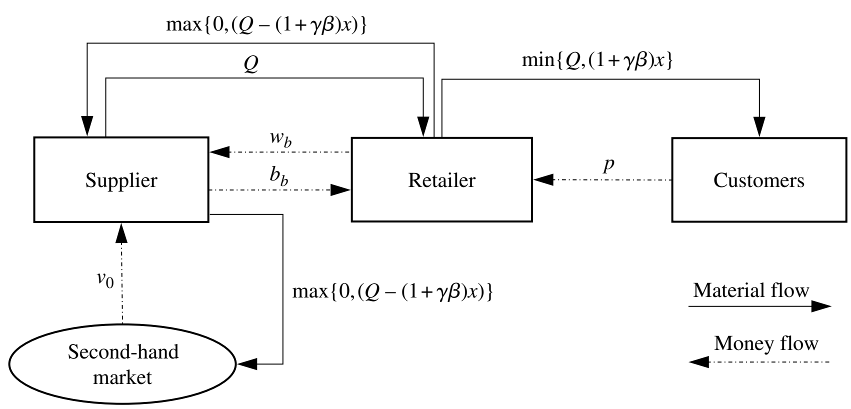
Taking expectation gives the retailer's expected profit function as follows, and we can derive Theorem 2:

$$\begin{aligned} E(\Pi_B^r) = {} & [p(1+\gamma\beta) - (b_b - h_1)(1+\gamma\beta) - (p + h_2)\alpha\beta(1+\gamma\beta)] \int_0^{Q/(1+\gamma\beta)} x f(x)\,dx \\ & - Q[p - (b_b - h_1) - (p + h_2)\alpha\beta] \int_0^{Q/(1+\gamma\beta)} f(x)\,dx + Q[(p - w_b) - (p + h_2)\alpha\beta]. \end{aligned} \quad (5)$$

Theorem 2. *The retailer's expected profit under the buyback contract model is concave in Q for a given β. The retailer's optimal order quantity is given by*

$$Q_B^r = (1+\gamma\beta) F^{-1}\left(\frac{(p - w_b) - \alpha\beta(p + h_2)}{(p - (b_b - h_1) - \alpha\beta(p + h_2))}\right). \quad (6)$$

Figure 2. The Buyback Contract Model (Which Handles Unsold Remaining Products)



Proof of Theorem 2. The second-order derivative of Equation (5) with respect to Q can be expressed as follows:

$$\frac{\partial^2 E(\Pi_B^r)}{\partial Q^2} = -(p-(b_b-h_1)-(p+h_2)\alpha\beta)\frac{f(Q/(1+\gamma\beta))}{1+\gamma\beta}.$$

Since $b_b - h_1 < w$ then $p-(b_b-h_1)-(p+h_2)\alpha\beta > 0$, we have $\partial^2 E(\Pi_T^r)/\partial Q^2 < 0$, and therefore the retailer's expected profit function $E(\Pi_B^r)$ is concave in Q for a given β. To calculate the retailer's optimal order quantity, it is enough to check the first-order condition $\partial E(\Pi_B^r)/\partial Q = 0$, which yields Equation (6). □

Based on Theorem 2, similar to Section 3.2, we can calculate the optimal Q and β by using Algorithm 2:

Algorithm 2

Step 1. Set $\beta = 0$.
Step 2. Calculate Q with respect to the current value of β using Equation (6).
Step 3. Calculate $E(\Pi_B^r)$ using Equation (5) for the current Q and β.
Step 4. Until $\beta = 1$, $\beta = \beta + \varepsilon$, go to Step 2.
Step 5. A combination of Q and β that returns the maximum $E(\Pi_B^r)$ is optimal under the buyback contract model from the retailer's perspective; i.e., Q_B^r and β_B^r.

Notice that Theorem 2 guarantees the optimal values of Q_B^r and β_B^r can be determined by using Algorithm 2. The supplier's profit function under the buyback contract model can be expressed in the following:

$$\Pi_B^s = \begin{cases} (w_b - m)Q - (b_b - v_0)(Q-(1+\gamma\beta)x) & Q > (1+\gamma\beta)x \\ (w_b - m)Q & Q \le (1+\gamma\beta)x. \end{cases} \tag{7}$$

From (7), the expected profit function of the supplier can be derived as follows:

$$E(\Pi_B^s) = Q(w_b - m) - (b_b - v_0)\int_0^{Q/(1+\gamma\beta)} (Q-(1+\gamma\beta)x) f(x)\,dx. \tag{8}$$

The supply chain's profit function is the sum of the retailer's and the supplier's profit functions. Thus, the expected profit of the supply chain system under the buyback contract model can be derived below:

$$\begin{aligned} E(\Pi_B^{SC}) &= [p(1+\gamma\beta)-(p+h_2)(1+\gamma\beta)\alpha\beta]\int_0^{Q/(1+\gamma\beta)} x f(x)\,dx - Q[p-(p+h_2)\alpha\beta]\int_0^{Q/(1+\gamma\beta)} f(x)\,dx \\ &\quad + Q[(p-m)-(p+h_2)\alpha\beta] + (v_0-h_1)\int_0^{Q/(1+\gamma\beta)} (Q-(1+\gamma\beta)x) f(x)\,dx. \end{aligned} \tag{9}$$

We have Theorem 3.

Theorem 3. *The supply chain's expected profit under the buyback contract model is concave in Q for a given β. The optimal order quantity Q from the whole supply chain's viewpoint is*

$$Q_B^{SC} = (1+\gamma\beta)F^{-1}\left(\frac{(p-m)-\alpha\beta(p+h_2)}{p+(h_1-v_0)-\alpha\beta(p+h_2)}\right). \tag{10}$$

Proof of Theorem 3. Calculating $\partial^2 E(\Pi_B^{SC})/\partial Q^2$ results in

$$\frac{\partial^2 E(\Pi_B^{SC})}{\partial Q^2} = -(p-(v_0-h_1)-(p+h_2)\alpha\beta)\frac{f(Q/(1+\gamma\beta))}{1+\gamma\beta} < 0.$$

Therefore, the supply chain's expected profit function is concave in Q for a given β. To calculate the supply chain's optimal order quantity, it is enough to make $\partial E(\Pi_B^{SC})/\partial Q = 0$, which gives Equation (10). □

Using a similar search procedure introduced for the retailer (i.e., Algorithm 2), it is easy to find optimal solutions Q_B^{SC} and β_B^{SC} from the whole supply chain's perspective using Theorem 3.

Theorem 4. *To coordinate the supply chain with respect to the retailer's decisions Q and β under the buyback contract model, it is enough to set the coordinator parameters b_b and w_b as Equations (11) and (12), respectively,*

$$b_b = \frac{\gamma v_0 \int_0^{Q_B^{SC}/(1+\gamma\beta_B^r)} x f(x)\,dx + \alpha(p+h_2)Q_B^{SC}}{\gamma \int_0^{Q_B^{SC}/(1+\gamma\beta_B^r)} x f(x)\,dx}, \tag{11}$$

$$w_b = \frac{b_b(p-m-p\alpha\beta_B^{SC}-h_2\alpha\beta_B^{SC}) - v_0(p-p\alpha\beta_B^{SC}-\alpha\beta_B^{SC}h_2) + m(p-p\alpha\beta_B^{SC}-\alpha\beta_B^{SC}h_2+h_1)}{(p-p\alpha\beta_B^{SC}-\alpha\beta_B^{SC}h_2+h_1-v_0)}. \tag{12}$$

Proof of Theorem 4. To coordinate the supply chain system, it is necessary for the retailer under the buyback contract model to make the decisions that are also optimal for the whole supply chain. Setting $Q_B^r = Q_B^{SC}$ (using Equations (6) and (10)) and also equating $\partial E(\Pi_B^{SC})/\partial\beta = \partial E(\Pi_B^r)/\partial\beta$, we can calculate the coordinating contract parameters w_b and b_b with which the retailer's optimal decisions on Q and β will be the same as the supply chain's. □

Observe that Theorem 4 guarantees that the supply chain is coordinated, i.e., optimal; however, this solution might be inferior to the retailer (i.e., the solution is not Pareto improving) and it makes the contract inapplicable. We show the result in Corollary 1.

Corollary 1. *The retailer under the buyback contract model is not guaranteed to have a higher profit than the pure wholesale pricing contract case, i.e., it does not achieve Pareto improving coordination.*

Corollary 1 is intuitive because the retailer could be better off under the wholesale pricing contract than the buyback contract if, e.g., the unit wholesale price under the buyback contract is much higher than the one under the wholesale pricing contract. Since there is no constraint to guarantee more profitability for the retailer, a reduction of the retailer's expected profit by changing its decisions from $Q_T^r\beta_T^r$ to $Q_B^r\beta_B^r$ might happen. Under such a situation, the retailer will refuse to participate in the plan. This finding highlights the fact that the commonly seen buyback contracting in the presence of MBG programs (e.g., in Walmart) might not guarantee Pareto improving supply chain coordination and hence is not going to work well in practice. To overcome this problem, in the next section, a dual-buyback contract is proposed.

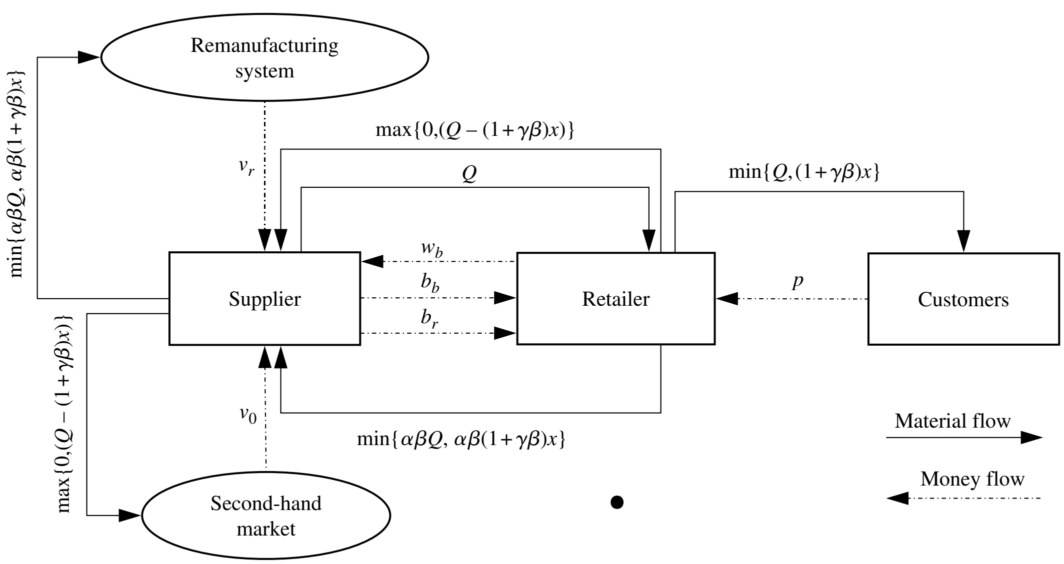
3.4. The Model with the Dual-Buyback Contracts

Under the DB contract, the supplier offers the retailer to return all the remaining unsold products and the consumer returned products at the end of selling period for buyback prices b_b and b_r, respectively. The proposed DB contract hence has three parameters (w_b, b_b, b_r). Figure 3 shows details of the proposed DB contract. Notice that the DB contract is widely seen in the publishing industry as both the consumer returned and unsold magazines at the retail places are all returned to the publishers. The unsold "new" magazines are usually kept for possible future sales (or selling in a secondary market), and the consumer returned ones are salvaged.

As shown in Figure 3, the supplier buys back both the unsold remaining products and the consumer returned products. The supplier can gain profit from selling the remaining products in a secondary market and also obtain profit from using the returned products in the remanufacturing process. The number of returned products at the end of the selling period is $\min\{\alpha\beta Q, \alpha\beta(1+\gamma\beta)x\}$. The retailer's profit function can be expressed as follows:

$$\Pi_{DB}^r = \begin{cases} (p(1+\gamma\beta)x - h_1(Q-(1+\gamma\beta)x) + b_b(Q-(1+\gamma\beta)x) - w_bQ - (p+h_2-b_r)\alpha\beta(1+\gamma\beta)x) & Q > (1+\gamma\beta)x \\ pQ - w_bQ - p\alpha\beta Q - h_2(\alpha\beta Q) + b_r(\alpha\beta Q) & Q \le (1+\gamma\beta)x, \end{cases} \quad (13)$$

Figure 3. The Dual-Buyback Contract Model That Handles Both the Unsold Remaining Products and the Consumer Returned Products



and therefore the retailer's expected profit can be derived below and we have Theorem 5:

$$E(\Pi_{DB}^r) = [p(1+\gamma\beta) - \alpha\beta(1+\gamma\beta)(p+h_2-b_r)] \int_0^{Q/(1+\gamma\beta)} x f(x)\,dx$$
$$+ (b_b - h_1) \int_0^{Q/(1+\gamma\beta)} (Q-(1+\gamma\beta)x) f(x)\,dx + Q[p - w_b - \alpha\beta(p+h_2-b_r)]$$
$$- Q[p-\alpha\beta(p+h_2-b_r)] \int_0^{Q/(1+\gamma\beta)} f(x)\,dx. \tag{14}$$

Theorem 5. *The retailer's expected profit under the dual-buyback contract is concave in Q for a given β. The retailer's optimal order quantity is*

$$Q_{DB}^r = (1+\gamma\beta) F^{-1}\left(\frac{p - w_b - \alpha\beta(p+h_2-b_r)}{p - \alpha\beta(p+h_2-b_r) - (b_b-h_1)}\right). \tag{15}$$

Proof of Theorem 5. The second-order derivative of Equation (14) with respect to Q can be found as follows:

$$\frac{\partial^2 E(\Pi_{DB}^r)}{\partial Q^2} = -(p-(b_b-h_1)-(p+h_2-b_r)\alpha\beta)\frac{f(Q/(1+\gamma\beta))}{1+\gamma\beta}.$$

Since $b_b - h_1 < w$ and $p-(b_b-h_1)-(p+h_2-b_r)\alpha\beta > 0$, we have $\partial^2 E(\Pi_{DB}^r)/\partial Q^2 < 0$ and therefore the retailer's expected profit function $E(\Pi_{DB}^r)$ is concave in Q for a given β. Checking the first-order condition leads to Equation (15). □

The following algorithm, Algorithm 3, can help find the optimal retailer's decisions under the DB contract model. Notice that Theorem 5 guarantees the optimal solution can be found by using Algorithm 3.

Algorithm 3

Step 1. Set β =0.
Step 2. Calculate Q related to the current β using Equation (15).
Step 3. Calculate $E(\Pi_{DB}^r)$ using Equation (14) for the current Q and β.
Step 4. Until $\beta = 1$, $\beta = \beta + \varepsilon$, go to step 2.
Step 5. A combination of Q and β that returns the maximum $E(\Pi_{DB}^r)$ is the optimal solution under the DB contract model from the retailer perspective; i.e., Q_{DB}^r and β_{DB}^r.

The supplier's profit function under the DB contract model is

$$\Pi_{DB}^s = \begin{cases} (Q(w_b-m) - b_b(Q-(1+\gamma\beta)x) - b_r(\alpha\beta(1+\gamma\beta)x) + v_0(Q-(1+\gamma\beta)x) + v_r(\alpha\beta(1+\gamma\beta)x)) \\ \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad Q > (1+\gamma\beta)x \\ Q(w_b-m) - b_r(\alpha\beta Q) + v_r(\alpha\beta Q) \qquad\qquad\qquad\qquad\qquad\qquad\qquad Q \le (1+\gamma\beta)x, \end{cases} \tag{16}$$

and the expected profit of the supplier is

$$E(\Pi_{DB}^s) = Q[(w_b-m) + \alpha\beta(v_r-b_r)] + (v_0-b_b)\int_0^{Q/(1+\gamma\beta)} (Q-(1+\gamma\beta)x) f(x)\,dx$$
$$+ (v_r-b_r)\alpha\beta(1+\gamma\beta)\int_0^{Q/(1+\gamma\beta)} x f(x)\,dx - \alpha\beta(v_r-b_r)Q\int_0^{Q/(1+\gamma\beta)} f(x)\,dx. \tag{17}$$

Similar to Section 3.3, the expected supply chain profit function under the DB contract model can be expressed as follows:

$$E(\Pi_{DB}^{SC}) = [p-(p+h_2-v_r)\alpha\beta](1+\gamma\beta)\int_0^{Q/(1+\gamma\beta)} x f(x)\,dx + (v_0-h_1)\int_0^{Q/(1+\gamma\beta)} (Q-(1+\gamma\beta)x) f(x)\,dx$$
$$+ Q[p+(v_r-p-h_2)(\alpha\beta)]\left[1-\int_0^{Q/(1+\gamma\beta)} f(x)\,dx\right] - mQ. \tag{18}$$

We have Theorem 6, which shows the concavity of the supply chain's expected profit under the DB contract model.

Theorem 6. *The supply chain's expected profit under the DB contract model is concave in Q for a given β. The optimal order quantity Q from the whole supply chain systems' viewpoint is*

$$Q_{DB}^{SC} = (1+\gamma\beta)F^{-1}\left(\frac{(p-m)-\alpha\beta(p+h_2-v_r)}{p-\alpha\beta(p+h_2-v_r)+(h_1-v_0)}\right). \tag{19}$$

Proof of Theorem 6. Calculating $\partial^2 E(\Pi_{DB}^{SC})/\partial Q^2$ results in

$$\frac{\partial^2 E(\Pi_{DB}^{SC})}{\partial Q^2} = -(p+(h_1-v_0)-(p+h_2-v_r)\alpha\beta)\frac{f(Q/(1+\gamma\beta))}{1+\gamma\beta} < 0.$$

Therefore, the supply chain's expected profit function is concave in Q for a given β. Equation (19) is found by checking the first-order condition. □

To identify the optimal values of quantity and market coverage decisions from the whole supply chain's perspective, i.e., Q_{DB}^{SC} and β_{DB}^{SC}, we can adopt a similar algorithm as in Algorithm 3. Theorem 7 shows the way to achieve Pareto improving coordination in the supply chain using the DB contract.

Theorem 7. *To achieve Pareto improving channel coordination using the dual-buyback contract, it is enough to set the coordinator parameters w_b and b_r as functions of b_b as Equations (20) and (21), respectively, and also satisfy (22) and (23) by adjusting b_b:*

$$\begin{aligned} w_b(b_b,b_r) = {} & [-pm-(p-m)[\alpha\beta_{DB}^{SC}(p+h_2-b_r)+(b_b-h_1)]+\alpha\beta_{DB}^{SC}(p+h_2-v_r)(b_b-h_1) \\ & +(v_0-h_1)[p-\alpha\beta_{DB}^{SC}(p+h_2-b_r)]+p\alpha\beta_{DB}^{SC}(p+h_2-b_r)] \\ & \cdot[-p+(v_0-h_1)+\alpha\beta_{DB}^{SC}(p+h_2-v_r)]^{-1}, \end{aligned} \tag{20}$$

$$b_r(b_b) = v_r + \frac{\gamma[b_b-v_0]\int_0^{Q_{DB}^{SC}/(1+\gamma\beta_{DB}^{SC})} x f(x)\,dx}{\alpha(1+2\gamma\beta_{DB}^{SC})\int_0^{Q_{DB}^{SC}/(1+\gamma\beta_{DB}^{SC})} x f(x)\,dx + Q_{DB}^{SC}\left(1-\int_0^{Q_{DB}^{SC}/(1+\gamma\beta_{DB}^{SC})} f(x)\,dx\right)}, \tag{21}$$

$$E[\Pi_T^r(Q_T^r,\beta_T^r)] \le E[\Pi_{DB}^r(Q_{DB}^{SC},\beta_{DB}^{SC},w_b,b_b,b_r), \tag{22}$$

$$E[\Pi_T^s(Q_T^r,\beta_T^r)] \le E[\Pi_{DB}^s(Q_{DB}^{SC},\beta_{DB}^{SC},w_b,b_b,b_r). \tag{23}$$

Proof of Theorem 7. To ensure that channel coordination can be achieved, the retailer's decision must be the same as the centralized decision making; therefore, by making $Q_{DB}^{SC} = Q_{DB}^r$ using Equations (15) and (19) and also setting $\partial E(\Pi_{DB}^{SC})/\partial\beta = \partial E(\Pi_{DB}^r)/\partial\beta$, we can calculate w_b and b_b using Equations (20) and (21), respectively. To convince both parties to participate in the DB contract, we have to guarantee Pareto improvement is attained, which can be done by setting the third coordinating parameter, i.e., b_b, such that both the retailer and the supplier can benefit (or at least does not lose) from the coordinated decisions, i.e., Q_{DB}^{SC}, β_{DB}^{SC} rather than decentralized uncoordinated decisions, i.e., Q_T^r, β_T^r. Therefore, we have the conditions (22) and (23). □

Notice that the maximum and minimum acceptable values for b_b such that both supply chain members have enough incentive to participate in the DB contract can be obtained from Equations (22) and (23). The minimum value of b_b can be calculated using Equation (22) such that the retailer accepts the DB contract. The maximum value of b_b can be calculated using Equation (23) with which the supplier accepts to participate in the DB contract. Thus, in real-world implementation, both members based on their relative bargaining power should agree on a feasible value for b_b, governed by (22) and (23). Based on the agreed b_b, using Equations (20) and (21) it is possible to calculate values for both w_b and b_b, which guarantee the Pareto improving coordination can be achieved in the supply chain.

In this study a linear bargaining power model is assumed to determine an acceptable solution. We define the bargaining power of the retailer with respect to the supplier as Ω, where $0 \le \Omega \le 1$; therefore the supplier's relative bargaining power will be $1-\Omega$. Based on the applied linear bargaining power model, we have $b_b = \Omega \cdot \max(b_b) + (1-\Omega)\min(b_b)$. We summarize the result in Corollary 2.

Corollary 2. *Under the DB contract model with a linear bargaining power model, Pareto improving coordination can be achieved by finding the values of $\max(b_b)$ and $\min(b_b)$ using (22) and (23), and the specific b_b is found to be $b_b = \Omega\max(b_b)+(1-\Omega)\min(b_b)$, where the retailer's bargaining power is Ω and the supplier's bargaining power is $1-\Omega$, and $0 \le \Omega \le 1$. The other contract parameters can be found by substituting the calculated b_b into (20) and (21).*

Table 1. The Three Investigated Test Problems

	Test problem 1	Test problem 2	Test problem 3
m	19	7	3.5
w	25	10	5.5
p	32	16	9.5
h_1	4	2	0.5
h_2	5	2.5	1
v_0	14	4	2
v_r	10	3	1.5
α	0.2	0.1	0.2
γ	0.8	0.7	0.7
Ω	0.5	0.5	0.5

4. Numerical Analysis

To illustrate the performance of the proposed model in achieving channel coordination, three test problems have been examined. Data sets for these three test problems are shown in Table 1 and they all satisfy the model assumptions and requirements of the problem. These numbers are also the rather general ones and we employ them to illustrate the analytical findings as well as show the applicability of the DB contract. In all the test problems, it is assumed that the demand is normally distributed with a mean of 200 and a standard deviation of 25; i.e., $x \sim \mathrm{N}(\mu = 200, \sigma = 25)$.

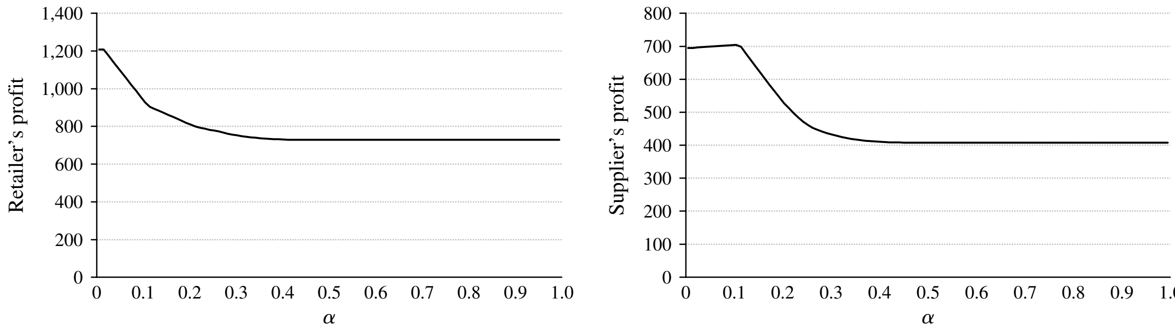
Table 2 shows the result of applying our proposed models on the three test problems. As shown in Table 2, although the buyback contract model creates more benefit for the whole supply chain than the traditional decision-making model with the pure wholesale pricing contract, it is not Pareto improving. In fact, the retailer suffers a loss. Therefore, from the application point of view, a buyback contract for remaining unsold products fails to achieve Pareto improving supply chain coordination in the presence of the MBG service program.

From Table 2, the DB contract creates more benefit for the whole supply chain than the pure wholesale pricing contract (under the traditional decision-making model) as well as for both supply chain members (i.e., the Pareto improving supply chain coordination is achieved). Comparing the pure wholesale pricing model with the DB contract model reveals that both members under the DB contract model earn more profit than

Table 2. Numerical Results in the Test Problems

	Test problem 1	Test problem 2	Test problem 3
	Traditional wholesale pricing contract		
β_T^r	0	0.840	0.190
Q_T^r	188.180	303.074	224.735
$E(\Pi_T^r)$	1,203.783	1,227.691	730.028
$E(\Pi_T^s)$	1,129.081	909.222	449.470
$E(\Pi_T^{SC})$	2,332.846	2,136.914	1,179.750
	Buyback contract		
β_B^r	0.220	1.000	0.670
Q_B^r	239.506	349.043	312.705
$E(\Pi_B^r)$	−167.040	659.812	−113.277
$E(\Pi_B^s)$	2,605.342	1,570.273	1,378.093
$E(\Pi_B^{SC})$	2,438.297	2,230.085	1,264.816
	Dual-buyback contract		
β_{DB}^r	0.530	1.000	0.900
Q_{DB}^r	287.455	350.591	345.805
$E(\Pi_{DB}^r)$	1,345.474	1,323.417	808.263
$E(\Pi_{DB}^s)$	1,270.772	1,004.948	527.453
$E(\Pi_{DB}^{SC})$	2,616.246	2,328.365	1,335.716
Min b_b	22.673	9.096	4.378
Max b_b	24.850	10.169	5.203
b_b	23.761	9.633	4.790
b_r	14.393	5.594	3.007
w_b	24.390	10.475	5.501

Figure 4. The Retailer's and the Supplier's Profitability Levels with an Increasing α



under the traditional model with the wholesale pricing contract. Thus, both members have enough incentive to participate in the DB contract.

Comparing values of decision variables Q and β under different scenarios reveals that both the proposed buyback contract related models increase the retailer's order quantity as well as the market coverage of the money-back guarantee service. However, the values of these two critical decisions under the DB contract are greater than the ones under the buyback contract. In addition, under the DB contract model, the overall profit of the supply chain is greater than that of the buyback contract. This is due to the benefit of using returned items in the remanufacturing process from the supplier's side.

To further show the performance of the DB contract under various conditions, a set of sensitivity analyses for two parameters α and γ are also conducted. Even though any data sets of our test problems can be used for sensitivity analyses, we employ the data set of test problem 3 to avoid duplication.

As shown in Figure 4, as expected, by increasing α, both the retailer's and the supplier's profits decrease to a certain level and then they will be fixed. The reason for this behavior is that increasing α beyond a threshold causes the market coverage decision β to be 0, and as a direct result, the quantity decision Q will also be fixed. In this example, β takes a value of 0 for $\alpha \geq 0.45$. According to the expected profit functions (13), (16), and (18), if $\beta = 0$ then both members' profit functions as well as the total supply chain's expected profit do not depend on α and therefore they do not vary by changing α. Figure 5 shows a similar behavior for the total supply chain's profit.

Figure 6 illustrates values of Q and β against changes in α. As shown in Figure 6, by increasing α, β takes a 0 value and Q will be fixed. Indeed, increasing α means offering the money-back guarantee service is less profitable. In this investigated example, β is equal to 1 for $\alpha \leq 0.1$ and β is equal to 0 for $\alpha \geq 0.45$.

Figures 7 and 8 show how expected profits of the retailer, the supplier, and the supply chain would vary when changing γ. As expected, increasing γ makes it more profitable for both the retailer and the supplier, as well as the whole supply chain system.

Figure 9 indicates that by increasing γ, the market coverage decision β reaches its maximum possible value, i.e., 1. According to Figure 9, if the parameter γ is smaller than a specific value (i.e., $\gamma \leq 0.31$ in this example) then the system refuses to provide a money-back guarantee service to customers, i.e., $\beta = 0$. In other words, if

Figure 5. The SC Profitability by Increasing α

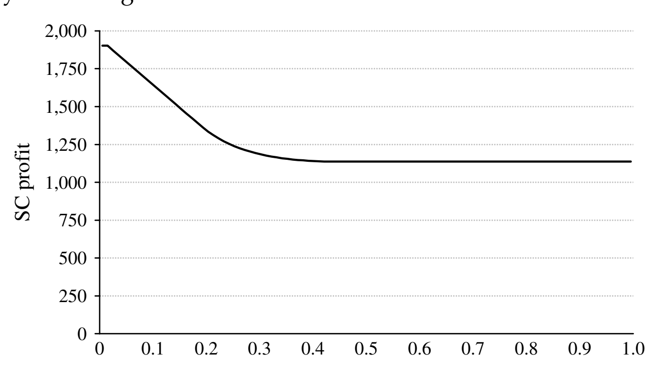


Figure 6. Changes in Q and β with an Increasing α

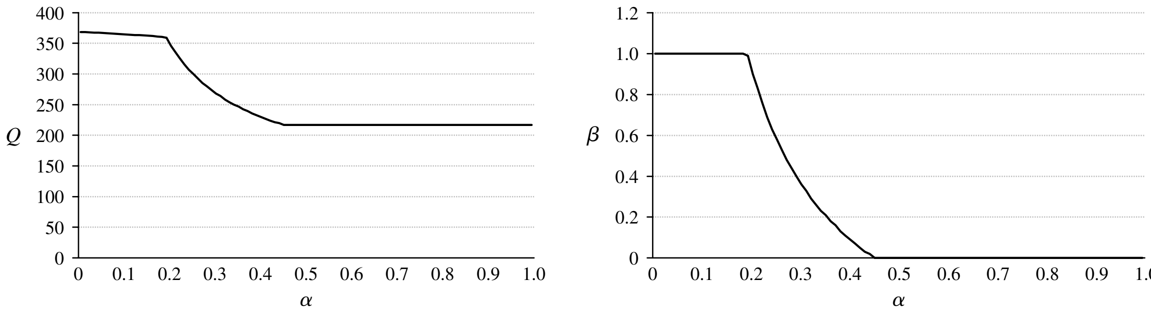


Figure 7. The Retailer's and the Supplier's Profitability Levels with an Increasing γ

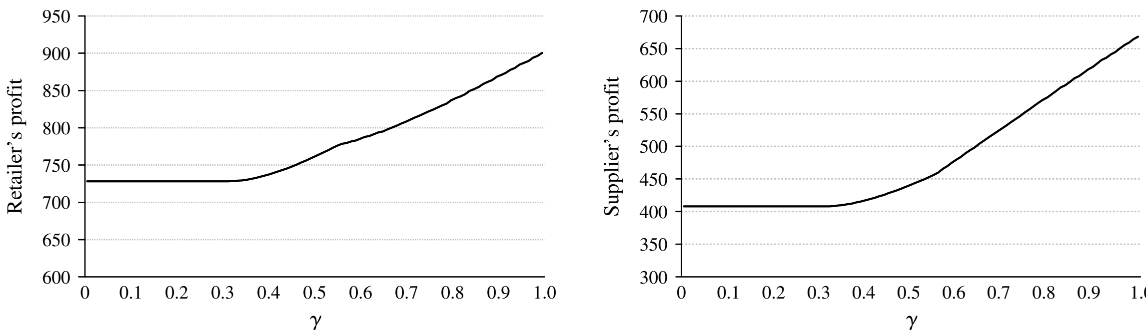


Figure 8. The SC Profitability by Increasing γ

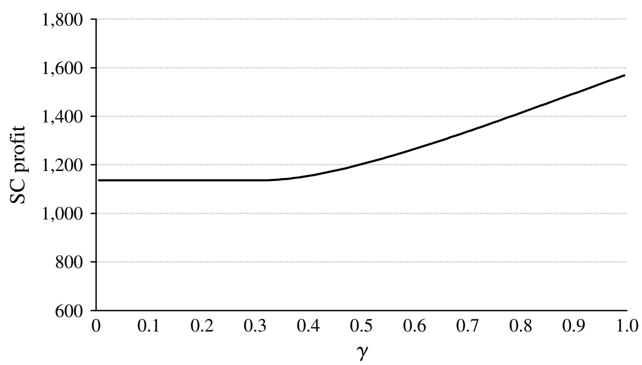
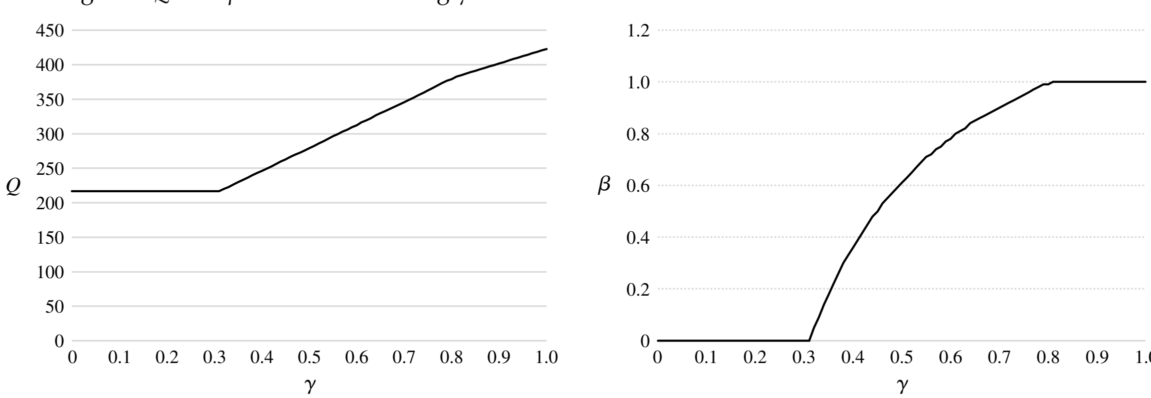


Figure 9. Changes in Q and β with an Increasing γ



the money-back elasticity is not high enough, then it is unwise to offer the money-back guarantee service to customers. On the other hand, for higher values of γ (i.e., $\gamma \geq 0.81$ in this example), it is beneficial and profitable for the supply chain to offer the money-back guarantee service to all customers.

5. Concluding Remarks

In this paper, motivated by the popular MBG service program and the importance of achieving Pareto improving supply chain coordination, we have conducted an analytical study. Our goal is to uncover whether some commonly seen contracts, such as the pure wholesale pricing contract, the buyback contract (for the unsold items), and the DB contracts can achieve Pareto improving coordination in the supply chain that offers the money-back guarantee service. We have considered the situation in which the retailer makes two decisions, namely, the order quantity and the market coverage for issuing the money-back guarantee service. The challenge behind the coordination task is the need to align incentives for these two decisions. Our analysis has revealed the fact that the pure wholesale pricing contract and the buyback contract both cannot achieve Pareto improving coordination. Thus, these two contracts are not good candidates to implement for achieving efficient supply chains in the presence of the money-back guarantee service. To overcome this challenge, we have revealed and proved that the DB contract, which is commonly seen in the industry, can help achieve Pareto improving supply chain coordination. Finally, with respect to the relative bargaining power of the retailer and the supplier, we have proposed the detailed contractual setting for the DB contract model under a linear bargaining setting.

To generate additional insights, we have conducted numerical analysis. Among various findings, it is very interesting to note that applying the DB contract can lead to an expansion of the MBG service program to cover more customers.

For future research, this work can be extended by considering specific operational rules to include/exclude a customer in the MBG service program (e.g., VIP customers versus ordinary customers). In addition, the product replacement service is an important alternative that helps protect customers from making a bold purchase. Thus, exploring the product replacement service together with the money-back guarantee service is an interesting, yet challenging, future research direction. Last but not least, some important parameters are treated as exogenous in the current model (e.g., the money-back-elasticity coefficient γ). Future research can be conducted to explore the cases when some of these parameters are endogenous.

Acknowledgments

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Endnotes

[1] In Hong Kong, the photo printing and processing company Fotomax offers two rates for photo printing, one with money-back guarantee (and a higher price) and one without (lower price).

[2] In NIKEiD, the mass customization program of Nike, only Nike's registered members but not every customer can enjoy the money-back guarantee service for free (Choi 2013).

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