

# Selling with Money-Back Guarantees: The Impact on Prices, Quantities, and Retail Profitability

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In this paper, we consider a retailer adopting a “money-back-guaranteed” (MBG) sales policy, which allows customers to return products that do not meet their expectations to the retailer for a full or partial refund. The retailer either salvages returned products or resells them as open-box items at a discount. We develop a model in which the retailer decides on the quantity to procure, the price for new products, the refund amount, as well as the price of returned products when they are sold as open-box. Our model captures important features of MBG sales including demand uncertainty, consumer valuation uncertainty, consumer returns, the sale of returned products as open-box items, and consumer choice between new and returned products and possibility of exchanges when restocking is considered. We show that selling with MBGs increases retail sales and profit. Furthermore, the second-sale opportunity created by restocking returned products enables the retailer to generate additional revenues. Our analysis identifies the ideal conditions under which this practice is most beneficial to the retailer. Offering an MBG without restocking increases the new product price. We show that if the retailer decides to resell the returned items as open-box, the price of the new product further increases, while open-box items are sold at a discount. On the other hand, customers enjoy more generous refunds along with lower restocking fees. The opportunity to resell returned products also generally decreases the initial stocking levels of the retailer. Our extensive numerical study substantiates the analytical results and sharpens our insights into the drivers of performance of MBG policies and their impact on retail decisions.

*Key words:* money-back guarantees; consumer returns; open-box sales; pricing; ordering

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## 1. Introduction

Retail industry is one of the largest sectors in the global economy, and the second largest sector in the United States. The insatiable demand by consumers for new technologies and innovations introduced to the market and the ensuing *must-have* products, amplified by the constant search for lower prices and extra services, have fueled competition among retailers. To improve customer satisfaction and boost the level of sales in this hyper-competitive environment, retailers are increasingly offering extra services (e.g., warranty plans, free shipping), as well as guarantees. Selling with “money-back guarantee” (MBG) is a prime example of such guarantees.

Under an MBG, the retailer allows customers to return products that do not meet their expectations—as a result of poor quality or a mismatch in taste—to the retailer for a full or partial refund. In effect, the retailer offers the customer an

insurance against potential dissatisfaction with the product. In return, the retailer prevents her store from being associated with product dissatisfaction. According to a survey by Schmidt and Kernan (1985), 98.4% of consumer respondents feel that they are satisfied with their purchase experience if the seller offers money-back on an unsatisfactory product. Clearly, this type of guarantee is particularly important for products sold over the Internet or through mail-order catalogs, where customers cannot enjoy the benefits of the traditional *touch-and-feel* shopping experience; hence, their ability to assess the quality of products is diminished considerably. In consequence, the likelihood of customers ending up with products that they simply do not like is enhanced (Tedeschi 2001). Needless to say, this mismatch is not limited to online channels or catalog sales. As retail industry grows with product proliferation, the number of customers who are dissatisfied with their purchases inevitably increases.

Retailers offering MBGs have to come to grips with the management of customer returns, which is especially problematic for products that have relatively short selling seasons and fast rates of obsolescence (i.e., short lifecycle products, fashion goods). It is known that the value of customer returns exceeds \$100 billion annually in the United States alone (Stock et al. 2002). The return rates vary significantly by category and by channel type, reaching 35% for high fashion apparel sold in traditional stores, and are typically higher for Internet and catalog sales (Guide et al. 2006). Interestingly, in most cases, the returned products are not defective. In a comprehensive survey, Sprague, Steger, and Douthit (2008) report that in the computer electronics industry where returns range from 11% to 20%, most customers returned their products because they “did not meet expectations.” More specifically, for 68% of returns, there was “no trouble found” by the customers; 27% of the products were returned due to “buyer’s remorse”; only 5% of the products returned were truly defective. However, regardless of the reason, returned products cannot be deemed sellable as “new,” even though the product could be *new* in the sense that it was never used. Major consumer electronics retailers such as Best Buy and e-tailers such as J-and-R, Newegg, etc., *restock* these returned items and sell them as *open-box* items at discounted prices.

Retailers can influence the amount of returns by limiting the amount of refund given. Although full refunds are still existent in practice, many retailers choose to charge “restocking fees” on returns to dissuade customers from returning products. According to a 2005 survey conducted by New York City’s Office of the Public Advocate, 44% of the retail stores charged restocking fees on returns (<http://pubadvocate.nyc.gov/news/restockingfees.html>). In most instances, restocking fees ranged between 10% and 20% of the original purchase price, while some could be as high as 30%. Similarly, for consumer electronics, Wal-Mart does not impose restocking fees, while other retailers like Best Buy, Amazon.com, and Target charge 15% for products like laptops and digital cameras (Grant 2006).

The above discussion highlights some of the economic implications of selling with MBGs. By providing some protection against possible misfit of the product with customer expectations, MBGs have the potential to increase sales. On the other hand, the retailer has to manage the returned products from dissatisfied customers along with its new product inventory. This activity has both cost and revenue implications. On the revenue side, the ability of the retailer to sell returned products as open-box items creates an opportunity to attract more price-conscious consumers and effectively pursue product

differentiation. For products facing uncertain demand over a short selling season and limited supply, open-box products can also aid in capturing some of the late demand, which would normally be lost. The downside of pursuing product differentiation is that open-box items can cannibalize part of new product demand. In addition, the retailer has to incur the costs associated with handling returns and repackaging them as open-box. Balancing the benefits and costs of returns induced by MBGs is a delicate task. The retailer needs to carefully select the prices of new and open-box products while simultaneously adjusting the restocking fees to encourage or discourage returns. These decisions have immediate operational consequences, in particular on stocking (order quantities). On one hand, product differentiation is likely to increase demand, which provides an incentive for the seller to increase the amount ordered from the supplier. On the other hand, some of this demand is for open-box items, which have already been previously purchased and returned. The opportunity to sell the same product twice provides an incentive for the seller to limit the amount ordered. These effects are even more pronounced in an uncertain demand environment. The motivation for this study stems from the need to analyze these pricing and ordering decisions and their joint impact on retail profitability in the context of MBGs.

We model the salient characteristics of MBG policies for a retailer who sells a short lifecycle product over a short selling season. Demand for the product over the selling season is uncertain, and the retailer has a single supply opportunity before the season starts.<sup>1</sup> We utilize a stochastic fluid model to capture the dynamics of customer arrivals during the selling season. Our optimization model maximizes the retailer’s expected profit by choosing the initial quantity to procure from her supplier, the selling prices, and the refund amount. A distinct feature of our model is the customer returns and the sale of these products as open-box items along with new products within the same selling season. For expositional clarity, we assume that returns can be repackaged and resold as open-box at no extra cost.<sup>2</sup> We also allow dissatisfied customers to exchange their product with an open-box one. Customers face uncertainty in their own valuations for both the new and open-box products, and make their decisions based on the prices and the refund (i.e., restocking fee). We investigate both the homogeneous case where customers have identical (uncertain) valuation and the heterogeneous case where the market consists of a mix of high and low valuation customers. To quantify the profit impact of offering an MBG and the incremental value of restocking and open-box sales, we also study the

scenarios where the retailer offers an MBG, but does not restock returned products and the case without MBGs. We compare the optimal decisions and profits in an extensive numerical study.

Our study confirms that MBG sales can be a significant profit-enhancing mechanism. A retailer can benefit from MBGs even if she does not restock returns, provided market demand is uncertain and customers face uncertainty in their ex-ante valuations. In this regard, our results provide support for the common practice of offering MBGs for the product categories that motivate this study (e.g., consumer electronics, catalog sales). When the aforementioned risks are more pronounced, the retailer can further improve her profits by reselling the returned products as open-box items at discounted prices. Evidence from our extensive numerical study suggests that the incremental profit gains from this product differentiation strategy (and resulting segmentation) can even exceed that of offering refunds alone. We also show how other market characteristics (such as customer heterogeneity) influence retailer profits and decisions. The insurance provided to the customers against potential dissatisfaction enables the retailer to command a higher price. When returned products are sold as open-box, the new product price increases along with the refund offered to customers. Essentially, customers are charged higher prices for new products but are also offered more generous return policies. The second-sale opportunity created by restocking returns typically reduces the retailer's initial stocking quantity and reduces her leftover inventory risk, although changes in prices and margins can also create scenarios where an increase is optimal.

## 2. Overview of Related Literature

MBG policies have been widely studied in the marketing and economics literature. Mann and Wissink (1988, 1990) state that an MBG acts as a risk-reducing mechanism for customers and provides a better match between customers' needs and product quality. Actually, an MBG can be an indicator of product quality, along with price and advertising, when customers cannot make an assessment prior to purchase (Moorthy and Srinivasan 1995). The more recent literature focuses on pricing and revenue aspects of MBG policies. Davis et al. (1995) show that MBGs can increase a seller's profits even with full refunds if the seller can extract a higher salvage value from the returned product (e.g., by eliciting a refund from the supplier) than can the customer. They claim that a seller offering an MBG can charge higher prices, because consumers are willing to pay a premium to mitigate the risk of a mismatch between their tastes and the products. Fruchter and Gerstner (1999) also

find that MBG policy results in higher prices both in a monopolistic and in a competitive market. Clearly, MBGs can be abused by opportunistic consumers who make good use of the products before returning them, even if they are satisfied—this is referred to as *free riding* or *moral hazard*. Davis et al. (1998) and Chu et al. (1998) argue that such behavior can be discouraged by providing *partial* refunds (by charging restocking/handling fees). Our paper augments this stream by specifically modeling the restocking of returned products, which also brings out the interaction between new and open-box prices. We show that restocking returns provides further incentives to the seller to increase the price of the new products. We also investigate the operational implications of this product differentiation opportunity, particularly on the optimal ordering quantity, in an uncertain demand environment.

In the context of *services* (which cannot be inventoried), Xie and Gerstner (2007) state that, in comparison with a no-refunds policy, refunds for service cancellations can be profitable without recourse to higher prices. This contrasts with earlier results on the implications of MBG policies for *product* returns. The authors claim that the profit improvement with MBG is fundamentally a consequence of the opportunity to sell the same service capacity more than once, rather than the premium charged for the refund policy (mainly due to the absence of moral hazard in the services context). Restocking returned products and offering them as open-box items is the product context analog of selling the same item more than once. While this results in a reduced *second* sale price (i.e., open-box price), the *primary* sale price (i.e., new product price) is increased in response.

There has been recent interest on consumer returns within the operations management (OM) literature. This literature recognizes consumers' uncertainty in product valuation prior to purchase and the role of refunds in mitigating these risks. Shulman et al. (2009) study pricing and restocking decisions of a seller offering two differentiated products. Market size is deterministic, but customers face uncertainty in terms of product fit and how much they are willing to pay. The seller has the option to provide information to customers to eliminate product misfit and hence returns. The authors identify conditions when the provision of this information is optimal for the seller. Shulman et al. (2011) extend this model to an environment with two competing retailers offering horizontally differentiated products and show that restocking fees in a duopoly can potentially be higher than what would have been in a monopolistic setting. Shulman et al. (2010) investigate the impact of reverse channel structure on the return policy and profits. They find that even if the retailer can obtain a higher

salvage value for returned products than the manufacturer could, it is possible for the retailer to charge a higher restocking fee when salvaging returned units than if the salvaging were done by the manufacturer. Su (2009) assumes an uncertain market size with customers facing uncertain valuations, and examines the impact of refund policies on supply chain performance and proposes coordination mechanisms. As in Su (2009), we assume aggregate demand uncertainty as well as customer valuation uncertainty. We complement the OM literature on consumer returns by introducing the option of restocking returned items and selling them as open-box items. This opens the opportunity for the seller to pursue a product differentiation strategy, a motivation for offering return policies not addressed in this stream.

Product returns are a central feature of closed-loop supply chain literature. Many papers in this stream investigate policies for managing inventories when there are customer returns (e.g., DeCroix and Zipkin 2005, DeCroix et al. 2005, Fleischmann et al. 2002, Kiesmüller and van der Laan 2001). These returned products are either remanufactured and sold as new, or disassembled into components which are then reused. Pricing decisions are not considered in these studies. Ferrer and Swaminathan (2006) model a manufacturer producing and selling both new and remanufactured products in a multi-period setting. Assuming remanufactured products are indistinguishable from new ones, they derive the optimal prices in monopoly and duopoly settings. Other papers consider segmented markets for new and remanufactured products (e.g., Debo et al. 2005, Ferguson and Toktay 2006). While pricing decisions are taken into account, these papers mostly treat the manufacturer's strategic decisions such as technology choice and recovery strategy in a competitive setting. A key aspect of the above papers is that the rate of product returns is taken as an exogenous parameter, typically a known fraction of past sales. In contrast, one of the defining elements of our paper is the fact that the firm can influence returns from consumers by controlling prices and restocking fees.

### 3. Model Description

We consider a retailer selling a single product under an MBG to price-sensitive customers over a single selling season starting at time 0 and ending at time  $T$ .<sup>3</sup> Before demand is realized, the retailer purchases an initial stock of  $q$  units from her supplier at unit cost  $c$  to sell during the season. We assume that the market consists of infinitesimal customers with individual, uncertain valuations for the product. Customers arrive continuously over time during the selling season, following a general stochastic fluid model. This

particular modeling choice is motivated by the work of Honhon et al. (2010), where it is shown (in the context of an assortment planning problem) that such a model is a very good approximation of a scenario where customers arrive stochastically at discrete epochs. It is also a natural choice to model the dynamics of customer arrivals for a short lifecycle product in a realistic and tractable manner. According to this construct, for any two time points  $t_1$  and  $t_2$  such that  $0 \leq t_1 < t_2 \leq T$ , the demand between time  $t_1$  and  $t_2$  is denoted by  $D_{[t_1, t_2]}$ . Minimum assumptions are placed on the demand process other than that  $D_{[t_1, t_2]}$  is stochastic and continuous. The total demand in the selling horizon is given by  $D_{[0, T]} \equiv D$ , which is a random variable on  $[0, \infty)$  with cumulative distribution  $G(\cdot)$  and density function  $g(\cdot)$ . The complement of  $G$  is denoted as  $\bar{G}$ . Consumers are rational decision makers; they make their purchase decisions as well as keep/return decisions to maximize their individual utility (details provided shortly). Any unsold product, new or returned, is salvaged at a price  $s$  per unit, with the usual assumption that  $s < c$ .

In this context, we distinguish two types of MBG policies.

Money-back guarantee with restocking (MBG-R). Customers are allowed to return products that do not meet their expectations back to the retailer for a refund. The retailer restocks these returned products and offers them to customers as open-box products. Consequently, customers have a choice between new and open-box items (provided inventories are positive). We also allow dissatisfied customers exchange for an open-box product (i.e., return the new product and buy an open-box item instead). Customers who cannot purchase the new product (due to unavailability) will consider the open-box product.

Money-back guarantee without restocking (MBG-NR). Customers are allowed to return products to the retailer as in the case of the MBG-R policy. However, the retailer does *not* restock the returns and instead salvages them at the end of the selling season. Therefore, there are no open-box sales; the retailer offers only new products to her customers.

To assess the effectiveness of these two MBG policies, we also consider the case where the retailer does not offer any guarantee. We call this benchmark policy **no money-back guarantee (NMBG)**. Under NMBG, the retailer carries only new products throughout the selling season.

We assume for simplicity that all returns are non-defective and can be resold as open-box products; a positive fraction of defective returns can be easily incorporated without changing the nature of our results. Likewise, we assume that the cost of repackaging returned products is negligible. Note that the retailer can control the amount of returns by

appropriately determining the *refund* amount,  $r$  per unit, to be given for each return. This equivalently implies a *restocking fee* charged on the original price paid by the customer.<sup>4</sup> We assume that all open-box sales are final; there is no refund offered for open-box items. This is most often the case in practice. For example, Newegg.com, one of the largest e-tailers offering open-box specials, explicitly states that it offers no MBG for open-box sales. Most other sellers also claim to have rather restricted returns policies, accepting returns only if the sold items are defective.

We use  $V$  to denote a customer’s valuation for a unit of the new product. *A priori*, the valuation  $V$  is unknown to the customer. Let  $F(\cdot)$  with support  $[0, \infty)$  denote the cumulative distribution of  $V$  and  $f(\cdot)$  denote its density (which are known to the customers). Let  $\bar{F} = 1 - F$ . The mean of  $V$  is  $EV = \mu$ . Customers value open-box products as inferior; a customer who has valuation  $v$  for a new product, values the open-box product as  $\beta v$ , where  $0 \leq \beta \leq 1$  is the *valuation discount factor*. To avoid triviality, we assume  $\beta\mu > s$ ; otherwise, the retailer is better off salvaging all returned items rather than attempting to sell them as open-box.

The sequence of events are as follows:

1. At time 0, the retailer decides on the initial stock  $q$ , the price of the new product  $p_n$ , the refund amount  $r$  (hence the restocking fee  $1 - r/p_n$ ), and depending on the MBG policy, the price of the open-box item  $p_o$ , to maximize her expected profit.
2. Random customer demand starts to realize. Each arriving customer makes a purchase decision (buy or not) and an appropriate product choice (new vs. open-box).
3. Customers realize their true valuations of the product. For simplicity, we assume that consumers learn their valuations right after purchasing the product. If a customer has purchased a new product, he/she decides to keep the product, return it for a refund, or exchange with an open-box item. We assume that exchanges happen first, and only the remaining open-box items are served to new customers.
4. All unsold products are salvaged at the end of the selling period, at time  $T$ .

Note that under our demand model, consumer returns start early on in the season (as soon as new product sales start). This is quite realistic, especially for short lifecycle products. Hence open-box items are offered side by side with new products for (almost) the entire selling season. In this regard, retailer setting the open-box price at time 0 is tantamount to assuming an identical price for open-box items, independent of the available inventory. We discuss the implica-

tions of (dynamic) pricing of open-box item contingent on inventory later on in our analysis.

Next, we provide the details of the consumer choice process. Consider the MBG-R policy. As noted earlier, customers are utility maximizers, and accordingly they make their purchase decisions based on the prices  $(p_n, p_o)$  and the refund  $r$  to maximize expected surplus. Customers do not anticipate inventory availability as they make these choices though (i.e., they do *not* behave strategically). Let  $EU_n$  and  $EU_o$  denote the expected customer surplus from buying a new and an open-box item respectively. Suppose that a customer has decided to purchase a new product. Based on the realized valuation  $v$  for the product, the customer surplus for keeping, returning for refund, and exchanging will be  $v - p_n$ ,  $r - p_n$ , and  $r - p_n + \beta v - p_o$ , respectively. The customer will choose the option that maximizes the surplus. Figure 1 illustrates the resulting decisions. Note that if  $p_o \geq \beta r$ , exchanges will never occur. Observe also that if a customer exchanges his/her product, the net inventory of open-box item does not change.<sup>5</sup>

Consequently, the customer’s expected surplus from buying a new product is

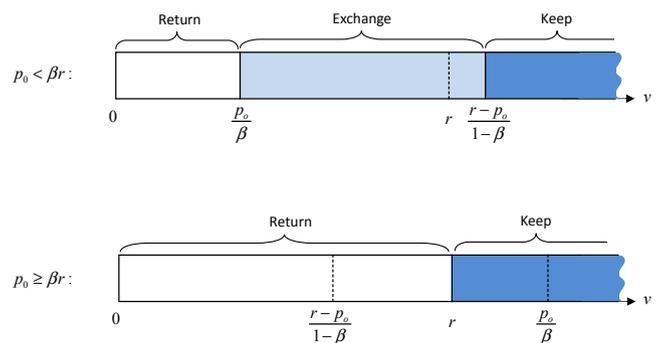
$$EU_n = E \max\{V, r, r + \beta V - p_o\} - p_n. \quad (1)$$

For open-box products the sales are final, so a customer receives an expected surplus of

$$EU_o = \beta\mu - p_o. \quad (2)$$

A customer decides to buy a new product if  $EU_n \geq EU_o$  and  $EU_n \geq 0$  and an open-box product if  $EU_o \geq EU_n$  and  $EU_o \geq 0$ . Note that we have not taken product availability into account yet. The retailer’s sales quantity depends not only on the consumer choices as prescribed above, but also on the amount of inventory available for both products. We deliberate more on this interaction in the subsequent section. As a final remark, note that when the retailer does not restock returns (i.e., under MBG-NR policy),

Figure 1 Consumer Decisions when Exchange Is Allowed



the customer decides to buy a new product if the expected surplus  $EU_n = E \max\{V, r\} - p_n \geq 0$ . Similarly, under NMBG policy, there is no refund offered; hence the customer purchasing decision boils down to  $EU_n = \mu - p_n \geq 0$ .

In the following section, we build on the above characterization of customer choice and purchase behavior and analyze the retailer's optimal decisions and profits under different MBG policies. Our basic framework assumes a homogenous customer population in which customer valuations  $V$  are identically and independently drawn from the distribution  $G(\cdot)$  (as in Su 2009). We discuss an extension to the heterogeneous case in section 5.

### 4. Analysis

In this section, we characterize the optimal prices, ordering quantities, and profits for the three MBG policies under the stochastic fluid model described before when customers have homogenous but uncertain valuations for the product. We first briefly cover cases with no guarantee (NMBG) and MBG with no restocking (MBG-NR). We then proceed with the study of the main scenario with restocking (MBG-R).

#### 4.1. Selling with No Money-Back Guarantee: NMBG Policy

Under the NMBG policy, a customer decides to purchase if  $EU_n = \mu - p_n \geq 0$ . Hence, the maximum price customers are willing to pay is  $\mu$ . Consequently, the retailer's optimal price for the new product is  $p_n^{*N} = \mu$ . For a meaningful problem, we require  $\mu > c$ ; otherwise, the retailer cannot make any positive profit. Given the optimal price, the retailer faces a standard newsvendor problem of determining the optimal order quantity to serve the total market demand  $D_{[0,T]} = D$ . Defining  $x^+ = \max\{x, 0\}$ , the retailer's expected profit is given as

$$\Pi^N(q) = \mu E \min\{D, q\} + sE(q - D)^+ - cq, \quad (3)$$

and is maximized at the critical fractile ordering quantity  $q^{*N}$  satisfying  $\bar{G}(q^{*N}) = (c - s)/(\mu - s)$ . The resulting optimal expected profit is  $\Pi^{*N} = \Pi^N(q^{*N})$ .

#### 4.2. Money-Back Guaranteed Sales with No Restocking: MBG-NR Policy

Under the MBG-NR policy, the retailer offers customers the option to return and obtain a refund  $r$  if they are not satisfied with the product. These returns are salvaged along with all unsold items at the end of the selling period. This is the partial refund model considered in Su (2009). Noting that the customer

demand is  $D$  only if  $E \max\{V, r\} \geq p_n$ , the retailer's expected profit can be expressed as

$$\begin{aligned} \Pi^{NR}(p_n, r, q) = & \underbrace{p_n E \min\{q, D\}}_{\text{sold}} \\ & - \underbrace{(r - s)F(r)E \min\{q, D\}}_{\text{returned}} + \underbrace{sE[q - D]^+}_{\text{unsold}} - cq. \end{aligned} \quad (4)$$

The first term in Equation (4) is the revenues from initial sales. A fraction  $F(r)$  of these customers is not satisfied with the product and thus return their purchases for a refund. The retailer pays a refund amount of  $r$  for each return and salvages it at price  $s$ . The second term accounts for the net impact of the customer returns. The third term reflects the salvage value obtained from unsold products while the last term is the procurement cost. The retailer's profit maximization problem becomes

$$\Pi^{*NR} = \max_{p_n \geq r \geq 0, q \geq 0} \Pi^{NR}(p_n, r, q).$$

PROPOSITION 1 (Su 2009). Under MBG-NR policy, the optimal price  $p_n^{*NR}$ , refund  $r^{*NR}$ , order quantity  $q^{*NR}$ , and the resulting optimal profit  $\Pi^{*NR}$  are given as

$$p_n^{*NR} = E \max\{V, s\}, \quad (5)$$

$$r^{*NR} = s, \quad (6)$$

$$\bar{G}(q^{*NR}) = \frac{c - s}{p_n^{*NR} - s} = \frac{c - s}{E \max\{V, s\} - s}, \quad (7)$$

$$\Pi^{*NR} = \Pi^{NR}(p_n^{*NR}, r^{*NR}, q^{*NR}). \quad (8)$$

Clearly, it is always better for the retailer to offer refunds. This follows because without refunds (i.e.,  $r = 0$ ) MBG-NR policy is identical to NMBG policy. Proposition 1 also establishes that the existence of a refund increases the price of the product. This result, which is in line with earlier literature, confirms that the insurance provided to the consumer against a possible misfit allows the charge of a premium when customers are utility maximizers. It is also easy to see that despite higher prices and lack of ability to resell the returned items, the retailer orders more.

#### 4.3. Money-Back Guaranteed Sales with Restocking: MBG-R Policy

Under MBG-R policy, the retailer resells returned products at a discount price. As customers are homogenous with respect to their valuations (and value new items higher than open-box ones) and the salvage value of unsold and returned items are the same, without loss of optimality, it can be assumed that the retailer will select prices  $p_n$  and  $p_o$  such that

all customers prefer to buy new products. In other words, there is no economic incentive for the retailer to (price-wise) undersell the product and profit from open-box sales only in the case of shortages or for exchanges. Elaborating further on the exchange option, we have the following result. We remark that proofs of all propositions and technical results are presented in the appendix in the online Supporting Information.

**PROPOSITION 2.** *At optimality, exchanges will not occur under MBG-R policy.*

From a practical perspective, it is quite unlikely that a customer who is not satisfied with a new product will return it to exchange for a lower priced open-box product. From a theoretical standpoint, however, such an option does exist, provided that open-box items are priced low enough. Proposition 2 establishes the fact that it does not make economic sense for the retailer to cut the price of the open-box to such levels. The retailer will always set  $p_o \geq \beta r$  such that open-box items are only reserved for customers who cannot buy the new product due to unavailability.

The retailer's expected profit under MBG-R policy is more involved than that of MBG-NR or NMBG policies, even when exchanges do not occur. To this end, suppose  $p_o \geq \beta r$ , and let  $\tau = \max\{t \leq T : D_{[0,t]} \leq q\}$  be the time new items are depleted in the selling season (or the season ends).<sup>6</sup> Clearly, if  $\tau < T$ , then the retailer runs out of stock of new items before the end of the season. If  $\tau = T$ , there is still some leftover inventory of new products at the end of the season. In either case, the sales of new items are given as  $D_{[0,\tau]}$ . A fraction  $F(r)$  of these customers will have *ex post* valuation lower than the refund amount  $r$  and decide to return the product and collect their refund. Sales of open-box items only start at time  $\tau$  and are limited by the amount of returned new products, that is,  $\min\{F(r)D_{[0,\tau]}, D_{(\tau,T)}\}$ . The number of salvaged new and open-box items is simply the remaining inventory of new and open-box items at the end of the season, which is given as  $q - D_{[0,\tau]} + F(r)D_{[0,\tau]} - \min\{F(r)D_{[0,\tau]}, D_{(\tau,T)}\}$ . To avoid triviality, we assume  $\beta\mu > s$ ; otherwise, the retailer is better off salvaging all returned items rather than attempting to sell them as open-box. With slight abuse of notation, the retailer's profit can then be expressed as

$$\begin{aligned} \Pi^R(p_n, p_r, r, q, D) &= p_n D_{[0,\tau]} - rF(r)D_{[0,\tau]} + p_o \min\{F(r)D_{[0,\tau]}, D_{(\tau,T)}\} \\ &\quad + s(q - D_{[0,\tau]} + F(r)D_{[0,\tau]} - \min\{F(r)D_{[0,\tau]}, D_{(\tau,T)}\}) \\ &\quad - cq. \end{aligned}$$

Observe that if  $\tau < T$ ,  $D_{[0,\tau]} = q$  and  $D_{[0,T]} > q$ ; on the other hand, if  $\tau = T$ ,  $D_{[0,\tau]} = D_{[0,T]} \leq q$ . In other words,  $D_{[0,\tau]} = \min\{D_{[0,T]}, q\}$ . Also note that  $D_{(\tau,T)} = D_{[0,T]} - D_{[0,\tau]}$ . Substituting these two terms, we can write the retailer's profit function more explicitly as

$$\begin{aligned} \Pi^R(p_n, p_r, r, q, D) &= p_n \min\{D_{[0,T]}, q\} - rF(r)E \min\{D_{[0,T]}, q\} \\ &\quad + p_o \min\{(D_{[0,T]} - q)^+, F(r) \min\{D_{[0,T]}, q\}\} \\ &\quad + s \left[ (q - D_{[0,T]})^+ + (F(r) \min\{D_{[0,T]}, q\} \right. \\ &\quad \left. - (D_{[0,T]} - q)^+ \right] - cq. \end{aligned}$$

Using the notation  $D_{[0,T]} \equiv D$  and taking expectations with respect to  $D$ , the retailer's expected profit under MBG-R policy becomes

$$\begin{aligned} \Pi^R(p_n, p_o, r, q) &= \underbrace{p_n E \min\{D, q\}}_{\text{new product sales}} - \underbrace{rF(r)E \min\{D, q\}}_{\text{returns}} \\ &\quad + \underbrace{p_o E \min\{(D - q)^+, F(r) \min\{D, q\}\}}_{\text{open-box sales}} \\ &\quad + sE \left[ \underbrace{(q - D)^+ + (F(r) \min\{D, q\} - (D - q)^+)^+}_{\text{unsold}} \right] - cq. \end{aligned} \quad (9)$$

To summarize, in Equation (9), the terms on the right-hand side represent the revenue from new product sales, refund for returns, revenue from open-box sales, salvage value from unsold new or open-box items, and ordering cost, respectively. Note that the retailer's expected profit  $\Pi^R(p_n, p_o, r, q)$  in Equation (9) reduces to the profit function in (4) when  $p_o = s$ , leading to the immediate insight that the retailer is always better off with a second opportunity to sell returned products, provided that she can still extract a premium over the salvage value. Naturally, this flexibility has impact on prices, refund levels, as well as the initial stocking quantity. The retailer determines her optimal course of action by solving the profit maximization problem

$$\Pi^{*R} = \max_{p_n \geq r \geq 0, p_n \geq p_o \geq \beta r, r \leq \mu, q \geq 0} \Pi^R(p_n, p_o, r, q).$$

**PROPOSITION 3.** *Under MBG-R policy, the optimal new product price  $p_n^{*R}$  and open-box price  $p_o^{*R}$  and the resulting optimal profit  $\Pi^{*R}$  are given as*

$$p_n^{*R} = E \max\{V, r^{*R}\}, \quad (10)$$

$$p_o^{*R} = \beta\mu, \tag{11}$$

while the optimal refund  $r^{*R}$  and order quantity  $q^{*R}$  should satisfy

$$q^{*R}(\beta\mu - s)\overline{G}((1 + F(r^{*R}))q^{*R}) - (r^{*R} - s)\mathbf{E} \min\{D, q^{*R}\} - \lambda^* = 0, \tag{12}$$

$$\begin{aligned} &[\mathbf{E} \max\{V, r^{*R}\} - (r^{*R} - s)F(r^{*R}) - \beta\mu]\overline{G}(q^{*R}) \\ &+ (\beta\mu - s)(1 + F(r^{*R}))\overline{G}((1 + F(r^{*R}))q^{*R}) \\ &- (c - s) = 0, \end{aligned} \tag{13}$$

$$\lambda^* \geq 0, \tag{14}$$

$$\lambda^* = 0 \text{ or } r^{*R} < \mu, \tag{15}$$

resulting in optimal expected profit  $\Pi^{*R} = \Pi^R(p_n^{*R}, p_o^{*R}, r^{*R}, q^{*R})$ .

Proposition 3 establishes the retailer’s optimal decisions and profit. Clearly, as in the case of no restocking, the optimal prices are set high enough to extract customer’s expected surplus entirely. In this case, this is done for both new and open-box items, which are sold at a discounted price. Observe also that the retailer’s optimal refund (and restocking fee) and initial stocking quantity decisions are more involved, requiring the simultaneous solution to two equations. Elaborating more on the optimal decisions, we can make inferences on the impact of restocking returned products.

**COROLLARY 1.** *Restocking returned products and selling them as open-box increase the refund offered for returns; that is,  $r^{*R} > r^{*NR}$ . The new product’s selling price also increases; that is,  $p_n^{*R} > p_n^{*NR}$ . The initial stocking quantity, however, can increase or decrease.*

Corollary 1 highlights that a retailer who resells her returns to lower paying customers should offer more generous return policies. The increased number of items that are available for resale constitutes a second profit-making opportunity for the retailer. Given the generous refund, the retailer is also able to command a higher margin on the new product price. The impact of restocking returned products on the initial stocking quantity is more intricate and involves the net effect of two oppositely directed factors. As restocking provides an additional selling opportunity for the retailer, intuitively, one would anticipate the initial stocking quantity to decrease. On the other hand, under the more generous returns policy with MBG-R, the retailer would potentially face a larger customer demand and would be inclined to stock more. In essence, the higher refund level and product prices alter the retailer’s overage and underage costs in a

way such that the initial quantity ordered can increase or decrease. To illustrate this, we provide three examples in Table 1. In these examples,  $\beta = 0.8$  and market size and customer valuation distributions are both Uniform(0,1). The three examples differ in terms of unit procurement cost and salvage value; in the first example  $c = 0.3$  and  $s = 0.1$ , in the second example  $c = 0.4$  and  $s = 0.1$ , and in the third example  $c = 0.4$  and  $s = 0.3$ . As shown in the table, compared with the case without restocking, the initial stocking quantity decreases for the first and third examples ( $q^{*R} < q^{*NR}$ ), but increases in the second example ( $q^{*R} > q^{*NR}$ ). Clearly, compared with the second example, the first and third examples involve smaller inventory risk due to lower procurement cost and higher salvage values. Hence, in both examples, one would expect the retailer to keep a larger initial stock (under both MBG-NR and MBG-R) as also seen in the table. Also note that the scale of reduction in the initial stocking quantity that can be achieved by reselling returned products is naturally proportionate to the size of the initial stock. Therefore, when the initial inventory is relatively small, as in the second example, the savings in initial stock due to reselling are rather limited, whereas the additional stock required to meet the increased customer demand under MBG-R is more significant, which in turn leads to an overall increase in the retailer’s initial stock.

Next, we investigate the effects of demand uncertainty. A fundamental question is whether demand uncertainty and consequent supply–demand mismatches create extra incentives for the retailer to offer MBG with restocking.

**PROPOSITION 4.** *Suppose that the retailer faces no uncertainty in demand. Then the retailer would decide to restock returns and sell them as open-box if and only if  $\beta\mu > s + \mathbf{E} \max\{V, s\} - c$ .*

Recall that for a retailer facing uncertain demand, restocking leads to higher profits provided that customers’ expected valuation for open-box products is higher than the salvage value ( $\beta\mu > s$ ). Proposition 4 shows that this is no longer sufficient if the retailer faces deterministic demand, in which case the retailer garners extra profit from reselling

**Table 1** The Effect of Restocking Returns on Optimal Initial Stocking Quantity

	MBG-NR Policy		MBG-R Policy	
	$q^{*NR}$	$\Pi^{*NR}$	$q^{*R}$	$\Pi^{*R}$
Example 1 ( $c = 0.3, s = 0.1$ )	0.506	0.0519	0.476	0.0642
Example 2 ( $c = 0.4, s = 0.1$ )	0.259	0.0136	0.293	0.0259
Example 3 ( $c = 0.4, s = 0.3$ )	0.592	0.0429	0.551	0.0490

returns only when customers attach a higher value for the open-box products. Alternatively, given a customer profile, the cost of not selling a product has to be higher (i.e., salvage value has to be lower) for the retailer to justify offering MBG-R. Otherwise, the retailer is better off selling only new products in the market. Evidently, uncertainty in customer demand renders restocking returns a profitable strategy for a wider range of market and operating conditions. This result has an interesting profit implication.

**PROPOSITION 5.** *The retailer's expected profit is higher when market demand is stochastically larger. However, a similar conclusion cannot be drawn unequivocally when market demand is less variable.*

Clearly, higher demand generates more profits for the retailer. A parallel result cannot be ascertained for reduced demand variability though. This is somewhat counter-intuitive, as the common wisdom suggests that variability should hurt profits. Proposition 5 confirms that restocking returns may create an opportunity for the retailer to profit from demand–supply mismatches. In particular, when the demand exceeds initial inventory, returned products become a supply source for these customers who would otherwise be lost. The precise technical conditions that govern this defection are derived in the proof of the proposition. Nevertheless, it can be deduced that this is more likely to happen when the salvage value of the product is low, but customers attach a good value to open-box items (low  $s$ , high  $\beta$ ). Under such (and perhaps not so common) conditions, it is possible that the retailer benefits from demand variability.

We conclude this section with a remark on the assumption of using a fixed open-box price  $p_o$  set at time 0. Suppose that the retailer employs a contingent pricing policy for open-box items, by dynamically adjusting its price depending on the inventory. When there is new product inventory available, it is always more profitable for the retailer to serve customer demand with new products; that is, open-box items would be priced such that customers always (weakly) prefer new items. Hence, the pricing of open-box items become relevant only when the initial stock  $q$  of new items is depleted (i.e., when  $\tau < T$ ). Even then, the *maximum* price the retailer can charge to customers for open-box items is  $\beta\mu$  (otherwise they would not purchase). Clearly, the same revenue can be obtained by pre-determined open-box price  $p_o = \beta\mu$  (see Proposition 3). Therefore, when customers do not act strategically and their valuations are homo-

genous, contingent pricing of open-box items does *not* generate additional revenues.

## 5. Introducing Customer Heterogeneity

Our analysis so far has assumed that customers have uncertain but identical valuations for new and open-box products. As noted earlier, one of the advantages of offering open-box items is to tap into a segment of the market that is more price-conscious. Clearly, the effects of serving the market with differentiated products are more pronounced when customers vary in terms of how much they are willing to pay for the product. In this section, we extend our basic framework to incorporate customer heterogeneity in product valuations. Given our prime interest on the role of restocking in an MBG environment, we consider only MBG policies with and without restocking. Also, motivated from the results of the previous section, we assume that the retailer does not offer exchanges and sets the open-box price at time 0 (no contingent pricing of open-box items).

The main model setting remains the same as in section 4. The key difference is that the random market size  $D$  now consists of both high-valuation customers (H-customers) and low-valuation customers (L-customers). Specifically, we assume that a known proportion  $\alpha$  of the market is H-customers, while the remaining  $(1 - \alpha)$  are L-customers. H-customers face uncertain valuation  $V$ , whose distribution  $F(\cdot)$  with corresponding density  $f(\cdot)$  is the same as before. The valuation of L-customers is denoted as  $v_L$ . For simplicity, we assume that  $v_L$  is a constant. We assume that  $EV = \mu > v_L > s$ ; that is, H-customers, on average, value the product more than L-customers, who in turn value the product higher than the salvage value.

Customer heterogeneity in willingness to pay brings forth new trade-offs for the retailer. In particular, the retailer can choose to position on the high-end, pricing high and selling only to H-customers. Alternatively, the retailer can price lower (and manipulate new and open-box products) to serve both market segments. We start our analysis with the case of no restocking.

### 5.1. MBG-NR Policy

Let  $\Pi^{NR1}(p_n, r, q)$  denote the retailer's expected profit when she serves only H-customers,  $p_n > v_L$ . In a similar vein, let  $\Pi^{NR2}(p_n, r, q)$  denote the retailer's expected profit when she also serves the L-customers,  $p_n \leq v_L$ . Maximizing  $\Pi^{NR1}(p_n, r, q)$  and  $\Pi^{NR2}(p_n, r, q)$  over their feasible ranges, we can determine the retailer's optimal decisions.

PROPOSITION 6. *When the retailer offers an MBG but does not restock returned items, the optimal price, refund amount, and initial stock quantity are characterized as:*

	Price	Refund	Order quantity
Serve H	$p^{*NR1} = E \max\{V, s\}$	$r^{*NR1} = s$	$\bar{G}\left(\frac{q^{*NR1}}{\alpha}\right) = \frac{c - s}{E \max\{V, s\} - s}$
Serve H & L	$p^{*NR2} = v_L$	$r^{*NR2} = s - \frac{F(r^{*NR2})}{f(r^{*NR2})}$	$\bar{G}\left(q^{*NR2}\right) = \frac{c - s}{v_L + \alpha(s - r^{*NR2})F(r^{*NR2}) - s}$

Note that Proposition 6 identifies the retailer’s optimal decisions under each case separately. The retailer will have to compare her profits and accordingly determine how she is going to position its product in the market; that is,  $\Pi^{*NR} = \max\{\Pi^{NR1}(p_n^{*NR1}, r^{*NR1}, q^{*NR1}), \Pi^{NR2}(p_n^{*NR2}, r^{*NR2}, q^{*NR2})\}$ . Elaborating more on the profit function, it can be seen that the retailer will target only the high end market with a high price, provided there are enough high-valuation customers (high  $\alpha$ ) and the premium they are willing to pay is sufficiently high ( $\mu$  is high compared with  $v_L$ ). In such a market, the extra revenue created from premium pricing offsets the loss of revenue from not serving the lower end of the market. In contrast, when the market is dominated by bargain hunters (low  $\alpha$ , high  $v_L$ ), it is more profitable for the retailer to include this segment and price lower.<sup>7</sup> Also, the retailer should be less generous in terms of her returns policy and offer a lower refund amount. This strategy not only restricts the number of returns, but also ensures that the retailer can still extract some positive value from salvaging them (i.e., the optimal refund is lower than the salvage value).

### 5.2. MBG-R Policy

When the retailer offers returned products as open-box, customers have to make a choice between the two versions. For H-customers, the expected surplus from new and open-box items is as in the homogenous case (without exchange),  $EU_n = E \max\{V, r\} - p_n$  and  $EU_o = \beta\mu - p_o$ , respectively. For L-customers, the expected surplus is  $EU_n = v_L - p$  when purchasing a new product and  $EU_o = \beta v_L - p_o$ , when purchasing an open-box item. Depending on the prices and refund amounts offered, the retailer can target different

market segments, and the choice between new and open-box products gives rise to several possibilities:

- CASE I. Serving H-customers only ( $p_n > v_L, p_o > \beta v_L$ );
- CASE II. Serving both H- and L-customers, where H-customers prefer new products and L-customers prefer open-box products ( $v_L - p_n < \beta v_L - p_o, E \max\{V, r\} - p_n \geq \beta\mu - p_o$ );
- CASE III. Serving both H- and L-customers, where both types prefer new products and L-customers do not purchase open-box products ( $p_n \leq v_L, v_L - p_n \geq \beta v_L - p_o, p_o > \beta v_L, E \max\{V, r\} - p_n \geq \beta\mu - p_o$ );
- CASE IV. Serving both H and L-customers, where both types prefer new products and L-customers purchase open-box products ( $p_n \leq v_L, v_L - p_n \geq \beta v_L - p_o, p_o \leq \beta v_L, E \max\{V, r\} - p_n \geq \beta\mu - p_o$ ).

The prices can also be set such that both customer types prefer open-box products; however, this pricing strategy cannot be optimal, as the retailer can simply increase the price of new product without losing demand. Therefore, it is sufficient to consider the above CASES I–IV. Unfortunately, it is not possible to formulate the retailer’s expected profit and subsequent decision-making problem in a unified manner; it is necessary to study each case separately. Let  $\Pi^{Ri}$  denote the retailer’s expected profit, where the superscript  $i = 1, \dots, 4$  refers to the four cases. The derivation and analysis of  $\Pi^{Ri}$  for each case is rather involved and not particularly revealing. For this reason, we provide an abbreviated summary of the characterization of the optimal decisions, leaving all derivation to the appendix in the online Supporting Information.

PROPOSITION 7. *Suppose that the retailer offers an MBG-R policy. The optimal new and open-box prices, the optimal refund amount, and the optimal initial stock quantity for each case can be characterized as follows:*

	New product price	Open-box price	Refund & order quantity
CASE I.	$p_n^{*R1} = E \max\{V, r^{*R1}\}$	$p_o^{*R1} = \beta\mu$	Equations (20), (21)
CASE II.	$p_n^{*R2} = E \max\{V, r^{*R2}\} - \beta(\mu - v_L)$	$p_o^{*R2} = \beta v_L$	Equations (23), (24) or (25), (26)
CASE III.	$p_n^{*R3} = v_L$	$p_o^{*R3} = \min\{v_L, \beta\mu\}$	Equations (28), (29)
CASE IV.	$p_n^{*R4} = v_L$	$p_o^{*R4} = \beta v_L$	Equations (31), (32)

The expressions characterizing the optimal refund and initial stock levels are provided in the appendix in the online Supporting Information.

Note that, as in the case of no restocking, it is possible to determine the optimal prices in closed form, while the optimal refund and initial stock level for each case can be determined from solving two simultaneous equations. The retailer's optimal profit is given by the best case; that is,  $\Pi^{*R} = \max\{\Pi^{*R1}, \Pi^{*R2}, \Pi^{*R3}, \Pi^{*R4}\}$ , and the optimal decisions are given by the corresponding case. Unfortunately, it is not possible to analytically compare the profits to determine ranges for each scenario to prevail as optimal for the retailer. Intuitively speaking, this depends on how customers value open-box items in general ( $\beta$ ), to what extent low valuation customers are bargain hunters ( $v_L$  relative to  $\mu$ ), and the relative sizes of the two market segments ( $\alpha$ ). Next, we elaborate on the retailer's optimal segmentation policy with respect to these parameters.

Figure 2 depicts the regions where each case is optimal for different levels of  $v_L$  and proportion of L-customers ( $1 - \alpha$ ). For this example,  $\beta = 0.8$ ,  $c = 0.3$ ,  $s = 0.1$ ,  $V \sim \text{Uniform}[0,1]$  and  $D \sim \text{Beta}[3,3]$ . Note that average valuation of H-customers is  $\mu = 0.5$ , so the valuation  $v_L$  of L-customers can be changed in the range  $[0,0.5]$ . As evident from Figure 2, for low  $v_L$  values, it is optimal for the retailer to focus only on the H-customers and maintain a relatively high price and margin (CASE I). This strategy continues to be the best for the retailer for moderate to high values of  $v_L$ , provided there are sufficient high-valuation customers in the market. If the high-valuation segment is limited, however, and there is a sizable discount-seeking customer group, it is better for the retailer to forgo margin in exchange for volume, and price lower to target also the L-customers with its new product (CASE III). Note that in both cases, the main purpose of having open-box items is to provide H-customers an alternative product when

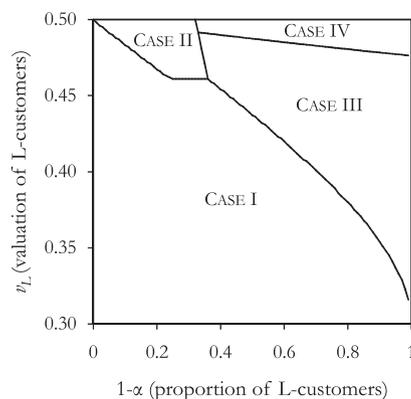
there is a shortage with the new product (i.e., capturing late demand). It is optimal for the retailer to serve L-customers with open-box items only when their valuation is sufficiently high (in our example, when the valuation of L-customers is at most 10% lower than average valuation of H-customers). Even then, it is better for the retailer to position her new product for this low-valuation segment provided its size is reasonably high, and she utilizes open-box items only as a secondary product option for the entire market in case of shortages (CASE IV). In contrast, when there is a distinct but not dominant segment of L-customers, then it is optimal for the retailer to pursue a strict segmentation strategy with differentiated products (CASE II). In this case, the primary target for the open-box sales is the L-customers, whereas new products are priced to serve the higher end market. As might be expected, when customers attach higher value to open-box items in general (higher  $\beta$ ), the retailer's optimal market segmentation strategy involves more of CASE II and CASE IV. In contrast, for low  $\beta$  values, the optimal segmentation strategy involves only CASE I and CASE III.

Restocking returned products and selling them as open-box lead to higher profit for the retailer also in the heterogeneous case. In the following section, we conduct numerical experiments to quantify the degree of improvement the retailer can obtain from this strategy and investigate the ideal conditions that would yield the highest return to the retailer.

## 6. Numerical Results

We conduct extensive numerical experiments to substantiate our analytical findings and complement them with new insights. Utilizing the heterogeneous customer population model developed in the previous section, we compare NMBG and MBG-NR policies to assess the value of offering MBG, while we assess the value of restocking returned products by comparing MBG-NR and MBG-R policies. By system-

Figure 2 Retailer's Optimal Market Segmentation Strategy



	New Products	Open-Box Products
CASE I	H-customers	H-customers (if shortage)
CASE II	H-customers	L-customers H & L-customers (if shortage)
CASE III	H & L customers	H-Customers (if shortage)
CASE IV	H & L customers	H & L-customers (if shortage)

atically varying market factors (such as degree of heterogeneity), and variability factors (such as demand), we aim to identify the key performance drivers of MBG policies. Lastly, we comment on the potential benefits of contingent pricing in a heterogeneous population setting.

Before proceeding to the details of our numerical study, we first give a high level summary of our results. Among the 14,920 different problems we generated in this study, we find that MBG-NR profits are 2.13% higher than NMBG profits, while restocking returned products (MBG-R) provides an *incremental* 7.36% profit over the MBG-NR policy, exceeding the extra profit earned from offering MBG only. Therefore, restocking returned units provides a *complementary* operational lever besides offering only refunds. Regarding prices, while MBG-NR policy charges a *premium* of 0.66% for providing the flexibility of returns, restocking further increases the new product price by 1.81% compared with MBG-NR policy. On the other hand, open-box items are sold at a 39.5% discount on average. Aside from extending the validity of the analytical results for the homogeneous population case (Proposition 1, Corollary 1) to the heterogeneous case, these results also confirm the impact of product differentiation induced by reselling returned products as open-box items. Consistent with Corollary 1, restocking returns increases the refund offered; customers receive on average more than double the refund (106.83% more) under MBG-R compared with MBG-NR policy. Hence, without an exception in our study, restocking returns results in *more generous* return policies; MBG-R charges 32.18% less restocking fee compared with MBG-NR. Overall, MBG-NR stocks 0.3% more initially than NMBG due to increased sales, but the opportunity to resell returned products under MBG-R leads to a 4.16% *reduction* in the initial stock quantity compared with MBG-NR. Hence, restocking returns *reduces the inventory risk* of the seller. Finally, in *none* of the 14,920 problems generated in this numerical study did dissatisfied customers return a new product and buy an open-box item instead (i.e.,  $p_o^{*R} \geq \beta r^{*R}$  in all cases), essentially showing that exchanges will not occur under MBG-R policy, extending the validity of Proposition 2 to a heterogeneous population setting.

### 6.1. Impact of Market Characteristics

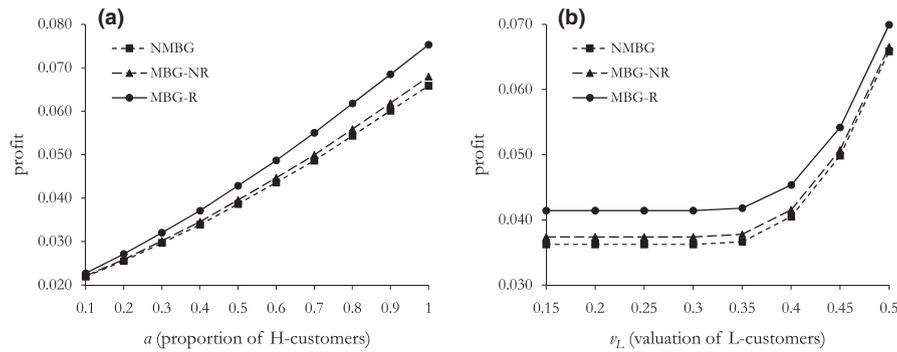
The composition of the market and the relative willingness to pay of the different market segment for new and open-box products can have significant bearing on the profitability of MBG policies. To this end, we explore the effects of market structure related factors: the proportion of H-customers in the market ( $\alpha$ ) and valuation of L-customers for the product ( $v_L$ ).

We first describe our experimental setup. We generate problems by varying parameters of a set of *base scenarios*. In the base scenarios, customer valuation  $V$  is represented by a Beta distribution with both shape parameters set to 1 (equivalent to a uniform distribution between 0 and 1) and random market size  $D$  is represented by a Beta distribution with both shape parameters set to 3 (a symmetric bell-shaped demand distribution in the interval [0,1].) Furthermore, we assume that the unit cost of the product  $c$  is 0.3, and the salvage value  $s$  is 0.1. We characterize a *problem setting* by a particular combination of parameter values for the proportion of H-customers  $\alpha$  and valuation of L-customers  $v_L$ . For each problem setting,  $\alpha$  assumes a value from the set  $\{0.1, 0.2, \dots, 1\}$  and  $v_L$  assumes a value from the set  $\{0.15, 0.20, \dots, 0.50\}$ .<sup>8</sup> We remark that the results presented for a particular factor are averaged over problem settings on all possible values of the other parameters. Note also that in the interest of space, we only present figures related to the profit impact and comment on the impact on the decision variables in the text when necessary.

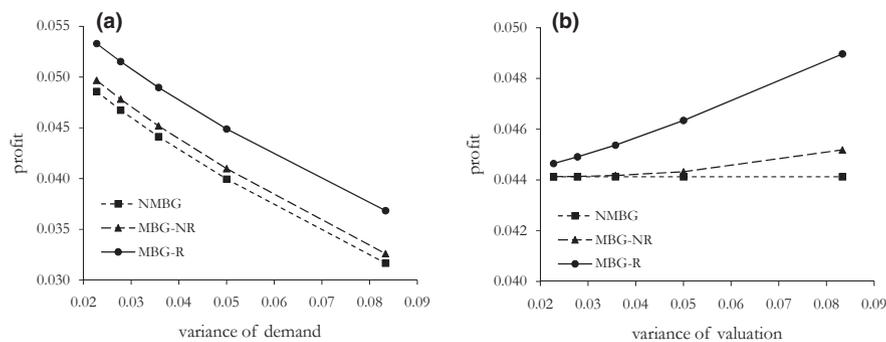
**6.1.1 Impact of Proportion of H-Customers.** A larger proportion of H-customers with higher valuations for the product implies better market conditions (in terms of willingness to pay) for the retailer. Consequently, the retailer can extract larger profits under both policies (see Figure 3a). The values of offering refunds as well as restocking increase as  $\alpha$  increases, while the gains are much stronger for restocking. This suggests that reselling returned products as open-box can be a significant profit-enhancing strategy when customers value the product highly (i.e., there are less price-conscious customers). Also, higher willingness to pay for new products induces the retailer to increase the new product price. The compensation for the customers is higher refunds and reduced restocking fees for returns. The open-box product price, however, is much less sensitive to the composition of the market. Finally, better market conditions result in higher initial stocking levels under all policies.

**6.1.2. Impact of L-Customer Valuations.** As  $v_L$  increases, the product is valued higher by L-customers, leading also to a better market potential for the product. Hence, profits improve under all policies (Figure 3b). As evident from Figure 3b, however, increasing  $v_L$  has an effect only beyond a certain threshold. Accordingly, the benefits from offering MBG with and without restocking diminish as  $v_L$  crosses a threshold value. This follows from the retailer's optimal market segmentation policy discussed in section 5. When the more price-conscious customers are deep discount seekers, it is optimal for the retailer to ignore them and target only the higher

**Figure 3** Impact of Proportion of H-Customers and Valuation of L-Customers on Profits



**Figure 4** Impact of Demand Variability and Valuation Variability on Profits



end of the market. As  $v_L$  increases beyond some threshold, L-customers start bearing profit potential for the retailer, so the new product price is decreased to serve both segments. Lower new product prices are coupled with more stringent return policies. The increase in the market potential for the product comes hand in hand with higher initial stocking quantity.

## 6.2. Impact of Variability

Uncertainty (variability) is undoubtedly one of the key drivers of the performance of MBGs. There are two sources of variability modeled in our framework: variability in customer demand and variability in consumer valuations. We run our experiments by extending the base scenarios to include these factors; the results are illustrated in Figure 4.

**6.2.1. Impact of Demand Variability.** We extend the base scenarios by varying the identical shape parameters of Beta distribution representing  $D$  in the set  $\{1,2,3,4,5\}$ . This results in problem settings with the same mean  $E[D] = 0.5$ . Figure 4a confirms, as expected, that demand variability has an adverse effect on retailer profits on average. Hence, the technical conditions required by Proposition 5 for the positive effects of variability are a rarity. To hedge against the risks of demand uncertainty, retailers reduce initial stocking quantities and hike up product prices

(both new and open-box). On the other hand, MBGs are in general more beneficial when demand variability increases. Observe, however, that the gains are much more pronounced when the retailer restocks returns. This corroborates the *inventory risk mitigation* potential of restocking, which is clearly more commanding when demand–supply mismatches are more likely. Substantiating the implications of Proposition 4, retailers facing highly uncertain demand are likely to benefit the most from open-box sales of returned merchandise.

**6.2.2. Impact of Valuation Variability.** We vary  $V$  to take on Beta distributions with identical shape parameters from the set  $\{1,2,3,4,5\}$ , resulting in problem settings with average valuation  $\mu = 0.5$ . Observe in Figure 4a that, unlike the demand variability, valuation variability tends to increase firm profits. This is because as  $V$  becomes more variable, the upper tail probability also increases, resulting in more customers who are willing to pay high prices. Accordingly, the retailer seizes this opportunity and achieves larger profits (by increasing product prices and decreasing refunds). However, the initial stocking quantities decrease as variability of  $V$  increases, as uncertainty in customer valuations constitutes a risk for the retailer. We can also infer that the gains from MBGs improve when  $V$  becomes more variable,

although the benefits are much higher when the retailer adopts MBG-R policy. Therefore, retailers introducing new products or selling highly innovative products would benefit more from allowing returns from dissatisfied customers and offering them as open-box at discounted prices.

### 6.3. Impact of Contingent Pricing of Open-Box Items

In section 4, we showed that when customers have homogenous valuations, dynamically adjusting the price of open-box products based on available inventory has *no* benefit for the retailer. This need not hold when customer valuations are heterogenous. To quantify the potential impact of a contingent pricing policy in this setting, we construct an upper bound on the retailer's expected profit. We do this by assuming that the retailer can always charge maximum prices for open-box items (this is, in general, not always achievable because a high-paying H-customer may arrive later than an L-customer). Further details can be obtained from the authors. Over our base scenarios, we find that the *upper bound* on the benefit from contingent pricing under MBG-R is on average only 1.8%. In 73.6% of the cases, the upper bound on the benefit is below 2%, and in 30% of the cases, contingent pricing has no impact. Collectively, our analytical and numerical results suggest that contingent pricing of open-box products has rather limited value for the retailer.

## 7. Concluding Remarks

We develop a model of a retailer selling a short lifecycle product over a finite selling horizon. Customer arrival dynamics is represented using a stochastic fluid model, which effectively reduces our framework to a newsvendor-type model. We analyze and compare the retailer's optimal pricing and ordering decisions and resulting profits under MBG with and without restocking, as well as cases where MBG is not offered. A distinct feature that sets our model apart from earlier work is the incorporation of an opportunity to resell the returned products as open-box items. Besides validating existing results in the literature concerning MBGs, we show that reselling returned products often results in decreased initial stocking quantities, diminishing the retailer's inventory risk and cost, as well as reducing her procurement costs, and therefore can significantly enhance retailer profits.

MBGs are widely observed in practice for short lifecycle products facing significant demand uncertainty (e.g., consumer electronics, IT equipment) and high risks of dissatisfaction (e.g., Internet sales, mail catalogs). When demand–supply mismatch and product dissatisfaction risks are more accentuated, the natural initial reaction is to tighten returns policies to limit

the amount of returns. Interestingly, our study shows that an alternative strategy of complementing the MBG with a reselling practice of returns can be very effective. Hence, highly innovative products, new technologies, or fashion-driven products (especially high-end ones) are likely to benefit the most from open-box sales of returned merchandize. We show that the benefit of reselling is also more pronounced when open-box items are valued highly by consumers and when there are relatively less price-conscious, discount-seeking customers. These results highlight the importance of improving the brand value of open-box items and signify to retail managers the importance of gaining information about market characteristic with respect to size and willingness to pay of different customer segments.

As our analytical model does not consider repackaging costs of returned products for the retailer and hassle costs for the customers, we have carried out numerical experiments on an extended model including these costs. As expected, higher repackaging costs render selling open-box items less attractive or even detrimental to retailer profits. It is also sometimes the case in practice that retailers take various non-monetary measures (e.g., requesting original packaging, special logistics arrangements) to create additional “hassle” for customers and discourage returns. Our results show that this is not a beneficial strategy for the retailer.

### Notes

<sup>1</sup>Therefore, we do not model long-term effects of consumer returns on customer demand (e.g., word-of-mouth effects of returns) or non-stationary demand patterns. These aspects are more relevant for durable goods or functional products facing longer selling periods and multiple procurement opportunities, which are beyond the scope of our study.

<sup>2</sup>Repackaging costs have rather predictable effects, which are discussed in our concluding remarks.

<sup>3</sup>In an earlier version of the paper, we considered a two-period periodic review model where open-box items are only offered in the second period. The present model allows open-box items to be sold from the very beginning.

<sup>4</sup>From a technical standpoint, dealing with a refund amount makes analysis simpler and presentation clearer. Without loss of generality, for the remainder of the article, we take the refund level as the retailer's decision.

<sup>5</sup>A consumer exchange involves the return of a unit of product (which is subsequently offered as open-box) and the consumption of an open-box product and therefore does not affect the inventory of open-box items.

<sup>6</sup>Note that  $p_o \geq \beta r$  implies that at optimality  $r \leq \mu$  as  $p_o \leq \beta \mu$ .

<sup>7</sup>We note that this result is also valid when the retailer does not offer any MBG.

<sup>8</sup>As  $\mu \geq v_L > s$ , we have  $0.5 \geq v_L > 0.1$ .

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## Supporting Information

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### Appendix: Proofs of Propositions

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