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Production and Operations Management

POMS Lima, Peru, December 2-4, 2021 (Virtual Edition)

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Jorge Vargas Florez • Irineu de Brito Junior
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Sebastian Villa Betancur • Michelle Rodríguez
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Editors

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Editors
Jorge Vargas Florez
Pontifical Catholic University of Peru
Lima, Peru

Irineu de Brito Junior
Sao Paulo State University
Sao Jose dos Campos, Sao Paulo, Brazil

Adriana Leiras
Pontifical Catholic University of Rio de Janeiro
Rio de Janeiro, Rio de Janeiro, Brazil

Sandro Alberto Paz Collado
Pontifical Catholic University of Peru
Lima, Peru

Miguel Domingo González Alvarez
Pontifical Catholic University of Peru
Lima, Peru

Carlos Alberto González-Calderón
Universidad Nacional de Colombia at Medellín
Medellín, Antioquia, Colombia

Sebastian Villa Betancur
Indiana University
Bloomington, IN, USA

Michelle Rodríguez
Universidad del Pacífico
Lima, Peru

Diana Ramirez-Rios
Rensselaer Polytechnic Institute
Troy, NY, USA

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Preface

This book crowns the effort of the reconstructed Latin America & the Caribbean chapter of the Production and Operations Management Society, POMS (http://www.poms.org), to keep a biannual POMS International Conference in the region, even with the challenge imposed by restrictions due to the COVID-19 pandemic. POMS is an international professional organization congregating production and operations management professionals and academicians worldwide and aims at extending and integrating knowledge in the field of production and operations management (POM). POMS disseminates POM concepts to managers, scientists, educators, students, public and private organizations, national and local governments, and the public. POMS International Conferences provide an opportunity to faculty, doctoral students, and practitioners to share knowledge and insights.

The first POMS International Conference organized by the Latin America & the Caribbean chapter was held in December 2018 in Rio da Janeiro, Brazil, with 164 participants, many from outside Latin America. It was an in-person meeting and very successful. Particularly, the traditional Latin American warmth and hospitality had been very appreciated by the international audience.

This second edition of the POMS Latin America & the Caribbean International Conference was hosted by the Pontifical Catholic University of Peru in Lima (PUC-Lima) in December 2021, and held online due to the COVID-19 limitations. It is a tribute to the chapter board's efforts and dedication that it could be conducted during these troubled times.

The 2021 POMS International Conference in Lima was held from December 01 to 03, 2021, with the theme being "The operations management for an innovative and resilient society." The event had 2 plenary sessions, 2 tutorial sessions, and 71 papers presented in 12 sessions with 83 participants.

The full papers presented in the proceedings were organized in the following tracks:

- Artificial Intelligence and Data Analytics in Operations
- Defense, Tourism, and other Emerging OM Issues
- Healthcare Operations Management
- Humanitarian Operations and Crisis Management
- Logistics and Supply Chain Management
- Marketing and Operations Management
- Product Innovation and Technology in Operations Management
- Resilience and Risk in Operations
- Service Operations and Servitization
- Sustainable Operations

These papers offer a representative sample of POM research undertaken in the Caribbean and Latin America. And they are a tribute to the tenacity of the chapter board members, who were able to organize an academic meeting during such challenging period. Congratulations to them.

University of São Paulo, São Paulo, Brazil Hugo Yoshizaki

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Correction to: Instant Deliveries: A Latin America Overview C1

Part I
Business Operations Management

Socially Optimal Retail Return Strategies Under the Influence of Endowment Effect

Ali Shirzadeh and Ehsan Elahi

Abstract As a solution to bring security for customers in the retail markets, product return policies are widely utilized. As a result, many retailers take various return leniency measures to ease the applicability of product returns for customers. This, in turn, increases the frequency of returns in the market, which has huge economic impacts on retailers. Therefore, it is necessary to accurately understand the impact of return policy social welfare. To enable this, we present a novel, inclusive analytical model capable of capturing the impacts of major factors affecting the customers' behavior, including return leniency, customers' heterogeneity, and the endowment effect, in addition to the other commonly studied factors in the literature (product expenses, hassle cost, salvage value). In this model, we mathematize the probability of purchasing, keeping, and returning products. Utilizing these probabilities, in turn, help us determine the optimal price and refund levels to optimize the social welfare. We use a set of numerical experiments over a wide range of parameters' values that should cover almost all practical circumstances. Our analysis shows optimal return strategies under various circumstances to maximize the social welfare.

Key words Product pricing · Product return · Return leniency · Social welfare maximization · Endowment effect

A. Shirzadeh · E. Elahi (✉)
Department of Management Science and Information Systems, College of Management, University of Massachusetts Boston, Boston, MA, USA
e-mail: shirzadehchaleshtari@umb.edu; ehsan.elahi@umb.edu

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1 Introduction

Product returns in retail markets have huge economic and environmental impacts. Optoro[1] estimates that returns cost retailers $400B each year in the United States alone.[2] In addition, every year, the United States generates 15 million tons of carbon emissions due to product returns.[3] The COVID-19 pandemic has further intensified the product return problems while further shifting the purchase behaviors toward e-commerce,[4] where at least 30% of all products are returned compared to 8.89% in brick-and-mortar stores.[5] On the other hand, many retailers have been implementing some measures of return leniency to ease the hassle of return for customers, which in turn increases the frequency and applicability of the product returns. This trend is being further intensified during the COVID-19 pandemic by adopting new policies such as a longer return window time that make product returns even easier [1, 2]. However, the return leniency can have varying degrees of time, money, effort, scope, and exchange on the return policy [3]. Therefore, the vast economic impact of the product returns necessitates a careful investigation of return policies.

Product return could happen due to the opportunistic manner of customers or the uncertainty in customers' valuation of a product (i.e., online purchases). Having opportunistic returns, the customer knows she wants to return the product from the moment of the purchase, but she makes a purchase to use the product for some while and then returns it. On the other hand, for customers with uncertain manners, the actual value of products is not clear before purchasing. In such cases, the actual value becomes apparent after purchase when she gets the chance to use the product. Upon the purchase, the customer knows only the range of values within which her true valuation would fall. If the customer is considering a product for the purchase, she knows in her mind up to what value she may be willing to pay for the product. This can happen more often in online shopping when customers cannot examine the product up-close before the purchase. In these situations, returning the product helps the customer make the purchase decision, knowing that she can return the product if she finds out the product is not worth the paid-price. There are, however, many factors that affect the customer's ultimate decision, such as the *product acquiring cost* and *salvage value* that we consider in our study.

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[1] Leading retailers and brands use Optoro to improve how they process, manage, and sell returned and excess inventory. www.optoro.com.

[2] Creating Value from Returns this Holiday Season. https://rla.org/media/article/view?id=1179

[3] Research and Markets – The World's Largest Market Research Store. https://www.researchandmarkets.com/reports/4911530/the-environmental-impact-of-e-commerce-2020?utm_source=dynamic & utm_medium=GNOM & utm_code=xmpm26 & utm_campaign=1344501+-+2020+Report+on+the+Environmental+Impact+of+E-Commerce & utm_exec=joca220gnomd

[4] The pandemic has pushed more sales online, and that means more returns, too https://www.post-gazette.com/business/money/2020/09/14/retail-shopping-covid-19-pandemic-sales-online-in-store-returns/stories/202009130028

[5] E-commerce Product Return Rate – Statistics and Trends [Infographic] https://www.invespcro.com/blog/ecommerce-product-return-rate-statistics/

Furthermore, in this study, we consider customer-related factors, such as uncertainty about the product valuation and *endowment effect,* referring to the tendency of consumers to feel a higher value for a product once they own it [4–6]. This behavior increases the likelihood that people will keep possession of objects even when their actual product valuation is less than their expected value. In other words, the endowment effect makes a customer experience negative utility just by returning something that they have already owned [3, 7].

Finally, we consider the factors usually set by retailers, such as the selling price, refund level, and return hassle cost, which typically depends on how the retailer implements return policies. To ease this hassle, retailers may implement some measures of return leniency. A more lenient return policy can also increase *return efficiency*, which is another factor that we include in our model. Return efficiency refers to the occasions when a customer intends to return but fails to do so. Naturally, a more difficult return process results in a lower return efficiency. This can also correlate with other reasons, such as customers losing the purchase receipt or missing the return deadline. Our final goal is to show how the return leniency impacts the return strategies of the retailers and their profit and social welfare. In correspondence with the literature, the measurement of social welfare is done via the surplus metric (or expected surplus) in this study.

This research contributes to the literature in several ways. First, we develop an inclusive analytical model that captures all major factors affecting the purchase and returns decisions. Prior research papers either did not include these factors or simplified them to such an extent that their conclusions did not reflect these factors in their closed-form solutions for the optimal level of price and refund. (see, for example, [8–10]). In this project, however, we will examine the social welfare maximization strategies based on product return policy under the assumptions of monopolist retailers and include (among other more commonly studied factors) customers' heterogeneity and return efficiency, return leniency, randomness in customers' valuation of the product, and the endowment effect.

In order to consider different aspects of return leniency in our study, we included the hassle cost to audit the cost leniency, and we have the variable of refund level for monetary leniency. For all other aspects of leniency, we have assumed a single parameter return efficiency. This is because leniency factors are not fixed in the literature (in various references, different factors have been assumed to impact leniency, such as [3]). Besides, we present the first analytical research (to the best of our knowledge), which captures the return leniency (even though some may discuss simplifications). This is a considerable contribution compared to all previous analytical researches who have either neglected the return leniency (although the experimental research proved the high impact of this factor in this context [3]) or simplified it to only the hassle cost of return [8, 9].

We investigate the impact of various parameters on the retailer's optimal pricing and refund policies and the resulting social welfare by conducting numerical experiments over a wide range of problem parameters. Despite its limitations, numerical analysis allows us to examine the behavior of social welfare, and return levels with fewer simplifying assumptions and in a realistic setting. Specifically, our research

contributes to the body of literature in this field by focusing on the following questions:

1. How can the price and refund be jointly optimized to maximize the social welfare under various market conditions?
2. What is the impact of various parameters on the resulting social welfare?
3. How the relative impact of return leniency on the purchase and return frequencies are compared to each other?

Our analyses show that return leniency increases social welfare, especially when the cost of acquiring product and salvage value are both high.

The remainder of this study is organized as follows: Sect. 2 reviews the related literature on product return management in revenue management. In Sect. 3, we describe the problem and its model setup. Section 4 presents the analytical framework. In Sect. 5, we present the numerical experiments, and Sect. 6 concludes the study with a few remarks.

2 Literature Review

To investigate the impact of various factors on the product return and social welfare, our research models the behavior of customers in a monopoly e-commerce market while capturing the impact of major related factors such as customers' heterogeneity, endowment effect, and customers' *return efficiency*, which refers to the occasions when a customer intends to return but fails to do so. Although the topic of product return has been studied in the literature, to the best of our knowledge, no research has studied all these factors together and addressed issues such as the impact of return leniency on the social welfare and retailers' optimal refund strategy and expected profit. Here we briefly review the related literature.

Product pricing in retail industry have been vastly studied, see for example [11–19]. When it comes to product return, there are researchers who study joint optimization of pricing and refund level in the context of supply chain management, such as [20–31]. In comparison, we focus on the joint optimization of price and refund level in the context of revenue management, excluding inventory management.

Research [8] studies the product return problem when target customers are homogeneous, return leniency solely consists of the impact of the *hassle* cost, and no endowment effect exists. In their model, every customer has the option of information acquisition to fully understand the value of the product before making a purchase, and in order to induce customers to stay informed or uninformed, the retailer has limited pricing and refund possible options. The authors characterize the optimal pricing and refund strategies for both informed and uninformed customers. They also characterize socially optimal pricing and refund strategies. The authors show the optimal refund is equal to the seller's salvage value for a returned unit unless customers are risk averse or if they can choose to acquire information on their own, or unless there exists a fully informed segment. In comparison, our research

studies the problem in a market with heterogeneous customers (different levels of product valuations), and captures the impact of the return leniency, and endowment effect. Our findings indicate the value of return leniency for the retailer and social welfare under different circumstances and show, considering the additional factors, the optimal refund can be below the seller's salvage value.

Shulman et al. [9] conducts a similar study with their main focus on profit maximization objective. They model a monopolist retailer who sells two horizontally differentiated products. The customers have the option of exchanging their purchased products with the other one. The fit between consumers' preferences and product characteristics is a source of uncertainty in their model, which is revealed only after the purchase. They consider customers' utility for the product type to be a binary variable which is a second source of uncertainty for certain portion of customers. The authors jointly optimize the price and restocking fee and study the impact of full information provision which resolves all sources of uncertainty. Their model allows returns only for the customers who does not find any use for the product. They show that the marginal value of information to the seller is decreasing in the operational efficiency of the seller's forward and reverse logistics process as well as the level of product uncertainty. In comparison, our model allows returns whenever they generate a higher utility. Moreover, our framework is capable of capturing a full range of market heterogeneity in terms of different customers' initial product valuation. Besides it addresses the return leniency and endowment effect, and allows capturing the impact of those factors.

Becher et al. [10] conducts a similar research while considering the endowment effect and customer heterogeneity but not the return leniency. In their model, they consider the possibility of a fixed amount of reduction in the customers' valuation of the product after the purchase. They characterize jointly optimized retailer's price and return fee decisions. They compare their results under profit and social welfare maximization objectives in the presence and absence of endowment effect as well as when the customers underestimate the endowment effect. The authors characterize the conditions under which the legal upper limits on the return fees increase the social welfare. In comparison, the randomness in customers' valuation of products in our model let the actual valuation attain any value above or below the expected value within the defined range. Moreover, our research assesses the impact of return leniency on retailer's optimal pricing and refund policies.

Akturk et al. [32] presents a similar joint pricing and return optimization study for the monopoly market to see how technology-enabled countermeasures may benefit the retailer by mitigating return abuse. In their model, they consider opportunistic consumers who purchase product with the full intention of returning it. Akturk, Ketzenberg [32] assume an option of customer profiling system to identify such customers by using their personal identification and transaction history. In addition, they take into account fraudulent returns associated with the situations when a person engages in criminal activity such as shoplifting, price switching, and receipt fraud, among others. In this regard, they assume a product tracking system which identifies fraudulent returns by recording each transaction of a product through the use of unique identifiers. They demonstrate the conditions under which it is

advantageous to adopt these technologies and when such investments should be avoided. In contrast, we consider a different type of customer heterogeneity where customers differ from each other by their needs and tastes regarding the product in question not their ethical behavior. We also incorporate major return influential factors such as return efficiency, endowment effect, and customer heterogeneity to capture their impact on the pricing and return strategies and the benefit of return leniency.

Most studies define return leniency based on the seller's return policy terms. See for example [33–37]. Suwelack and Krafft [38] note there are significant differences in retailers' return policy terms. [3, 39, 40] each classify the return policies in terms of different restriction factors, such as time, money, and scope. Analytical researches either simplify their modeling assumptions by neglecting return leniency, such as [10, 32], or restricting the leniency to the return hassle cost, such as [8, 9]. In our research, however, our model captures the impact of return leniency through a combination of hassle cost and return efficiency, which we define as the percentage of customers who intend to return the product and manage to do so. Lower return efficiency could be, in part, the result of higher hassle cost as well as all other factors that make the return more challenging (low return leniency).

Customers' hesitancy to return supports the endowment effect theory which considers a gap between valuation of a product before and after a purchase [4–6]. In other words, endowment effect happens when customers are reluctant to lose the ownership of products by returning them. Most of the experiments on the endowment effect have examined it immediately after an object is obtained. Strahilevitz and Loewenstein [41] show the endowment effect changes by the duration of ownership. The vast literature on the endowment effect demonstrates its influential impact on consumer's behavior and in particular on their returning behavior (for reviews see, for example, [42, 43]). Janakiraman and Ordóñez [44] find that longer deadlines for returning increase the attachment to the item. Kim and Wansink [34] identify an interaction between seller's recommendation and return policies, so that lenient return policies yield more positive post-purchase evaluations when the product was recommended. Our findings show that endowment effect increases the sensitivity of social welfare and retailers' profit respect to return leniency, while enabling the retailers to optimally offer higher refund levels.

3 Model Setup

A monopolist retailer sells a product online with unit price p. Each potential customer i has a unit demand for the product and has her own reservation price for the product, R_i, which reflects the value that the customer believes for the product. R_i is a uniformly distributed random variable over $\left[\overline{R_i} - \delta, \overline{R_i} + \delta\right]$, where $\overline{R_i}$ is the mean of the uniform distribution. From the retailer's perspective, $\overline{R_i}$ itself is also a uniformly distributed variable over the interval $[L, U]$, which reflects the variation in

mean reservation prices of its pool of customers. Before buying the product, customer i is only aware of the distribution of his/her own reservation price for the product, not the exact amount of R_i. After buying the product, the actual amount of R_i is revealed to the customer, and hence the utility of buying and keeping the product, which would be R_i-p. Obviously, the utility can be negative when the revealed reservation price is less than the product price.

Having bought the product, a customer has the choice to return the product if he/she is not satisfied with it. Upon return, the customer has to endure some form of hassle cost h, as well as the disutility associated with the endowment effect, γR_i, where γ is the endowment effect factor. The case of $\gamma = 0$ represents the situation when customers experience no endowment effect. Modeling the endowment effect in this fashion is similar to the analytical model in Becher, Feess [10].

On the other hand, upon return, a customer receives the refund value of βp, where $0 \leq \beta \leq 1$. The cases of $\beta = 1$ and $\beta = 0$ refer to full refund and no refund policies, respectively. So, the utility of purchasing and returning the product is $-(1 - \beta)$ $p - h - \gamma R_i$. To decide whether to return the product or not, the customer checks if he would get more utility by returning the product or by keeping it. Therefore, the return is preferable when $R_i - p < -(1 - \beta)p - h - \gamma R_i$, or equivalently $R_i < v_r$, where $v_r = (\beta p - h)/(1 + \gamma)$ is the *return value*. In this situation, the customer might fail to return the product due to different reasons, such as losing the receipt, missing the deadline, or simply forgetting. To take into account this possibility, we add to our model a return efficiency factor α ($0 \leq \alpha \leq 1$), which reflects the probability of returning the product when return is preferable. Higher return leniency corresponds with less hassle cost and possibly higher return efficiency factor. Hence, the utility of a customer who has already bought the product can be stated as:

$$U_i = \begin{cases} R_i - p & \text{if } v_r \leq R_i (\text{when customer keeps the product}), \text{ or} \\ & \text{if } R_i < v_r \text{ and customer fails to return the product} \\ & \quad \text{with the probability of } (1 - \alpha) \\ (\beta - 1)p - h - \gamma R_i & \text{if } R_i < v_r \text{ and customer returns the product} \\ & \quad \text{with the probability of } \alpha \end{cases}. \tag{1}$$

Considering the customers' uncertainty about the actual valuation of the product, a customer decides to buy the product if and only if the expected utility of the purchase is positive.

For the retailer, there exist a total expense of c to acquire and sell each unit of the product, and it sells each unit of the returned product with a salvage of s. To avoid selling and return arbitrage, we assume that $s<c$, which is a common assumption in the literature (see e.g., [8, 9]).

4 Problem Formulation

In this section we analytically determine the social welfare outcome of each pricing and refund strategy of the retailer, and show how the optimal price p^* and refund β^*can be specified.

Considering the stochastic utility of purchasing the product according to (1), *Proposition 1* characterizes the conditions under which customer i purchases the product. In other words, the proposition characterizes the conditions under which the customer's expected utility of purchase is positive.

Proposition 1 *Customer i purchases the product if and only if*

(i) $\overline{R}_i > \max(v_r + \delta, p)$, *or*

(ii) $v_r^e - \delta \leq \overline{R}_i \leq v_r^e + \delta$ *and one of the following two conditions is fulfilled:*

- $B^2 - 4AC < 0$
- $B^2 - 4AC \geq 0$ *and* $\overline{R}_i \notin [r_1, r_2]$

where

$$A = \alpha + \gamma,$$
$$B = 2\delta - 2p + (2\delta + 2p)(1 - \alpha) + (-2(\beta - 1)p + 2h - 2\gamma_e\delta)\alpha,$$
$$C = (\delta + v_r - 2p)(\delta - v_r) + (-\delta + v_r - 2p)(v_r + \delta)(1 - \alpha)$$
$$+(2(\beta - 1)p - 2h - \gamma(-\delta + v_r))(v_r + \delta)\alpha,$$
$$r_1 = \frac{-B - \sqrt{B^2 - 4AC}}{2A} \text{and } r_2 = \frac{-B + \sqrt{B^2 - 4AC}}{2A}.$$

Part (i) of *Proposition 1* states a situation in which the customer's average reservation price is so high that guarantees a positive expected utility for the customer, which in turn results in a purchase. On the other end of the spectrum, when $\overline{R}_i < v_r - \delta$, the customer never buys the product since his expected utility of purchase is always negative. In the middle range of $\overline{R}_i$, as expressed by part (ii) of *Proposition 1*, the customer's expected utility is a convex quadratic function of $\overline{R}_i$ (see the proof of *Proposition 1* for more details). This means, depending on the sign of the determinant of this function, the customer's expected utility is positive only outside the range of the two roots of this function, r_1 and r_2, or it is always positive if the function does not have a root. In other words, the customer's expected utility as a function of $\overline{R}_i \in [L, U]$, crosses the line of zero utility either once or twice. This is quite a counter intuitive result. If a given customer's average reservation price, $\overline{R}_i$, results in positive expected utility, then one expects an increase in $\overline{R}_i$ should result in an increase in the expected utility and hence a more desirable purchase. This is not necessarily the case when the customer is subject to endowment effect and his expected utility as a function of $\overline{R}_i$ has two roots, r_1 and r_2. In this case customers with $\overline{R}_i < r_1$ might experience a positive expected utility of purchase while customers with larger average reservation price in the range of $r_1 < \overline{R}_i < r_2$ do not buy the product due to a negative expected utility of purchase (see Fig. 1).

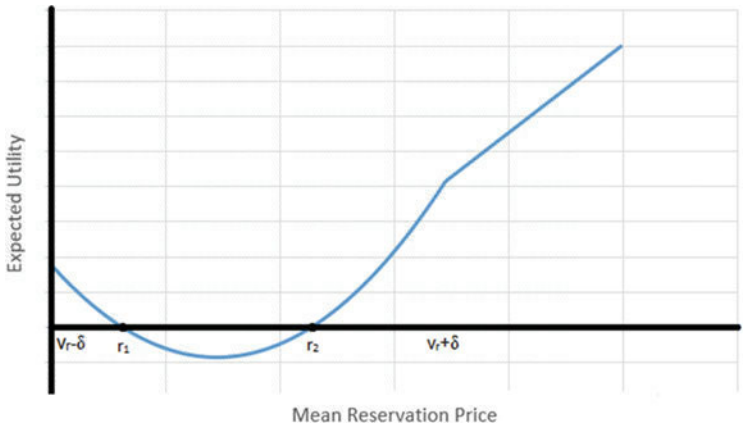

Fig. 1 Expected utility of purchase at different mean reservation prices

Let Φ be the set of average reservation prices which result in a positive expected utility for the customer, as characterized by proposition 1. That is:

$$\Phi = \left\{\overline{R}_i \in [L, U] \middle| E\left[U_i\left(\overline{R}_i\right)\right] > 0\right\}$$

Then, from the retailer's perspective, whose customers' average reservation prices are uniformly distributed over *[L, U]*, the probability of the purchase of a given customer *i* can be stated as:

$$P^{Purchase} = \frac{\int_{x \in \varphi} dx}{U - L} \tag{2}$$

As we indicated earlier, customer *i* keeps a purchased product if his actual reservation price, which is revealed after the purchase, turns out to be higher than the return value, $v_r = (\beta p - h)/(1 + \gamma)$. Even when this condition is not fulfilled, the customer might fail to return the product with a probability of $1 - \alpha$. *Proposition 2* characterizes the probability of a customer buys and keeps the product, $\Pr^{Keep}$, as well as the probability of a customer buys and returns the product, $\Pr^{Return}$. It is easy to verify that $\Pr^{Purchase} = \Pr^{Keep} + \Pr^{Return}$.

Proposition 2 *The probability of purchasing and keeping and the probability of purchasing and returning the product are determined by the following relations.*

$$\Pr^{Keep} = \frac{1}{2\delta(U-L)}\left(\frac{\overline{r_i}^2}{2} + (\delta - v_r)\overline{r_i} + (1-\alpha)\left(\frac{-\overline{r_i}^2}{2} + (\delta + v_r)\overline{r_i}\right)\right)\Big|_{v_r - \delta}^{v_r + \delta, \overline{r}_i \in \varphi} + \frac{U - \max(v_r + \delta, p)}{U - L} \tag{3}$$

$$\Pr^{Return} = \frac{1}{2\delta(U-L)}\left(\alpha\left(\frac{-\overline{r_i}^2}{2} + (\delta + v_r)\overline{r_i}\right)\right)\Big|_{v_r - \delta}^{v_r + \delta, \overline{r}_i \in \varphi} \tag{4}$$

Now we study the social welfare maximizing strategies of the retailer, i.e. the optimal selling price, p^*, and refund level, β^*, that maximize the social welfare. The efficiency requires the product to be delivered to precisely those customers whose product valuation exceed the acquisition cost (see e.g. [8, 10]). This simply infers that the price has to be set equal to cost of acquiring the product, c, in order to obtain the most overall efficiency. Assuming this optimal price, we proceed with specification of the refund. When a purchase happens and the given customer i keeps the product, the retailer and the customer surplus are R_i-c and none, respectively, so the overall surplus form the purchase is R_i-c, but when the customer returns the product after the purchase, the customer surplus turns $-h - (1-\beta)p - \gamma R_i$ and the retailer surplus changes to$s - c + (1-\beta)p$, so in this situation, the overall surplus from the purchase is$s - c - h - \gamma R_i$. Therefore, the overall surplus of purchasing and possibly returning the product for the retailer and customer i is

$$\Gamma_i = \begin{cases} R_i - c \\ \quad \begin{cases} f\ v_r \le R_i \quad customer\ keeps\ the\ product \\ f\ v_r > R_i \quad customer\ keeps\ the\ product\ with\ a\ probability\ of\ (1-\alpha) \end{cases} \\ s - c - h - \gamma R_i \\ \quad if\ v_r > R_i \quad customer\ returns\ the\ product\ with\ a\ probability\ of\ \alpha \end{cases} \tag{5}$$

Between the two keeping and return outcomes, the efficiency requires the one with the higher overall surplus happens. Based on this necessity, the refund level is simply inferred by the following proposition.

Proposition 3 *The efficient refund level, β^*, which maximizes the expected overall surplus is s/c.*

This specifies the absolute value of the refund equal to the salvage value of the product, which is again consistent with similar findings of the literature (see e.g. [8, 10]).

When the pricing and return strategies are in favor of surplus maximization, we denote the maximum surplus that is obtained as a result of each purchase decision by a given customer i as the maximal surplus, S_i. The following proposition specifies the maximal surplus expected.

Proposition 4 *The expected maximal surplus subsequent each purchase decision equals the following.*

$$
\begin{aligned}
E(S_i) = {} & \frac{1}{U-L}\int_{L}^{\min\left(\max\left(L,\frac{s-h}{1+\gamma}-\delta\right),U\right),r\in\varphi} ((\overline{r}_i - c)(1-\alpha) + (s-c-h-\gamma\overline{r}_i).\alpha). \\
& d\overline{r}_i + \frac{1}{U-L}\int_{\min\left(\max\left(L,\frac{s-h}{1+\gamma}-\delta\right),U\right)}^{\min\left(\max\left(L,\frac{s-h}{1+\gamma}+\delta\right),U\right),r\in\varphi} \\
& \frac{1}{4\delta}\left(\begin{array}{l}(\alpha+\gamma\alpha)\overline{r}_i^{\,2} \\ +(4\delta+2(-\delta-s+h-\gamma\delta)\alpha)\overline{r}_i \\ +\left(\begin{array}{l}-4c\delta \\ +\left(\delta-\dfrac{s-h}{1+\gamma}+2s-2h-\gamma\left(-\delta+\dfrac{s-h}{1+\gamma}\right)\right)\left(\dfrac{s-h}{1+\gamma}+\delta\right)\alpha\end{array}\right)\end{array}\right). \\
& d\overline{r}_i + \frac{1}{U-L}\int_{\min\left(\max\left(L,\frac{s-h}{1+\gamma}+\delta\right),U\right)}^{U,r\in\varphi} (\overline{r}_i - c). \\
& d\overline{r}_i
\end{aligned}
\tag{6}
$$

5 Numerical Experiments

In this section we investigate the impact of various parameters on the refund strategies of the retailer, along the overall surplus as a measure of social welfare. In order to conduct these experiments, we normalize [*L*,*U*] over [1, 2], and to avoid any negative values for the actual realization of the reservation prices, we confine the customers' reservation price uncertainty level, δ, to be always less than 1. This type of normalization of reservation prices is consistent with the literature (see, e.g., [8, 9]). To capture and demonstrate the impact of problem parameters, we consider a wide range of variations for each parameter from extremely low to extremely high levels in order to capture any likely realistic situation. Albeit for the sake of coherence and simplicity, we only present the results under the extreme cases, as the outcomes of the mid-levels are interpolation of the extreme cases. However, we present outcomes for the full range of return leniency variables. Moreover, to make our results more general, we define the two extreme levels of each parameter in terms of the normalized interval limits *L* and *U*; as shown in Table 1. We also associate the return efficiency with the hassle cost of return, since we expect a higher efficiency when returning the product is easier (low hassle cost) and vice versa. We consider the combination of the two as a measure of return leniency.

Return leniency clearly stimulates return in the market via reducing the negative impacts of returns for the customers. Subsequently, on one hand, this enhances

Table 1 Values of basic parameters for the numerical experiments

Parameter	Symbol	Low value	High value
Reservation price uncertainty	δ	$0.1 \times (U - L)$	$0.5 \times (U - L)$
Cost of acquiring the product	c	$\frac{1}{3} \times \frac{U+L}{2}$	$\frac{U+L}{2}$
Return Leniency (Hassle cost of return, Return efficiency)	(h, α)	$(0.1 \times c, 0.45)$	$(0.01 \times c, 0.9)$
Product salvage value	s	$0.1 \times c$	$0.9 \times c$
Endowment effect	γ	0.1	0.5

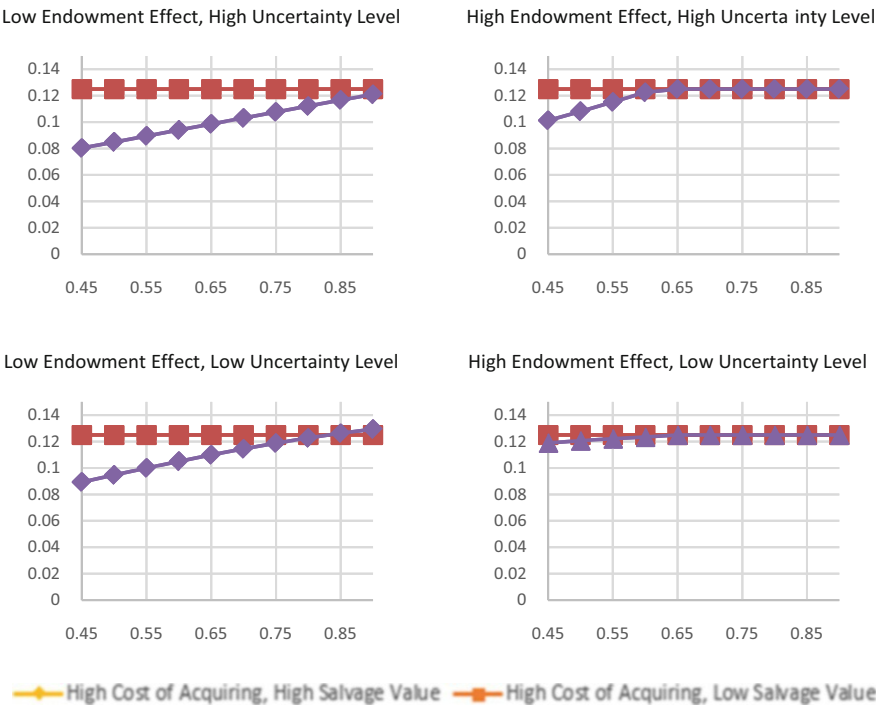

Fig. 2 Maximal surplus versus Return Efficiency (as a measure of return leniency)

customer's surplus by alleviating the negative impact of undesirable purchases, but on the other hand, increases negative surplus of the retailer while increasing the frequency of return. Due to these contradicting impacts, the overall result is not simply predictable. We study this topic in this section in terms of sensitivity of maximal surplus with respect to return leniency.

Figure 2 shows the sensitivity of maximal surplus respect to return leniency under different market conditions. The results of this part show that when the cost of acquiring is low, maximal surplus has no sensitivity respect to return leniency. Therefore, we are only presenting the results under high cost of acquiring in the figure. Based on the figure, there is no sensitivity when the salvage value is low

either, since in this case, the actual value of the product for the customer hardly turns less than the price, therefore the return decision is not preferable for the customer, and with no return in the market, the return leniency plays no role in the outcomes. But when the cost of acquiring and salvage value are both high, maximal surplus is increasing respect to return leniency. This suggests that the positive impact of return leniency on the customers' surplus overweigh its negative impact on the retailer's surplus under the market conditions that we examined in here. In this situation, the sensitivity of maximal surplus respect to return leniency is less when the endowment effect is high or uncertainty is low, since under these conditions, fewer returns happen in the market.

Results of this part are also comparable with the [3] finding regarding the higher impact of the leniency on the purchases with respect to the returns. This finding is important as it economically justifies striving for more return leniency by retailers when the profit of higher purchase rates overweighs the expenses of more frequent returns. Figure 3 presents a set of graphs that visualize the results of our experiments in this regard. The first (left-hand-side) vertical axes in these graphs present the purchase probability of a given customer under the profit maximizing price and refund strategies of the retailer, while the second (right-hand-side) vertical axes stand for probability of return. Our results show that at low levels of endowment effect, the purchase and return probabilities hardly change while increasing the leniency level, unless the salvage value and uncertainty are both high where the return probability is decreasing respect to the return leniency. The trend is generally reverse when the problem is subject to high endowment effect. Under such condition, the return probability is usually increasing respect to the return leniency, while the purchase probability is increasing if the cost of acquiring is high, and if not, the purchase probability shows some decreases followed by increases unless the uncertainty is low and salvage value is high. Under the latter conditions, the return probability is decreasing respect to the return leniency.

6 Conclusion

In this paper we presented an analytical model to capture the impact of various parameters on the customers' purchase and return behavior in a monopoly online market. The model includes for the first time, to the best of our knowledge, the impact of several influential factors, among which customer heterogeneity and return leniency, are novel in the product return literature (revenue management context). We specified the conditions under which a given customer makes a purchase. This helped us determine the probabilities of purchasing, keeping, and returning the product, which in turn enabled us to calculate the optimal price and refund level aiming to optimize the overall surplus as a measure of social welfare.

We conducted extensive numerical experiments using normalized problem parameters to help us with generalization of the results. Through these numerical experiments, we examined the sensitivity of retailer's optimal refund and its

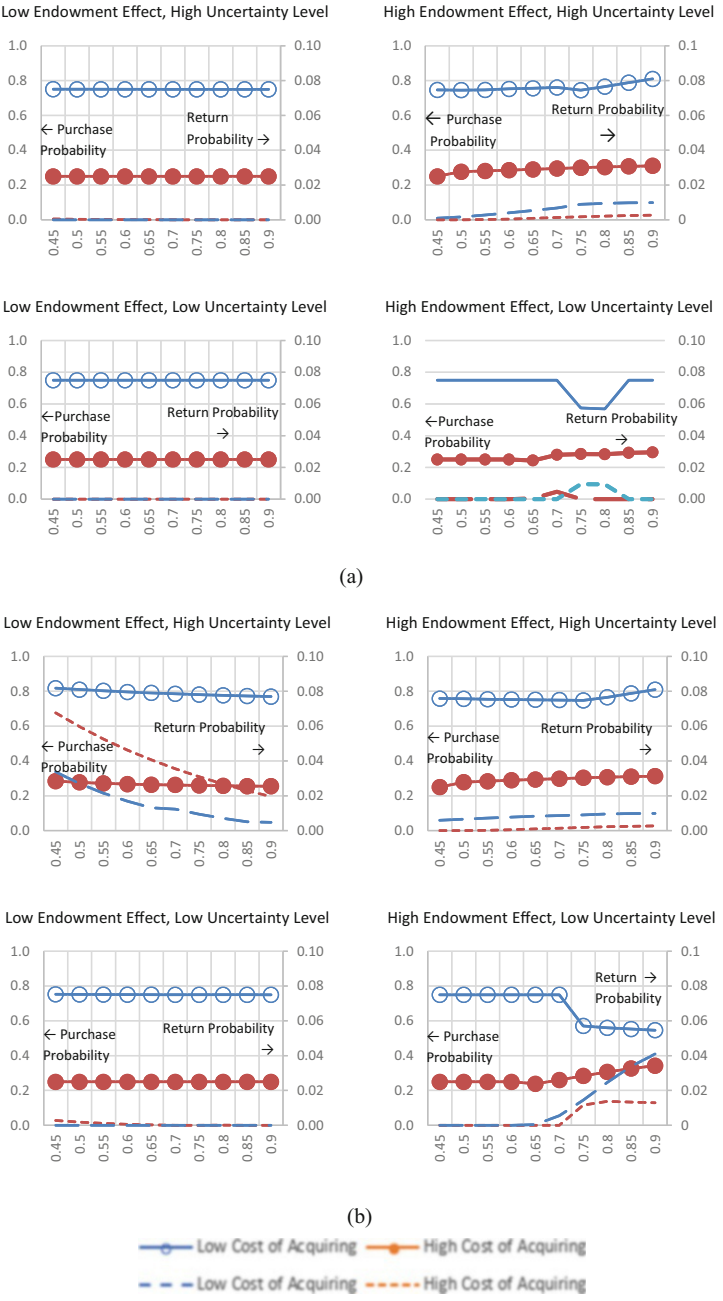

Fig. 3 Probabilities of purchase and refund versus Return Efficiency at (**a**) low salvage value, (**b**) high salvage value

expected profit and overall surplus with respect to the return leniency, whose results help retailers decide on taking measures toward providing return leniency to the customers.

Our results showed that has minor role when it comes to the impact of return leniency on the social welfare. There, the salvage value of product and cost of acquiring are the key factors, such that high values of those parameters result in increasing trend of overall surplus toward return leniency, unless the endowment effect and uncertainty are also high. Therefore, other than the specified conditions, higher return leniency does not lead to higher social welfare, thus is not justifiable, and this is more pronounced when the expenses of providing higher leniency are also considered.

We also examined the hypothesis of higher impact of return leniency on purchases compared to the return decisions. Our results showed that this is not always the case when the product price is optimized in accordance with the return leniency. There are cases where higher return leniency does not impact market demand, or even reduces it, such as when the salvage value and endowment effect are both high, and uncertainty and cost of acquiring are low. While under such conditions, the return leniency results in higher return frequency, there are cases that the negative impact of return leniency exists for both demand and returns. High salvage value and uncertainty, and low cost of acquiring, and negligible endowment effect is a clear condition of such.

The research of this paper can be extended in many different aspects. To mention a few, different market structures other than the monopoly can be studied, such as duopoly or oligopoly, the pricing and return strategies can be examined for the product bundles, and the impact of product quality, price adjustment strategy, and return insurance policies can be jointly studied with the current subject matter.

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