Should a manufacturer sell refurbished returns on the secondary market to incentivize retailers to reduce consumer returns?

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Abstract

Consumer electronics returns are typically returned by the retailer to the manufacturer for a full refund of the wholesale price. This practice does not sufficiently motivate the retailer to reduce the volume of returns. Different mechanisms have been proposed to incentivize the retailer to reduce returns, such as a reduced wholesale price for returns below a target, but they do not consider the subsequent disposition of returns. The high value of returns usually justifies refurbishment and resale. We study how competition between refurbished returns sold by the manufacturer and new products sold at the retailer affects retailer behavior. We find that the retailer never exerts more effort to reduce returns when faced with competition through the online store. The manufacturer's profitability, however, is always higher with an online store. The online store is also preferable to a strategy where the manufacturer only partially refunds the retailer for returns.

Keywords: supply chain management, manufacturer-retailer supply chain, consumer returns, secondary market

1 Introduction

Consumer returns are products that are returned by consumers to retailers or manufacturers shortly after purchase for a full or near full refund. These are not overstocks, which are unsold products shipped from retailers to manufacturers at the end of a selling season. The average return rate for

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online German retailers is 13% but can be as high as 50 to 70% for certain products (Pur et al. 2013). Return rates for consumer electronics range between 11% and 20%, and have been rising over the years (Douthit et al. 2011). Reasons for returns include a mismatch between product characteristics and consumer needs, buyer remorse, installation and usage problems, as well as missing parts or functionality (see e.g. Ferguson et al. 2006, Pur et al. 2013, Scheriau 2016). Thus, while some returned products are defective, between 80% and 90% of returns are essentially like new, and require little or no work if they are resold as refurbished products (Douthit et al. 2011, Pur et al. 2013); these are referred to as false failure returns (Ferguson et al. 2006). In the case of electronics products, which are the focus of this paper, retailers typically do not have the technical expertise to distinguish between defective and false failure returns. For this reason, retailers frequently ship returns back to manufacturers for a full refund of the wholesale price (Ferguson et al. 2006, Scheriau 2016).

While retailers incur some costs associated with handling returns, manufacturers incur most costs (Ferguson et al. 2006). In fact, Douthit et al. (2011) indicate that manufacturers spend billions of dollars with consumer returns. Consequently, manufacturers have explored different options to reduce such costs. Consider our industry partner, Philips, a manufacturer of consumer electronics. The vast majority of Philips sales are through physical and online retailers, such as Mediamarkt, Saturn, Red Zac, Amazon, and Otto. Philips operates an online store for direct sales to consumers, but for the DACH-region (Austria, Germany and Switzerland) sales through that channel account for only 0.3% of the total (Philips Austria GmbH 2018). Philips refunds retailers the full wholesale price for all returns it receives from them. In the electronics industry, legal concerns prevent manufacturers and retailers from selling consumer returns as new products (Pinçe et al. 2016). Consequently, alternative disposition options need to be considered, such as salvaging (recycling for materials recovery) and refurbishing. Historically, Philips has salvaged its returns. Another possibility is for Philips to reduce return rates. It is estimated that reducing the rate of returns by 10% could increase manufacturers' profits by up to 5% (Pur et al. 2013). This can be accomplished through many initiatives, such as improved product design, increasing effort during the sales process to reduce product mismatch with customer needs, and tightening return policies.

Manufacturers already constantly improve product designs in response to customer feedback (e.g. Cooper 2001). Hence, retailers play an essential role in reducing return rates. Retailers can tighten return policies (e.g., through restocking fees), however, many retailers hesitate to go down this route due to its negative impact on sales, and competitive pressure (see e.g. Shulman et al. 2011). As a result full refund policies are still common in practice (Heiman et al. 2005, Pur et al. 2013). Retailers can improve their sales process, through, for example, spending more time with consumers to find the products that best meet their needs in physical stores. Given the extra cost incurred by retailers in this option, manufacturers must incentivize retailers to exert this extra effort. In the U.K. Philips grants retailers a wholesale price reduction if returns are below a certain threshold (Scheriau 2016). Similarly, motivated by HP operations in the U.S., Ferguson et al. (2006) propose a target rebate contract, where the manufacturer pays the retailer a certain amount for each unit of returns below a contractually agreed upon target.

We can then broadly categorize the options available to reduce returns costs for manufacturers such as Philips as: (i) inducing retailer effort to reduce return rates, and (ii) more effectively reusing returns through refurbishment and resale (as opposed to salvaging). Because the refurbishment process is relatively fast, refurbished consumer returns typically belong to the same technological generation as corresponding new products sold by retailers (Ferguson et al. 2006, Guide et al. 2006). As a result, perhaps due to cannibalization issues, refurbished products are usually sold in a separate channel, an online outlet store operated by the manufacturer. Such online outlet stores exist for manufacturers such as HP[1], however, it does not exist for our industry partner Philips. Refurbishing and selling in a separate channel, however, creates strategic interactions with retailers because retailers can exert effort to reduce the volume of returns (and hence reduce the volume of refurbished products sold by the manufacturer), and they can control the new product price to compete with the manufacturer's refurbished products. Our main research question is then: Should a manufacturer sell refurbished returns on a separate channel to incentivize a retailer to reduce consumer returns? We split this broad question into three related questions:

1. Does the presence of an online store where the manufacturer can sell refurbished returns increase the effort of the retailer to reduce returns?

2. Does the online store increase the manufacturer's profit? If so, by how much?

3. Compared with a strategy where the manufacturer charges restocking fees to the retailer in

[1] http://www.hp.com/sbso/buspurchase_refurbished.html, accessed 10/05/18

order to induce retailer effort to reduce returns without an online store, when is the online store strategy preferred for the manufacturer?

To address these questions, we consider the impact of a manufacturer's online store on the (costly) effort exerted by the retailer as well as the overall profitability of the manufacturer, relative to a benchmark where there is no online store and all returns are salvaged at a fixed unit salvage value. In addition to an online store, we consider another option to increase retailer effort: the manufacturer simply charges the retailer a restocking fee for returns, similarly to what some retailers do to consumers. In this paper, the term "online store" refers to any channel that does not involve the retailer, and where the manufacturer has pricing power for refurbished products.

This paper is organized as follows. Section 2 summarizes the related literature and positions our paper and its contribution. In Section 3 we describe our model, while Section 4 presents our analytic and numerical analyses. Section 5 summarizes our main findings and discusses avenues for further research. All proofs and supporting numerical results are presented in an online supplement.

2 Literature review

Our paper draws fromtwo different streams within the broad domain of closed-loop supply chain (CLSCs) research: consumer returns and product disposition. In this section we provide an overview of related work in these areas and position our work accordingly.

One part of the literature on consumer returns generally analyzes whether, how, and to what extent consumers should be refunded for product returns, that is, the optimal design of return policies under both monopoly and competitive situations (see e.g. Ketzenberg and Zuidwijk 2009, Shulman et al. 2009, 2010, 2011, Yalabik et al. 2005). The key trade-off here is that one can lower the cost associated with returns through stricter policies (e.g. restocking fees) at the expense of lower sales. Chu et al. (1998) and Davis et al. (1998) show that a full refund policy is not optimal when consumers are opportunistic. Empirical studies indicate, however, that full refund policies are commonly found (see e.g. Heiman et al. 2005, Pur et al. 2013). Ofek et al. (2011) consider consumer returns in a dual channel competition (bricks and clicks) between retailers. They model different return rates between the channels and show that the effort to reduce returns in the bricks channel (through costly store assistance) may increase when the online store is opened. They do not consider competition between new and refurbished products (where refurbished products originate from consumer returns), which is key to our research. All of this research focuses on the relationship between retailers and consumers. As previously discussed, a large part of the cost associated with consumer electronics returns is borne by the manufacturer. By taking this into account, our model differs from and extends this literature by considering a supply chain consisting of a manufacturer, a retailer and consumers, and, importantly, considering a manufacturer's profitable disposition decision for returns: refurbishment and resale in a secondary market that competes with new products sold at retailers. In addition, we consider an alternative return policy between the manufacturer and the retailer, where there is a restocking fee similarly to return policies for consumers at some retailers.

In another part of the consumer returns literature, contracts to incentivize a retailer to reduce returns are studied form a manufacturer's viewpoint. Ferguson et al. (2006) study how to encourage the retailer to induce effort to reduce the volume of false failure returns through a target rebate contract. Huang et al. (2011) suggest a quantity discount contract that specifies a payment to the retailer at an amount that decreases in the number of returns. An integration of consumer returns policy and manufacturer refund policy under demand uncertainty is considered in Xiao et al. (2010), Ruiz-Benitez and Muriel (2014), and Liu et al. (2014). Our paper is related to this literature in that we also acknowledge that the manufacturer can incentivize the retailer to reduce returns, without directly controlling retailer effort. We contribute to this literature by proposing a new mechanism that is found in practice, namely when the manufacturer adds an online store for refurbished products, which increases the residual value of returns, and also competes with the retailer.

The research reviewed above does not consider the best disposition for returns, which is a central decision in CLSCs. For reviews of this literature see Guide and Van Wassenhove (2009) or Souza (2013). A key issue in this research stream is the optimal allocation of end-of-life or end-of-use returns to different disposition options, including remanufacturing, spare parts extraction, and recycling (see e.g. Ferguson et al. 2011, Geyer et al. 2007, Guide and Van Wassenhove 2001, Inderfurth et al. 2001). Ferguson and Toktay (2006) analyze an OEM's strategy to compete with a third-party remanufacturer (3PR) of end-of-use returns, or cores (*not* consumer returns). They present conditions under which (i) the OEM preemptively collects cores but does not remanufacture them, (ii) the OEM collects and remanufactures the cores, and (iii) the OEM lets the 3PR enter the market and remanufacture the cores. Similarly to our setting, Gan et al. (2017) also consider a setting where a manufacturer sells new products via a retailer and remanufactured products via a direct (online) channel. Choi et al. (2004) study the effect of the residual value of returns for the manufacturer on the return policy. Specifically, they analyze the manufacturer's choice of selling returned items on an e-marketplace, rather than salvaging them. Different than us, however, both Ferguson and Toktay (2006) and Gan et al. (2017) consider end-of-use returns rather than consumer returns, while Choi et al. (2004) model excess inventories returned by the retailer to the manufacturer due to demand uncertainty. As a result they do not consider retailer effort to reduce consumer returns, which in our case are used for remanufacturing and resale in the online store. There are only a few papers that address the optimal disposition decision for consumer returns. Guide et al. (2006) argue that consumer electronics returns are often time sensitive and manufacturers should make quick disposition decisions. Some papers, e.g. Li et al. (2011) or Reimann (2016), assume that refurbished consumer returns are perfect substitutes for new products, which is not our setting. More closely related is research where refurbished consumer returns are imperfect substitutes for new products. Akcay et al. (2013) and Crocker and Letizia (2014) address a retailer's disposition decision of either salvaging, or reselling consumer returns on a secondary market after a possible refurbishment. Reimann and Zhang (2013) and Pinçe et al. (2016) analyze how a *manufacturer* should allocate consumer returns between resale in a secondary market, and fulfillment of warranty claims. Motivated by practical examples, we complement this stream of research by analyzing a manufacturer's disposition of consumer returns as refurbishment and resale in a secondary market that competes with the retailer's new products. The objective is to reduce the cost associated with returns when the retailer can also exert effort to reduce returns and hence reduce the manufacturer's source for refurbishment, which can undercut the competition from the manufacturer.

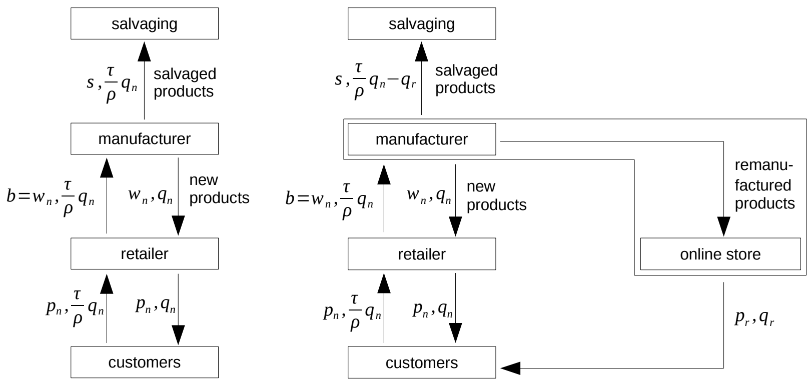
3 Model

3.1 Structure of the model

Consider a supply chain consisting of one manufacturer and one retailer. Reflecting the reality of the consumer electronics industry underlying our research, the retailer buys new products from the manufacturer at a unit wholesale price w_n and sells these units to consumers at a unit retail price p_n. Consumers can return products to the retailer within a grace period for a full refund of the retail price. In turn, the retailer ships the returns back to the manufacturer for a full refund of the wholesale price $b = w_n$.

The volume of returns can be influenced by the effort the retailer takes during the sales process. For example, the retailer can spend more time with the consumer to provide better information about the functionality of the product relative to alternatives. As in Ferguson et al. (2006), we model this effort by the decision variable $\rho \geq 1$, where the case $\rho = 1$ is interpreted as the standard effort exerted by the retailer. The actual effort undertaken by the retailer results in a return rate $\frac{\tau}{\rho}$. That is, when $\rho = 1$ the retailer faces a volume of returns of τq_n, where q_n is the sales volume of new products. Increasing ρ reduces returns, yet at a decreasing rate; this functional specification is the same as in Ferguson et al. (2006). Exerting effort ρ results in a cost $a(\rho - 1)$ to the retailer. Note that, without loss of generality, we assume that the standard effort $\rho = 1$ incurs no cost. Note that the cost of effort is a function solely of the effort ρ, and not of the quantities (e.g. q_n); the idea here is that effort impacts the return rate ($\frac{\tau}{\rho}$), which impacts the quantity of returns $\frac{\tau}{\rho} q_n$. This formulation is in line with the literature in modeling cost of effort (e.g. Taylor 2002, Ferguson et al. 2006, Savaskan et al. 2004). These functional specifications for the effect of effort on return rate, and for the cost of effort are chosen for tractability. In our numerical analysis, we have considered several other functional specifications to test robustness of our insights, namely: (i) effect: $\frac{\tau}{\rho}$, cost: $a(\rho^2 - 1)$; (ii) effect: $1 - \rho\tau$, cost: $a(\rho - 1)$; (iii) effect: $1 - \rho\tau$, cost: $a(\rho^2 - 1)$. In all of these cases, we obtain consistency of insights with our chosen functional specification. Thus, we only present the results for quadratic cost of effort (case (i)) in the Online Supplement.

In the status quo of our motivating industry partner Philips, the manufacturer salvages, i.e. recycles all returns $\frac{\tau}{\rho} q_n$ at a per-unit salvage value s. The unit salvage value s is net of all costs related to handling the return, and transportation cost, if any, to the recycler. This situation is depicted in Figure 1a) and will be referred to as model N (for **n**o online store) in the remainder of the paper. Figure 1b) shows the extended model, where the manufacturer can now sell some of the returns as refurbished units at a unit price p_r, a decision variable, in its **o**nline store, hereafter named model O, as is the case with HP and Philips. Returns not sold in the online store are salvaged at the unit salvage value s. Finally, we assume that the manufacturer does not have a return policy for the refurbished products sold at the online store, and hence there are no product returns from the sale of refurbished products. This assumption is necessary for tractability. In practice, the volume of such returns would be rather small: for a return rate of consumer electronics of 15% (Douthit et al. 2011), such returns would constitute at most 2.3% (0.15^2) of sales, hence we ignore them in our model for tractability reasons. In other words, we essentially ignore returns from returns, a second-order effect, and concentrate on first-order effects.



a) model N b) model O

Figure 1: Closed-loop supply chain model without and with an online store

Note that we assume that the manufacturer only sells new products to consumers through the retailer, for tractability. Although this is admittedly a simplification of reality in the case of consumer electronics, it allows us to focus on the strategic interaction between new products sold by the retailer and the refurbished products sold by the manufacturer at the online outlet store, which originate from consumer returns at the retailer. New products sold by the manufacturer directly to consumers are likely not to be impacted by retailer effort to reduce returns, which is a key element of our research question. In addition, for many electronics manufacturers, direct sales to consumers constitute a relatively small portion of their revenues. For example, at HP, 80% of its revenues worldwide and across all segments originated through channel partners in 2016.[2] Even more pronounced, in our motivating industry partner Philips (Philips Austria GmbH 2018), sales of new products directly to consumers through the online store account for only 0.3% of total sales in the DACH-region (Austria, Germany and Switzerland).

3.2 Supply side of the model

The supply side of the model is characterized by the cost structure for manufacturing new products and refurbishing returns. Specifically, the unit cost of manufacturing a new product is c_n, while the unit cost of refurbishing a return for sale at the online store is c_r, where the unit refurbishing cost c_r includes the cost of handling the return, transportation to/from the refurbishment facility, and any remarketing cost.

Assumption 1. *The sum of the unit cost of refurbishing a returned product and the salvage value s has to be less than the unit cost of manufacturing a new product, i.e. $c_r + s < c_n$, and c_r is the same for all refurbished products.*

First, this assumption implies that $c_r < c_n$, which is in line with previous research (see e.g. Savaskan et al. 2004). In our context it is a mild assumption and reflects the reality of consumer electronics returns; it is justified by the fact that, as previously stated, between 80% and 90% of consumer electronics returns are false failures, and hence only require light refurbishing, such as repackaging, software updates, and minor cosmetic work (see e.g. Pur et al. 2013).

Second, notice that, if Assumption 1 does not hold, then the manufacturer is better off salvaging the returns, and manufacturing and selling new units to meet demand for refurbished products, that is, refurbishing is not economically viable. We rule out such uninteresting case.

3.3 Demand side of the model

The demand side of the model is comprised of consumers with a heterogeneous WTP for new products ϕ. Without loss of generality we normalize the market size to one.

Assumption 2. *A consumer's WTP for the new product ϕ is uniformly distributed in the interval* $[0, 1]$.

[2] `https://www8.hp.com/us/en/hp-labs/innovation-journal-issue2/channel-partners.html`, accessed 10/09/18.

Assumption 3. *A consumer of type ϕ has a WTP for the refurbished product equal to $\delta\phi$, where $0 < \delta < 1$ is a discount factor that is constant across consumers.*

These are common assumptions in the CLSC literature and have been used in, among others, Agrawal et al. (2016), Atasu et al. (2008), Atasu and Souza (2013), Ferguson and Toktay (2006), Ferrer and Swaminathan (2006), Galbreth et al. (2013), Orsdemir et al. (2014), Oraiopoulos et al. (2012), Pinçe et al. (2016), Souza (2013), Subramanian et al. (2013), as they ensure tractability because they result in linear demand functions, as described below. While empirical research (e.g. Abbey et al. 2015, Ovchinnikov 2011) suggest that the constant δ portion of Assumption 3 is not met in various practical applications, two recent papers, namely Abbey et al. (2017) and Kleber et al. (2018), convincingly show that structural insights obtained using the constant δ assumption are robust. That is, the decision variables move in the same direction with respect to parameters, and the equilibrium regions are the same in competitive models, with similar threshold-type rules for certain parameters for the occurrence of a particular equilibrium region. In sum, assumptions 2 and 3 do not drive the key results in the CLSC literature.

As a result of Assumption 2, the cumulative distribution function (cdf) of WTP for the new product is thus $F(\phi) = \phi$, and hence the demand for the new product in model N is given by $q_n(p_n) = 1 \cdot \Pr\{\phi > p_n\} = 1 - p_n$. Conversely, in model O the quantity of new products is given by $q_n(p_n, p_r) = 1 - \frac{p_n - p_r}{1-\delta}$ and the quantity of refurbished products is $q_r(p_n, p_r) = \frac{p_n - p_r}{1-\delta} - \frac{p_r}{\delta}$ (see e.g. Souza 2013, for a complete derivation).

Assumption 4. *$\delta > c_r + s$.*

This assumption is a necessary condition for the viability of selling refurbished items compared to salvaging them for material recovery only. Observe that the per-unit revenue on the secondary market $(p_r - c_r)$ can never exceed $\delta - c_r$. Thus, if the assumption is violated, that is, if $s \geq \delta - c_r$, then salvaging the returns would be preferable over refurbishing and selling them. Table 1 summarizes our notation.

3.4 Decision problems

The sequence of events and decisions in models O and N are determined by the following assumption.

Table 1: Notation

Parameters	
δ	Marginal WTP for a refurbished product relative to a new one ($0 < \delta < 1$)
c_n	Unit cost of manufacturing a new product ($0 < c_n < 1$)
c_r	Unit cost of refurbishing a return for sale at the online store ($0 \leq c_r < c_n$)
a	Cost of effort ($a > 0$)
s	Salvage value for returned products
τ	Return rate associated with the standard effort to reduce returns ($0 \leq \tau < 1$)
Decision variables	
w_n	Unit wholesale price of a new product
p_n	Unit retail price of a new product
p_r	Unit price of the refurbished product (only in model O)
ρ	Retailer effort to reduce returns ($\rho \geq 1$)
Auxiliary variables	
b	Unit refund for a returned product to the retailer ($b = w_n$)
q_n	Sales quantity (demand) for new products
q_r	Sales quantity (demand) for refurbished products
Π_i^j	Profit of party i ($i \in \{M, R\}$) in model j ($j \in \{N, O, NB\}$)

Assumption 5. *The manufacturer and the retailer play a Stackelberg game with the manufacturer as the Stackelberg leader in a single-period setting.*

The assumption that the manufacturer is the Stackelberg leader is appropriate to supply chains where the manufacturer has a strong brand and enough channel power to set wholesale prices. It has also been employed in other CLSC research that explicitly considers two echelons, manufacturers and retailers (Crocker and Letizia 2014, Savaskan et al. 2004).

We assume symmetric information about all the key parameters such as costs and demands in both models. The single period can be viewed as a stationary solution over an infinite horizon with identical periods, i.e. we abstract from any transient behavior. This is reasonable when the supply and demand characteristics of the problem do not change over time such as when the product is in the maturity stage of its life cycle. Such single-period model in an infinite horizon setting is fairly standard in the CLSC literature (see, among others, Abbey et al. 2017, Agrawal et al. 2016, Atasu et al. 2008, Atasu and Souza 2013, Ferguson et al. 2006, Galbreth et al. 2013, Orsdemir et al. 2014, Ovchinnikov 2011, Ray et al. 2005, Souza 2013, Subramanian et al. 2013).

Referring to Figure 1a), in model N the manufacturer only decides upon the wholesale price w_n, and, subsequently, the retailer sets the unit retail price of a new product p_n and the effort

ρ to reduce consumer returns. The retailer may exert effort to reduce returns because, although costly, the retailer makes zero profit for each return, whereas the retailer makes a positive profit $p_n - w_n$ for each unit sold and not returned. Note that an increase in effort ρ decreases the volume of returns $\frac{\tau}{\rho}$, increasing net sales to the manufacturer $q_n(p_n)\left(1 - \frac{\tau}{\rho}\right)$. The profit functions for the retailer and manufacturer are, respectively:

$$\Pi_R^N(p_n, \rho) = q_n(p_n)(p_n - w_n)\left(1 - \frac{\tau}{\rho}\right) - a(\rho - 1), \tag{1}$$

$$\Pi_M^N(w_n) = q_n(p_n)\left(w_n\left(1 - \frac{\tau}{\rho}\right) - c_n + \frac{\tau}{\rho}s\right), \tag{2}$$

and the decision model is stated as:

$$\begin{aligned} \max_{w_n} \quad & \Pi_M^N(w_n) && \text{(model N)} \\ s.t. \quad & (p_n^*, \rho^*) \in \arg\max_{p_n, \rho \geq 1} \Pi_R^N(p_n, \rho) \\ & 0 \leq q_n(p_n) \leq 1 \\ & 0 \leq w_n \leq 1 \\ & \Pi_M^N(w_n^*) \geq 0 \\ & \Pi_R^N(p_n^*, \rho^*) \geq 0. \end{aligned}$$

Referring to Figure 1b, in model O the manufacturer has an additional decision variable, namely the unit retail price of the refurbished product p_r. The profit functions for the retailer and manufacturer are, respectively:

$$\Pi_R^O(p_n, \rho) = q_n(p_n - w_n)\left(1 - \frac{\tau}{\rho}\right) - a(\rho - 1), \tag{3}$$

$$\Pi_M^O(w_n, p_r) = q_n\left(w_n\left(1 - \frac{\tau}{\rho}\right) - c_n\right) + q_r(p_r - c_r) + (\frac{\tau}{\rho}q_n - q_r)s, \tag{4}$$

where we have simplified the notation above and write $q_n = q_n(p_n, p_r)$ and $q_r = q_r(p_n, p_r)$. There is now an additional constraint in the decision model that ensures that the quantity of refurbished products cannot exceed the volume of returns:

$$\begin{aligned}
\max_{w_n,p_r} \quad & \Pi_M^O(w_n,p_r) && \text{(model O)}\\
s.t. \quad & (p_n^*,\rho^*) \in \arg\max_{p_n,\rho\geq 1} \Pi_R^O(p_n,\rho)\\
& 0 \leq q_n(p_n,p_r) \leq 1\\
& 0 \leq w_n \leq 1\\
& 0 \leq q_r(p_n,p_r) \leq \frac{\tau}{\rho} q_n(p_n,p_r)\\
& \Pi_M^O(w_n^*,p_r^*) \geq 0\\
& \Pi_R^O(p_n^*,\rho^*) \geq 0.
\end{aligned}$$

Finally, the following technical assumption ensures the concavity of the profit functions.

Assumption 6. $\delta < \frac{8(1-\tau)}{8-8\tau+\tau^2}$.

This technical assumption is fairly mild. Typical return rates τ are below 50% (see e.g. Guide et al. (2006)), and so Assumption 6 requires $\delta < 94\%$, which is well above discount factors observed in practice. For example, discount factors between 50% and 85% are reported in Guide and Li (2010) and Subramanian and Subramanyam (2012) for different product categories.

4 Analysis

In this section, we provide the analysis that answers our research questions listed in section 1. Research questions 1 (whether the online store increases retailer effort), 2 (whether the manufacturer's profit is higher with an online store), and 3 (whether a restocking fee strategy is better than establishing an online store) in sections 4.1, 4.2, and 4.3, respectively.

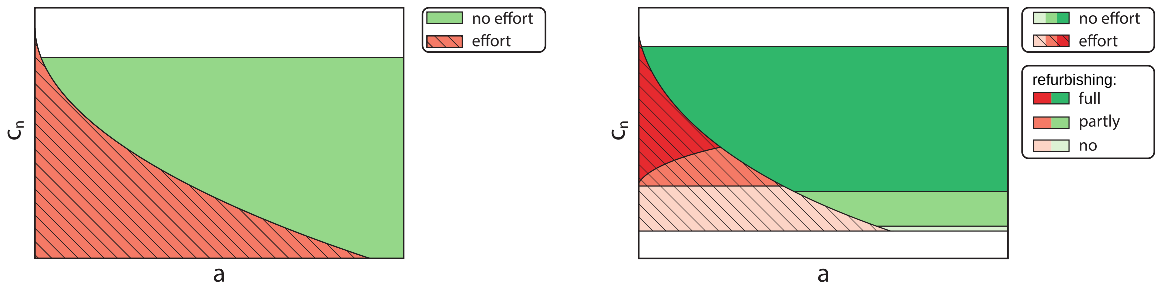
4.1 Impact of an online store on retailer effort

Solving models N and O through backward induction yields the result summarized in Lemma 1.

Lemma 1. *There exist two threshold functions for the unit manufacturing cost c_n^N and c_n^O. In model N, it is optimal for the OEM to induce extra effort ($\rho > 1$) by the retailer when $c_n \leq c_n^N$. Similarly, in model O, the retailer is induced to exert extra effort when $c_n \leq c_n^O$.*

The optimal level of extra effort in model N is given by $\rho^* = \frac{\tau}{2} + \frac{1-c_n}{4}\sqrt{\frac{\tau}{a}}$. *In model O, the optimal level of extra effort is given by* $\rho^* = \frac{\tau}{4}\frac{2-\delta}{1-\delta} + \frac{1-c_n-2(\delta-p_r)}{4\sqrt{1-\delta}}\sqrt{\frac{\tau}{a}}$.

To illustrate Lemma 1, Figure 2 displays the different equilibrium regions as a function of the unit manufacturing cost c_n and the cost of effort a for models N (a) and O (b). Given the complexity of the threshold functions c_n^N and c_n^O it is not possible to analytically prove $c_n^N < c_n^O$ in general, and consequently whether effort is always higher in one of the two models. However, Theorem 1 presents a strong result for that case where both models prescribe $\rho > 1$.



(a) model N

(b) model O

Figure 2: Equilibrium regions for models N (a) and O (b) (parameters: $\tau = 0.3$, $s = 0.07$, $c_r = 0.1$, $\delta = 0.3$)

Theorem 1. *If it is optimal for the retailer to exert effort* ($\rho > 1$) *in both models, then the effort* ρ *is always higher in model N than in model O.*

Theorem 1 indicates that the only possibility where the effort in model O can be higher than in model N is when $\rho > 1$ in model O, while $\rho = 1$ in model N. As mentioned above, we can not analytically determine whether such a situation may exist. However, an extensive numerical analysis[3] has shown that **for realistic parameter settings, the effort the retailer exerts is never higher in the presence of an online store.** This also implies that it can never be optimal for the OEM to induce extra retailer effort under the presence of the online store, when it is not also optimal to do so without the online store.

The following proposition provides the intuition for this result.

[3]We discuss the experimental design of our numerical analysis and the detailed results below in Section 4.2.

Proposition 1. *The equilibrium prices for new products in both models satisfy:*
(i) $w_n^{j,\rho>1} \leq w_n^{j,\rho=1} \qquad j \in \{N, O\}$,
(ii) $p_n^{j,\rho>1} \leq p_n^{j,\rho=1} \qquad j \in \{N, O\}$.

We first observe that the manufacturer charges a lower wholesale price when it is optimal for the retailer to exert effort. In other words, the manufacturer induces the retailer to increase effort by lowering the wholesale price. In turn, the retailer lowers the retail price p_n, increasing sales. This result is consistent with Philips' policy in the UK to offer a lower wholesale price in exchange for a lower level of returns (caused by an increased effort by the retailer). However, this is only optimal when c_n is relatively small. In that case, the large sales quantity leads to a large marginal effect of reducing returns for both players. As c_n increases this effect gets smaller and eventually is offset by a reduced manufacturer's profit from the discounted wholesale price. At that point, the equilibrium switches to the region where the retailer exerts no more effort in reducing returns. This effect is pronounced by the fact that for the manufacturer the residual value of the returns is higher in the presence of the online store. Consequently the manufacturer has less incentives to induce the retailer to exert more effort.

Previous research has focused on reducing consumer returns in order to reduce the associated costs. For example, in Ferguson et al. (2006) a contractual mechanism—the target rebate contract—is proposed to induce retailer effort for reducing consumer returns. In their case, however, the further disposition of these returns is not explicitly modeled; only an associated cost is avoided for every unit not returned. Because we allow for the manufacturer to compete with the retailer through an online store, which is commonly observed in practice, our results indicate that reducing consumer returns may not be the preferred option. Rather we find that recapturing sufficient value from the consumer returns may be a (preferable) substitute to reducing consumer returns. Below we analyze the profit implications of our findings to further deepen our understanding of the manufacturer's optimal strategy with respect to consumer returns.

4.2 Impact of an online store on manufacturer profit

Considering that the establishment of an online store can never increase retailer effort to reduce returns, one wonders whether the manufacturer is actually better off with the online store. It turns out that this is indeed the case:

Theorem 2. *Model O always results in a higher manufacturer profit than model N.*

This result is intuitive when it is optimal for the manufacturer to refurbish and resell the returns ($q_r > 0$), because this is an additional degree of freedom available to the manufacturer, who is the Stackelberg leader, for disposition of the returns, hence driving the result. However, Theorem 2 holds even when the manufacturer decides not to sell any refurbished returns on the online store, i.e. when $q_r = 0$. For this case, Proposition 2 provides the intuition. This proposition extends a similar result found in Chiang et al. (2003) for the case where only new products are sold and consequently sales effort and returns are not considered.

Proposition 2. *When the manufacturer does not operate the online store, i.e. $q_r = 0$, then:*
(i) If $\rho^N = \rho^O = 1$, then $w_n^N = w_n^O$ and $p_n^N > p_n^O$.
(ii) If $\rho^N > \rho^O > 1$, then $w_n^N > w_n^O$ and $p_n^N > p_n^O$.

Observe that the retail price is always lower in the presence of the online store. Thus, the retailer deters entry by the manufacturer through more competitive pricing, resulting in higher sales. In addition, Proposition 2(i) also shows that when it is optimal not to exert effort in either model, the wholesale prices across models are identical. Thus, the manufacturer sells more products to the retailer without changing his wholesale price, thereby increasing his profits. On the other hand, when it is optimal to exert effort in both models, Proposition 2(ii) shows that the manufacturer has to lower the wholesale price. However, this reduction is outweighed by the sales increase due to the retail price reduction, resulting in higher profits, according to Theorem 2. Together, these results imply that by threatening to operate the online store, without following up on that threat, the manufacturer extracts extra profits from his supply chain relationship with the retailer, albeit without achieving an increasing effort from the retailer.

Previous CLSC research indicates that a monopolist OEM remanufacturer introduces a refurbished (remanufactured) version of its product if $c_r \leq \delta c_n$, that is, the unit refurbishing cost is low enough relative to the unit cost of the new product, and the market acceptance of refurbished products δ is high (e.g. Atasu et al. 2008, Ferguson and Toktay 2006, Souza 2013). However, that research does not consider the supply chain relationship with a retailer, which in our setting sells the OEM's new product, controls the new product price, and the level of returns. Our work builds on this body of work and shows the benefits of OEM refurbishing by considering the strategic interactions with a retailer, and in the context of consumer returns, which are the primary inputs for refurbished products, and whose level can also be controlled by the retailer through effort.

To numerically quantify the magnitude of the benefit that the manufacturer derives from establishing the online store, we utilize a full-factorial experimental design where we assign two values, one low and one high, to each of the relevant parameters as shown in Table 2. These values are chosen to reflect a wide range of industrial settings. The values for the relative WTP for a refurbished product δ are taken from Subramanian and Subramanyam (2012), whereas return rates τ are similar to those in Guide et al. (2006).[4] The values for unit costs c_n and c_r/c_n are consistent with those reported in Guide et al. (2006), Ferguson et al. (2006), and Ferguson et al. (2011). The two values of relative salvage value s/c_n represent low and high values considering that necessarily $s < c_n$. Finally, the values for the cost of effort a were calibrated after some preliminary analysis. The experimental design yields $2^6 = 64$ instances. The two models N and O are then solved numerically for each instance.

Table 2: Experimental design

Parameter	Low	High
δ	0.5	0.85
τ	0.15	0.5
c_n	0.1	0.5
c_r/c_n	0.1	0.4
s/c_n	0	0.5
a	0.001	0.01

Tables 3 provides the average ratio of different decision variables between models O and N across all 64 instances.[5] profit improvement for the manufacturer associated with the introduction of the online store is 79%, while the retailer's profit is only 59% of her profit when there is no online store. The reduction in effort associated with the introduction of an online store is about 16%. Interestingly, on average, the wholesale price does not change, while the retail price drops by about 13% when the online store exists. These results illustrate the analytic findings, and indicate that

[4]Note that here we took into account the fact that the reported return rates in Guide et al. (2006) might already include some sales effort, and hence we choose $\tau = 0.5$ for a high level.

[5]The full set of results are presented in Table 10 in the Online Supplement. The average (across all 64 instances)

the introduction of an online store increases the manufacturer's profit while reducing the retailer's profit quite significantly. While the online store does not help in reducing returns, it forces the retailer to lower its price, increasing the sales of new products. Together with the fact that the manufacturer does not lower its wholesale price at the same rate as the retail price declines, this increases the manufacturer's profits.

Table 3: Average ratio of variables (%) between models O and N

Metric	Value (%)
Average ratio for manufacturer's profit $\frac{\Pi_M^O}{\Pi_M^N}$	179
Average ratio for retailer's profit $\frac{\Pi_R^O}{\Pi_R^N}$	59
Average ratio for effort $\frac{\rho^O}{\rho^N}$	84
Average ratio for retail price $\frac{p_n^O}{p_n^N}$	87
Average ratio for wholesale price $\frac{w_n^O}{w_n^N}$	100

Table 4 provides the distribution of instances into different regions for ρ and q_r, where we observe the following. First, in the vast majority of instances (60 out of 64), it is indeed optimal for the manufacturer to refurbish and resell returns ($q_r > 0$ in model O). Second, there are four instances where there is no equilibrium in model N, but there is an equilibrium in model O. This happens when c_n is high, and consequently the wholesale and new product prices are too high to yield positive profits for both firms in model N. With the introduction of an online store, the extra profit enabled by selling refurbished returns ensures positive profits for both firms, as the manufacturer is able to reduce the wholesale price. Third, in exactly half the instances in model O, the retailer exerts extra effort ($\rho > 1$). In contrast, without an online store, the retailer exerts extra effort much more often, namely in 40 instances, while minimum effort is exerted in only 20 instances. This again highlights the negative structural effect the online store has on the retailer's effort.

Table 5 provides further insights into the profits and decision variables, when segregated according to regions of q_r and ρ as in Table 4, as follows. First, in the few instances where the manufacturer only threatens to operate the online store but sets $q_r = 0$, his average profit is still more than 30% higher than in model N. In these instances, the threat of the online store prompts the retailer to reduce her efforts and retail price by 5%, on average, while the manufacturer charges

Table 4: Distribution of instances in the experimental design

Nr. of cases in each region			N		
			$\rho = 1$	$\rho > 1$	No equilibrium
O	$\rho = 1$	$q_r = 0$	2	0	0
		$q_r > 0$	18	8	4
	$\rho > 1$	$q_r = 0$	0	2	0
		$q_r > 0$	0	30	0

a slightly lower wholesale price, reaping almost all of the benefits from increased new product sales. Second, when the manufacturer does refurbish and resell returns ($q_r > 0$), the retailer significantly reduces its new product price, by 14% on average, to compete with the manufacturer and limit the manufacturer's pricing power. This move drastically reduces the retailer's profit, however, by 78% when $\rho = 1$ and by 39% when $\rho > 1$. Finally, utilizing the online store for reselling refurbished returns is not a perfect substitute for incentivizing the retailer to reduce returns. Rather, the manufacturer increases its profits from the utilization of both strategies ($\rho > 1$ and $q_r > 0$) in roughly half the instances, according to Table 4. This highlights a key contribution of this paper, which is to show the significant benefits of simultaneously reducing the volume of returns (like in Ferguson et al. (2006)), and finding effective disposition for returns (like in Pinçe et al. (2016)).

4.3 Restocking fee vs. online store

Thus far we have compared the status quo observed in our industry partner (no online store) with another approach, also seen in practice, to introduce an online outlet store for dealing with returns. We have seen that the online store significantly increases manufacturer profit, but leads to a lower effort by the retailer to reduce returns. One wonders whether an alternative mechanism for dealing with returns should be preferred: a restocking fee charged by the manufacturer to the retailer, similar to the practice of some retailers of charging restocking fees to consumers. So far, we have considered that the retailer is fully refunded for each returned product by the manufacturer. We now introduce a refund rate b as a new decision variable set by the manufacturer: the manufacturer only refunds an amount $0 \leq b \leq w_n$ to the retailer for each returned product, which also means a unit restocking fee of $w_n - b$. Figure 3 illustrates this model. Now, the profit functions for the

Table 5: Ratio of variables (%) according to different regions of q_r and ρ

$\frac{\Pi_M^O}{\Pi_M^N}$ $\left(\frac{\Pi_R^O}{\Pi_R^N}\right)$		(%)	N		
			$\rho = 1$	$\rho > 1$	No equilibrium
O	$\rho = 1$	$q_r = 0$	133 (89)	–	–
		$q_r > 0$	227 (65)	178 (22)	∞ (∞)
	$\rho > 1$	$q_r = 0$	–	130 (89)	–
		$q_r > 0$	–	156 (61)	–

$\frac{\rho^O}{\rho^N}$		(%)	N		
			$\rho = 1$	$\rho > 1$	No equilibrium
O	$\rho = 1$	$q_r = 0$	100	–	–
		$q_r > 0$	100	58	∞
	$\rho > 1$	$q_r = 0$	–	95	–
		$q_r > 0$	–	79	–

$\frac{p_n^O}{p_n^N}$ $\left(\frac{w_n^O}{w_n^N}\right)$		(%)	N		
			$\rho = 1$	$\rho > 1$	No equilibrium
O	$\rho = 1$	$q_r = 0$	97 (100)	–	–
		$q_r > 0$	87 (97)	86 (109)	∞ (∞)
	$\rho > 1$	$q_r = 0$	–	95 (100)	–
		$q_r > 0$	–	86 (99)	–

manufacturer and retailer are:

$$\Pi_R^{NB}(p_n, \rho) = q_n(p_n)\left[p_n(1 - \frac{\tau}{\rho}) - w_n + \frac{\tau}{\rho}b\right] - a(\rho - 1), \tag{5}$$

$$\Pi_M^{NB}(w_n, b) = q_n(p_n)\left(w_n - c_n - \frac{\tau}{\rho}b + \frac{\tau}{\rho}s\right). \tag{6}$$

The decision model, termed NB, is given by:

$$
\begin{aligned}
\max_{w_n, b} \quad & \Pi_M^{NB}(w_n, b) && \text{(model NB)} \\
s.t. \quad & (p_n^*, \rho^*) \in \arg\max_{p_n, \rho \geq 1} \Pi_R^{NB}(p_n, \rho) \\
& 0 \leq q_n(p_n) \leq 1 \\
& s \leq w_n \leq 1 \\
& s \leq b \leq w_n \\
& \Pi_M^{NB}(w_n^*, b^*) \geq 0 \\
& \Pi_R^{NB}(p_n^*, \rho^*) \geq 0.
\end{aligned}
$$

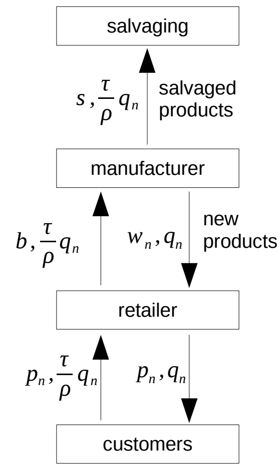


Figure 3: Closed-loop supply chain model without an online store, but a restocking fee for returns

Note that model N from Section 3 is a special case of model NB where $b = w_n$. Unfortunately, for model NB a closed-form solution can not be obtained. Thus, to be able to compare strategy NB with the online store strategy O, we again resort to a numerical analysis using the experimental design from Table 2. Again, for the sake of brevity we only present a summary of the results here, while the full set of results are available in Table 11 in the Online Supplement. Table 6 provides the distribution of instances into different regions for ρ and q_r, as in Table 4 in the previous section. Similarly to model N, there are four instances without an equilibrium for model NB, as it cannot ensure positive profits for both firms. In all other 60 instances,the introduction of a restocking fee always induces the retailer to exert effort in model NB.

Table 6: Distribution of instances in the experimental design

Nr. of instances in each region			NB		
			$\rho = 1$	$\rho > 1$	No equilibrium
O	$\rho = 1$	$q_r = 0$	0	2	0
		$q_r > 0$	0	26	4
	$\rho > 1$	$q_r = 0$	0	2	0
		$q_r > 0$	0	30	0

Table 7 shows, for each variable, the ratio of this variable's values between models O and NB, in percentage terms. The main finding is that, from the manufacturer's perspective, introducing the online store is on average preferable to charging a restocking fee, with an average profit increase of 37%. However, there is a small number of instances when the manufacturer should prefer a restocking fee, which are shown in the third column in Table 7. In these instances, when introducing the online store the manufacturer only makes 72%, on average, of the profit achievable with a restocking fee. This only happens when c_n, c_r, s and τ are high, while δ is low, and combined they comprise only 4 out of 64 instances in the study. The combination of high c_n and τ implies a lower profitability of the primary market, a low δ implies a small secondary market potential, and high values of c_r and s further reduce the profitability of refurbishing. In other words, only when the secondary market environment is very unfavorable and the primary market is small would the manufacturer prefer charging restocking fees to operating an online store, thereby inducing the retailer to exert more effort in reducing returns. We also note that it is always optimal for the manufacturer to charge the maximum possible restocking fee, i.e. to refund only $b = s$. Note that the manufacturer can not refund less than s, otherwise the retailer would prefer salvaging the returns herself.

To conclude our analysis, we provide a deeper analysis of a particular instance of parameter values, which closely reflects the situation of our industry partner that motivated this study: $c_n = 0.1$, $\tau = 0.15$, $\frac{c_r}{c_n} = 0.4$, $\frac{s}{c_n} = 0.5$, and $\delta = 0.85$. We note that very similar parameter values have also been reported in related contexts of consumer electronics (see e.g. Ferguson et al. (2011), Ginsburg (2001), Guide et al. (2006), Subramanian and Subramanyam (2012)). The results are

Table 7: Average ratios of variables between models O and NB (in %)

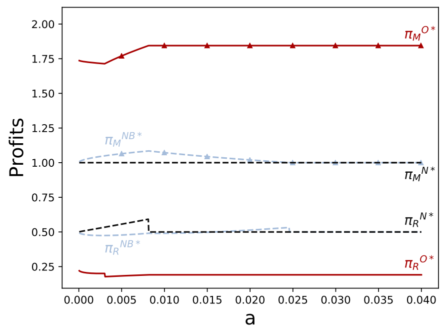
	Overall	c_n, c_r, τ, s high, δ low	All other cases
Average ratio for manufacturer's profit $\frac{\Pi_M^O}{\Pi_M^{NB}}$	137	72	144
Average ratio for retailer's profit $\frac{\Pi_R^O}{\Pi_R^{NB}}$	72	129	68
Average ratio for effort $\frac{\rho^O}{\rho^{NB}}$	50	46	50
Average ratio for retail price $\frac{p_n^O}{p_n^{NB}}$	87	98	86
Average ratio for wholesale price $\frac{w_n^O}{w_n^{NB}}$	108	120	107

shown in Figure 4 as a function of the cost of effort a.

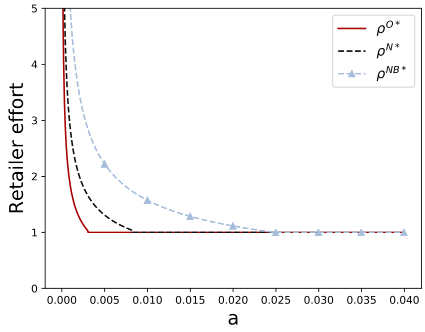
Figure 4(a) indicates that the manufacturer's profit is more than 75% higher in model O than in model N, while model NB only yields up to about 10% higher profit for the manufacturer than in model N. Conversely, the retailer is least profitable when faced with an online store. Figure 4(b) shows that this increase in the manufacturer's profit happens despite a significant reduction in the retailer's effort. Only at very high values of a the gap in effort closes across models. Figure 4(c), (d) and (e) highlight that the manufacturer's profit increase comes from a much larger sales quantity of new products, despite a similar wholesale price. In sum, in this setting the manufacturer should introduce an online store.

5 Conclusion

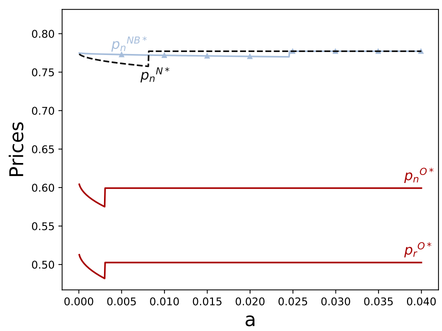
In this paper we have studied a manufacturer's strategy to sell refurbished consumer returns in an online store as an alternative tool to incentivizing the retailer to exert more sales effort through a (possible) restocking fee. We find that introducing the online store where the refurbished products are sold further reduces the retailer's effort. Only when the refurbished market conditions are very unfavorable and the new product market is small, we find the manufacturer to be better off with the restocking fee strategy. In our numerical analysis this only applied to about 6% of the cases. In the remaining cases, the reduced effort is more than offset by the profit gains from the refurbished market and gains from the strategic interaction on the primary market. Specifically, the existence of the online store induces the retailer to significantly lower the retail price thereby increasing sales, while the manufacturer hardly needs to change his wholesale price. In those cases we find that the manufacturer can achieve an average profit gain of about 44%. Thus our findings highlight the



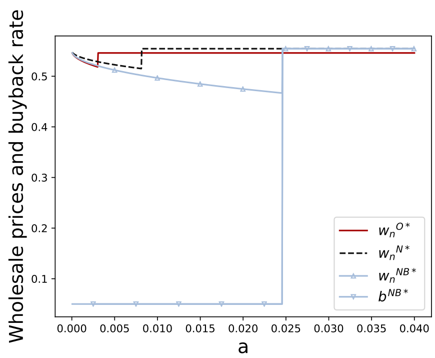
(a) Comparison of the normalized profits ($\Pi_M^N = 1$)



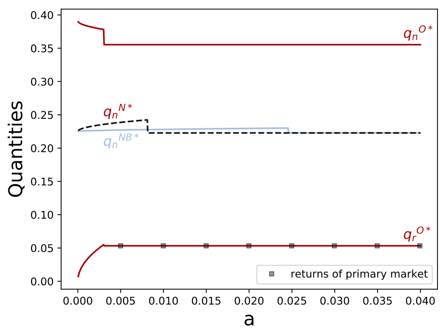
(b) Comparison of the efforts



(c) Comparison of the prices for new and refurbished products



(d) Comparison of the wholesale prices and refund fee



(e) Comparison of the quantities

Figure 4: Results for the instance $c_n = 0.1$, $\tau = 0.15$, $\frac{c_r}{c_n} = 0.4$, $\frac{s}{c_n} = 0.5$, and $\delta = 0.85$

importance of effectively reusing consumer returns, in addition to reducing the volume of returns.

As with all research, ours is not without limitations. For tractability, we consider a monopolistic manufacturer selling to a single retailer in a single period. Thus, without the existence of an online store, this mimics a monopoly setting for a product in the maturity stage of its life cycle. An interesting avenue for further research is to extend the model with the more realistic scenario of new product competition among manufacturers and/or multiple retailers. Manufacturers of consumer electronics also sell new products directly to consumers online, although that volume is much smaller than through channels for some manufacturers, for example, direct sales revenues account for only 0.3% of sales for Philips in the DACH region, and for 20% at HP worldwide. Manufacturers also sell their products to different competing retailers. Studying the effect of a secondary market introduction in this competitive setting could generate additional insights into the relationship between the volume of consumer returns and the optimal disposition of returns. Some preliminary investigation in the setting where the manufacturer also sells new products directly to consumers reveals, however, that the resulting model is analytically intractable, and can only be analyzed numerically. Life cycle dynamics, could also be introduced, as in Atasu et al. (2008).

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