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Multichannel retail competition with product returns: Effects of restocking fee legislation

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Abstract

The Internet's explosive growth enabled new ways to reach customers, but product returns became problematic. Today, most brick-and-mortar stores have either been integrated into or replaced by the online channel. We model the competition among sales channels and analyze its equilibrium structure. We consider two competing retailers and three sales channel configurations—brick-and-mortar, click-and-mortar and strictly online—and derive the conditions under which a Nash equilibrium exists. We rule out product returns in the brick-and-mortar channel, but online purchases can be returned (possibly subject to a restocking fee). Our model allows for repeated returns of an item and its reintroduction into the forward supply chain. We investigate the effect of restocking fees and customer's perceived channel value on the equilibrium as well as the impact of EU legislation addressing free returns. We also analyze some extensions of the model and conduct a numerical analysis to explore whether restocking fee legislation helps or hinders online business. Our results indicate that the equilibrium structure is determined by the values of the return rate, the refund rate, and the online channel attraction. Also, it results profitable to refurbish and reintroduce returned items into the forward chain multiple times. Lastly, in the context of whether to charge or not a restocking fee and the introduction of a new EU legislation, we can conclude that retailers charging a restocking fee should put more effort in order to increase consumer's perceived value, meaning that customers will accept a restocking fee provided they view the online purchase as having higher quality than a B&M purchase.

Keywords: multichannel competition, online retailing, returns management, restocking fee, multinomial logit demand model

1 Introduction

The explosive growth of the Internet has allowed for the introduction of new channels to reach customers. An ever-increasing number of people have easy access to the Internet: as of June of 2019, it is estimated that more than half of the world's total population used the Internet, with a penetration (percentage of individuals, of any age, who could access the Internet at home via any device type and connection) of 85% and almost 90% in Europe and in North America, respectively (Internet World Stats, 2019). These values will only increase and so continue to engender for reaching and connecting new channels with customers. Thus is born the “multichannel phenomenon”, whereby traditional brick and mortar (B&M) stores are integrated into or replaced by the online channel. A B&M retailer can choose to continue using only her physical channel or to integrate (or replace) it with the “click” channel arm. We refer to retailers who so diversify as “click and mortar”(C&M) retailers. On the one hand, a multichannel structure has the positive effect of enabling the retailer to expand her market by reaching otherwise unreachable customers; on the other hand, negative effects of that structure include the possibility of one channel “cannibalizing” the other (Zhang, 2009). Retailers should therefore carefully monitor and coordinate their channels.

1.1 The returns issue under multichannel competition

When a retailer expands to the online market, she inevitably encounters the major issue of product returns: return rates; extra transportation costs; testing, and remanufacturing activities; and so forth (Roellecke et al., 2018). When returns occur, retailers must collect, sort, and test the returned items: thereafter retailers can—depending on how constrained they are by residual value concerns—refurbish, remanufacture, recycle, or discard returned items (Difrancesco and Huchzermeier, 2016; Gallino and Moreno, 2019). Smartly salvaging returned items is not a trivial decision and it simultaneously involves considerations on price, quantity, and costs (Seeberger et al., 2019). Retailers can also decide to outsource some or all of these activities to a third party. In any case, the retailer incurs the considerable cost of (directly or indirectly) managing returns, which affects total profit and the entirety of closed-loop supply chain management. This is the reason why product return has always concerned retailers and, in some cases, also led to extreme decisions, like the one from the UK fast fashion retailer Quiz, who recently decided to cut its partnership with Zalando because of the too high return rate (Retail Gazette, 2019). The problem of returns arises mainly because customers cannot actually see and try out the item of interest; hence they are not sure whether the product will satisfy their expectations and needs. Customers cannot confirm that expectation until the item is delivered. Of course, this generalization is less applicable to certain product categories: books, DVDs, and toothpaste involve much less uncertainty than do clothes, shoes, and food (Kacen et al., 2013).

At the same time, shopping online yields additional value—especially for customers who prefer to shop quickly and comfortably from home by comparing items and prices with just a few clicks (see Section 2.2). Some retailers attempt to mitigate the negative effect of returns by way of restocking fee (Shulman et al., 2009; Su, 2009; Shulman et al., 2011). However, some studies show that a more lenient return policy increases postreturn purchasing level (Petersen and Kumar, 2009; Bower and Maxham, 2012). Retailers must also accommodate the constraints imposed by restocking fee legislation. Until June of 2014, for example, EU companies were not allowed to charge a restocking fee for products worth over € 40. As a consequence, online retailers operating in Europe had to monitor their processes and costs carefully. Despite these cost considerations and in response to the growth in online sales, some retailers are now moving towards "omnichannel retailing"(Apics, 2014): customers seek additional services and increased flexibility from all the channels—for instance, the option of buying online and then picking up in store and, if necessary, returning the item directly to the store (Aberdeen Group, 2013; Apics, 2014; Lebensmittel Zeitung, 2014; Business Reporter, 2016). However, offering these options requires that the retailer increases internal collaboration and visibility: the share of real-time orders as well as order fulfillment and product information across channels and departments (Aberdeen Group, 2013; Apics, 2014).

1.2 Contribution to the current literature

The amount of sales deriving from online commerce is still relatively small compared with that from traditional retailing (worldwide, online sales is estimated to have been 12.2% in 2018; Statista, 2019. Yet the online market's growth is increasing rapidly, and the expectation is that more and more B&M retailers will go online and hence that competition among retailers will intensify even further. However, online retailers do not always efficiently manage their business, especially with regard to product returns. The rapid development of e-commerce, together with intensifying competition and inefficient returns management, confirms the strong relevance of our focus here on the issue of multichannel competition with product returns.

Today, we can find the existence of a variety of channel configurations, and retailers migrating from one configuration to another. For example, we observe retailers closing their B&M stores, like the US C&M retailer Macy's, who has started to reduce her physical presence by shutting down several of its stores (Business Insider, 2020), or even the second-oldest B&M bookstore in Italy who recently closed because it could not survive the tough competition of its online competitors (La Repubblica, 2020). At the same time, we also see online retailers opening B&M stores, like the Chinese e-commerce giant JD.com, who has recently announced the opening of 1,000 high tech supermarkets within the next 5 years (Mingtiandi, 2018), or Amazon going offline with Amazon Go, Amazon Books, and lastly with the acquisition of Whole Foods. With this last movement, Amazon not only succeeded in enlarging its physical presence, but also managed to reduce the high cost of product returns, exploiting the widespread presence of Whole Foods, especially in urban areas. All of these examples highlight the variety of channels adoption we observe in practice and make us question about the factors that drive retailers' channel configuration and profitability in such competitive and dynamic environment.

We shall consider two competing retailers who must each decide whether to retain a traditional B&M structure or to integrate that structure with an online arm; in the latter case, retailers decide also to whether or not abandon the B&M channel and sell online only. Unlike most research in this field, our paper integrates multichannel competition with the returns issue: although the online channel reaches more customers, product returns are more complicated and also more costly. In addition to the retailer's cost of product returns, customers face a cost—the restocking fee—of product mismatch. The purpose of this paper is to examine the competition between multiple sales channels with product returns and to analyze both the equilibrium structure and the effect of a restocking fee. In this way, we can determine whether (and under what conditions) a B&M retailer would find it advantageous to go partially or fully online. More in particular, we explore the best channel configuration for a retailer to adopt when she (partially) expands online, given the other retailer's channel configuration, as well as the best strategy for a retailer to adopt when the other retailer (partially) expands online. We focus our attention on the combined effect of (a) consumer's perceived value when buying from different channels and (b) a restocking fee. With reference to recent EU legislation concerning returns, we investigate how the introduction of a restocking fee affects the equilibrium structure. We discuss the equilibria structure and the effect of the major parameters on such equilibria, analyzing the components that drive retailers towards one equilibrium or another.

We follow the model developed by Difrancesco et al. (2018) where, especially for an online business that requires "low touch" refurbishment, a given item can be returned and re-introduced into the primary market several times after possible refurbishment activities. Therefore, in our model, we assume that the same item can be returned repeatedly, looping in the supply chain multiple times; that possibility allows us to analyze the effect of product aging on retailer profit and the equilibrium (even though we analyze a one-shot game, we explicitly consider this looping of returned products). We also model the effect of consumer perceived value when buying from different channels: in particular, we analyze the factors that affect mainly the online channel's perceived value, including the restocking fee. To simplify the presentation we assume that all customers can access the online channel. The Internet's continued growth is such that this assumption, though somewhat unrealistic now, will become increasingly accurate over time (Ofek et al., 2011).

The rest of our paper is organized as follows. Section 2 provides an overview of the current literature, and Section 3 introduces our formulation of the model. Section 4 presents the results and analyzes the structure of equilibria, including an extension to the case of full refunds and identical product valuation across channels. Section 5 offers a numerical analysis, and Section 6 presents our conclusions and suggestions for future research.

2 Literature review

We can identify and classify the current literature addressing multichannel competition with product returns into four main streams: (i) supply chain structure under multiple channel competition, (ii) customer's channel choice, (iii) returns quality, and (iv) return policies.

2.1 Supply chain structure under multiple channel competition

The issue of multichannel competition first arose near the end of the 1990s. The Internet was little used then, but the presence of alternatives (e.g., catalog sales) to traditional B&M retail sowed the seeds of multichannel competition. Balasubramanian (1998) is one of the earliest papers to model competition between brick-and-mortar retailers and direct-market retailers. In the last decade, the Internet's spectacular rise as a sales channel has led many researchers and practitioners to focus on multiple channel competition and its effect on supply chain structure and sales channel equilibria. Some studies have found that incorporating an online arm does not always yield higher profits for retailers or manufacturers (e.g., Kumar and Ruan, 2006). Zhang (2009) formulates a three-stage game for competing B&M retailers: in the first stage, they decide whether to adopt a single or multichannel strategy; in the second stage, they determine the advertising level; and in the third stage they establish the price. Yoo and Lee (2011) show that the manufacturer's establishment of an Internet arm need not lead to lower prices or increased consumer welfare. Ofek et al. (2011) conclude that, when competition is strong, retailers competing both on price and on level of store assistance might prefer to remain offline.

In contrast, other studies indicate that competition due to a multichannel sales structure is not necessarily harmful. For example, Pan et al. (2002) analyze the competition between a click-and-mortar retailer, and a "pure play" Internet e-tailer. These authors conclude that, if customers perceive the online arm of the C&M retailer to be better than the pure play e-tailer, then the B&M retailer should also go online and charge higher prices there. Chiang et al. (2003) present the case of a manufacturer that introduces a direct channel to compete with the B&M retailer. This development induces that retailer to reduce the selling price, which increases sales. At this point, the greater sales volume increases manufacturer profit irrespective of which channel is responsible for those sales. Cattani et al. (2006) analyze the case of a manufacturer that sells to customers both through a retailer and through its own Internet channel. The result of their study is surprising: the best strategy is for the manufacturer to set the wholesale price so as to maximize its own profit because the multichannel competition results in a profitable segmentation of the market. Bernstein et al. (2008) analyze an oligopoly setting in which B&M retailers evaluate the option of expanding to the online market. The paper considers the possibility of an equilibrium when all retailers adopt a strict B&M approach, when only some retailers go online, and when all retailers go online. The authors conclude that it always pays off to sell online, so the equilibrium result is the C&M structure. Ryan et al. (2012) analyze the competition between an online retailer and a marketplace system, which enables the retailer to reach more customers but at the cost of paying a fixed fee to the marketplace system and agreeing to share revenue. Fu et al. (2013) consider the scenario of a manufacturer that starts to compete with the retailer either by going online or by opening a B&M store. Hsiao and Chen (2014) investigate competition, pricing, and the equilibrium structure of a manufacturer and a retailer when both players, neither players, or only one player chooses to sell through a proprietary Internet channel (i.e., in addition to the traditional channel). Rodriguez and Aydin (2015) develop a dual channel model with the manufacturer selling through both its own direct channel and through the retailer (who carries a subset of the product assortment). The problem analyzes three pricing decisions (wholesale price charged to the retailer, selling price in the direct channel, and selling price at the retailer) and reveals that, despite the competition, the manufacturer will always benefit from adding a retail channel because it increases its total market share. Matsui (2016) analyzes two competing manufacturers selling differentiated products. The paper investigates the existence of an equilibrium when different channel options are available, namely "Strategy R" (i.e., the manufacturer distributes only through the retail channel); "Strategy D" (i.e., the manufacturer distributes only through its direct channel), and "Strategy RD" (i.e., the manufacturer distributes in both retail and direct channel). The results show that, at equilibrium, one manufacturer sells only though the direct channel, while the other manufacturer sells through both its direct channel and retail channel. Chen and Chen (2017) investigates when and under which conditions a B&M retailer should use her physical channel, integrate it or completely replace it with an online channel. The paper analyzes how to set the prices and return policy in each channel.

Our paper considers a multichannel scenario with product returns. Starting from the case of two brick-and-mortar retailers, we extend our analysis to include an online arm and conclude with the case of two strictly online retailers. We then identify possible equilibria in the different cases depending on the channel combinations involved and the various parameter settings.

2.2 Customer's channel choice

In a multichannel context, customers might exhibit varying degrees of channel acceptance. For different product categories, Kacen et al. (2013) explore the willingness of customers to accept the online channel: customers do not hesitate to buy books, DVDs, and toothpaste online, but they are reluctant to purchase food online. Retailers need to recognize the main drivers of a customer's channel choice. In this section, we cite some of the most relevant studies that identify these drivers. The main factors related to shopping at *traditional* B&M stores are: the travel cost and the time spent physically visiting the shop (Cattani et al., 2006; Chen et al., 2008; Forman et al., 2009; Ofek et al., 2011; Yoo and Lee, 2011; Fu et al., 2013; Balakrishnan et al., 2014) and standing in queues at the checkout (Hult et al., 2019); the risk of product unavailability (Chen et al., 2008; Kacen et al., 2013); and the level of store assistance (Ofek et al., 2011; Kacen et al., 2013). With *online* shopping, the relevant issues include: not being able to see the product in person and try it out (Gupta et al., 2004; Forman et al., 2009; Yoo and Lee, 2011; Fu et al., 2013; Kacen et al., 2013); delayed gratification owing to delivery time (Gupta et al., 2004; Chen et al., 2008; Forman et al., 2009; Yoo and Lee, 2011; Fu et al., 2013; Kacen et al., 2013; Balakrishnan et al., 2014) or failed delivery (Hult et al., 2019); computer accessibility and/or Internet speed (Cattani et al., 2006; Yoo and Lee, 2011); shipping charges (Forman et al., 2009; Yoo and Lee, 2011; Kacen et al., 2013); inconvenient product return (Yoo and Lee, 2011; Kacen et al., 2013); and the privacy and security of online payment (Burke, 2002; Montoya-Weiss et al., 2003; Balakrishnan et al., 2014). Despite these concerns, there are several advantages to online shopping: the ease and comfort of buying from home, including the comparison of products and prices (Burke, 2002; Gupta et al., 2004; Cattani et al., 2006; Kacen et al., 2013; Hult et al., 2019); a wider selection of products and brands (Burke, 2002; Fu et al., 2013); and access to detailed product information and reviews (Hult et al., 2019). Cattani et al. (2006) also mention the online channel's shipping fees and the higher taxes that B&M retailers must sometimes charge. However, the authors omit these two factors from the analysis because their effects are roughly offsetting. Table 1 summarizes and classifies the aforementioned variables that drive the customer's choice of retail channel. In our modeling of what makes a channel attractive to customers, an interesting role is played by product value (i.e., the value that customers assign to owning the product). Some papers distinguish between the value of a product purchased online and the value of that same product purchased from a B&M retailer.

Table 1: Variables influencing customers channel selection

Channel	Variable	References
B&M	Travel cost and time	Cattani et al. (2006), Chen et al. (2008), Forman et al. (2009), Ofek et al. (2011), Yoo and Lee (2011), Balakrishnan et al. (2014), Fu et al. (2013), Hult et al. (2019)
	Product availability at the store	Chen et al. (2008), Kacen et al. (2013)
	Level of store assistance	Ofek et al. (2011), Kacen et al. (2013)
	Taxes	Cattani et al. (2006), Fu et al. (2013)
Online	No physical inspection	Gupta et al. (2004), Forman et al. (2009), Yoo and Lee (2011), Fu et al. (2013), Kacen et al. (2013),
	Delayed gratification/possession	Gupta et al. (2004), Chen et al. (2008), Forman et al. (2009), Yoo and Lee (2011), Balakrishnan et al. (2014), Fu et al. (2013), Kacen et al. (2013), Hult et al. (2019)
	IT accessibility and skills	Cattani et al. (2006), Ofek et al. (2011)
	Shipping charge	Forman et al. (2009), Yoo and Lee (2011), Kacen et al. (2013)
	Inconvenient product return	Yoo and Lee (2011), Kacen et al. (2013)
	Offer of alternative sales option	Montoya-Weiss et al. (2003), Bernstein et al. (2008)
	Comfort of buying from home	Burke (2002), Gupta et al. (2004), Cattani et al. (2006), Kacen et al. (2013)
	Brand trust and familiarity	Pan et al. (2002)
	Detailed product information and reviews	Hult et al. (2019)
	After sale customer support	Burke (2002), Pan et al. (2002), Balakrishnan et al. (2014)
	Brand selection and variety	Burke (2002), Fu et al. (2013)
	Privacy and security payment	Burke (2002), Montoya-Weiss et al. (2003), Balakrishnan et al. (2014)

For example, Chiang et al. (2003) and Fu et al. (2013) consider it reasonable for customers to assign a lower value to the item purchased online because its inspection was merely virtual and its possession was delayed. Pan et al. (2002) and Bernstein et al. (2008) assume that customers assign a higher value to items purchased over a C&M channel (as compared with an online-only channel) because the existence of a physical store increases customer trust and familiarity with the brand, gives customers an additional channel to purchase the same product, and may well offer a better customer service (e.g., allowing for the in-store-pickup—and return—of items ordered online; see Gallino and Moreno, 2014). In our paper, customer utility is modeled as a function of the product's value, its selling price and a parameter that captures shopping costs (e.g., cost of travel to the store, time spent shopping, and risk of product unavailability) and the restocking fee. In line with Chiang et al. (2003) and Fu et al. (2013), our base model assumes that customers assign a lower value to items purchased online for the reasons detailed previously. We then follow Pan et al. (2002) and Bernstein et al. (2008) in extending our model to the case where customers assign a higher value to products purchased online (as when the items purchased involve less uncertainty).

2.3 Returns quality

An important aspect of returns management is analyzing the residual quality of returns. Souza et al. (2002) present a model in which the remanufacturer, before processing returned items, groups them into different classes according to their residual quality. Depending on this classification, returns are either remanufactured or sold “as is” at a lower price. Galbreth and B ´lackburn (2006) analyze the problem of devising an acquisition and sorting policy for returned items that a manufacturer buys from a third party. Guide et al. (2008) propose a model in which returns arrive at a disposition center, where they either enter a queue for remanufacturing or are salvaged. The key factor in the remanufacturing decision is the expected remanufacturing time, since remanufacturing costs are increasing in that time. Tao et al. (2012) formulate a multiperiod stochastic dynamic problem in order to determine the optimal ordering/remanufacturing policy when the quality of returned products varies. We follow Difrancesco et al. (2018) and consider the *age* of returns (i.e., the average number of times that the same item is returned and, after being refurbished, reintroduced into the supply chain) as the primary factor in returns classification: through cycle count $N-1$, returns are reintroduced into the market after being refurbished; at cycle count N, returns exit the supply chain (e.g., through scrap or sale in a secondary market). Especially for short lived products (e.g., fashion products), it is reasonable to assume that, after a certain number of loops, the item will not be sold in the primary market anymore: besides quality and cost issues, the short selling season implies a fast product turnover. The management issue involves deciding when to forgo refurbishment and instead discard merchandise, considering the trade-off between the refurbishment cost of returns and the purchasing cost for new materials.

2.4 Return policies

Return policies affect customer choices. Customers demand increases when retailers adopt a lenient return policy (Ketzenberg and Zuidwijk, 2009; EHI Retail Institute et al., 2013; UPS, 2013; PriceWaterhouseCooper, 2013). At first glance, then, it would seem that retailers should prefer to adopt more lenient return policies in order to attract more customers. Furthermore, some studies (Petersen and Kumar, 2009; Bower and Maxham, 2012; Griffis et al., 2012) underscore the importance of lenient policies by showing that customers who receive a free return significantly increase their postreturn buying level. Notwithstanding these benefits, a lenient return policy will also facilitate opportunistic behavior on the part of customers (Shulman et al., 2010; Bloomberg Businessweek, 2014; Ruiz-Benítez et al., 2014; Shang et al., 2017) and, of course, increase the return rate. For these reasons, several studies emphasize the relevance of a restocking fee (Shulman et al., 2009; Su, 2009; Shulman et al., 2011). These circumstances have spawned a new type of business; for example, Clarus Marketing Group (based in Middletown, Connecticut) offers to pay for an unlimited number of returns to any retailer for an annual fee of \$ 49 (GeekWire, 2014). So after about seven returns (at the approximate cost of \$ 7 per returned item), the service will pay off for the retailer and also customers needn't be dunned for restocking fees.

Local legislation is another factor that can affect return policies. Recall our example of European countries, where retailers were formerly prohibited from assessing return costs to customers on items worth more that € 40. Although e-tailers were initially required to absorb the cost of returns, now they can charge customers for this cost (European Parliament and the Council of the European Union, 2011). This creates a dilemma for the European online retailer: should its free return policy be continued or should the retailer, at long last, shift the burden of return costs to customer? Consistent with Petersen and Kumar (2009) and Bower and Maxham (2012), the PwC study (PriceWaterhouseCooper, 2013) reveals that, in response to the introduction of a restocking fee, 17% of interviewed German customers would no longer buy online, 50% would buy less online than before, and 39% would switch to another e-tailer offering a free return policy. Similar results are reported in studies by UPS (2013) and ibi research (2014). These findings explain why many e-tailers declared that they would continue their free return policies in EU countries (Welt am Sonntag, 2014). In this paper we discuss the introduction of a restocking fee and analyze how it could affect (a) product value as perceived by customers and (b) the sales channel equilibrium.

Although an extensive literature addresses multichannel sales and returns management, few papers consider them in combination, and often do so mainly under the marketing point of view (e.g., pricing strategy, customers channel selection, and level of store assistance). Following Ofek et al. (2011), we integrate the retailer's returns management issue with multichannel sales. Much as in Bernstein et al. (2008) and Ofek et al. (2011), the channels considered here include the B&M and the C&M retailers; however, we add the possibility of a strictly online channel. In particular, we consider a multichannel environment in which the retailer must choose which channel to employ—and whether that channel's online component (if any) is an option or the only option. The importance of modeling also the online channel alone (i.e., not in combination with the physical channel in the C&M configuration) derives from the need to analytically study whether there exists the possibility (and under which conditions) in which C&M retailers may find it more profitable to abandon the physical arm and fully move online. This would help justifying the behavior we observe in practice, where some C&M retailers (e.g., the UK chain Mothercare) decide to abandon the physical arm and fully move online, and provide managerial insights on how to control the key parameters that bring to the shutdown. Unlike Ofek et al. (2011), whose decision variables are the level of store assistance and the selling price, we follow the approach of Bernstein et al. (2008) and let the selling price of each retailer be the decision variable. Yet unlike Bernstein et al.

(2008), we consider the possibility of product returns. Differently from Bernstein et al. (2008), our study is based on a more detailed and deeper analysis of the multichannel environment: we do not limit our work to analyze and compare the equilibria structure, prices and profits, but we also focus on studying the behavior of a retailer in terms of her own online expansion as well as in response to the online expansion of the other retailer. We explore the best strategy for a retailer when she (partially) expands online, given the other retailer's channel adoption, as well as the best strategy for a retailer to adopt when the other retailer (partially) expands online. We discuss the equilibria structure and the effect of the major parameters on such equilibria, analyzing the components that drive retailers towards one equilibrium or another. Differently from Bernstein et al. (2008), we explicitly incorporate in our model the possibility of product returns: as discussed in Section 1.1, product returns represent a significant aspect of online commerce, as they engender several challenges and opportunities for retailers. In particular, we model the possibility for a given item to be returned and re-introduced into the primary market several times after refurbishment activities. This is motivated by the empirical evidence we observe in practice for some online retailers, as we had the opportunity to study during our visits to Zalando's facilities (including the logistics center where the refurbishment activities take place). Zalando, one of the largest European fashion online retailers, reintroduces returned items multiple times into the primary market—after refurbishment activities. (For the interested reader, a detailed analysis on online fashion retailers with refurbishment can be found in Difrancesco et al., 2018). The trade-off for retailers to balance is the refurbishment cost of returns versus the purchasing cost for new materials from suppliers (since the difference is replaced by returned items). Our model also incorporates the possibility of a restocking fee for returning products. In light of recent legislation on restocking fees in Europe, we are motivated to investigate its consequences for both customers and retailers. As retailers are operating in an ever-increasing competitive environment and are often affected by high return rate, we believe that including product returns in our analysis can bring an interesting contribution to the current literature. To the best of our knowledge, none of the existing studies has simultaneously analyzed multichannel competition with the possibility for online retailers (or the online arm in C&M retailers) to refurbish and reintroduce returned items in the forward chain several times, and its effect on equilibria configurations.

3 Model formulation for the multichannel problem with product returns

In this section, we introduce our model for the multichannel problem with product returns. We define retailer competition and consumer behavior as well as the utility and profit functions. Table 2 provides an overview of the notation used.

Table 2: Notation

Symbol	Definition
i	Retailer index ($i = 1, 2$)
C	Set of channel alternatives
U_k	Consumer utility associated with alternative $k \in C$
v	Consumption value
p_k	Selling price at channel k
ε_k	Consumers' idiosyncratic tastes about the sales alternatives
$\sigma > 0$	Scale parameter representing the degree of heterogeneity among consumers (standard deviation of the taste distribution)
q_k	Probability of choosing channel k
$\theta > 0$	Scale parameter for the consumption value when buying from the Internet channel
N	Maximum number of times the same item can be returned before leaving the supply chain
r	Percentage of refund, ($0 < r \leq 1$)
c	Acquisition price from the supplier
λ	Product return rate ($0 < \lambda < 1$)
λ_N	Product returns leaving the supply chain after N loops
$H[N]$	Refurbishment cost function
π_i	Retailer i's profit

3.1 Retailer competition

We consider a duopoly scenario in which two competing retailers selling a single product must choose their respective sales channel structures. In particular, a traditional brick and mortar retailer decides whether to go online and, if so, whether to integrate or completely replace her B&M channel with the online one. We define the set of channel alternatives as C and identify six possible channel configurations as follows: Case I: B&M vs. B&M, where both retailers operate as B&M ($C = \{1, 2\}$); Case II: B&M vs. C&M, where one retailer operates as B&M and the other operates as C&M ($C = \{1, 2, 2o\}$); Case III: C&M vs. C&M, where both retailers operate as C&M ($C = \{1, 1o, 2, 2o\}$); Case IV: B&M vs. Online, where one retailer operates as B&M and the other as pure online player ($C = \{1, 2o\}$); Case V: C&M vs. Online, where one retailer operates as C&M and the other as pure online player ($C = \{1, 1o, 2o\}$); and Case VI: Online vs. Online, where both retailers operate as pure online players ($C = \{1o, 2o\}$). Each retailer's decision variable is the selling price in each channel. When customers buy through the online arm, they can return the item and do so with probability λ ($0 < \lambda < 1$); however, they can be charged a restocking fee and thus receive only a partial refund r ($0 < r \leq 1$).

It is important to note that we model neither returns nor refunds for the traditional B&M retailer: when buying through this channel, customers are not allowed to return items. Our choice derives from the current legislation in the EU countries, which does not include the right of withdrawal for purchases in store, unless the product is defective (European Parliament and the Council of the European Union, 2011). Therefore, European B&M retailers can arbitrarily decide whether or not to allow product returns and refunds. We observe in practice that the return rate for European B&M retailers is very low (e.g., approx. 75% of the German B&M retailers face a return rate smaller than 3%; Insitut fuer Handelsforschung, 2014). Considering that such rate also includes returns for product defects, it results that the return rate deriving from product mismatch—which is the main focus of our paper—is insignificant. Furthermore, differently from other countries (e.g., the US), many European B&M retailers do not allow product refunds, but rather product exchange or voucher for a future purchase. Following these considerations, we model neither returns nor refunds for the B&M retailer. We allow a given item to be returned several times (up to a maximum of N times). All the items returned for less than N times are refurbished and reintroduced into the primary market. All the items returned for N times are disposed of. Since our study focuses on the steady-state phase and considers average values for the parameters, every period λ_N returned items are at their Nth loop. Therefore, they leave the system. The remaining $\lambda - \lambda_N$ returned items are at their $(N-1)th, (N-2)th, \ldots, 1st$ loop, so they are reintroduced into the primary market. Figure 1 provides a stylized representation of the supply chain that specifies the material flows and profit component for each channel. Each returned item is refurbished according to the

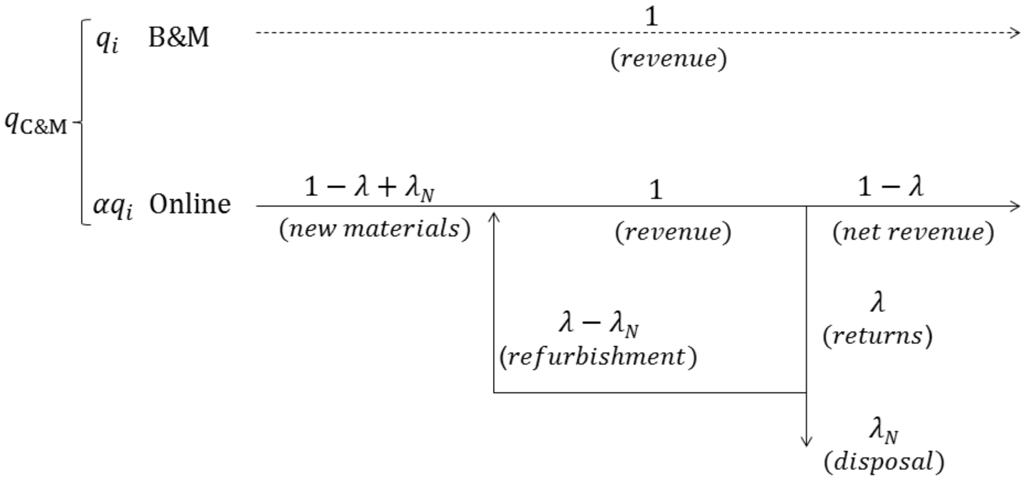

Figure 1: Stylized supply chain for the C&M retailer with B&M arm (dashed line) and Online arm (continuous line)

cost function H and then resold in the market at the same price as new items (see Difrancesco et al., 2018). The implication is that in steady-state retailers can order less product from the supplier—although they must cover all those costs related to returns management (see Guide et al., 2006; Difrancesco et al., 2018). At the Nth loop, λ_N returns will be discarded and therefore leave the supply chain. To reflect the supply chain structure's design, we express the disposal rate as $\lambda_N = ((1-\lambda)\lambda^N)/(1-\lambda^N)$[1]. This means that a higher N is equivalent to lower λ_N and higher $(\lambda - \lambda_N)$ with a consequent higher number of items to be refurbished and reintroduced into the market. We remark that retailers must keep track of (a) the refurbishment of products with different ages and (b) the refurbishment costs which depend not only on the parameters but also on the returns age itself. If the refurbishment cost is expressed as a function of cumulative age, then the structure of our model is such that the total refurbishment cost ends up as a function of the maximum age N. Therefore, for ease of exposition we simply define the refurbishment function $H[N]$ as depending solely on N (when no confusion would result, we shall write H in place of $H[N]$).

3.2 Consumer behavior

As discussed in Section 2.2, several factors influence the customer's choice of sales channel. We do not model the net effect; rather we consider the presence of factors that increase customer valuation of the online channel (e.g., consumer comfort and savings in cost and time when buying from home, more brand selection and variety, product availability) and of others that decrease that valuation (e.g., delayed possession and gratification due to delivery lead time, no way of touching or testing the product before buying it, restocking fee, and "hassle" costs). The retailer can affect these factors—for example, by setting up a user-friendly website or providing several payment choices in order to increase customer comfort when buying online.

Consumers choose a retailer so as to maximize their expected utility. Market attraction is modeled using a multinomial logit (MNL) demand model, as in Anderson and de Palma (1987), Anderson et al. (1992), and Bernstein et al. (2008). We assume that the whole market is covered—in other words, that there is no outside option[2]. The utility that a customer receives when purchasing an item from sales alternative k at price p_k is written as

$$U_k = V_k + \varepsilon_k = v_k - p_k + \varepsilon_k, \qquad k \in C; \tag{1}$$

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[1] For a detailed explanation of the formula, please refer to Difrancesco et al. (2018).

[2] We do not model the possibility of total market expansion in the short term; however, we notice that such market expansion can affect the equilibrium structure in the long term. The presence of the outside alternative can easily be modeled adding to the denominator of expression (2) the term $\exp(v_o/\sigma)$, where v_o represents the valuation for the outside alternative.

The first term (V_k) represents the observable component of the utility function, where $v_k = v$ in the B&M channel, $v_k = \theta v$ in the online channel, v is the consumption value (we assume that this value is the same irrespective of the firm and the product), and θ is a scale parameter for the consumption value when buying from the Internet channel. Values of θ smaller than 1 correspond to the case of a consumer who attributes a lower value to the purchase through the online channel rather than the purchase through the traditional one. In our base model we assume $\theta < 1$ (although the $\theta \geq 1$ scenario will also be discussed). The second term (ε_k) is an unobservable component deriving from consumers' idiosyncratic tastes: consumers have heterogeneous valuations of such product characteristics as color and brand image. In line with the literature (Anderson and de Palma, 1987; Anderson et al., 1992; Bernstein et al., 2008), we assume that the ε_k are independent and identically distributed (i.i.d.) random variables with a double exponential distribution with mean zero and variance $(\sigma^2\pi^2)/6$. The term $\sigma > 0$ expresses the degree of heterogeneity among customers. Now the probability that a consumer chooses to buy from channel $k \in C$ is given by

$$q_k = \frac{\exp(\frac{v_k - p_k}{\sigma})}{\sum_{j \in C} \exp(\frac{v_j - p_j}{\sigma})}. \tag{2}$$

Before proceeding with our analysis, we briefly recall a property of the MNL model that will prove useful for characterizing our first-order conditions (see Appendix). The partial derivative of the choice probabilities with respect to the prices are

$$\frac{\partial q_k}{\partial p_k} = \frac{q_k(q_k - 1)}{\sigma}, \qquad \text{and} \qquad \frac{\partial q_k}{\partial p_j} = \frac{q_k q_j}{\sigma} \qquad k, j \in C, \ \ k \neq j. \tag{3}$$

Thus we can use the MNL logit model to describe the substitution effect among sales channels. We denote by q_i the probability that a customer chooses to purchase from retailer i selling through the B&M channel or online channel only, and by q_{io} the probability that a customer chooses to purchase from the online arm of retailer i who adopts the C&M configuration. We can now use (2) and, for the C&M configuration, express q_{io} as function of q_i, thereby eliminating the former from our statement of the problem[3]:

$$q_{io} = \alpha q_i \qquad \text{with } \ \alpha = \exp\left(\frac{(\theta - 1)v}{\sigma}\right), \qquad i = 1, 2. \tag{4}$$

We denote by p_i the price of retailer i. We assume that click-and-mortar retailers charge the same prices for the "brick" and "click" channels; according to Ofek et al. (2011), this assumption is

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[3] Consider a C&M retailer. We define the choice probability for the B&M arm by means of (2) and, dividing both the numerator and the denominator by $\exp\left(\frac{v-p_i}{\sigma}\right)$, it results in: $q_i = \frac{\exp\left(\frac{v-p_i}{\sigma}\right)}{\exp\left(\frac{v-p_i}{\sigma}\right)+\exp\left(\frac{\theta v-p_i}{\sigma}\right)} = \frac{1}{1+\exp\left(\frac{(\theta-1)v}{\sigma}\right)}$. Similarly, we define the choice probability for the Online arm by means of (2): $q_{io} = \frac{\exp\left(\frac{\theta v-p_i}{\sigma}\right)}{\exp\left(\frac{\theta v-p_i}{\sigma}\right)+\exp\left(\frac{v-p_i}{\sigma}\right)} = \frac{1}{\exp\left(\frac{(1-\theta)v}{\sigma}\right)+1}$. We can now re-write q_{io} as: $q_{io} = \frac{1}{1+\frac{1}{\exp\left(\frac{(\theta-1)v}{\sigma}\right)}} = \exp\left(\frac{(\theta-1)v}{\sigma}\right)\frac{1}{1+\exp\left(\frac{(\theta-1)v}{\sigma}\right)} = \alpha q_i$, being $\alpha = \exp\left(\frac{(\theta-1)v}{\sigma}\right)$.

consistent not only with industry practice (80% of retailers have similar prices among different channels) but also with customer expectations (customers expect a given retailer to charge equal prices across different channels). Next, we express the choice probabilities for the two retailers in each of the six scenarios considered.

Case I: Brick-and-mortar vs. Brick-and-mortar (B&M vs. B&M)

We consider the symmetric scenario in which two retailers each adopt the B&M configuration. The utilities associated with each channel are $V_1 = v - p_1$ and $V_2 = v - p_2$, and the choice probabilities are $q_1 = \frac{\exp(\frac{v-p_1}{\sigma})}{\exp(\frac{v-p_1}{\sigma}) + exp(\frac{v-p_2}{\sigma})} = \frac{1}{1+\exp(\frac{p_1-p_2}{\sigma})}$ and $q_2 = \frac{\exp(\frac{v-p_2}{\sigma})}{\exp(\frac{v-p_1}{\sigma}) + exp(\frac{v-p_2}{\sigma})} = \frac{1}{1+\exp(\frac{p_2-p_1}{\sigma})}$.

Case II: Brick-and-mortar vs. Click-and-mortar (B&M vs. C&M)

We now consider the case where retailer 1 adopts a B&M configuration while retailer 2 adopts a C&M configuration. The utility functions when buying from the B&M channel (channel 1), the B&M channel in the C&M configuration (channel 2), and the online channel in the C&M configuration (channel $2o$) are, respectively:

$$V_1 = v - p_1; \qquad V_2 = v - p_2; \qquad V_{2o} = \theta v - p_2. \tag{5}$$

The probability of a customer choosing channel alternative k is determined by substituting the utility functions, as given by (5), into expression (2); we thus obtain $q_1 = \frac{1}{1+(1+\alpha)\exp(\frac{p_1-p_2}{\sigma})}$ for the B&M retailer and $q_2 = \frac{1}{1+\alpha+\exp(\frac{p_2-p_1}{\sigma})}$ and $q_{2o} = \alpha q_2$ for the C&M retailer. With a similar reasoning, we derive the choice probabilities in the remaining cases.

Case III: Click-and-mortar vs. Click-and-mortar (C&M vs. C&M)

Here we present the case of both retailers adopting the C&M configuration. The choice probabilities for Case III are $q_1 = q_2 = 1/2(1+\alpha)$ and $q_{1o} = q_{2o} = \alpha q_1$.

Case IV: Brick-and-mortar vs. Online (B&M vs. Online)

Next we consider the scenario where retailer 1 adopts the B&M channel and retailer 2 the Online channel. The choice probabilities are $q_1 = \frac{1}{1+\alpha\exp(\frac{p_1-p_2}{\sigma})}$ and $q_2 = \frac{1}{1+\alpha^{-1}\exp(\frac{p_2-p_1}{\sigma})}$.

Case V: Click-and-mortar vs. Online (C&M vs. Online)

We now present the case in which retailer 1 adopts the C&M configuration and retailer 2 the Online one. The choice probabilities are $q_1 = \frac{1}{1+\alpha(1+\exp(\frac{p_1-p_2}{\sigma}))}$ and $q_{1o} = \alpha q_1$ for the C&M retailer and $q_2 = \frac{1}{1+\exp(\frac{p_2-p_1}{\sigma})(\frac{1}{\alpha}+1)}$ for the online retailer.

Case VI: Online vs. Online (Online vs. Online)

Finally, we examine the scenario under which both retailers adopt the Online channel. The choice probabilities are $q_1 = \frac{1}{1+\exp(\frac{p_1-p_2}{\sigma})}$ and $q_2 = \frac{1}{1+\exp(\frac{p_2-p_1}{\sigma})}$.

3.3 Profit functions

We start by analyzing and investigating the existence of an equilibrium under the brick-and-mortar and click-and-mortar channels; thereafter, we extend the analysis to include the online channel. Be π_i the profit of retailer i. The profit function for the B&M retailer is given as follows:

$$\pi_i = (p_i - c)q_i. \tag{6}$$

The B&M retailer has a market share q_i and a unit revenue of p_i, net of the purchasing cost c.

The profit function for the C&M retailer is given as follows:

$$\pi_i = (p_i - c)q_i + (1 - \lambda r)p_i \alpha q_i - (1 - \lambda + \lambda_N)c\alpha q_i - (\lambda - \lambda_N)\alpha q_i H[N], \tag{7}$$

where the first term represents the revenue from sales in the B&M arm, net of the purchasing cost c; the second term is the revenue from sales in the Online arm, net of refunds to customers; the third term represents the purchasing cost for new items—given that refurbished ones are reintroduced into the market—net of disposal; the fourth term is the refurbishment cost[4].

The profit function for the Online retailer is given as follows:

$$\pi_i = (1 - \lambda r)p_i q_i - (1 - \lambda + \lambda_N)cq_i - (\lambda - \lambda_N)q_i H[N], \tag{8}$$

where the first term represents the revenue from sales in the Online arm, net of refunds to customers; the second term is the purchasing cost for new items—given that refurbished ones are reintroduced into the market—net of disposal; the third term represents the refurbishment cost.

The model's complexity precludes our modeling either the store cost in the B&M store and the channel cost in the Online case; both retailers are marginally profitable, and this approach is consistent with the literature. For the reader's convenience we summarize our assumptions so far.

(A1) The entire market is covered—that is, there is no outside option.

(A2) Consumption value v is the same across different channels.

(A3) The ε_k are i.i.d. random variables with a double exponential distribution with mean zero and variance $\sigma^2\pi^2/6$.

(A4) In the C&M case, retailers charge the same price in both channels.

(A5) The values of $c, \lambda, \lambda_N, r, N, H[N]$ are identical for all retailers.

(A6) The same item can be returned a maximum number of N times.

(A7) For the base model, the purchasing cost from the supplier (c) and the refund rate (r) satisfy the following conditions: $c > \frac{(\lambda-\lambda_N)H[N]}{\lambda-\lambda_N-r\lambda}$, $r < \frac{\lambda-\lambda_N}{\lambda}$, and $r > 0$.

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[4] As an example, consider the following values for the purchasing cost, return rate, disposal rate, and refund rate: $c =$ € 4, $\lambda = 0.3$, $\lambda_N = 0.02$, $r = 0.85$. A comparison of B&M (retailer 1) with Online (retailer 2) reveals that the latter enjoys a unit purchasing cost savings of about € 1.12 and a unit revenue decline that is proportional to 0.255 (since in this case $p_1 > p_2$). Despite these cost savings, we find that $\pi_1 = 1.90 > \pi_2 = 1.71$ because of the negative effect of returns (due to refurbishment costs and payback).

4 Equilibria analysis

We shall present and analyze the six cases deriving from the different channel combinations. We proceed to characterize the equilibrium prices and profits for each of the scenario introduced. We summarize in Table 3 the equilibria solutions. Proofs are given in the Appendix.

Table 3: Equilibria prices and profits for each of the six configurations (the first value into parenthesis refers to retailer 1; the second value to retailer 2)

Channel configuration	**Price** $(p_1; p_2)$	**Profit** $(\pi_1; \pi_2)$
I. B&M vs. B&M	$(c+2\sigma; c+2\sigma)$	$(\sigma; \sigma)$
II. B&M vs. C&M	$\left(c+\frac{\sigma}{1-q_1}; \frac{\sigma}{1-q_2}+\frac{c+\alpha c-\alpha(c-H)(\lambda-\lambda_N)}{1+\alpha-\alpha r\lambda}\right)$	$\left(\frac{q_1}{1-q_1}\sigma; \frac{q_2(\alpha(r\lambda-1)-1)}{q_2-1}\sigma\right)$
III C&M vs. C&M	$\left(\frac{\sigma}{1-q_1}+\frac{c+\alpha c-\alpha(c-H)(\lambda-\lambda_N)}{1+\alpha-\alpha r\lambda}; \frac{\sigma}{1-q_2}+\frac{c+\alpha c-\alpha(c-H)(\lambda-\lambda_N)}{1+\alpha-\alpha r\lambda}\right)$	$\left(\frac{1+\alpha-\alpha r\lambda}{1+2\alpha}\sigma; \frac{1+\alpha-\alpha r\lambda}{1+2\alpha}\sigma\right)$
IV. B&M vs. Online	$\left(c+\frac{\sigma}{1-q_1}; \frac{\sigma}{1-q_2}+\frac{c-(c-H)(\lambda-\lambda_N)}{1-r\lambda}\right)$	$\left(\frac{q_1}{1-q_1}\sigma; \frac{q_2(r\lambda-1)}{q_2-1}\sigma\right)$
V. C&M vs. Online	$\left(\frac{\sigma}{1-q_1}+\frac{c-c(\lambda-\lambda_N)+(\lambda-\lambda_N)H}{1-r\lambda}; \frac{\sigma}{1-q_2}+\frac{c+\alpha c-\alpha c(\lambda-\lambda_N)+(\lambda-\lambda_N)\alpha H}{1+\alpha-\alpha r\lambda}\right)$	$\left(\frac{q_1(\alpha(r\lambda-1)-1)}{q_1-1}\sigma; \frac{q_2(1-r\lambda)}{1-q_2}\sigma\right)$
VI. Online vs. Online	$\left(\frac{\sigma}{1-q_1}+\frac{c-(c-H)(\lambda-\lambda_N)}{1-r\lambda}; \frac{\sigma}{1-q_2}+\frac{c-(c-H)(\lambda-\lambda_N)}{1-r\lambda}\right)$	$(\sigma-\sigma r\lambda; \sigma-\sigma r\lambda)$

We observe that, apart from the B&M vs. B&M configuration, the equilibria prices and profits depend, among others, on the values of the parameters r (refund rate), λ (return rate), θ (online channel attraction), and N (number of times the same item can loop in the supply chain). A more detailed analysis of how each parameter influences the equilibria structure will be provided in the following sections.

We now compare, for each of the six cases presented, the equilibria prices and profits. The following results are based on the assumption of $\theta < 1$. Further extensions will be considered later. The quantity thresholds (useful for the definition of the next propositions) are defined as follows:

$$K_1 = \frac{1+\alpha-\alpha r\lambda}{2+3\alpha-\alpha r\lambda}; \quad K_2 = \frac{q_1^V(1+\alpha(1-r\lambda)}{1+\alpha q_1^V(1-r\lambda)}; \quad K_3 = \frac{q_2^{IV}(1-r\lambda)}{1-r\lambda q_2^{IV}+\alpha(1-r\lambda)(1-q_2^{IV})};$$

$$K_4 = \frac{1+\alpha-\alpha r\lambda}{2+3\alpha-(1+3\alpha)r\lambda}; \quad K_5 = \frac{1}{2+\alpha-\alpha r\lambda};$$

$$\mathrm{K}_6 = \frac{1-r\lambda}{2+\alpha-(1+\alpha)r\lambda}; \quad K_9 = \frac{q_2^V(1-r\lambda)}{1-r\lambda q_2^V+\alpha(1-r\lambda)(1-q_2^V)}.$$

Proposition 1 *Consider a duopoly setting with product returns and all possible retailer configurations as defined in Table 3. A comparison of the equilibria for each of the six cases yields the following statements.*

(i) $p_1^I = p_2^I$; $\pi_1^I = \pi_2^I$.

(ii) $p_1^{II} > p_2^{II}$; $\pi_1^{II} < \pi_2^{II}$.

(iii) $p_1^{III} = p_2^{III}$; $\pi_1^{III} = \pi_2^{III}$.

(iv) $p_1^{IV} > p_2^{IV}$; $\pi_1^{IV} > \pi_2^{IV}$.

(v) $p_1^{V} > p_2^{V}$; $\pi_1^{V} < \pi_2^{V}$ *when* $q_1^{V} < K_9$; $\pi_1^{V} > \pi_2^{V}$ *otherwise.*

(vi) $p_1^{VI} = p_2^{VI}$; $\pi_1^{VI} = \pi_2^{VI}$.

A proof is given in the Appendix. The superscripts in the prices and profits defined in Proposition 1 refers to the channel configuration we are analyzing, among the possible six introduced in Section 3.2. These results will be useful for characterizing the equilibria structure of the scenarios analyzed in the next sessions.

4.1 Retailer's online expansion (Case with $\theta < 1$ and $r < 1$)

In this section, we consider two competing retailers and discuss if and under which conditions one of the two retailers finds it convenient to (partially) expand online. More in particular, we study the effect on equilibrium structure when (i) one of the two competing B&M retailers expands partially (i.e., adopts a C&M configuration) or fully (i.e., adopts an Online configuration) online; (ii) the C&M retailer competing versus the B&M retailer moves fully online; and (iii) one of the two competing C&M retailers moves fully online. Using the results of Table 3, we can compare the different scenarios and derive our conclusions. Given the symmetrical structure of the problem, we discuss the scenario of retailer 2 expanding online; the same conclusions can be derived when considering retailer 1 expanding online.

4.1.1 Physical retailer (partially) expanding online

We first study whether one of the two B&M retailers finds it attractive to (partially) move online, adopting either a C&M or Online configuration, when the other retailer maintains a B&M configuration. We compare the scenarios and formulate the following proposition (a proof is given in the Appendix):

Proposition 2 *Consider a B&M retailer in a duopoly setting with product returns. If* $r < 1$ *and* $\theta < 1$*, then the following statements hold.*

(i) *A comparison of the equilibria for Cases I (B&M vs. B&M) and II (B&M vs. C&M) yields the B&M vs. C&M (Case II) configuration as Nash equilibrium when* $q_2^{II} < K_5$*, and the B&M vs. B&M (Case I) configuration as Nash equilibrium when* $q_2^{II} > K_5$.

(ii) *A comparison of the equilibria for Cases I (B&M vs. B&M) and IV (B&M vs. Online) always yields the B&M vs. B&M (Case I) configuration as Nash equilibrium.*

The results show that, when competing with a B&M retailer, retailer 2 finds the C&M more attractive only if a threshold value K_5 is met. Such value is determined by the parameters α (modeling the online channel attraction), the return rate λ, and the refund rate r. In particular, when λ and/or r increase, the threshold value also increases and the equilibrium migrates versus the B&M vs. B&M configuration since it is harder to meet the threshold value K_5. In fact, in this case, retailer 2 choosing a C&M configuration would carry the burden of a higher return rate and/or refund rate and, therefore, finds the C&M configuration less attractive. Vice versa, if α increases, the threshold value decreases and retailer 2's configuration at equilibrium migrates versus the C&M one. In this case, the online channel attraction increases and, therefore, the online arm's choice probability also increases. As a consequence, also the C&M retailer's profit increases.

Moreover, the results show that, when competing with a B&M retailer, retailer 2 never finds the Online channel more attractive than the B&M one because she would get a lower profit due to the refund cost and low online channel attraction (since we are considering the case with $\theta < 1$). Therefore, the B&M vs. B&M configuration will always be preferable to the B&M vs. Online.

4.1.2 Click-and-mortar retailer moving fully online

We next investigate whether and under which conditions retailer 2, adopting a C&M configuration, finds it attractive to abandon the physical arm and move fully online, when retailer 1 adopts either a B&M or a C&M configuration. We summarize our results in the next proposition (a proof is given in the Appendix).

Proposition 3 *Consider a C&M retailer in a duopoly setting with product returns. If* $r < 1$ *and* $\theta < 1$*, then the following statements hold.*

(i) *A comparison of the equilibria for Cases II (B&M vs. C&M) and IV (B&M vs. Online) yields the B&M vs. C&M (Case II) configuration as Nash equilibrium when* $q_2^{II} > K_3$*, and the B&M vs. Online (Case IV) configuration as Nash equilibrium when* $q_2^{II} < K_3$*.*

(ii) *A comparison of the equilibria for Cases III (C&M vs. C&M) and V (C&M vs. Online) yields the C&M vs. Online (Case V) configuration as Nash equilibrium when* $q_2^{V} > K_4$*, and the C&M vs. C&M (Case III) configuration as Nash equilibrium when* $q_2^{V} < K_4$*.*

The results show that, when competing with either a B&M or a C&M retailer, retailer 2 finds the Online configuration more attractive than the C&M one only if a threshold value is met. Such value is determined by the parameters α, λ, and r. When λ and/or r increase, the threshold value decreases and the equilibrium migrates versus the B&M vs. C&M configuration (see case (i) of Proposition 3) or the C&M vs. C&M configuration (see case (ii) of Proposition 3). In fact, if retailer 2 chooses a full Online configuration, she would carry the burden of a higher return rate and/or refund rate and, therefore, finds it more advantageous to maintain a physical arm. Vice versa, if α increases, the threshold value also increases and retailer 2's configuration at equilibrium migrates versus the Online one, despite the presence of a partial refund. In this case, the Online channel attraction increases and, therefore, the online arm's choice probability also increases. As a consequence, also the Online retailer's profit increases.

4.2 Retailer's channel adjustments when the other player moves online (Case with $\theta < 1$ and $r < 1$)

In this section, we investigate whether and under which conditions a retailer finds it convenient to change her channel configuration when the other moves (partially) online. We explore the possibility of new equilibria deriving from retailer 1's adjustments to retailer 2's (partial) online shift, i.e., consider the possibility for retailer 1 to (i) partially move online (adopting a C&M configuration) when the other retailer adopts a C&M configuration; (ii) partially move online (adopting a C&M configuration) when the other retailer adopts an Online configuration; (iii) fully move online (adopting an Online configuration) from either a B&M or C&M configuration when the other retailer adopts an Online configuration. We summarize below our results (a proof is given in the Appendix).

Proposition 4 *Consider a duopoly setting with product returns where one retailer moves (partially) online. If* $r < 1$ *and* $\theta < 1$*, then the following statements hold.*

(i) *A comparison of the equilibria for Cases II (B&M vs. C&M) and III (C&M vs. C&M) yields the B&M vs. C&M (Case II) configuration as Nash equilibrium when* $q_1^{II} > K_1$*, and the C&M vs. C&M (Case III) configuration as Nash equilibrium when* $q_1^{II} < K_1$*.*

(ii) *A comparison of the equilibria for Cases IV (B&M vs. Online) and V (C&M vs. Online) yields the B&M vs. Online (Case IV) configuration as Nash equilibrium when* $q_1^{IV} > K_2$*, and the C&M vs. Online (Case V) configuration as Nash equilibrium when* $q_1^{IV} > K_2$*.*

(iii) *A comparison of the equilibria for Case IV (B&M vs. Online) and VI (Online vs. Online) always yields the B&M vs. Online configuration as Nash equilibrium.*

(iv) *A comparison of the equilibria for Cases V (C&M vs. Online) and VI (Online vs. Online) yields the C&M vs. Online (Case V) configuration as Nash equilibrium when* $q_1^{V} > K_6$*, and the Online vs. Online (Case VI) configuration as Nash equilibrium when* $q_1^{V} < K_6$*.*

When retailer 2 adopts a C&M channel configuration, retailer 1 also finds it convenient to adopt a C&M channel configuration only if a threshold value is met. In particular, when the values of r and/or λ increase, then the threshold value decreases and the equilibrium migrates versus the B&M vs. C&M configuration. Retailer 1 choosing a C&M configuration would indeed carry the burden of a higher return rate and/or refund rate and, therefore, finds the C&M configuration less attractive. Vice versa, if the online channel attraction increases, the threshold value increases and retailer 2's configuration at equilibrium migrates versus the C&M vs. C&M one.

When retailer 1 is competing with an online retailer, the results show the existence of a threshold value (dependent on r, λ, and α) for the B&M configuration to be preferable to the C&M one. With similar reasoning as before, when the refund rate and/or return rate increases, it is more advantageous for retailer 1 to maintain the physical configuration (B&M configuration); as the online channel attraction increases, the C&M configuration becomes more attractive for retailer 1. Our analysis also reveals that retailer 1 never finds the Online configuration more attractive than the B&M configuration because she would get a lower profit (due to the refund cost and lower online channel attraction) and B&M vs. Online configuration will always be preferable to the Online vs. Online one. Hence, our results show that a retailer may not always find it attractive to move online, despite the other retailer's doing so.

When retailer 2 adopts an Online channel configuration, retailer 1 (adopting a C&M) also finds it convenient to adopt an Online channel configuration only if a threshold value is met. In particular, when the values of r and/or increase, then the threshold value decreases and the equilibrium migrates versus the C&M vs. Online configuration because, otherwise, retailer 1 would carry the burden of a higher return rate and/or refund rate. When the online channel attraction increases, the threshold value also increases and retailer 1's configuration at equilibrium tends to the Online one.

The Appendix provides an analysis for when $\theta > 1$ and $r < 1$, which leads to different results.

4.3 Discussion of results

From the results reported in Sections 4.1 and 4.2, we can conclude that a retailer may not always find it attractive to (fully) move online, despite the other retailer's doing so. As our analysis shows, the B&M vs. B&M configuration is always preferable to the B&M vs. Online one, and the B&M vs. Online is always preferable to the Online vs. Online one. In general, we observe that the profitability of a (partial) online configuration is driven by a threshold value, which is a function of the refund rate r, the return rate λ, and the online channel attraction θ (which is represented into the parameter α). In particular, when λ and/or r increase, we observe that the equilibrium structure migrates versus the (partial) physical configurations because of the higher return rate and/or refund rate (and related costs) that the retailer would have to face. Vice versa, as the value of θ increases, the online channel attraction also increases. As a consequence, the online arm's choice probability and the retailer's profit increase and, therefore, the configuration at equilibrium tends to the C&M or Online ones. Thus, retailers have to proper control and manage the return rate, the refund rate, and the channel attraction because such parameters drive the equilibrium structure.

It is worth noting that the value for the threshold limits identified in our propositions may vary also according to the specific industry we are considering in terms of return rate (e.g., return rate for fashion products is considerably higher than return rate for food or beauty products; Statista, 2018), refurbishment cost (e.g., refurbishment cost of fashion items is much lower than that for electronic items), and even geographic area (e.g., in 2018, the share of online shoppers who returned a product was 53% in Germany vs. 32% in Poland; Statista, 2019). Hence, when evaluating the best strategy in terms of channel configurations, retailers should always consider the characteristics of the specific product/industry. Also, we notice that the equilibria results are affected by the value of N. However, given the structure of the solution, it is not possible to analytically isolate its effect; therefore, we will study the impact of N through the numerical analysis in Section 5.

Retailers who want to operate online should focus on increasing the customer attractiveness of their online channel (e.g., improve online services, decrease fit uncertainty, offer higher variety of payment methods, etc.), decreasing the refund rate and the return rate. For example, Warby Parker recently introduced the virtual try-on app, where users can get a real time detailed scan of their face and then see how a pair of glasses will look on them. In this way, they can reduce the fit uncertainty derived from purchasing online and, as a consequence, the return rate and return processing costs. In order to decrease the return rate, Amazon has adopted the drastic measure to "bann serial returners" from future purchases (The Wall Street Journal, 2018) and Bloomingdales attaches tags on clothes, which cannot be returned if the tag has been removed (Bloomberg Businessweek, 2014). Especially the refund rate and the return rate are becoming more and more challenging factors in today's business, where retailers report–particularly in some industry like fashion–extremely high return rates, up to 50-60% (Difrancesco et al., 2018) and local legislation imposes regulations on refund policies. Concerning the refund rate, it is not always trivial for retailers to decide charging a restocking fee due to local legislation or marketing strategy. In the next section, we model the scenario with full refund ($r = 1$) and derive new insights and managerial implications for this scenario.

4.4 Extensions

4.4.1 Full refund policy ($r = 1$)

We now explore the consequences of adopting a "full refund" returns policy including the effect on retailers' profits and channel choices. We follow the same procedure as in Sections 4.1 and 4.2, but here we set $r = 1$. So now, when customers return an item purchased online, the retailer must pay back a full refund. We explore both scenarios with $\theta < 1$ (i.e., customers assign a lower value to items purchased online) and $\theta > 1$ (i.e., customers assign a higher value to items purchased online). We define the following quantities useful for the definition of the next proposition:

$$B_1 = \frac{1+\alpha(1-\lambda)}{2+\alpha(3-\lambda)};\;\; B_2 = \frac{q_1^V(1+\alpha(1-\lambda))}{1+q_1^V(1-\lambda)};\;\; B_3 = \frac{q_2^{IV}(1-\lambda)}{1-\lambda q_2^{IV}+\alpha(1-\lambda)(1-q_2^{IV})};$$

$$B_4 = \frac{1+\alpha-\alpha\lambda}{2+3\alpha-(1+3\alpha)\lambda};\;\; B_6 = \frac{1-\lambda}{2+\alpha-(1+\alpha)-\lambda};\;\; B_7 = \frac{1-\lambda}{2-\lambda}.$$

The results of this scenario are summarized as follows.

Proposition 5 *Consider a duopoly setting with product returns and all possible retailer configuration. If there is a full refund return policy (i.e., $r = 1$) and if $\theta \neq 1$, then the following statements hold.*

(i) *A comparison of the equilibria for Cases I (B&M vs. B&M) and II (B&M vs. C&M) always yields the B&M vs. B&M (Case I) configuration as Nash equilibrium.*

(ii) *A comparison of the equilibria for Cases I (B&M vs. B&M) and IV (B&M vs. Online) always yields the B&M vs. B&M (Case I) configuration as Nash equilibrium.*

(iii) *A comparison of the equilibria for Cases II (B&M vs. C&M) and IV (B&M vs. Online) yields the B&M vs. C&M (Case II) configuration as Nash equilibrium when $q_2^{II} > B_3$, and the B&M vs. Online (Case IV) configuration as Nash equilibrium when $q_2^{II} < B_3$.*

(iv) *A comparison of the equilibria for Cases V (C&M vs. Online) and III (C&M vs. C&M) yields the C&M vs. C&M (Case III) configuration as Nash equilibrium when $q_2^V < B_4$, and the C&M vs. Online (Case V) configuration as Nash equilibrium when $q_2^V > B_4$.*

(v) *A comparison of the equilibria for Cases II (B&M vs. C&M) and III (C&M vs. C&M) yields the C&M vs. C&M (Case III) configuration as Nash equilibrium when $q_1^{II} < B_1$, and the B&M vs. C&M (Case II) configuration as Nash equilibrium when $q_1^{II} > B_1$.*

(vi) *A comparison of the equilibria for Cases IV (B&M vs. Online) and V (C&M vs. Online) yields the B&M vs. Online (Case IV) configuration as Nash equilibrium when* $q_1^{IV} > B_2$*, and the C&M vs. Online (Case V) configuration as Nash equilibrium when* $q_1^{IV} < B_2$*.*

(vii) *When* $\theta < 1$*, a comparison of the equilibria for Cases IV (B&M vs. Online) and VI (Online vs. Online) always yields the B&M vs. Online (Case IV) configuration as Nash equilibrium; when* $\theta > 1$*, a comparison of the equilibria for Cases IV (B&M vs. Online) and VI (Online vs. Online) yields the B&M vs. Online (Case IV) configuration as Nash equilibrium when* $q_1^{IV} > B_7$*, and the Online vs. Online (Case VI) configuration as Nash equilibrium when* $q_1^{IV} < B_7$*.*

(viii) *A comparison of the equilibria for Cases V (C&M vs. Online) and VI (Online vs. Online) yields the C&M vs. Online (Case V) configuration as Nash equilibrium when* $q_1^{V} > B_6$*, and the Online vs. Online (Case VI) configuration as Nash equilibrium when* $q_1^{V} < B_6$*.*

The proof is similar to that of Propositions 2-4 (see Appendix). We observe that the new equilibria structure is similar to that presented for $r < 1$ and $\theta < 1$, with the addition of two new equilibria: when comparing Case II (B&M vs. C&M) with Case I (B&M vs. B&M), the B&M vs. B&M configuration is always an equilibrium. Given the fact that now online retailers (and C&M retailers relatively to the online arm) face the burden of a full refund, the B&M vs. B&M will result a preferable configuration. When comparing Cases IV and VI (exclusively in the case of $\theta > 1$), the Online vs. Online configuration is also an equilibirum, provided that a certain threshold value is met. If $\theta > 1$, then the online channel becomes more attractive for customers and therefore generates more profit for the retailer; hence also the Online vs. Online configuration (Case VI) is an equilibrium, despite the burden of a full refund policy.

We also notice that the new threshold values identified in Proposition 5 corresponds to those of Propositions 2-4 when setting $r = 1$ (i.e., full refund rate). More in particular, in the case of $r = 1$ and $\theta < 1$, the new threshold values for the physical configuration to be an equilibrium increase/decrease in a way that they are more easily met. The reason is that, when retailers offer a full refund policy but customers perceive the online channel as less attractive than the physical one, the (partial) physical configuration is more profitable than the (partial) online one and, therefore, will be more often the preferred configuration at equilibrium. This results in the B&M and C&M configurations to be more often preferred to the C&M/online and online configurations, respectively. In the case of $r = 1$ and $\theta > 1$, the threshold values for the C&M/Online configurations to be an equilibrium increase/decrease in a way that are more easily met. This results in the C&M and Online configurations to be more often preferred to the B&M/C&M configurations. If retailers offer a full refund policy and if customers perceive the online channel as more attractive, demand in the online channel increases. As a consequence, the (partial) Online configuration is more profitable than the (partial) physical one and, therefore, will be more frequently the preferred configuration at equilibrium.

Overall, we can say that adopting a full refund policy (because, e.g., of legislative constraints or marketing policy) increases the return cost for retailers, which makes the Online channel less profitable and leads retailers to prefer a B&M configuration. However, when customers perceive the online purchase as having higher quality than the B&M purchase, demand in the Online channel (or online arm in the C&M channel) increases and this can compensate for the higher cost due to full refund, leading to the existence of the Online configuration at equilibrium.

4.4.2 Same product value among different sales channels ($\theta = 1$)

In this section, we extend the model by assuming that consumers assign the same value to buying online and to buying from B&M retailers. We therefore conduct the analysis with $\theta = 1$ and vary r ($r = 1$ or $r \in]0, 1[$). We define the following quantities useful for the definition of the next proposition:

$$M_1 = \frac{2-\lambda}{5-\lambda}; \quad M_{1r} = \frac{2-r\lambda}{5-r\lambda}; \quad M_2 = \frac{q_1^V(2-\lambda)}{1+q_1^V(1-\lambda)};$$

$$M_3 = \frac{q_2^{IV}(1-\lambda)}{2-\lambda-q_2^{IV}}; \quad M_{3r} = \frac{q_2^{IV}(1-r\lambda)}{2-r\lambda-q_2^{IV}}; \quad M_4 = \frac{2-\lambda}{5-4\lambda}; \quad M_{4r} = \frac{2-r\lambda}{5-4r\lambda};$$

$$M_{5r} = \frac{1}{3-r\lambda}; \quad M_6 = \frac{1-\lambda}{3-2\lambda}; \quad M_{6r} = \frac{1-r\lambda}{3-2r\lambda}; \quad M_{7r} = \frac{1-r\lambda}{2-r\lambda}; \quad M_8 = \frac{1}{2-r\lambda}.$$

The new equilibria are characterized as follows.

Proposition 6 *Consider a duopoly setting with product returns and all possible retailer configuration. If there is a full refund return policy (i.e., $r = 1$) and if $\theta = 1$, then the following statements hold.*

(i) *A comparison of the equilibria for Cases I (B&M vs. B&M) and II (B&M vs. C&M) always yields the B&M vs. B&M (Case I) configuration as Nash equilibrium.*

(ii) *A comparison of the equilibria for Cases I (B&M vs. B&M) and IV (B&M vs. Online) always yields the B&M vs. B&M (Case I) configuration as Nash equilibrium.*

(iii) *A comparison of the equilibria for Cases II (B&M vs. C&M) and IV (B&M vs. Online) yields the B&M vs. C&M (Case II) configuration as Nash equilibrium when $q_2^{II} > M_3$, and the B&M vs. Online (Case IV) configuration as Nash equilibrium when $q_2^{II} < M_3$.*

(iv) *A comparison of the equilibria for Cases V (C&M vs. Online) and III (C&M vs. C&M) yields the C&M vs. C&M (Case III) configuration as Nash equilibrium when* $q_2^V < M_4$*, and the C&M v. Online (Case V) configuration as Nash equilibrium when* $q_2^V > M_4$*.*

(v) *A comparison of the equilibria for Cases II (B&M vs. C&M) and III (C&M vs. C&M) yields the C&M vs. C&M (Case III) configuration as Nash equilibrium when* $q_1^{II} < M_1$*, and the B&M vs. C&M (Case II) configuration as Nash equilibrium when* $q_1^{II} > M_1$*.*

(vi) *A comparison of the equilibria for Cases IV (B&M vs. Online) and V (C&M vs. Online) yields the B&M vs. Online (Case IV) configuration as Nash equilibrium when* $q_1^V < M_2$*, and the C&M vs. Online (Case V) configuration as Nash equilibrium when* $q_1^V > M_2$*.*

(vii) *A comparison of the equilibria for Cases IV (B&M vs. Online) and VI (Online vs. Online) always yields the B&M vs. Online (Case IV) configuration as Nash equilibrium.*

(viii) *A comparison of the equilibria for Cases V (C&M vs. Online) and VI (Online vs. Online) yields the C&M vs. Online (Case V) configuration as Nash equilibrium when* $q_1^V > M_6$*, and the Online vs. Online (Case VI) configuration as Nash equilibrium when* $q_1^V < M_6$*.*

The proof is similar to that of Propositions 2-4 (see Appendix). We observe that the new equilibria structure is similar to that presented for $r < 1$ and $\theta < 1$, with the addition of one new equilibrium: when comparing Case I (B&M vs. B&M) with Case II (B&M vs. C&M), the B&M vs. B&M configuration always results a Nash equilibrium. Although customer perceived value has increased, it is not yet high enough to benefit retailers who must issue full refunds to customers for returned products. Therefore, in this case, B&M vs. B&M configuration results to be always preferable to the B&M vs. C&M one. We also notice that the new threshold values identified in Proposition A.9 corresponds to those of Proposition 5 when setting $\theta = 1$. More in particular, the new threshold values for the (partial) online configuration to be an equilibrium increase/decrease in a way that they are more easily met. The reason is that, when retailers offer a full refund policy and customers perceive the physical and online channels as identical, the (partial) online configuration becomes more profitable than the (partial) physical one (compared to the case with $r = 1$ and $\theta < 1$) and, therefore, will be more often the preferred configuration at equilibrium. This results in the C&M/online and online configurations to be more often preferred to the B&M and C&M ones, respectively, compared to the case with $r = 1$ and $\theta < 1$.

We next explore the case when $r < 1$ and $\theta = 1$.

Proposition 7 *Consider a duopoly setting with product returns and all possible retailer configuration. If* $\theta = 1$ *and also* $r < 1$*, then the following statements hold.*

(i) *A comparison of the equilibria for Cases I (B&M vs. B&M) and II (B&M vs. C&M) yields the B&M vs. B&M (Case I) configuration as Nash equilibrium when* $q_2^{II} > M_{5r}$*, and the B&M vs. C&M (Case II) configuration as Nash equilibrium when* $q_2^{II} < M_{5r}$*.*

(ii) *A comparison of the equilibria for Cases I (B&M vs. B&M) and IV (B&M vs. Online) yields the B&M vs. B&M (Case I) configuration as Nash equilibrium when* $q_2^{IV} > M_8$*, and the B&M vs. Online (Case IV) configuration as Nash equilibrium when* $q_2^{IV} < M_8$*.*

(iii) *A comparison of the equilibria for Cases II (B&M vs. C&M) and IV (B&M vs. Online) yields the B&M vs. C&M (Case II) configuration as Nash equilibrium when* $q_2^{II} > M_{4r}$*, and the B&M vs. Online (Case IV) configuration as Nash equilibrium when* $q_2^{II} < M_{4r}$*.*

(iv) *A comparison of the equilibria for Cases V (C&M vs. Online) and III (C&M vs. C&M) yields the C&M vs. C&M (Case III) configuration as Nash equilibrium when* $q_2^{V} < M_4$*, and the C&M v. Online (Case V) configuration as Nash equilibrium when* $q_2^{V} > M_4$*.*

(v) *A comparison of the equilibria for Cases II (B&M vs. C&M) and III (C&M vs. C&M) yields the C&M vs. C&M (Case III) configuration as Nash equilibrium when* $q_1^{II} < M_{1r}$*, and the B&M vs. C&M (Case II) configuration as Nash equilibrium when* $q_1^{II} > M_{1r}$*.*

(vi) *A comparison of the equilibria for Cases IV (B&M vs. Online) and V (C&M vs. Online) yields the B&M vs. Online (Case IV) configuration as Nash equilibrium when* $q_1^{IV} > M_2$*, and the C&M vs. Online (Case V) configuration as Nash equilibrium when* $q_1^{IV} < M_2$*.*

(vii) *A comparison of the equilibria for Cases IV (B&M vs. Online) and VI (Online vs. Online) yields the B&M vs. Online (Case IV) configuration as Nash equilibrium when* $q_1^{IV} > M_{7r}$*, and the Online vs. Online (Case VI) configuration as Nash equilibrium when* $q_1^{IV} < M_{7r}$*.*

(viii) *A comparison of the equilibria for Cases V (C&M vs. Online) and VI (Online vs. Online) yields the C&M vs. Online (Case V) configuration as Nash equilibrium when* $q_1^{V} > M_{6r}$*, and the Online vs. Online (Case VI) configuration as Nash equilibrium when* $q_1^{V} < M_{6r}$*.*

The proof is similar to that of Propositions 2-4 (see Appendix). We observe that the new equilibria structure is similar to that presented for $r < 1$ and $\theta < 1$, with the addition of two new equilibria: when comparing Case IV (B&M vs. Online) with Case I (B&M vs. B&M), also the B&M vs. Online configuration is an equilibrium, provided that a certain threshold value is met. When comparing Cases IV and VI, the Online vs. Online configuration is also an equilibirum, provided that a certain threshold value is met. Since the burden of product returns for retailers in mitigated by the introduction of a restocking fee and customers' channel attraction is now the same in the physical and online channels, the online channel generates higher profits; hence also the B&M vs. Online and Online vs. Online configurations can be an equilibrium. As already discussed for the previous results, the same observations can be made when comparing the new threshold values identified in Proposition 7 with those of Propositions 2-4, with a consequent shift of the equilibria towards the C&M and Online configurations.

From the comparison of Propositions 2-4, 5, A.9, and 7 we can conclude that: (i) when retailers offer a full refund policy, they have to face the burden of the refund cost, which tends to shift the equilibria towards the B&M vs. B&M configuration; (ii) the online channel attraction increase leads to more equilibria involving a (partial) online configuration; (iii) the combination of full refund and higher online channel attraction makes possible the existence at equilibrium of the Online vs. Online configuration, so that the increase of demand in the online channel can compensate for the higher cost due to full refund; (iv) in the context of whether to charge or not a restocking fee and the introduction of a new EU legislation (see Section 2.4), we can conclude that retailers charging restocking fee should put more effort in order to increase consumers perceived value (e.g., offer additional services, provide product full information on the web site and easy payment through website), meaning that customers will accept a restocking fee provided they view the online purchase as having higher quality than a B&M purchase.

5 Numerical Analysis

The purpose of this section is to confirm our theoretical results by conducting a numerical analysis. In particular, given the inability (due to the model complexity) of doing so analytically, we want to further elaborate the effect of the refund rate r and the returns age N on equilibrium profits. We assume the following refurbishment cost function: $H[N] = H_0 + H_1 N$. We model θ as an increasing function of r (since the greater the refund, the *more* attractive the online channel) and λ as an increasing function of r (since the greater the refund, the *higher* the return rate; see Anderson et al., 2009; Shulman et al., 2011; Difrancesco et al., 2018). In particular, we put $\theta = A_0 + A_1 r$ and $\lambda = \lambda_0(1 + \beta r)$, where β represents the sensitivity of the return rate to the refund. We consider the following parameters: $v = 15$, $c = 4$, $H_o = 0.1$, $H_1 = 0.05$, $A_1 = 0.632$, $\sigma = 2$, and $A_0 \geq 0$. The A_0 term captures those factors that determine the value of θ (consumer comfort and savings in cost and time, more brand selection and variety, product availability; delayed possession and gratification, no way to inspect the product before buying it, hassle costs)—except for r, which is modeled separately. In Tables 4 and 5 we characterize the two retailers' profits as a function of the product's perceived value, the percentage of refund on returns, the return rate, and the returns age. We first present the scenario without considering the effect of returns age (Table 4) so as to

Table 4: Profits in Cases I–VI under varying r and A_0

r	0.70	0.70	0.70	0.70	0.70	0.70	0.85	0.85	0.85	0.85	0.85	0.85	1.00	1.00	1.00	1.00	1.00	1.00
λ	0.24	0.24	0.24	0.24	0.24	0.24	0.28	0.28	0.28	0.28	0.28	0.28	0.32	0.32	0.32	0.32	0.32	0.32
A_0	0.27	0.37	0.46	0.56	0.65	0.75	0.27	0.37	0.46	0.56	0.65	0.75	0.27	0.37	0.46	0.56	0.65	0.75
θ	0.71	0.81	0.90	1.00	1.09	1.19	0.81	0.90	1.00	1.09	1.19	1.28	0.90	1.00	1.09	1.19	1.28	1.38
π_1^I	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*
π_2^I	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*
π_1^{II}	*1.78*	*1.60*	*1.32*	*0.96*	*0.62*	*0.36*	*1.61*	*1.33*	*0.98*	*0.64*	*0.37*	*0.20*	*1.35*	*1.01*	*0.67*	*0.40*	*0.22*	*0.12*
π_2^{II}	*1.97*	*1.95*	*1.91*	*1.85*	*1.79*	*1.74*	*1.91*	*1.84*	*1.76*	*1.67*	*1.59*	*1.54*	*1.76*	*1.64*	*1.51*	*1.42*	*1.35*	*1.31*
π_1^{III}	*1.78*	*1.62*	*1.42*	*1.22*	*1.06*	*0.96*	*1.60*	*1.39*	*1.18*	*1.01*	*0.90*	*0.83*	*1.35*	*1.12*	*0.94*	*0.82*	*0.75*	*0.72*
π_2^{III}	*1.78*	*1.62*	*1.42*	*1.22*	*1.06*	*0.96*	*1.60*	*1.39*	*1.18*	*1.01*	*0.90*	*0.83*	*1.35*	*1.12*	*0.94*	*0.82*	*0.75*	*0.72*
π_1^{IV}	*3.70*	*2.98*	*2.36*	*1.86*	*1.47*	*1.18*	*3.08*	*2.45*	*1.93*	*1.53*	*1.22*	*0.99*	*2.55*	*2.01*	*1.59*	*1.27*	*1.02*	*0.84*
π_2^{IV}	*0.85*	*1.06*	*1.34*	*1.70*	*2.14*	*2.68*	*0.97*	*1.22*	*1.54*	*1.95*	*2.45*	*3.02*	*1.10*	*1.39*	*1.76*	*2.21*	*2.74*	*3.33*
π_1^{V}	*3.62*	*2.86*	*2.22*	*1.73*	*1.41*	*1.22*	*2.91*	*2.23*	*1.72*	*1.37*	*1.17*	*1.06*	*2.26*	*1.71*	*1.34*	*1.13*	*1.01*	*0.95*
π_2^{V}	*0.69*	*0.75*	*0.81*	*0.84*	*0.87*	*0.88*	*0.68*	*0.73*	*0.77*	*0.80*	*0.82*	*0.83*	*0.66*	*0.69*	*0.73*	*0.76*	*0.77*	*0.78*
π_1^{VI}	*1.67*	*1.67*	*1.67*	*1.67*	*1.67*	*1.67*	*1.53*	*1.53*	*1.53*	*1.53*	*1.53*	*1.53*	*1.36*	*1.36*	*1.36*	*1.36*	*1.36*	*1.36*
π_2^{VI}	*1.67*	*1.67*	*1.67*	*1.67*	*1.67*	*1.67*	*1.53*	*1.53*	*1.53*	*1.53*	*1.53*	*1.53*	*1.36*	*1.36*	*1.36*	*1.36*	*1.36*	*1.36*

isolate the effect of the restocking fee on retailer profits; in Table 5 we let N vary and analyze how the restocking fee and N together affect the profit. In Table 4, in order to compare different values of θ under a given refund rate, we let A_0 vary from 0.27 to 0.75. Table 4 shows that, when customers associate a higher value to the online channel ($\theta > 1$), the solution with $r < 1$ generates a higher profit (than the solution with $r = 1$) for both retailers in the Online vs. Online case, in the C&M vs. Online case, and also in the C&M vs. C&M case. Focusing on the combination $\theta > 1$ and $r < 1$, we notice that—in the C&M vs. Online case—the profit of retailer 2 (online) is increasing in θ (since she operates only online, she is more affected by customer perceived value) whereas greater θ leads to lower profits for retailer 1 (C&M). If we further increase θ while fixing $r = 1$, then the online channel becomes even more attractive to customers. Yet this solution is still not attractive for retailers in the C&M vs. C&M, C&M vs. Online, and Online vs. Online cases because of the higher refund and higher number of returns to process, which leads to lower profits than when $r < 1$.

Exploring the case with $r = 1$ and increasing θ, we find that in the C&M vs. Online competition there is a profit increase only for retailer 2 (online). The reason is that only the online arm takes advantage of an increase in θ, and since retailer 1 (C&M) also has a B&M arm, the benefit of greater θ will fail to compensate for the higher return rate (and, therefore, higher refurbishment cost) and the higher cost of issuing full refunds to customers. In this setting, under C&M vs. C&M competition the profits of both retailers will actually decrease. B&M vs. B&M and Online vs. Online configurations are not affected by increasing θ when $r = 1$. It is worth reiterating that, when a full refund policy is followed (because, e.g., of legislative constraints or marketing policy), then the online channel becomes more attractive to customers and hence more profitable (than the

C&M channel) for retailers. If refunds are only partial then, in the C&M vs. Online case, the online retailer benefits from an increase in that channel's perceived value while the C&M retailer does not. Similar results hold in the B&M vs. Online case, where again only the online retailer benefits from an increase in the online channel's perceived value. We therefore conclude that, when consumers assign a higher value to the online channel, online retailers who charge restocking fees should strive to increase consumer perceived value (e.g., offer additional services, provide full product information, enable easy payment through the website). Under the C&M vs. Online competition, the online retailer with higher θ (θ=1.28 vs. θ=0.81) increases her profit from 0.68 to 0.78, although she offers full refunds and has a higher return rate only in the second case. We observed previously that, unlike B&M profit, online profit declines in response to an increase in r. Similarly, also the C&M profit—despite the positive effect of higher r on its B&M arm—decreases in Case II and in Case III; in Case V, however, if $\theta < 1$ then increasing r has a positive effect on the C&M retailer's profit because she benefits from the online retailer's reduced attractiveness (see Table 4).

Table 5: Profits in Cases I–VI under varying r and N

r	0.80	0.80	0.80	0.80	0.80	0.80	1.00	1.00	1.00	1.00	1.00	1.00
λ	0.15	0.15	0.15	0.15	0.15	0.15	0.18	0.18	0.18	0.18	0.18	0.18
N	1	2	3	4	5	6	1	2	3	4	5	6
π_1^I	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*
π_2^I	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*	*2.00*
π_1^{II}	*1.65*	*1.62*	*1.62*	*1.62*	*1.62*	*1.62*	*1.34*	*1.27*	*1.26*	*1.26*	*1.26*	*1.26*
π_2^{II}	*1.93*	*1.96*	*1.96*	*1.96*	*1.96*	*1.96*	*1.78*	*1.85*	*1.86*	*1.86*	*1.86*	*1.86*
π_1^{III}	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.36*	*1.36*	*1.36*	*1.36*	*1.36*	*1.36*
π_2^{III}	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.36*	*1.36*	*1.36*	*1.36*	*1.36*	*1.36*
π_1^{IV}	*3.49*	*3.20*	*3.17*	*3.17*	*3.18*	*3.18*	*2.73*	*2.44*	*2.40*	*2.40*	*2.40*	*2.40*
π_2^{IV}	*1.01*	*1.10*	*1.11*	*1.11*	*1.11*	*1.11*	*1.20*	*1.35*	*1.37*	*1.37*	*1.37*	*1.37*
π_1^{V}	*3.32*	*3.10*	*3.07*	*3.07*	*3.08*	*3.08*	*2.37*	*2.22*	*2.19*	*2.19*	*2.19*	*2.20*
π_2^{V}	*0.70*	*0.78*	*0.79*	*0.79*	*0.79*	*0.79*	*0.67*	*0.77*	*0.78*	*0.78*	*0.78*	*0.78*
π_1^{VI}	*1.76*	*1.76*	*1.76*	*1.76*	*1.76*	*1.76*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*
π_2^{VI}	*1.76*	*1.76*	*1.76*	*1.76*	*1.76*	*1.76*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*

Looking exclusively at Table 5, we see that the online retailer's profit increases with N and also the C&M retailer's profit in case II increases with N; this means that retailers find more profitable to loop returns several times. This explains the empirical evidence we observe in practice, where some retailers decide to refurbish and reintroduce returned items in the primary market several times. This solution amounts to a combination of the positive effect of the savings from purchasing fewer new items and the negative effect of refurbishment costs. We also notice that, as N increases, the quantity λ_N goes rapidly to zero (according to the definition of λ_N given in Section 3.1) and, therefore, after values of $N = 3$ the results do not show any significant sensitivity to N. This means that it would result optimal for online retailers and C&M retailers to set a value of $N = 2$ or $N = 3$. After that, the extra effort to refurbish and reintroduce returned items in the forward chain will not generate any further benefit.

We now consider the effect of the return rate λ on the profits. We observe that an increase in λ always decreases the profits because of the higher refurbishment cost and lower net sales. Another interesting result is the variety of possible equilibria. Upon closer examination, we realize that each equilibrium is extremely sensitive to variation in the parameters: one equilibrium case can easily be transformed into another one simply by changing a coefficient slightly. Consider, for example, Case II (B&M vs. C&M) and Case III (C&M vs. C&M) when $r < 1$ and $\theta < 1$ (see Table 4). If $A_o = 0.27$, then Case II is equilibrium because $q_1^{II} = 0.471 > K_1 = 0.469$ (the equilibrium profits in this scenario are $\pi_1^{II} = 1.78, \pi_2^{I} = 1.97$). Yet when A_o increases slightly from 0.27 to 0.37, Case III is equilibrium because $q_1^{II} = 0.402 < K_1 = 0.47$ (here the equilibrium profits are $\pi_1^{III} = \pi_2^{III} = 1.62$).

6 Conclusions and future directions

Our study analyzed the competition between two retailers who must decide how to structure their sales channel (traditional B&M, C&M, or Online). On the one hand, an online presence (be it online or a C&M Internet arm) offers the possibility of reaching a larger number of customers (or a different category of them). On the other hand, online transactions beget the returns issue: customers who buy an item online can return it for a (partial or full) refund. We investigated the effects of stricter versus more lenient return policy in terms of a restocking fee and the effect of returns age on customers' perceived value of the product. We showed how each of these factors has both a positive and negative effect: a full refund policy increases customers perceived value but also increases the retailer's returns cost; similarly, a high returns age increases the retailer's refurbishment cost yet has the advantage of lowering the purchase cost of new items. Although online retailers generally prefer a partial refund policy, legislative edicts or the retailer's own marketing strategy may preclude this option; in that case, retailers should undertake to increase customer perceived value while increasing their own profit. In view of recent legislation on return policy, we discussed online retailers who have announced that they will continue to offer full refunds on returns in order to maintain their European market share. For these retailers, one strategy would be to maintain a full refund policy while increasing customer perceived value so as to generate an overall increase in the equilibrium profit. With regards to the returns age, we observed how looping the same item several times—though it entails additional costs—can nonetheless have a positive net effect. We showed in Section 5 that, in several cases, equilibrium profits are increasing in N.

In a competitive environment it is critical to appreciate how sensitive the equilibrium cases are to parameter variations; moreover, a minimal change in the sales quantity, refund rate, customer perceived value, or other factor could lead to a different equilibrium structure. An interesting example comes from the US, where traditional retailers have recently launched an advertisement warning that the e-commerce group Alibaba will be the next beneficiary of a sales tax loophole, which will suddenly make the online retailer much more attractive for customers, and thus more profitable (Financial Times, 2014). Therefore, retailers who aim to survive in such fragile environment must properly manage their chosen sales channel, their processes, their returns activities and returns policy, and customer needs. Even more important is being aware of—and being prepared to cope with—instability due to the surrounding environment. In order to create and increase customer perceived value, retailers must evolve by adapting to new market needs, engaging customers to an ever greater extent, and creating a dialogue with customers that goes beyond the prosaic connection between seller and buyer.

We conclude with the words of eBay's president in an interview with McKinsey Publishing (McKinsey, 2014), which evidence future directions of multichannel retail business and the development of a new relationship between customers and e-tailers: "Now every merchant, every retailer must have an omnichannel strategy or they won't survive. [...] I should say the death of the store has been greatly exaggerated. There will be a transformation of retail real estate, but not an end of it. [...] I think stores are going to become as much distribution and fulfillment centers as they are full-fledged shopping experiences [...] Building engaging experience across channels is incredibly important [...] But now, understanding how to connect with your core customers across every way they want to connect—not the way you want them to connect but the way they want to connect with you—is a different skill [...] Understanding how to engage in a world of exploding social networks, how to use search, how to use catalog, how to optimize, and how to engage. I think that is going to become a core part of the playbook for retailers and merchants of all sizes around the world."

Although our work captures several facets of the multichannel problem with product returns, some interesting extensions of the current model are worth exploring. First of all, one could enlarge the scenario from two retailers to n players competing in the same market and then analyze how the equilibrium and profits evolve. Another extension of interest is a more detailed development of the backward chain, exploring the possibility that a portion of the returned items can generate additional profit (e.g., through sales in a secondary market). The online alternative might then become more attractive to retailers because adopting it could increase their margins. A third extension would consider different refund rates across channels: given the real-life differences in restocking fees of online retailers, it is possible that profits (and the equilibrium structure) could be affected by those differences. Similarly, one could introduce channel costs by modeling, for example, the cost of the store and employees (for the B&M channel) and of a warehouse and product transportation (for the Online channel). Two additional choices that merit analysis are (i) for also the B&M retailer to allow product returns and (ii) whether to introduce other factors that affect customer perceived value and hence demand—for example, increasing the return window (i.e., allowing customers to return items after a longer time).

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Appendix

A.1 Case with $\theta < 1$

Proof of equilibria configurations

In this section, we derive the equilibria prices and profits for the six configurations presented in Table 3 of the paper.

Case I: B&M vs. B&M

The equilibrium prices and profits for Case I directly follow from the results reported in (Anderson et al., 1992).

Case II: B&M vs. C&M

Differentiating π_i with respect of p_i and using the property of the MNL model defined by (3), we obtain:

$$\begin{aligned}
\frac{\partial \Pi_1}{\partial p_1} &= q_1 + (p_1 - c)\frac{q_1}{\sigma}(q_1 - 1), \\
\frac{\partial \Pi_2}{\partial p_2} &= \frac{(q_2 - 1)}{\sigma} q_2 (p_2 - c - (1 - \lambda r)\alpha p_2 + (1 - \lambda - \lambda_N)\alpha c + (\lambda - \lambda_N)\alpha H[N]) \\
&\qquad + q_2((1 - \lambda r)\alpha + 1).
\end{aligned} \tag{A.9}$$

Setting these two equations to zero yields the equilibrium prices expressed in Table 3; after substituting these prices into (5), we obtain the equilibrium profits expressed in table 3. The proof that this represents the unique equilibrium is similar to the proof for the B&M vs. B&M case, which is given in (Anderson et al., 1992).

Case III: C&M vs. C&M

Differentiating π_i with respect of p_i and using the property of the MNL model defined by (3), we obtain:

$$\begin{aligned}\frac{\partial \Pi_i}{\partial p_i} = \frac{(q_i-1)}{\sigma} q_i(p_i - c - (1-\lambda r)\alpha p_i &+ (1-\lambda-\lambda_N)\alpha c + (\lambda-\lambda_N)\alpha H[N]) \\ &+ q_i((1-\lambda r)\alpha + 1).\end{aligned} \tag{A.10}$$

Setting this equation to zero yields the symmetrical equilibrium prices expressed in Table 3; after substituting these prices into (5), we obtain the equilibrium profits. The proof that this represents the unique equilibrium follows (Anderson et al., 1992).

Case IV: B&M vs. Online

Differentiating π_i with respect of p_i and using the property of the MNL model defined by (3), we obtain:

$$\begin{aligned}\frac{\partial \Pi_1}{\partial p_1} &= q_1 + (p_1 - c)\frac{q_1}{\sigma}(q_1 - 1), \\ \frac{\partial \Pi_2}{\partial p_2} &= \frac{1}{\sigma} q_2(\sigma - r\sigma\lambda - p_2(-1+q_2)(-1+r\lambda) + c(-1+q_2)(-1+\lambda-\lambda_N) \\ &\qquad - H[N](-1+q_2)(\lambda-\lambda_N)).\end{aligned} \tag{A.11}$$

Setting these two equations to zero yields the equilibrium prices expressed in Table 3; after substituting these prices into (5), we obtain the equilibrium profits. The proof that this represents the unique equilibrium follows (Anderson et al., 1992).

Case V: C&M vs. Online

Differentiating π_i with respect of p_i and using the property of the MNL model defined by (3), we obtain:

$$\begin{aligned}\frac{\partial \Pi_1}{\partial p_1} &= \frac{(q_1-1)}{\sigma} q_1(p_1 - c - (1-\lambda r)\alpha p_1 + (1-\lambda-\lambda_N)\alpha c + (\lambda-\lambda_N)\alpha H[N]) \\ &\qquad + q_1((1-\lambda r)\alpha + 1) \\ \frac{\partial \Pi_2}{\partial p_2} &= \frac{1}{\sigma} q_2(\sigma - r\sigma\lambda - p_2(-1+q_2)(-1+r\lambda) + c(-1+q_2)(-1+\lambda-\lambda_N) \\ &\qquad - H[N](-1+q_2)(\lambda-\lambda_N)).\end{aligned} \tag{A.12}$$

Setting these two equations to zero yields the equilibrium prices expressed in Table 3; after substituting these prices into (5), we obtain the equilibrium profits. The proof that this represents the unique equilibrium follows (Anderson et al., 1992).

Case VI: Online vs. Online

Differentiating π_i with respect of p_i and using the property of the MNL model defined by (3), we obtain:

$$\begin{aligned}\frac{\partial \Pi_i}{\partial p_i} = \frac{1}{\sigma} q_i(\sigma - r\sigma\lambda - p_i(-1+q_i)(-1+r\lambda) + c(-1+q_i)(-1+\lambda-\lambda_N) \\ - H[N](-1+q_i)(\lambda-\lambda_N)).\end{aligned} \tag{A.13}$$

Setting this equation to zero yields the symmetrical equilibrium prices expressed in Table 3; after substituting these prices into (5), we obtain the equilibrium profits. The proof that this represents the unique equilibrium follows (Anderson et al., 1992).

Proof of Proposition 1

(i) The proof directly follow from the results reported in (Anderson et al., 1992).

(ii) We first show that, in Case II, $p_1 > p_2$.

The proof follows (Bernstein et al., 2008). Using the equilibrium prices derived in Case II, we subtract p_2 from p_1 and divide by σ:

$$\frac{p_1 - p_2}{\sigma} = \frac{q_1 - q_2}{(q_1-1)(q_2-1)} + \frac{\alpha(H[N] + c(r-1))\lambda + (c - H[N])\lambda_N}{(-1+\alpha(r\lambda-1))\sigma}. \tag{A.14}$$

Let $x := \frac{p_1-p_2}{\sigma}$. According to the MNL demand model, the market shares for retailer 1 and retailer 2 are (respectively) $q_1 = \frac{1}{1+(1+\alpha)e^x}$ and $q_2 = \frac{1}{1+\alpha+e^{-x}}$. Substituting these values into (A.14), we obtain

$$x = \frac{e^{-x}}{1+\alpha} + \frac{1}{\alpha(1+\alpha e^x)} - \frac{1}{\alpha} + \frac{\alpha(H[N] + c(r-1))\lambda + (c-H[N])\lambda_N}{(\alpha(r\lambda-1)-1)\sigma} := A(x). \tag{A.15}$$

Now define $f_1(x) = x$ and $f_2(x) = A(x)$. Then:

- $f_1(x)$ is an increasing function of x and $f_1(0) = 0$; and
- $f_2(x)$ is a decreasing function of x and $f_2(0) = \frac{1}{1+\alpha} + \frac{1}{\alpha(1+\alpha)} - \frac{1}{\alpha} + \frac{\alpha(H[N]+c(r-1))\lambda+(c-H[N])\lambda_N}{(\alpha(r\lambda-1)-1)\sigma}$, which is positive when $c > \frac{(\lambda-\lambda_N)H[N]}{\lambda-\lambda_N-r\lambda}$ and $r < \frac{\lambda-\lambda_N}{\lambda}$.

This means that $f_1(x)$ and $f_2(x)$ cross only at point $\bar{x}$ and that $0 < \bar{x} < x_o$. That is, $0 < \frac{\bar{p_1}-\bar{p_2}}{\sigma} < x_o$ and, by the monotony of the exponential function, $\exp(\frac{\bar{p_1}-\bar{p_2}}{\sigma}) > 1$ ($p_1 - p_2 > 0$).

From this result, together with the definition of q_1^{II} and q_2^{II} given in Sections 3.2, it follows that $q_1^{II} < q_2^{II}$. In the light of these findings, we analyze now the profits as defined in Table 3. Since $q_1^{II} < q_2^{II}$, it results $\pi_1^{II} < \pi_2^{II}$.

(iii) It follows from the definition of q_i^{III} given in section 3.2 and from the equilibrium prices and profits given by Table 3.

(iv) The proof follows (Bernstein et al., 2008). Using the equilibrium prices of Case IV (see Table 3), we subtract p_2 from p_1 and divide by σ:

$$\frac{p_1 - p_2}{\sigma} = \frac{q_1 - q_2}{(q_1 - 1)(q_2 - 1)} + \frac{(H[N] + c(r-1))\lambda + (c - H[N])\lambda_N}{(r\lambda - 1)\sigma}. \tag{A.16}$$

Let $x := \frac{p_1 - p_2}{\sigma}$. According to the MNL demand model, the market shares for retailer 1 and retailer 2 are then $q_1 = \frac{1}{1+\alpha e^x}$ and $q_2 = \frac{1}{1+1/(\alpha e^x)}$. Substituting these values into (A.16), we obtain

$$x = \frac{e^{-x}}{\alpha} - \alpha e^x + \frac{(H[N] + c(r-1))\lambda + (c - H[N])\lambda_N}{(r\lambda - 1)\sigma} := A(x). \tag{A.17}$$

Define $f_1(x) = x$ and $f_2(x) = A(x)$. Then the following statements hold:

- $f_1(x)$ is an increasing function of x and $f_1(0) = 0$.
- $f_2(x)$ is a strictly decreasing function of x, and setting $f_2(x) = 0$ yields $x_o = \ln\left[\frac{H(\lambda-\lambda_N)+c((-1+r)\lambda+\lambda_N)-\sqrt{((H+c(-1+r))\lambda+(c-H)\lambda_N)^2+4(-1+r\lambda)^2\sigma^2}}{2\alpha(-1+r\lambda)\sigma}\right]$, which is positive when $c > \frac{(\lambda-\lambda_N)H[N]}{\lambda-\lambda_N-r\lambda}$ and $r < \frac{\lambda-\lambda_N}{\lambda}$.

This means that $f_1(x)$ and $f_2(x)$ cross in one point only, $\bar{x}$, with $0 < \bar{x} < x_o$. That is, $0 < \frac{\bar{p}_1-\bar{p}_2}{\sigma} < x_o$ and, by the monotony of the exponential function, $\exp(\frac{\bar{p}_1-\bar{p}_2}{\sigma}) > 1$ $(p_1 - p_2 > 0)$. From this result, together with the definition of q_1^{IV} and q_2^{IV} given in Sections 3.2, it follows that $q_1^{IV} > q_2^{IV}$ and $\pi_1^{IV} > \pi_2^{IV}$.

(v) We first prove that $p_1^V > p_2^V$. Using the equilibrium prices of Case V (see Table 3), we subtract p_1 from p_2 and divide by σ:

$$\frac{p_2 - p_1}{\sigma} = \frac{q_2 - q_1}{(-1 + q_2)(-1 + q_1)} + \frac{H[N](\lambda - \lambda_N) + c((-1 + r)\lambda + \lambda_N)}{(-1 + r\lambda)(-1 + \alpha(-1 + r\lambda))\sigma} \tag{A.18}$$

Let $x := \dfrac{p_2 - p_1}{\sigma}$. According to the MNL demand model, the market shares for retailer 1 and retailer 2 are then $q_1 = \frac{1}{1+\alpha+\alpha/e^x}$ and $q_2 = \frac{1}{1+e^x/\alpha+e^x}$. Substituting these values into (A.18), we obtain

$$x = \frac{\alpha e^{-x}}{1+\alpha} - \frac{e^x}{\alpha + \alpha e^x} + \frac{H[N](\lambda - \lambda_N) + c((-1 + r)\lambda + \lambda_N}{(-1 + r\lambda)(-1 + \alpha(-1 + r\lambda))\sigma} := A(x). \tag{A.19}$$

Define $f_1(x) = x$ and $f_2(x) = A(x)$. Then the following statements hold:

- $f_1(x)$ is an increasing function of x and $f_1(0) = 0$.
- $f_2(x)$ is a strictly decreasing function of x, and evaluating $f_2(x)$ in zero yields $f_2(0) = -\frac{1}{2\alpha} + \frac{\alpha}{1+\alpha} + \frac{H[N](\lambda - \lambda_N) + c((-1+r)\lambda + \lambda_N)}{(-1+r\lambda)(-1+\alpha(-1+r\lambda))\sigma}$, which is negative when $c > \frac{(\lambda-\lambda_N)H[N]}{\lambda-\lambda_N-r\lambda}$ and $r < \frac{\lambda-\lambda_N}{\lambda}$

This means that $f_1(x)$ and $f_2(x)$ cross in one point only, $\bar{x}$, with $\bar{x} < 0$. That is, $\frac{\bar{p}_2-\bar{p}_1}{\sigma} < 0$ and, by the monotony of the exponential function, $\exp(\frac{\bar{p}_2-\bar{p}_1}{\sigma}) < 1$ $(p_2 - p_1 < 0)$.

From this result, together with the definition of q_1^V and q_2^V, given in sections 3.2, it derives that $\pi_1^V < \pi_2^V$ when $q_1^V < K_9$; $\pi_1^V > \pi_2^V$ otherwise.

(vi) $p_1^{VI} = p_2^{VI}$; $\pi_1^{VI} = \pi_2^{VI}$. It follows from the definition of q_i^{VI} given in section 3.2 and from the equilibrium prices and profits given by Table 3.

Proof of Proposition 2

When retailer 1 adopts a B&M configuration and retailer 2 should decide between a B&M and C&M configurations, retailer 2 compares the equilibrium profits in the two scenarios. Using the results of Proposition 1, it follows that, if $q_2^{II} > K_5$, then $\pi_2^I > \pi_2^{II}$. Therefore, retailer 2 has no incentive to deviate from adopting the channel B&M, so the B&M vs. B&M case is a Nash equilibrium. If $q_2^{II} < K_5$, then $\pi_2^I < \pi_2^{II}$. Therefore, retailer 2 has no incentive to deviate from adopting the channel C&M, so the B&M vs. C&M case is a Nash equilibrium. When retailer 1 adopts a B&M configuration and retailer 2 should decide between a B&M and Online configurations, retailer 2 compares the equilibrium profits in the two scenarios. Using the results of Proposition 1, it always results $\pi_2^I > \pi_2^{IV}$. Therefore, retailer 2 has no incentive to deviate from adopting the channel B&M, so the B&M vs. B&M case is a Nash equilibrium.

Proof of Proposition 3

When retailer 1 adopts a B&M configuration and retailer 2 should decide between a C&M and Online configurations, retailer 2 compares the equilibrium profits in the two scenarios. Using the results of Proposition 1, it follows that, if $q_2^{II} > K_3$, then $\pi_2^{II} > \pi_2^{IV}$. Therefore, retailer 2 has no incentive to deviate from adopting the channel C&M, so the B&M vs. C&M case is a Nash equilibrium. If $q_2^{II} < K_3$, then $\pi_2^{II} < \pi_2^{IV}$. Therefore, retailer 2 has no incentive to deviate from adopting the Online channel, so the B&M vs. Online case is a Nash equilibrium. When retailer 1 adopts a C&M configuration and retailer 2 should decide between a C&M and Online configurations, retailer 2 compares the equilibrium profits in the two scenarios. Using the results of Proposition 1, it follows that, if $q_2^V < K_4$, then $\pi_2^{III} > \pi_2^V$. Therefore, retailer 2 has no incentive to deviate from adopting the channel C&M, so the C&M vs. C&M case is a Nash equilibrium. If $q_2^V > K_4$, then $\pi_2^{III} < \pi_2^V$. Therefore, retailer 2 has no incentive to deviate from adopting the Online channel, so the C&M vs. Online case is a Nash equilibrium.

Proof of Proposition 4

When retailer 2 adopts a CM channel configuration and retailer 1 should decide between a B&M and C&M configurations, retailer 1 compares the equilibrium profits in the two scenarios. Using the results of Proposition 1, it follows that, if $q_1^{II} > K_1$, then $\pi_1^{II} > \pi_1^{III}$. Therefore, retailer 1 has no incentive to deviate from adopting the channel B&M, so the B&M vs. C&M case is a Nash equilibrium. If $q_1^{II} < K_1$, then $\pi_2^{II} < \pi_2^{III}$. Therefore, retailer 1 has no incentive to deviate from adopting the channel C&M, so the C&M vs. C&M case is a Nash equilibrium.

When retailer 2 adopts an Online channel configuration and retailer 1 should decide between a B&M and C&M configurations, retailer 1 compares the equilibrium profits in the two scenarios. Using the results of Proposition 1, it follows that, if $q_1^{IV} > K_2$, then $\pi_1^{II} > \pi_1^{IV}$. Therefore, retailer 1 has no incentive to deviate from adopting the channel B&M, so the B&M vs. Online case is a Nash equilibrium. If $q_1^{IV} < K_2$, then $\pi_1^{II} < \pi_1^{IV}$. Therefore, retailer 1 has no incentive to deviate from adopting the channel C&M, so the C&M vs. Online case is a Nash equilibrium.

When retailer 2 adopts an Online channel configuration and retailer 1 should decide between a B&M and Online configurations, retailer 1 compares the equilibrium profits in the two scenarios. Using the results of Proposition 1, it always results $\pi_1^{IV} > \pi_1^{VI}$. Therefore, retailer 1 has no incentive to deviate from adopting the channel B&M, so the B&M vs. Online case is a Nash equilibrium.

When retailer 2 adopts an Online channel configuration and retailer 1 should decide between a C&M and Online configurations, retailer 1 compares the equilibrium profits in the two scenarios. Using the results of Proposition 1, it follows that, if $q_1^V > K_6$, then $\pi_1^V > \pi_1^{VI}$. Therefore, retailer 1 has no incentive to deviate from adopting the channel C&M, so the C&M vs. Online case is a Nash equilibrium. If $q_1^V < K_6$, then $\pi_1^V < \pi_1^{VI}$. Therefore, retailer 1 has no incentive to deviate from adopting the Online channel, so the Online vs. Online case is a Nash equilibrium.

A.2 Case with $\theta > 1$

Our main assumption (among others) underlying the results so far is that customers buying online perceive themselves obtaining *less* utility ($\theta < 1$) than in offline retail channel because there is no way to try out the item, possession is delayed waiting for delivery, and the possibility of a restocking fee. In this section, we investigate the case of *more* utility being associated with an online purchase. As discussed in Section 2 of the paper, some research highlights the positive effects associated with online purchasing and a consequent higher utility ($\theta > 1$). The hypothesized consumer preference for online shopping can be justified by the consumer's savings in cost and time, the comfort of buying from home, enhanced brand selection and variety, and greater product availability. We replicate the different scenarios analyzed in Section 4 of our paper (Case I remains the same), but now assuming that $\theta > 1$ (and $r < 1$), and look for changes in the equilibria structure. We formulate the following propositions, the proofs of which follow the same reasoning as in the $\theta < 1$ case. Be $R_1 = \dfrac{q_2^{IV}(1 - r\lambda)}{1 - r\lambda q_2^{IV}}$:

Proposition A.8 *Consider a duopoly setting with product returns and all possible retailer configurations. Under the assumption of $\theta > 1$ (and $r < 1$), a comparison of the equilibria for each of the six cases yields the following statements.*

(i) $p_1^I = p_2^I$; $\pi_1^I = \pi_2^I$.

(ii) $p_1^{II} > p_2^{II}$; $\pi_1^{II} < \pi_2^{II}$.

(iii) $p_1^{III} = p_2^{III}$; $\pi_1^{III} = \pi_2^{III}$.

(iv) $p_1^{IV} < p_2^{IV}$; $\pi_1^{IV} > \pi_2^{IV}$ *when* $q_1^{IV} > R_1$ *and* $q_2^{IV} < M_8$; $\pi_1^V < \pi_2^V$ *otherwise.*

(v) $p_1^V < p_2^V$; $\pi_1^V > \pi_2^V$ *when* $q_1^V < K_9$; $\pi_1^V < \pi_2^V$ *otherwise.*

(vi) $p_1^{VI} = p_2^{VI}$; $\pi_1^{VI} = \pi_2^{VI}$.

Proposition A.9 *Consider a duopoly setting with product returns and all possible retailer configurations. If $\theta > 1$ (and $r < 1$), then the following statements hold.*

(i) *A comparison of the equilibria for Cases I (B&M vs. B&M) and II (B&M vs. C&M) yields the B&M vs. B&M (Case I) configuration as Nash equilibrium when $q_2^{II} < K_5$, and the B&M vs. C&M (Case II) configuration as Nash equilibrium when $q_2^{II} > K_5$.*

(ii) *A comparison of the equilibria for Cases I (B&M vs. B&M) and IV (B&M vs. Online) yields the B&M vs. B&M (Case I) configuration as Nash equilibrium when $q_2^{IV} < M_8$, and the B&M vs. Online (Case IV) configuration as Nash equilibrium when $q_2^{II} > M_8$.*

(iii) *A comparison of the equilibria for Cases II (B&M vs. C&M) and IV (B&M vs. Online) yields the B&M vs. C&M (Case II) configuration as Nash equilibrium when* $q_2^{II} > K_3$*, and the B&M vs. Online (Case IV) configuration as Nash equilibrium when* $q_2^{II} < K_3$*.*

(iv) *A comparison of the equilibria for Cases V (C&M vs. Online) and III (C&M vs. C&M) yields the C&M vs. C&M (Case III) configuration as Nash equilibrium when* $q_2^{V} < K_4$*, and the C&M v. Online (Case V) configuration as Nash equilibrium when* $q_2^{V} > K_4$*.*

(v) *A comparison of the equilibria for Cases II (B&M vs. C&M) and III (C&M vs. C&M) yields the B&M vs. C&M (Case II) configuration as Nash equilibrium when* $q_1^{II} > K_1$*, and the C&M vs. C&M (Case III) when* $q_1^{II} < K_1$

(vi) *A comparison of the equilibria for Cases IV (B&M vs. Online) and V (C&M vs. Online) yields the B&M vs. Online (Case IV) configuration as Nash equilibrium when* $q_1^{IV} > K_2$*, and the C&M vs. Online (Case V) configuration as Nash equilibrium when* $q_1^{IV} < K_2$*.*

(vii) *A comparison of the equilibria for Cases IV (B&M vs. Online) and VI (Online vs. Online) yields the B&M vs. Online (Case IV) configuration as Nash equilibrium when* $q_1^{IV} > M_{7r}$*, and the Online vs. Online (Case VI) configuration as Nash equilibrium when* $q_1^{IV} < M_{7r}$*.*

(viii) *A comparison of the equilibria for Cases V (C&M vs. Online) and VI (Online vs. Online) yields the C&M vs. Online (Case V) configuration as Nash equilibrium when* $q_1^{V} > K_6$*, and the Online vs. Online (Case VI) configuration as Nash equilibrium when* $q_1^{V} < K_6$*.*

In contrast to the $\theta < 1$ setting, when $\theta > 1$ there exist two new possible equilibria involving at least one online retailer: the B&M vs. Online case (when comparing it with the B&M vs. B&M scenario) and the Online vs. Online case (when comparing it with the B&M vs. Online scenario). This result is due to the increase in θ, which makes the online channel more attractive not only to customers but also to retailers and, therefore, more likely to be a retailer's channel choice compared to the case with $\theta < 1$.

As already observed in Section 4 of the manuscript, the profitability of a (partial) online configuration is driven by a threshold value, which is function of the refund rate r, the return rate λ, and the online channel attraction θ (which is represented into the parameter α). In particular, when λ and/or r increase, we observe that the equilibrium structure migrates versus the (partial) physical configurations because of the higher return rate and/or refund rate (and related costs) that the retailer would have to face. Vice versa, as the online channel attraction increases, the configuration at equilibrium tends to the C&M or Online ones. Thus, retailers have to proper control and manage the return rate, the refund rate, and the channel attraction because such parameters drive the equilibrium structure.