ISSN 1611-1699/eISSN 2029-4433

JOURNAL of BUSINESS ECONOMICS & MANAGEMENT

2025
Volume 26
Issue 3
Pages 507–532
https://doi.org/10.3846/jbem.2025.23778

A NEW E-COMMERCE MODEL FOR FREE-RIDING BEHAVIOR IN DECENTRALIZED SUPPLY CHAINS

Andreea MARIN-PANTELESCU [1], Alina CONSTANTINESCU [2], Mihai Daniel ROMAN [3], Adela SOCOL [4], Lidija KRAUJALIENĖ [5]✉

[1]*Faculty of Business and Tourism, Bucharest University of Economic Studies, Bucharest, Romania*
[2]*Faculty of Science and Arts, Valahia University of Targoviste, Targoviste, Romania*
[3]*Faculty of Economic Cybernetics, Statistics and Informatics, Bucharest University of Economic Studies, Bucharest, Romania*
[4]*Faculty of Economics, University "1 Decembrie 1918" of Alba Iulia, Alba Iulia, Romania*
[5]*Business Innovation and Communication School, Kazimieras Simonavičius University, Vilnius, Lithuania*

Article History:
- received 16 December 2024
- accepted 7 February 2025

Abstract. The complexity of consumer free-riding behavior is a current significant problem, as modern online purchasing channels sharply compete with the traditional ones. The purpose of this study is to examine the impact of showrooming behavior by free-rider consumers on product valuation within a decentralized supply chain. Also, we examine how the consumers' use of the benefits of the experience achieved in the offline channel to buy from the online channel influences their product valuation in a decentralized supply chain and influences the profits' level of offline retailers. We develop an e-commerce model for product valuation when customers visit a brick-and-mortar unit for products and then buy them online. Results have indicated that the free-riding customers' product valuation is between online and offline customer product valuations and the price at which the customer becomes a showrooming customer is influenced not only by the offline price, but also by the degree of the online channel acceptance and the shopping services value factor. This study has managerial consequences in decision-making of sellers, especially for traditional stores which to maximize the profit must optimize the offline additional services, to reduce the phenomenon of free-riding and at the same time not to generate additional costs.

Keywords: e-commerce, free-rider, supply chain, multichannel shopping, showrooming, valuation mode.

JEL Classification: D82, L81, C61, C72, M31.

✉Corresponding author. E-mail: ***lidija.kraujaliene@ksu.lt***

1. Introduction

Modern consumers are increasingly attracted to online product purchase channels, given that the range of stores and online sales platforms has diversified hugely lately and the migration from offline stores is accentuated. Currently, online retailing has experienced a much wider development than the offline one (Wang et al., 2022b), there are various types of online distribution for manufactures (Lim et al., 2016), such as direct distribution on their own platform or distribution on an independent platform specialised in e-commerce who buys, acquires the products from the manufacturer or charges a predetermined commission (Hult et al., 2019), fact that led to the appearance of multiple distribution and supply channels (Pi et al., 2022), that are in competition or in a collaborative relationship.

Nowadays, amid e-commerce expansion, catalyzed by the COVID-19 pandemic, brick-and-mortar retailers are forced to implement strategies that improve their competitiveness or to avoid bankruptcy (Chen & Chi, 2021). However, the physical stores where the products are exposed create an opportunity for many consumers to analyse and compare targeted characteristics of products, as offline stores tempt them by offering trial samples, explanations from sellers and attractive product layout (Zhou et al., 2018). This creates free-rider consumer behaviors and channel-switching habits of customers, which either initially turn to offline searches for products after which they make the purchase from the online store – "showrooming" or proceed in the opposite manner – "webrooming" (Nosi et al., 2022; Goraya et al., 2022).

Consumers can use one of the following shopping models: showrooming, webrooming, the exclusively offline shopping mode or the exclusively online shopping manner, depending on the benefits that each of them provides (Redondo & Charron, 2023). For each consumer, the value of products is influenced by cognitive biases, and the neutral valuation of goods is difficult to achieve, because there are numerous psychological mechanisms and personal idiosyncratic needs or preferences that affect the way consumers determine and perceive product valuation (Liu et al., 2022b; Zhong et al., 2023). Value judgments on the quality of the products formed during the direct touch-and-feel shopping experience in offline stores contribute decisively to the determination of product valuation, so free-riding experiences in a dual-channels supply chain affect how consumers set their own valuations on products and reduce consumer perception asymmetries regarding product quality (Pi et al., 2022).

Establishing product value is a process primarily impregnated by the consumer's subjectivism, the psychological resorts that trigger the degree of utility of a good, the perception of the quality level of the product, as well as by objective factors, such as those specific to the market, product availability, price, adjacent transport costs, etc. To such a mixed background of factors that affect the establishment of product valuation for consumers is added the phenomenon of free-riding, which influences consumers' perceptions and contributes to the final choice of the purchasing channel.

Free-riding behavior catalyses cannibalization processes between offline and online channels, which requires sellers to differentiate products between channels and to establish price or quality differences between the products offered, to optimize profits in both ways of selling, offline or online (Tian et al., 2022). The most important challenges that sellers face in optimizing results involve strategies to differentiate prices, product quality and the types of products they provide in the two types of channels, offline and online.

Inspired by the previous literature considerations, we address the following research questions:

RQ1. How is the customers' valuation of products influenced by their free-rider behaviors and channel-switching habits? What are the impacts on product valuation of the free-rider consumers' showrooming behavior to use the benefits of the experience obtained in the offline to buy from the online channel? How does the extremal purchase behavior, either to buy only online or only offline, affect the product valuation?

RQ2. How does product valuation in the presence of free-rider behavior influence the utility function of customers, the probabilities of choosing the online or offline channel, as well as the specific demand of the online or offline channel? Can product valuation in the presence of free-riding behavior contribute to optimizing profit on the offline channel?

To address these questions, we set the following research objectives:

O1. Defining a product valuation that mathematically models the customer's free-riding behavior and the extremal preferences of customers only for online or offline purchasing, in compliance with the assumptions imposed by the economic reality.

O2. Determining the expressions corresponding to the utility function of customer for the previous established product valuation of customer, setting the offline and the online channel probabilities of choosing and the offline and the online channel demand.

O3. Providing a decentralized supply chain model and optimizing the expected profit function in the offline channel, depending on the additional services provided to customers.

To achieve these purposes, we consider a decentralized supply chain, consisting of a retailer that operates through an online sales channel and another that sells through a physical, offline store. We focus on the behavior of customers who initially turn to the offline channel, to view and/or test the product and get information about it from specialised personnel. Such a consumer develops a free-rider behavior, more precisely showrooming and goes to the next stage of acquisition to an online channel, where he makes the purchase, capitalizing on the experience gained in the offline channel.

This study analyses how the consumer's free-riding behavior is reflected in product valuation, determined as the difference between the value they are willing to pay for that product and its utility. In modelling of product valuation, the types of decision-making at the extremes of customer buying behavior are also considered, represented by those who buy either directly from the online channel or directly from the offline channel. This represents an innovative research direction and covers an information niche identified in the previous literature. We start by configuring the customers' properties with the valuation of the product and then developing according to this demand, the usefulness of the customer's choice and the expected offline profit functions. For the developed models, we made numerical examples to test the validity of the results.

The contribution of the article to the literature results from the fact that it addresses a little-explored topic, regarding the incorporation of the effects of free-riding behavior in establishing the product valuation of consumer. To the best of our knowledge, the existing studies on free-rider problem do not consider the situation in which the product valuation of customer is modelled both in the free-riding behavior approach and in the extreme purchasing behaviors either online or offline.

Against such a background of scarcity of the previous literature, this study proposes an innovative model of product valuation for the decentralized supply chain, going through the stages of establishing the valuation of the customer's product, the utility function and the demand function corresponding to the online and offline channel. The profit optimization of offline merchants affected by free-riding behavior is modelled, considering the model developed for the product valuation of customers.

The following sections of the paper present the literature review (section 2), describe the research methodology (section 3) and develop the product valuation and demand function models in the decentralized supply model, as well as present the findings (section 4). Section 5 presents the results and discussions for the decentralized supply model, and the final section contains the conclusions and future directions of research.

2. Literature review

There are mainly three streams of previous literature related to our study, regarding the comprehensive approach to the free-riding phenomenon and its statistics, product valuation with the showrooming effects, and the influence of free-rider behavior on the profitability of retailers.

The first topic of the relevant literature describes the expansion of e-commerce in the contemporary period and thus shows the foundations on which the free-riding phenomenon has developed. The e-commerce growth in the last seven years from 1450.3 billion USD to 3640.6 billion USD and its growth perspective is to achieve 5557.5 billion in 2027 (Zavialova & Lindlahr, 2023). The e-commerce growth rate (14.4% yearly) is much greater than total worldwide sales in 2021–2016 periods that is only 1.065% growth rate, as displayed in Figure 1 (Statista, 2023).

The development of the Internet era in the 1990s has favored the evolution of e-commerce, which created impressive growth in the last two decades. It is assessed that 87% of shoppers research online before acquiring and mobile shopping sums 63% of all e-commerce sales and it is estimated that by 2040, 95% of all acquisitions will be made online (Statista, 2024a).

In the Western countries, about 55% of millennials try a product in-store but buy it online (Zollo et al., 2020) and in the US 73% of consumers shop both online and in physical stores (Nosi et al., 2022). The multi-channel shopping is on the rise, with consumers gradually utilizing a range of technological devices like laptops and smartphones to shop all the time, day or night (Chen et al., 2022).

Globalization has changed the ways in which actors interact in all types of contemporary markets (Batten et al., 2023; Caporin et al., 2021) and nowadays, consumers are putting their health and time in the first place. More than that, they are looking to avoid crowded places and enjoy well-being and accessibility. For that, in the retail sector, the consumers are visiting physical stores solely to view or try a product, with the intention of purchasing it online (Goraya et al., 2022). This procedure is known as multichannel shopping, which offers the possibility for consumers to buy through different channels without suffering additional costs (Heitz-Spahn, 2013). The application of multichannel strategies by sellers may ease the creation of superior consumer knowledge, thereby enabling sellers to obtain financial benefits from such actions (Marino & Lo Presti, 2019).

In most countries, around 2 percent of e-commerce sites visitors turn to shop products (between 2023 Q1 and 2024 Q1) (Statista, 2024b). The competition between sellers is becoming more and more aggressive and consumers tend to visit more sites and to see more offers before shopping. Also, the free-rider effect (to observe the same product in various sources – on-line or off-line and to buy the cheaper product) tend to lower the on-line shopping sales.

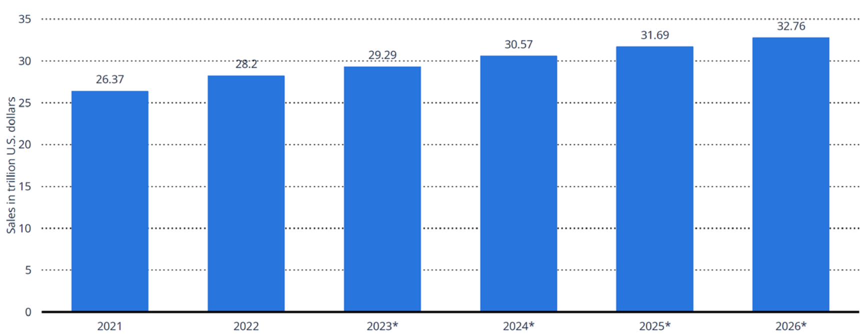

Figure 1. Total retail sales worldwide from 2021 to 2026, in trillion U.S. dollars (source: Statista, 2023)

Cross-channel comportment, classified as cross-channel free-riding or within-firm lock-in, involves a first engagement of the consumer with a sales channel, followed by a change of channel and seller, in the case of free-riding or followed only by a change of channel and not of the seller, in the case of within-firm lock-in (Maggioni et al., 2020).

The prevalence of the free-riding phenomenon in contemporary economies makes the subject to be intensely analyzed in specialized studies, in both forms of manifestation, showrooming or webrooming. In the tug-of-war between online and offline retailing, the previous literature positions the benefits and costs of both alternatives and emphasizes that the choice of channel is not only based on price, but also on mechanisms of perception of product quality by consumers (Chimborazo-Azogue et al., 2021; Gensler et al., 2017). Unlike physical stores, online retail platforms still have disadvantages, which prevent consumers from buying directly from online, related to the lack of information resulting mainly from the inability to feel and touch the targeted products before delivery (Wang et al., 2024). Consumers' showrooming impetus is catalyzed by retailers' strategies to increase their sales by setting up physical showrooms where products can be inspected and encouraging customers to buy online from the same retailer, through methods of placing tablets in stores, barcodes, QR codes, high-speed Internet and recommendations from sellers (Zhang et al., 2020).

The aspects that differentiate showrooming from webrooming are the subject of a vast literature, intensely explored from multiple perspectives, such as how channel combinations affect individual customer experiences, respectively the impact of webrooming and showrooming on smart shopping perceptions and feelings (Flavián et al., 2020). The authors showed that consumers who chose webrooming as a form of purchase believe that they saved more time and/or effort to a greater extent than those who chose showrooming.

The second subject explored by previous studies and relevant to our theme is related to the product valuation of consumers manifested in free-riding conditions. Although the phenomenon of free-rider attracts the interest of research and there are numerous studies in the field, the specific previous literature on the influence of free-rider behavior of consumer on the customer's product valuation is not vast.

The utility function is a tool that describes the level of satisfaction or happiness that a consumer obtains from various goods (Mohajeryami et al., 2016), and consumers collect information from various sales channels and purchase products from the channel that maximizes their utilities (Basak et al., 2017). In order to make the optimal decision regarding retail price setting or profit maximization, the economic organizations need to know the customers purchasing behavior and decision, described in the specialized literature through the customer purchasing utility function (Liu et al., 2022a; Méndez-Vogel et al., 2023; Peng et al., 2022; Zhai et al., 2022; Yuan et al., 2022).

The free-rider problem represents a market failure that occurs when the beneficiary of different common resources does not pay for producing or consuming them. Free riders are usually a problem for common pool resources users because they overuse the resources and consequently it is possible to under-produce, overuse or degrade these goods. Also, it is not fair to consume a resource without pay, compared with other consumers.

Usually, the free-rider problem can be expressed in terms of Prisoner dilemma. Two players can choose whether to contribute or not to the production of a common resource. The possible decisions are for each player to Contribute or to not contribute – to Defect (promise to other player the contribute behavior and to Defect).

The payoff matrix is expressed in Figure 2. If both players contribute, then they have the same payoff – 5 units each, if both of them defect, then they obtain 2 unites each, and in the

		Player 2	
		Contribute	*Defect*
Player 1	*Contribute*	5, 5	1, 6
	Defect	6, 1	2, 2

Figure 2. Prisoner's Dilemma on free-rider problem (source: prepared by authors)

situation which one contribute and one defect, the contributor had 1 reword unit and the defector had 6 reword units (he uses the good without contribution).

In this game the Nash equilibrium is (Defect, Defect) strategy, but the Pareto optimum is (Contribute, Contribute) that indicate a failure of cooperation between participants – for static game. Of course, that indicates a tendency to free-rider and finally both of them obtain lower payoffs. This behavior can be different in the case of repeated, dynamic game, where is possible to implement cooperative strategies.

The third theme of prior literature that arouses our interest is represented by the impact that the value of free-rider products has on retailers' profitability and competitiveness. Volume of services offered by the offline store, are directly correlated with the level of demand and with the quantities stored by the offline store, both in the case of centralized scenarios or in the case of decentralized ones (Yin et al., 2022).

Regardless of the nature of the relationship between the main two channels, online and offline, both in the case of decision models, centralized or decentralized, the market demand but especially the preferences of the customers towards certain particular qualities of the products, require partial or total coordination of the two channels when we are talking about the manufacturer's investments in improving the product and the retailer's investments in advertising and services, so a financial effort of the manufacturer to modernize can cause the retailer to make an additional effort to increase the advertising level (Truong & Truong, 2022).

The literature on dual-channel management has extended rapidly and focuses on the competition in price and/or marketing effort (Yang et al., 2015; Politis et al., 2014), the efficiency of online, physical retail and hybrid stores (Levary & Mathieu, 2000), pricing choices of a retail and direct channel (Ahn et al., 2002), price differences between an offline channel and an online channel (Chun & Kim, 2005) and optimal pricing strategy for a retailer selling its product through both the traditional and the Internet channel (Khouja et al., 2010).

In a decentralized channel, manufacturers have a superior chance to control a higher direct price than in a centralized channel (Yang et al., 2021). This also allows retailers to raise their retail prices. The digitalization of supply chains has an important power on both the resilience and performance of these chains (Yang et al., 2024).

An analysis of a dual channel supply chain (consisting in a producer who sells a unique good in its online channel, and a traditional seller) reveals that a free-rider behavior of retailers' pre-sale service (Guo et al., 2022). In this way the retailer's optimal effort level decreases at the same time together with the producer's profit and the performance of the overall supply chain.

In the situation where the online and offline channel are owned by different owners, channel conflict manifests itself and competition intensifies, and free-riding behavior undermines the online retailer's profit (Liu et al. 2020). Price battles between online and offline channels erode the profitability of retailers/manufacturers, as online channels manage to save time, space, labor costs and thus offer lower prices than in offline channels, which, in order to attract customers and obtain greater competitive advantages, are forced to offer additional services, that lead to increased costs (such as more timely releases, more thoughtful free experience, more convenient return or exchange services, etc.) (Zhang et al., 2023).

It's not just the prices that make consumers experience show-rooming behavior and swing between offline and online channels. For physical retailers it is important to understand what types of additional services and what intensity to set to keep the customer on the offline channel and at the same time does not affect their profit maximization target. Approaches to this issue show that through the effort of additional services of the offline store (sales promotion, advertising, exhibition halls, etc.) the consumer demand can be influenced (Wang & Chaolu, 2022). The solutions that could lead to optimizing the results of offline retailers and reducing the free-riding behavior of customers are related to consumer orientation in omnichannel strategy, segmentation and personalization marketing strategies (Moliner & Tortosa-Edo, 2024).

3. Model framework

Based on Liu's et al. (2022a) approach to customer channel choice, in this paper we propose a new function for modelling free-riding customer purchase utility, a function that now depends not only on the customer's acceptance of the online channel, but also on the experience gained in the offline channel. Consequently, in this manner, we intend to improve the demand functions used in establishing the optimal decision that maximizes profits corresponding to supply channels.

We denote with p_{on}, the unit manufacturer online retail price, and with p_{off}, the unit offline retail price. The online retail price includes both the production cost and the online selling cost c_{on}, while the offline retail price (Yin et al., 2022), includes the acquisition cost, p_{acq} and the offline selling cost, c_{off}, which means that $p_{on} \leq p_{off}$.

If v denote the product valuation of customer, according to Liu et al. (2022a), v is a continuous random variable uniformly distributed, $v \sim U\left[0,\bar{v}\right]$ with the appropriate density, $u\left(v\right)$. Also, we consider that on the offline channel, the customer benefits from a series of additional services, s, $s \in \mathbb{R}$, $s \geq 1$, such as, shopping assistance or product trial, provided in the offline shop. The service level s is biger than unit when the shop provides a service which effectively contributes to increasing the desire to buy, and s is equal to unit, when the shop provide no additional service (Li et al., 2013). So, the offline selling cost c_{off}, it reflects, among other things, the cost of the services provided $C\left(s\right)$, where $C\left(s\right)$ is a convex increasing function depending on the service level s (Yin et al., 2022).

The offline shopping services, s, when $s > 1$, also contributes to increase product valuation from v to $\beta\left(s\right)v$, with a factor $\beta\left(s\right)$, named the shopping services valuation factor, which is described by a continuous concave over unit function (Liu et al., 2022a).

In Table 1 we describe the notations used in the following to define and investigate the properties of the expression that we suggest for free-riding product valuation, to describe the appropriate demand function and to provide the model through which the optimal offline channel stocking and the optimal services cost can be established.

Regarding α, the online channel customer acceptance, $\alpha \in \left[0,1\right]$. When $\alpha = 1$, the online acceptance is maximum, 100%, the customer's visit to the offline store being without any additional contribution. When $\alpha = 0$, the online acceptance is minimal, 0%, and the customer certainly prefers the offline store.

Table 1. Notations and interpretations (source: prepared by authors)

Notations	Interpretations
p_{on}	Unit manufacturer online retail price
p'_{on}	Unit online retailer price
p_{off}	Unit offline retail price
p_{acq}	Acquisition cost
c_{on}	Online selling cost
c_{off}	Offline selling cost
s	Additional services, $s \in \mathbb{R}$, $s \geq 1$
$C(s)$	Cost of the provided services, a convex increasing function
$\beta(s)$	Shopping services valuation factor
$\gamma(s)$	Added value of the online retailer
α	Customer acceptance of manufacturer online channel, $\alpha \in [0,1]$
θ	Customer acceptance of retailer online channel, $\theta \in [0,1]$
v	Product valuation of customer, a continuous random variable, $v \sim U[0,\bar{v}]$
$u(v)$	Density of v
v_{on}	Online product valuation of customer
$v_{free\ riding}$	Free-riding product valuation of customer using manufacturer website
$v'_{free\ riding}$	Free-riding product valuation of customer using retailer website
v_{off}	Offline product valuation of customer
U_{on}	Manufacturer online utility function of customer
U'_{on}	Retailer online utility function of customer
U_{0ff}	Offline utility function of customer
U_{choice}	Choice utility function of customer, $U_{choice} = max\{0,\ U_{on},\ U_{0ff}\}$
D	Market size

End of Table 1

Notations	Interpretations
P_{on}	Choosing online channel probability
P_{off}	Choosing offline channel probability
d_{on}	Demand on the online channel, $d_{on} = D \times P_{obn}$
d_{off}	Demand on the offline channel, $d_{off} = D \times P_{off}$
ε_{off}	Uncertainty caused by markets changes, is a continuous random variable
f	Density function of ε_{off}
F	Cumulative distribution function of ε_{off}
m	Average of ε_{off}
$\left[a,b\right]$	Values range of ε_{off}
Q	Ordered quantity
z	Offline product channel stocking factor, $z = Q - d_{off}$
φ	Unsold products unit salvage
$EP_{off}\left(s,z\right)$	Expected offline profit function

The free-riding customer behavior is the situation in which, directly or after visiting the offline store, the customer decides to purchase the product using the online channel (Chou et al., 2016; Wang et al., 2022a). The purchasing channel switching is usually motivated by the lower level of the online price, p_{on}, but it implies the assumption by the customer of some disadvantages such as the extension of the purchase time or the possibility of impediments related to delivery (Zhang et al., 2021; Tahirov & Glock, 2022; Xu et al., 2022). Moreover, the offline retailer can control the level of additional services, s, reducing them when predicting weak free-riding customers behavior or, on the contrary, he can refill them when there is a significant free-riding behavior (Tian et al., 2022). This leads to the necessity of the most appropriate mathematical modelling of the free-riding online customer utility. For this reason, in the following section, we propose a new utility free-riding function that includes both the total acceptance of the online channel, corresponding to the situation where the customer directly uses the online channel or when the offline services do not contribute to increasing product valuation, as well as the situation where the acceptance of the channel online is null and the customer relying only on the offline product valuation.

To achieve the objectives of our study, which were announced in the first section, we formulated the following working hypothesis:

Hypothesis H_1: The customer free-riding product valuation is between online and offline customer product valuation.

Proposition 1, presented in section 4.1, is formulated to validate this hypothesis. Also, in section 4.2, we performed the mathematical calculations to provide the expressions of customer utility, of channel choosing probabilities and of offline and online product demand. In the same section we formulate Proposition 2 which provides, from the point of view of economic interpretation, the maximum valuation of the online product price for which the customer can become free-riding.

To find the decentralized supply chains model, in section 4.3, through Proposition 3, we show both that the expected profit function of offline channels admits a local maximum valuation and the way to find the optimal valuations for the offline channel stocking and for services provided cost, valuations that maximize the profit offline. To complete our research, we proceed to section 5, in which a series of numerical simulations is presented to explain the implementation of our model. We emphasize that all the mathematical proofs are original and part of them, those of the Propositions, are in the Appendix.

4. Results

The objective of this section is to bring improvements to the existing theory and models concerning the purchasing behavior of customers in the context where the consumer must choose one of the available marketing channels to acquire a certain product. The buyer has multiple purchase channels at their disposal, such as manufacturer's online channel, the retailer's offline channel or the retailer's online channel. We propose a new function for the mathematical modelling of the consumer's free-riding valuation. We present and prove certain theoretical results regarding the properties of this function.

4.1. The product valuation of customer

If we focus our attention on the product valuation variation, then in the situation where the online channel belongs to the manufacturer, the customer online product valuation is the same as the customer product valuation because the manufacturer website is one of the factors that matter in the product valuation of the customer. Also, we can say that it can increase from the v valuation to the $\beta(s)v$, where the valuation is multiplied by the contribution brought by shopping services, and more, for the situation in which the customer, after visiting the offline store, decides to be free-riding customer and he returns on online channel to purchase the product, we propose a free-riding product valuation:

$$v_{free\ riding} = \left[\alpha + (1-\alpha)\beta(s)\right]v. \tag{1}$$

For this new free-riding product valuation formula, the following assumption must be verified.

Proposition 1. When the shopping services valuation factor $\beta(s)$ is greater than or equal to unit ($\beta(s) \geq 1$), and the customer acceptance of manufacturer online channel α takes values from 0 to 1 ($\alpha \in [0,1]$), then the free-riding valuation is between online valuation and offline valuation:

$$v_{on} \leq v_{free\ riding} \leq v_{off}. \tag{2}$$

Or,

$$v \le \left[\alpha + (1-\alpha)\beta(s)\right]v \le \beta(s)v. \tag{3}$$

The purpose of Proposition 1 is to validate the Hypothesis 1 presented earlier. Furthermore, besides to the property ensured by Proposition 1, the free-riding product valuation, $v_{free\ riding}$, through the analytical expression proposed by us, presents, in addition to the existing expressions from the specialized literature (Liu et al., 2022a), the advantage that it also models limit, the extreme situations, of total acceptance or total elimination of the purchase option from the online channel. Thus, for the situation where the customer decides to purchase directly online, without considering the offline store as an alternative, or when his visit did not at all change the decision to buy online, we have online acceptance 100%, with $\alpha = 1$ and $\beta(s) = 1$ and the relation (2) becomes:

$$v_{on} = v_{free\ riding} = v_{off}. \tag{4}$$

Or in other words, the customer free-riding product valuation is equal to both online and offline customer product valuation. In the opposite situation, in which the customer decides to make the purchase offline, presenting an online acceptance of 0%, with $\alpha = 0$ and appreciating that the purchase from the offline store has a series of precise advantages with $\beta(s) > 1$, the relationship (3) becomes:

$$v \le \beta(s)v = \beta(s)v. \tag{5}$$

Which is equivalent to the situation where the customer free-riding product valuation is equal to offline valuation but exceeds online customer product valuation.

$$v_{on} \le v_{free\ riding} = v_{off}. \tag{6}$$

For the other valuations of $\alpha \in (0,1)$ and $\beta(s) \ge 1$, the customer is in the free-riding position.

4.2. The demand function corresponding to online and offline channels

Using the definition of the purchasing utility (Liu et al., 2022a) as well as the product valuation modelled as in relation 1, the customer's utility function, corresponding respectively to the offline and online purchase, is:

$$U_{on} = \left[\alpha + (1-\alpha)\beta(s)\right]v - p_{on} = \alpha v + (1-\alpha)\beta(s)v - p_{on}. \tag{7}$$

And the following (Liu et al., 2022a):

$$U_{0ff} = \beta(s)v - p_{off}. \tag{8}$$

By optimizing the utility function, the customer decides to choose the purchase channel and at the same time, the demand function can be determined. So,

$$U_{choice} = max\left\{0,\ U_{on},\ U_{0ff}\right\}. \tag{9}$$

The utility is zero, $U_{choice} = 0$, when it is considered that the purchase of the product is not useful and therefore it is not purchased.

Using relations (7) and (8), we can say that relation (9) can also be written:

$$U_{choice} = \begin{cases} U_{on}, & when \quad \dfrac{p_{on}}{\alpha+(1-\alpha)\beta(s)} < v \le \dfrac{p_{off}-p_{on}}{\alpha\left[\beta(s)-1\right]} \\ U_{off}, & when \quad v > max\left(\dfrac{p_{off}-p_{on}}{\alpha\left[\beta(s)-1\right]}, \dfrac{p_{off}}{\beta(s)}\right) \\ 0, & when \quad v \le min\left(\dfrac{p_{on}}{\alpha+(1-\alpha)\beta(s)}, \dfrac{p_{off}}{\beta(s)}\right) \end{cases}. \tag{10}$$

Because $U_{on} \ge U_{off} \Leftrightarrow v \le \dfrac{p_{off}-p_{on}}{\alpha\left[\beta(s)-1\right]}$ and $U_{on} > 0 \Leftrightarrow v > \dfrac{p_{on}}{\alpha+(1-\alpha)\beta(s)}$, also, $U_{on} < U_{off}$ $\Leftrightarrow v > \dfrac{p_{off}-p_{on}}{\alpha\left[\beta(s)-1\right]}$ and $U_{off} > 0 \Leftrightarrow v > \dfrac{p_{off}}{\beta(s)}$.

The probability of choosing the offline channel is $P_{off} = P\left(U_{choice} = U_{off}\right)$, so from relation (10) we obtain:

$$P_{off} = P\left(v > max\left(\frac{p_{off}-p_{on}}{\alpha\left[\beta(s)-1\right]}, \frac{p_{off}}{\beta(s)}\right)\right) = \int_{max\left(\frac{p_{off}-p_{on}}{\alpha\left[\beta(s)-1\right]}, \frac{p_{off}}{\beta(s)}\right)}^{\bar{v}} u(v)dv. \tag{11}$$

For the calculation of P_{off}, we explain:

$$max\left(\frac{p_{off}-p_{on}}{\alpha\left[\beta(s)-1\right]}, \frac{p_{off}}{\beta(s)}\right) = \begin{cases} \dfrac{p_{off}-p_{on}}{\alpha\left[\beta(s)-1\right]}, & if\ p_{on} < p_{off}\left(1-\alpha+\dfrac{\alpha}{\beta(s)}\right) \\ \dfrac{p_{off}}{\beta(s)}, & if\ p_{on} \ge p_{off}\left(1-\alpha+\dfrac{\alpha}{\beta(s)}\right) \end{cases}. \tag{12}$$

Because:

$$\frac{p_{off}-p_{on}}{\alpha\left[\beta(s)-1\right]} > \frac{p_{off}}{\beta(s)} \Leftrightarrow p_{on} < p_{off}\left(1-\alpha+\frac{\alpha}{\beta(s)}\right). \tag{13}$$

Proposition 2. When $max\left(\dfrac{p_{off}-p_{on}}{\alpha\left[\beta(s)-1\right]}, \dfrac{p_{off}}{\beta(s)}\right) = \dfrac{p_{off}-p_{on}}{\alpha\left[\beta(s)-1\right]}$, we have the the following ordering of the price values:

$$p_{on} < p_{off}\left(1-\alpha+\frac{\alpha}{\beta(s)}\right) < p_{off}. \tag{14}$$

The statement of Proposition 2 can be interpreted as a customer can change the offline channel by returning to the online one and thus, he became a free-riding customer, only in the situation where the offline price is set at a value lower than $p_{off}\left(1-\alpha+\dfrac{\alpha}{\beta(s)}\right)$. Substituting in relation (11), the results given by relation (12), we obtain:

$$P_{off} = \begin{cases} 1 - \dfrac{p_{off} - p_{on}}{\bar{v}\alpha\left(\beta(s) - 1\right)}, & if\ p_{on} < p_{off}\left(1 - \alpha + \dfrac{\alpha}{\beta(s)}\right) \\ 1 - \dfrac{p_{off}}{\bar{v}\beta(s)}, & if\ p_{on} \geq p_{off}\left(1 - \alpha + \dfrac{\alpha}{\beta(s)}\right) \end{cases}. \tag{15}$$

The demand in the offline channel:

$$d_{off} = \begin{cases} \left[1 - \dfrac{p_{off} - p_{on}}{\bar{v}\alpha\left(\beta(s) - 1\right)}\right] \times D, & if\ p_{on} < p_{off}\left(1 - \alpha + \dfrac{\alpha}{\beta(s)}\right) \\ \left[1 - \dfrac{p_{off}}{\bar{v}\beta(s)}\right] \times D, & if\ p_{on} \geq p_{off}\left(1 - \alpha + \dfrac{\alpha}{\beta(s)}\right) \end{cases}. \tag{16}$$

Where with D was denoted the market size. Regarding the probability of choosing the online channel: $P_{on} = P\left(U_{choice} = U_{on}\right)$, from the relation (10), when $\dfrac{p_{on}}{\alpha + (1-\alpha)\beta(s)} < \dfrac{p_{off} - p_{on}}{\alpha\left[\beta(s) - 1\right]}$ which means: $p_{on} < p_{off}\left(1 - \alpha + \dfrac{\alpha}{\beta(s)}\right)$, we obtain:

$$P_{on} = P\left(\frac{p_{on}}{\alpha + (1-\alpha)\beta(s)} < v \leq \frac{p_{off} - p_{on}}{\alpha\left[\beta(s) - 1\right]}\right) = \int_{\frac{p_{on}}{\alpha+(1-\alpha)\beta(s)}}^{\frac{p_{off}-p_{on}}{\alpha[\beta(s)-1]}} u(v)\,dv$$

$$\Leftrightarrow\ P_{on} = \frac{\left[\alpha + (1-\alpha)\beta(s)\right]p_{off} - \beta(s)p_{on}}{\bar{v}\alpha\left(\beta(s) - 1\right)\left[\alpha + (1-\alpha)\beta(s)\right]}. \tag{17}$$

So:

$$P_{on} = \begin{cases} \dfrac{\left[\alpha + (1-\alpha)\beta(s)\right]p_{off} - \beta(s)p_{on}}{\bar{v}\alpha\left(\beta(s) - 1\right)\left[\alpha + (1-\alpha)\beta(s)\right]}, & if\ p_{on} < p_{off}\left(1 - \alpha + \dfrac{\alpha}{\beta(s)}\right) \\ 0, & if\ p_{on} \geq p_{off}\left(1 - \alpha + \dfrac{\alpha}{\beta(s)}\right) \end{cases}. \tag{18}$$

And the demand in the online channel:

$$d_{on} = \begin{cases} \dfrac{\left[\alpha + (1-\alpha)\beta(s)\right]p_{off} - \beta(s)p_{on}}{\bar{v}\alpha\left(\beta(s) - 1\right)\left[\alpha + (1-\alpha)\beta(s)\right]} \times D, & if\ p_{on} < p_{off}\left(1 - \alpha + \dfrac{\alpha}{\beta(s)}\right) \\ 0, & if\ p_{on} \geq p_{off}\left(1 - \alpha + \dfrac{\alpha}{\beta(s)}\right) \end{cases}. \tag{19}$$

4.3. The decentralized supply chains model

In this section, we study how the optimal decision changes if we use the modelling proposed by us in section 4.1 for the valuation of the free-riding product, $v_{free\ riding}$. We will consider the case where the supply chain is made up of two independent members, namely, the online store unit and the offline store unit. The two units operate each by pursuing the maximization of their own profit, thus being in the position of competitors on the market, but still having a common interest, that of selling as large a quantity as possible of the assortment of the same product.

We will put special emphasis on the situation where the offline store focuses on making optimal decisions to avoid the situation where a customer who has benefited from the services of visiting the offline store, decides to switch the channel and thus make the online purchase.

Thus, our research aims to study the optimal level of offline services, expressed through their related costs, the research necessary to optimize the interest of the physical store, that of reducing the phenomenon of free-riding.

To achieve this, the offline expected profit function, EP_{off}, must be maximized. The offline expected profit depends on two variables, namely the offline channel stocking factor of product which is equal with the difference between ordered quantity and demand, $z = Q - d_{off}$ and the additional services s which is expressed by the cost of the services provided, $C(s)$. Also EP_{off} considers a continuous random variable that describes the uncertainty caused by changes in market ε_{off}, with f, F, m and $[a,b]$ that are its density function, cumulative distribution function, average and values range respectively, and the unit salvage of the unsold products, denoted by φ.

Forwards we consider offline expected profit function given by Liu et al. (2022a):

$$EP_{off}(s,z) = (p_{off} - c_{off})(d_{off} + m + z + 1 - b) - p_{acq}(d_{off} + z) - C(s) -$$

$$(p_{off} - c_{off} - \varphi)\int_{a}^{z} F(\varepsilon_{off})\, d\varepsilon_{off}. \tag{20}$$

Proposition 3. If the free-riding product valuation, $v_{free\ riding}$, is $v_{free\ riding} = [\alpha + (1-\alpha)\beta(s)]v$ then the offline expected profit is a concave function.

Proposition 3 provides the optimal offline channel stocking factor of product z, and the optimal cost of the services provided, $C(s)$, in which the offline expected profit reaches the maximum value. These two values, which by the way constitute the local extremum point of the offline expected profit function ($EP_{off}(s,z)$) are determined by solving the system obtained by equating the first-order partial derivatives to 0, equations system which is described and can be consulted in the Appendix.

5. Discussion

To investigate the impact of the customer online channel acceptance and of the experience gained in the offline channel, on the profit variation, in this section, we generate four numerical examples that show how the offline profit is influenced when the customer's online acceptance and experience gained in the offline channel varies. Taking into account the modelling previously proposed for free-riding product valuation, as well as the corresponding form of the relationship (20) that gives the offline expected profit, in Figure 3, we represented

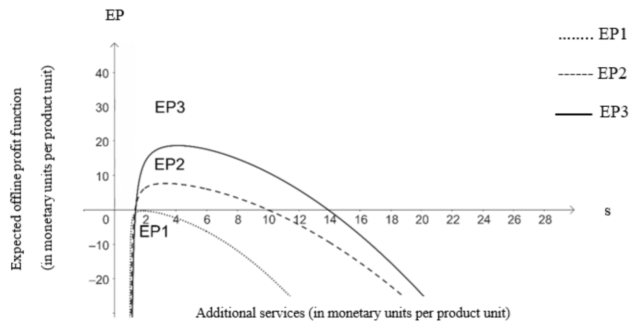

Figure 3. The impact of the customer online channel acceptance on the offline profit variation (source: own projection using GeoGebra Calculator Suite)

the profit variation corresponding to three valuations of online acceptance. Thus, the profit variation $EP1$, corresponds to an online acceptance of 60%, $\alpha = 0.6$, also $EP2$ and $EP3$, correspond respectively to values $\alpha = 0.5$ and $\alpha = 0.4$. The other parameters are considered the same in all three cases, namely $p_{acq} = 10$, $p_{off} = 20$, $p_{on} = 12$, the sale cost $c_{off} = 5$, $\bar{v} = 100$, the shopping services value factor $\beta(s) = s^{\tau}$, with $\tau = 0.8$, the market size, $D = 200$, $\varphi = 8$, the services provided $C(s) = 0.1s^2$ and $\varepsilon_{off} \sim U[10, 20]$.

As can be seen from Figure 3, the decrease in the valuation of the customer online channel acceptance is directly reflected in the increase in the valuation of the expected offline channel profit:

$$\alpha = 0.6 > \alpha = 0.5 > \alpha = 0.4, \tag{21}$$

require:

$$EP1 < EP2 < EP3. \tag{22}$$

Also, for the three examples considered, we observe that the offline channel can register a profit only in the situation where the customer online channel acceptance does not exceed the value of 60% and the effort of the offline shopping services, s, keeps a value above unity but not greater than 10 in the case of an online acceptance of 50%, respectively 14 units for an acceptance of 40%, exceeding these values also leads to the profit non-recording of the offline channel.

For the value $\alpha = 0.4$, the market size reduced by 10 times, $D = 20$ and the other parameters remaining unchanged, we studied the level of the expected profit when $\beta(s) = s^{\tau}$ varies. Thus, we considered three values for τ, namely $\tau = 0.8$, $\tau = 0.7$ and $\tau = 0.6$ to be able to interpret the profit variation, $EP1$, $EP2$ and $EP3$, variation given by the level of services, Figure 4.

Thus, for:

$$\tau = 0.8 > \tau = 0.7 > \tau = 0.6. \tag{23}$$

Is obtained:

$$EP1 < EP2 < EP3. \tag{24}$$

which is interpreted as follows: Along with the increase of the shopping services valuation factor, an increase in offline profit is also recorded.

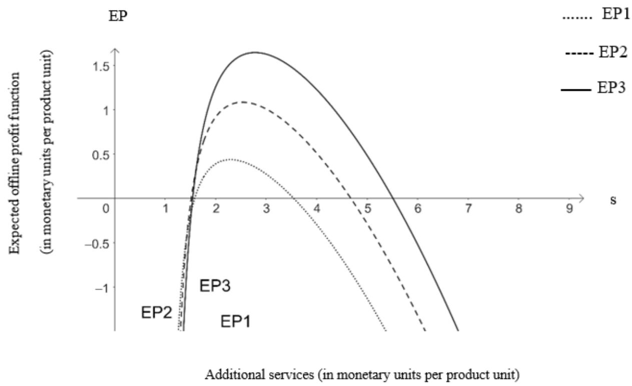

Figure 4. The impact of the experience gained in the offline channel on the offline profit variation, when the online acceptance is 40% (source: own projection using GeoGebra Calculator Suite)

To provide a better exploration of expected profit according to the effort of offline services, we kept all the levels of the parameter values that were used in the previous example and we only varied the value of the percentage in which the customer accepts the online channel. Thus, in the calculation processing that led to Figure 5, we considered an acceptance of 50%, corresponding to $\alpha = 0.5$, while in the calculation processing corresponding to Figure 6, the acceptance was 70%, which means $\alpha = 0.7$.

Simultaneously exploring the evolution of the expected offline profit (*EP*) shown in Figures 4, 5 and 6, it can be said that as the customer acceptance value of the online channel increases (α), the maximum value that can be reached by the profit of the offline retailer decreases simultaneously with the subtraction of the interval corresponding to the additional services effort (*s*) for which the profit is positive.

We selected one of the three offline expected profit functions which have been plotted in these three graphs mentioned above (Figures 4–6), namely EP2. It can be observed that an increase in online acceptance of the customer, from the value of 40% to the value of 60%, the other parameters remaining the same, involves a decrease in the maximum allowed value of the profit by approximately 16 times, from the value of 1.6 to the value of 0.1. Also, the length of the interval corresponding to the effort of offline services, *s*, decreases approximately eight times, from 4 units to less than half a unit.

In a decentralized supply chain consisting of two different retailers – one with a physical store and the other operating through an online channel – this study provides a framework for product valuation from the customers' perspectives and demonstrates that the valuation of free-riding falls between online and offline valuations. This free-riding valuation is based on the combination of customers' acceptance of the sellers' online channel (α, which is influenced by their experiences gained from offline channels), the shopping services valuation factor ($\beta(s)$), and the product valuation from the customers' perspectives (*v*). Additionally, we demonstrate that customers' acceptance of seller online channel (α), founded on the experience gained in the offline channel, plays a decisive role in the profit equation of offline retailers whose physical stores allow free-rider autotelic customers experiences, satisfy their

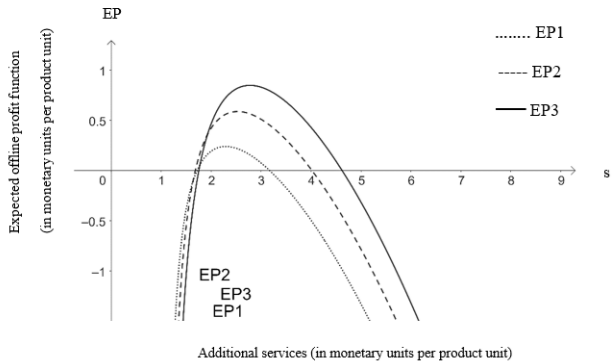

Figure 5. The impact of the experience gained in the offline channel on the offline profit variation, when the online acceptance is 50% (source: own projection using GeoGebra Calculator Suite)

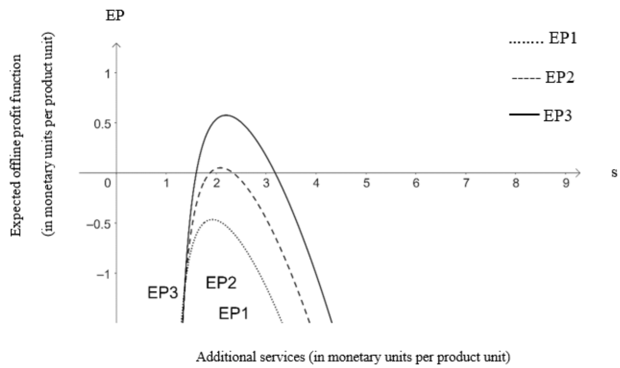

Figure 6. The impact of the experience gained in the offline channel on the offline profit variation, when the online acceptance is 70% (source: own projection using GeoGebra Calculator Suite)

haptic expectations and needs for touch, without convincing them to buy directly, but for various reasons turn to online channels for purchases.

There are several practical implications for offline retailers in profit management derived from these findings, which are described below. In the primary instance, offline retailers must focus on the types of additional services offered in their physical store, as this will help reduce showrooming, encourage customers to make in-store purchases, and optimize profit. The challenge for physical retailers lies in discovering the optimal combination of product pricing (p_{off}), product stocking factor (z), and the additional services (s) that effectively retain customers in the physical store for their purchases. On the other hand, brick-and-mortar retailers need to understand the mechanisms that could lead to a decrease in customers' acceptance of retailers' online channel (α, based on experiences gained from the offline channel), and implement strategies that persuade customers to buy from their physical store.

First, our study shows that offline retailers, faced with free-riding customers and showrooming behavior, could optimize their profit in situations where customers prefer online channels by offering a level of additional services that retain customers for in-store purchases, without negatively impacting their target profit margins. Although price remains a key factor influencing free-riding and showrooming behaviors, our model emphasizes the significance of additional services provided by brick-and-mortar stores in retaining customers (Zhang et al., 2023; Wang & Chaolu, 2022). Effective marketing segmentation and personalization strategies, the development of multichannel sales, and proper supply chain management can all help reduce showrooming and enhance the efficiency of in-store retailers (Moliner & Tortosa-Edo, 2024). Our research is in line with prior studies indicating that showrooming can harm brick-and-mortar retailers when the additional services offered by these physical stores do not persuade customers to make purchases in-store, leading them to migrate to online channels instead (Lei & He, 2024; Mitra, 2022; Liu et al., 2020).

Second, in the showrooming context, customers' acceptance of retailers' online channels – based on their experiences gained in offline channel – serves as the cornerstone for managing profits within the framework of offline retailers. Identifying the mechanisms underlying consumers' choices between online and offline shopping channels could significantly contribute to optimizing the profit of today's offline retailers. They must understand that the choice of purchase channel is based on a complex set of individual distinctions among consumers and intrinsic factors external to the individual, that characterize each respective purchase channel. Although pioneering studies in the field of psychological factors influencing multichannel customer behavior date back nearly two decades, the topic remains open to interpretations and new discoveries, the practical utility of which can be leveraged by offline retailers to maximize profits.

Behind the central concept we have used regarding the customers' acceptance of retailers' online channel (α, based on the experience gained from the offline channel) lie sophisticated reasoning and complex psychological traits of customers, along with objective characteristics of the purchasing channels that they can compare. All products are theoretically suitable for free-riding and showrooming, but electronics, fashion, furniture, and home products are the categories that lend themselves best to showrooming, given their characteristics, such as high prices and functionalities, or the need for fit, which are analyzed in physical stores prior to online purchases (Sharma et al., 2023).

The competition between online and offline channels is conducted with different and rather disproportionate means, favoring online stores, which benefit from advanced technologies for interactive product presentation, 24-hour accessibility from any Internet-connected location, and modern promotional methods, including electronic word-of-mouth signals about the product quality and customers' experiences (Rosillo-Diaz et al., 2024). As e-commerce expands, multichannel distribution fosters the development of channel change, showrooming, and webrooming behaviors, which adequately address the main limitation of online sales: the need for physical trials (Loupiac & Le Nagard, 2024). The opportunity for customers to experience physical trials in brick-and-mortar stores incurs significant costs related to supply expenses, logistics, storage spaces, and specialized personnel, and even under these conditions, it is sometimes impossible for all products to be physically available in stores (Loupiac & Le Nagard, 2024). Offline sellers are compelled to compete with online retailers implementing increasingly advanced augmented and highly interactive technologies, mobile shopping gamification, smart gloves etc. (De Canio & Fuentes-Blasco, 2021). Recent development in product testing related to virtual try-on technologies based on augmented reality have negatively impacted the supremacy of physical product testing, further reducing the likelihood that customers will purchase from offline channels (Loupiac & Le Nagard, 2024).

Modern marketing methods for identifying the relationships between consumer preferences and purchasing channels choices provide practical support to offline merchants in profit management. Multichannel customer behavior can be influenced by various combinations of psychographic features such as risk attitudes (readiness to take risks), cognitive abilities (need for cognition), motivation (chronic shopping orientation, autotelic or instrumental need for touch, resistance to change, exploratory buying behavior tendency), personality (neuroticism, openness, conscientiousness, agreeableness, extraversion), and decision-making style (rational, intuitive, dependent, avoidant, maximizing, regret), as well as several external factors influencing channel choice, including channel attributes (information, service quality, price advantage), marketing efforts (promotions), social influences, contextual factors (time pressure, regional or technological accessibility), and channel experience (retailer loyalty) (Blomker & Albrecht, 2024).

6. Conclusions

In this study, we investigate the influence of showrooming behavior on the product valuation of customers, which has been ignored in the previous literature, but proves to have a significant issue in competitiveness of companies. We consider a decentralized supply chain consisting of two distinct retailers, one that operates through a physical store and one that owns an online channel. The customer's choice to purchase similar products between offline and online channels depends on the product valuation, for which we have developed a valid and appropriate mathematical model. This model considers both the free-riding behavior of customers who use the experience gained in the online channel to complete their purchases in the online channel, and the choice of either the online or offline channel. It should be emphasized that our approach has the additional advantage that free-riding product valuation completely covers the range defined by online and offline product valuations, while respecting all the conditions regarding the ordering of the price values corresponding to each channel or free-riding situation.

We prove that the free-ride valuation is between the consumer on-line valuation and the consumer off-line valuation. Also, we establish the price range for free-riding, respectively the interval between on-line prices and off-line prices for free-riding. The model results indicate a concave expected profit function for the seller.

This study provides several managerial implications. When is noticed an increase in the preference of customers to use the online store, before or after visiting the offline one, our results can be useful for the economic decisions of the offline stores, which must establish a level of services that, on the one hand, reduce the phenomenon of free-riding but which at the same time does not generate too much cost effort, thus ensuring profit optimization.

Taking into account on the one hand the growing trend of customers' appetite to purchase online, and on the other hand the results obtained in our research, namely that when customer online acceptance increases, the maximum expected profit is reduced regardless of how great the effort of the offline channel is, we can conclude that in order to increase the profit, the retail stores have apply our results to determine the optimal value of the effort simultaneously with the optimization of other operational parameters which lead to increased profitability.

While this study addresses the challenging issue of determining the free-riding product valuation and optimizing profits for offline retailers facing free-riding customers and showrooming, it presents some limitations. This study does not differentiate between various product categories and does not delve into the psychological and/or contextual factors that could underpin the acceptance of online channels by free-rider consumers who engage in showrooming. The study develops a valid mathematical model and numerical simulations without using other research techniques, such as empirical studies, experiments or interviews, which could yield different results. The investigation focuses on a decentralized supply chain involving two different retailers: one with a physical store and another operating through an online channel. Other supply chain types, such as centralized or hybrid models, are not examined, although studying them could reveal important aspects for the retailers involved, particularly regarding profit optimizing in scenario involving free-riding and showrooming customer exposure. Additionally, the research does not consider the reverse face of cross-channel behavior, represented by webrooming, where customers discover products online and then purchase them in physical stores.

Regarding further directions, our future research considers the application of the proposed formula for modelling the valuation of the free-riding product for the determination of centralized or hybrid supply chains models. This study can be extended to situations where there is online competition between the manufacturer's website and the website of an online shop or retailer.

Acknowledgements

Mihai Daniel Roman's work was partially supported by the project "Societal and Economic Resilience within multi-hazards environment in Romania", funded by European Union – NextgenerationEU and Romanian Government, under National Recovery and Resilience Plan for Romania, contract No. 760050/ 23.05.2023, code PNRR-C9-I8-CF 267/ 29.11.2022, through the Romanian Ministry of Research, Innovation and Digitalization, within Component 9, Investment I8.

Author contributions

The authors contributed equally to the elaboration of this research.

Disclosure statement

Authors have no competing financial, professional, or personal interests from other parties.

References

Ahn, H. S., Duenyas, I., & Zhang, R. Q. (2002). *Price competition between retailers and manufacturer-owned stores* (Working paper). University of California, Berkeley. Retrieved October 1, 2024, from https://repository.hkust.edu.hk/ir/Record/1783.1-50297

Batten, J. A., Bilgin, M. H., Demir, E., & Gozgor, G. (2023). Does globalization affect credit market controls? *International Review of Economics* & *Finance*, *85*, 21–43. https://doi.org/10.1016/j.iref.2022.11.012

Basak, S., Basu, P., Avittathur, B., & Sikdar, S. (2017). A game theoretic analysis of multichannel retail in the context of "showrooming". *Decision Support Systems*, *103*, 34–45. https://doi.org/10.1016/j.dss.2017.09.002

Blomker, J., & Albrecht, C.-M. (2024). Psychographic segmentation of multichannel customers: investigating the influence of individual differences on channel choice and switching behavior. *Journal of Retailing and Consumer Services*, *79*, Article 103806. https://doi.org/10.1016/j.jretconser.2024.103806

Caporin, M., Naeem, M. A., Arif. M., Hasan, M., Vo, X. V., & Shahzad, S. J. H. (2021). Asymmetric and time-frequency spillovers among commodities using high-frequency data. *Resources Policy*, *70*, Article 101958. https://doi.org/10.1016/j.resourpol.2020.101958

Chen, Y., & Chi, T. (2021). How does channel integration affect consumers' selection of omni-channel shopping methods? An empirical study of U.S. consumers. *Sustainability*, *13*, Article 8983. https://doi.org/10.3390/su13168983

Chen, Y., Liu, X., Huang, K., & Tang, H. (2022). Pricing and service effort decisions of book dual-channel supply chains with showrooming effect based on cost-sharing contracts. *Sustainability*, *14*, Article 11278. https://doi.org/10.3390/su141811278

Chimborazo-Azogue, L.-E., Frasquet, M., Molla-Descals, A., & Miquel-Romero, M.-J. (2021). Understanding mobile showrooming based on a technology acceptance and use model. *Sustainability*, *13*, Article 7288. https://doi.org/10.3390/su13137288

Chou, S. Y., Shen, G. C., Chiu, H. C., & Chou, Y. T. (2016). Multichannel service providers' strategy: Understanding customers' switching and free-riding behavior. *Journal of Business Research*, *69*(6), 2226–2232. https://doi.org/10.1016/j.jbusres.2015.12.034

Chun, S. H., & Kim, J. C. (2005). Pricing strategies in B2C electronic commerce: Analytical and empirical approaches. *Decision Support Systems*, *40*(2), 375–388. https://doi.org/10.1016/j.dss.2004.04.012

De Canio, F., & Fuentes-Blasco, M. (2021). I need to touch it to buy it! How haptic information influences consumer shopping behavior across channels. *Journal of Retailing and Consumer Services*, *61*, Article 102569. https://doi.org/10.1016/j.jretconser.2021.102569

Flavián, C., Gurrea, R., & Orús, C. (2020). Combining channels to make smart purchases: The role of webrooming and showrooming. *Journal of Retailing and Consumer Services*, *52*, Article 1012923. https://doi.org/10.1016/j.jretconser.2019.101923

Gensler, S., Neslin, S. A., & Verhoef, P. C. (2017). The showrooming phenomenon: It's more than just about price. *Journal of Interactive Marketing*, *38*, 29–43. https://doi.org/10.1016/j.intmar.2017.01.003

Goraya, M. A. S., Zhu, J., Akram, M. S., Shareef, M. A., Malik, A., & Bhatti, Z. A. (2022). The impact of channel integration on consumers' channel preferences: Do showrooming and webrooming behaviors matter? *Journal of Retailing and Consumer Services*, *65*, Article 102130. https://doi.org/10.1016/j.jretconser.2020.102130

Guo, J., Zhou, Y., & Lic, B. (2022). Service-cost-sharing contract design for a dual-channel supply chain with free riding. *Journal of Systems Science and Systems Engineering*, *31*(3), 338–358. https://doi.org/10.1007/s11518-022-5523-y

Heitz-Spahn, S. (2013). Cross-channel free-riding consumer behavior in a multichannel environment: An investigation of shopping motives, sociodemographics and product categories. *Journal of Retailing and Consumer Services*, *20*(6), 570–578. https://doi.org/10.1016/j.jretconser.2013.07.006

Hult, G. T. M., Sharma, P., Morgeson, F. V., & Zhang, Y. (2019). Antecedents and consequences of customer satisfaction: Do they differ across online and offline purchases? *Journal of Retailing*, *95*(1), 10–23. https://doi.org/10.1016/j.jretai.2018.10.003

Khouja, M., Park, S., & Cai, G. G. (2010). Channel selection and pricing in the presence of retail-captive consumers. *International Journal of Production Economics*, *125*(1), 84–95. https://doi.org/10.1016/j.ijpe.2010.01.005

Lei, Q., & He, J. (2024). Online customized strategy for manufacturers to counter showrooming behavior in a dual-channel supply chain. *IMA Journal of Management Mathematics*, *35*(4), 715–735. https://doi.org/10.1093/imaman/dpae009

Levary, R. R., & Mathieu, R. G. (2000). Hybrid retail: Integrating e-commerce and physical stores. *Industrial Management*, *42*(5), 6–21.

Li, M., Feng, H., Chen, F., & Kou, J. (2013). Optimal versioning strategy for information products with behavior-based utility function of heterogeneous customers. *Computers & Operations Research*, *40*(10), 2374–2386. https://doi.org/10.1016/j.cor.2013.03.010

Lim, Y. S., Heng, P. C., Ng, T. H., & Cheah, C. S. (2016). Customers' online website satisfaction in online apparel purchase: A study of Generation Y in Malaysia. *Asia Pacific Management Review*, *21*(2), 74–78. https://doi.org/10.1016/j.apmrv.2015.10.002

Liu, C., Dan, B., Zhang, X., & Zhang, H. (2022a). Composite contracts for dual-channel supply chain coordination with the existence of service free riding. *Journal of Theoretical and Applied Electronic Commerce Research*, *17*(2), 789–808. https://doi.org/10.3390/jtaer17020041

Liu, C., Dan, Y., Dan, B., & Xu, G. (2020). Cooperative strategy for a dual-channel supply chain with the influence of free-riding customers. *Electronic Commerce Research and Applications*, *43*, Article 101001. https://doi.org/10.1016/j.elerap.2020.101001

Liu, C., Lee, C. K. M., & Zhang, L. L. (2022b). Pricing strategy in a dual-channel supply chain with overconfident consumers. *Computers & Industrial Engineering*, *172*(A), Article 108515. https://doi.org/10.1016/j.cie.2022.108515

Loupiac, P., & Le Nagard, E. (2024). Understanding the role of physical trial for good shopping decisions. *RAUSP Management Journal*, *59*(3), 312–328. https://doi.org/10.1108/RAUSP-12-2023-0245

Maggioni, I., Sands, S. J., Ferraro, C. R., Pallant, J. I., Pallant, J. L., Shedd, L., & Tojib, D. (2020). Consumer cross-channel behaviour: Is it always planned? *International Journal of Retail & Distribution Managemen*t, *48*(12), 1357–1375. https://doi.org/10.1108/IJRDM-03-2020-0103

Marino, V., & Lo Presti, L. (2019). Stay in touch! New insights into end-user attitudes towards engagement platforms. *Journal of Consumer Marketing*, *36*(6), 772–783. https://doi.org/10.1108/JCM-05-2018-2692

Méndez-Vogel, G., Marianov, V., Lüer-Villagra, A., & Eiselt, H. A. (2023). Store location with multipurpose shopping trips and a new random utility customers' choice model. *European Journal of Operational Research*, *305*(2), 708–721. https://doi.org/10.1016/j.ejor.2022.06.008

Mitra, (2022). Economic models of price competition between traditional and online retailing under showrooming. *Decision*, *49*(1), 29–63. https://doi.org/10.1007/s40622-021-00293-7

Mohajeryami, S., Moghaddam, I. N., Doostan, M., Vatani, B., & Schwarz, P. (2016). A novel economic model for price-based demand response. *Electric Power Systems Research*, *135*, 1–9. https://doi.org/10.1016/j.epsr.2016.03.026

Moliner, M. A., & Tortosa-Edo, V. (2024). Multirooming: Generating e-satisfaction throughout omnichannel consumer journey design and online customer experience. *Journal of Research in Interactive Marketing*, *18*(3), 349–369. https://doi.org/10.1108/JRIM-05-2023-0149

Nosi, C., Zollo, L., Rialti, R., & Ciappei, C. (2022). Why do consumers free ride? Investigating the effects of cognitive effort on postpurchase dissonance. *Journal of Consumer Marketing*, *39*(5), 417–431. https://doi.org/10.1108/JCM-02-2021-4436

Peng, Y., Wang, W., Li, S., & Veglianti, E. (2022). Competition and cooperation in the dual-channel green supply chain with customer satisfaction. *Economic Analysis and Policy*, *76*, 95–113. https://doi.org/10.1016/j.eap.2022.08.001

Pi, Z., Fang, W., Perera, S. C., & Zhang, B. (2022). Enhancing the online buyer perception of consumer experience products in a dual-channel supply chain: A new role of free-riding. *International Journal of Production Economics*, *253*, Article 108600. https://doi.org/10.1016/j.ijpe.2022.108600

Politis, Y., Giovanis, A., & Binioris, S. (2014). Logistics service quality and its effects on customer satisfaction in the manufacturing companies' supply chains: Empirical evidence from Greece. *Journal of Modelling in Management*, *9*(2), 215–237. https://doi.org/10.1108/JM2-05-2012-0016

Redondo, I., & Charron, J. P. (2023). Variety of shopping modes: Theoretical framework, pivotal factors, and managerial implications. *Journal of Business Economics and Management*, *24*(5), 857–876. https://doi.org/10.3846/jbem.2023.20438

Rosillo-Diaz, E., Munoz-Rosas, J. F., & Blanco-Encomienda, F. J. (2024). Impact of heuristic–systematic cues on the purchase intention of the electronic commerce consumer through the perception of product quality. *Journal of Retailing and Consumer Services*, *81*, Article 103980. https://doi.org/10.1016/j.jretconser.2024.103980

Sharma, N., Sharma, A., Dutta, N., & Priya, P. (2023). Showrooming: A retrospective and prospective review using the SPAR-4-SLR methodological framework. *International Journal of Retail & Distribution Management*, *51*(11), 1588–1613. https://doi.org/10.1108/IJRDM-12-2022-0513

STATISTA. (2024a). *Worldwide retail e-commerce sales*. Retrieved July 15, 2024, from https://www.statista.com/statistics/379046/worldwide-retail-e-commerce-sales/

STATISTA. (2024b). *Online shopper conversion rate worldwide*. Retrieved July 15, 2024, from https://www.statista.com/statistics/439576/online-shopper-conversion-rate-worldwide/

STATISTA. (2023). *Industries & Markets*, *Retail market worldwide* (p. 5). Retrieved July 15, 2024, from https://www.statista.com/statistics/443522/global-retail-sales/

Tahirov, N., & Glock, C. H. (2022). Manufacturer encroachment and channel conflicts: A systematic review of the literature. *European Journal of Operational Research*, *302*(2), 403–426. https://doi.org/10.1016/j.ejor.2021.12.006

Tian, C., Xiao, T., & Shang, J. (2022). Channel differentiation strategy in a dual-channel supply chain considering free riding behavior. *European Journal of Operational Research*, *301*(2), 473-485. https://doi.org/10.1016/j.ejor.2021.10.034

Truong, D., & Truong, M. D. (2022). How do customers change their purchasing behaviors during the COVID-19 pandemic? *Journal of Retailing and Consumer Services*, *67*, Article 102963. https://doi.org/10.1016/j.jretconser.2022.102963

Wang, Q., Ji, X., & Zhao, N. (2024). Embracing the power of AI in retail platform operations: Considering the showrooming effect and consumer returns. *Transportation Research Part E*, *182*, Article 103409. https://doi.org/10.1016/j.tre.2023.103409

Wang, T. Y., Chen, Z. S., Govindan, K., & Chin, K. S. (2022a). Manufacturer's selling mode choice in a platform-oriented dual channel supply chain. *Expert Systems with Applications*, *198*, Article 116842. https://doi.org/10.1016/j.eswa.2022.116842

Wang, W.-B., Sun, Q., Yan, X.-X., & Liu, Y.-Q. (2022b). Dual-channel supply chain financing operation strategy considering free-riding effect under different power structures. *Sustainability*, *14*, Article 9379. https://doi.org/10.3390/su14159379

Wang, X., & Chaolu, T. (2022). The impact of offline service effort strategy on sales mode selection in an e-commerce supply chain with showrooming effect. *Journal of Theoretical and Applied Electronic Commerce Research*, *17*, 893–908. https://doi.org/10.3390/jtaer17030046

Xu, S., Tang, H., Lin, Z., & Lu, J. (2022). Pricing and sales-effort analysis of dual-channel supply chain with channel preference, cross-channel return and free riding behavior based on revenue-sharing contract. *International Journal of Production Economics*, *249*, Article 108506. https://doi.org/10.1016/j.ijpe.2022.108506

Yang, F., Hu, P., Zhao, F., & Hu, C. (2015). Customer returns model in a dual-channel supply chain. *Journal of Modelling in Management*, *10*(3), 360–379. https://doi.org/10.1108/jm2-03-2015-0014

Yang, W., Zhang, J., & Yan, H. (2021). Impacts of online consumer reviews on a dual-channel supply chain. *Omega*, *101*, Article 102266. https://doi.org/10.1016/j.omega.2020.102266

Yang, Z., Shang, W.-L., Miao, L., Gupta, S., & Wang, Z. (2024). Pricing decisions of online and offline dual-channel supply chains considering data resource mining. *Omega*, *126*, Article 103050. https://doi.org/10.1016/j.omega.2024.103050

Yin, C. C., Chiu, H. C., Hsieh, Y. C., & Kuo, C. Y. (2022). How to retain customers in omnichannel retailing: Considering the roles of brand experience and purchase behavior. *Journal of Retailing and Consumer Services*, *69*, Article 103070. https://doi.org/10.1016/j.jretconser.2022.103070

Yuan, X., Bi, G., Li, H., & Zhang, B. (2022). Stackelberg equilibrium strategies and coordination of a low-carbon supply chain with a risk-averse retailer. *International Transactions in Operational Research*, *29*(6), 3681–3711. https://doi.org/10.1111/itor.13140

Zavialova, S., & Lindlahr, S. (2023). *eCommerce: Market data and analysis*, *market insights reports*. STATISTA. Retrieved July 15, 2024, from https://www.statista.com/study/42335/ecommerce-report/

Zhai, Y., Bu, C., & Zhou, P. (2022). Effects of channel power structures on pricing and service provision decisions in a supply chain: A perspective of demand disruptions. *Computers & Industrial Engineering*, *173*, Article 108715. https://doi.org/10.1016/j.cie.2022.108715

Zhang, C., Li, Y., & Ma, Y. (2021). Direct selling, agent selling, or dual-format selling: Electronic channel configuration considering channel competition and platform service. *Computers & Industrial Engineering*, *157*, Article 107368. https://doi.org/10.1016/j.cie.2021.107368

Zhang, T., Li, G., Chen, T. C. E., & Shum, S. (2020). Consumer inter-product showrooming and information service provision in an omni-channel supply chain. *Decision Sciences*, *51*(5), 1232–1264. https://doi.org/10.1111/deci.12415

Zhang, X., Xu, Y., Chen, X., & Liang, J. (2023). Pricing decision models of manufacturer-led dual-channel supply chain with free-rider problem. *Sustainability*, *15*, Article 4087. https://doi.org/10.3390/su15054087

Zhong, Y., Shen, W., & Ceryan, O. (2023). Information provision under showrooming and webrooming. *Omega*, *114*, Article 102724. https://doi.org/10.1016/j.omega.2022.102724

Zhou, Y-W., Guo, J., & Zhou, W. (2018). Pricing/service strategies for a dual-channel supply chain with free riding and service-cost sharing. *International Journal of Production Economics*, *196*, 198–210. https://doi.org/10.1016/j.ijpe.2017.11.014

Zollo, L., Filieri, R., Rialti, R., & Yoon, S. (2020). Unpacking the relationship between social media marketing and brand equity: the mediating role of consumers' benefits and experience. *Journal of Business Research*, *117*, 256–267. https://doi.org/10.1016/j.jbusres.2020.05.001

APPENDIX

Proof of Proposition 1

When $\alpha \in [0,1] \Rightarrow 1-\alpha \geq 0$ but $1 \leq \beta(s)$, then:

$$1-\alpha \leq (1-\alpha)\beta(s) \Rightarrow 1 \leq \alpha + (1-\alpha)\beta(s). \tag{25}$$

Multiplying the relationship (25) with a positive valuation *v*, we have:

$$v \leq \left[\alpha + (1-\alpha)\beta(s)\right]v. \tag{26}$$

On the other hand, when

$$\beta(s) \geq 1 \textit{ and } \alpha \geq 0 \;\Rightarrow 1- \beta(s) \leq 0 \Rightarrow \alpha(1-\beta(s)) \leq 0 \Rightarrow$$

$$\Rightarrow \alpha - \alpha\beta(s) \leq 0 \Rightarrow \alpha + \beta(s) - \alpha\beta(s) \leq \beta(s) \Rightarrow$$

$$\Rightarrow \alpha + (1-\alpha)\beta(s) \leq \beta(s). \tag{27}$$

And from the relationship (27), we have:

$$\alpha + (1-\alpha)\beta(s)v \leq \beta sv. \tag{28}$$

Finally, relation (3) follows from relations (26) and (28).
Therefore, we have proved the Proposition 1.

Proof of Proposition 2

From relation (13) we obtain:

$$pon < pof\, f1 - \alpha + \alpha\beta s. \tag{29}$$

For the second inequality, we start from relation (27) which implies:

$$\alpha + (1-\alpha)\beta(s) \leq \beta(s) \;\Leftrightarrow\; 1-\alpha + \frac{\alpha}{\beta(s)} < 1 \Leftrightarrow \;\Leftrightarrow\; p_{off}\left(1-\alpha + \frac{\alpha}{\beta(s)}\right) < p_{off}. \tag{30}$$

Using the results obtained in the previous calculations (relations (29) and (30)), we obtain:

$$p_{on} < p_{off}\left(1-\alpha+\frac{\alpha}{\beta(s)}\right) < p_{off}. \tag{31}$$

Therefore, we have proved the Proposition 2.

Proof of Proposition 3

The offline expected profit function is (Liu et al. 2022a):

$$EP_{off}(s,z) = (p_{off}-c_{off})(d_{off}+m+z+1-b) - p_{acq}(d_{off}+z) - C(s) -$$

$$(p_{off}-c_{off}-\varphi)\int_a^z F(\varepsilon_{off})\,d\varepsilon_{off}. \tag{32}$$

To prove that the offline expected profit is a concave function we have to prove that its second-order differential is negative defined, which is equivalent to showing that: $\frac{\partial^2 EP_{off}}{\partial s^2} < 0$ and $|H(s,z)| > 0$. The partial derivatives of the first order are:

$$\frac{\partial EP_{off}}{\partial s}(s,z) = (p_{off}-c_{off}-p_{acq})D\frac{(p_{off}-p_{on})}{\overline{v}\alpha}\frac{\beta'(s)}{(\beta(s)-1)^2} - C'(s). \tag{33}$$

and

$$\frac{\partial EP_{off}}{\partial z}(s,z) = p_{off}-c_{off}-p_{acq}-(p_{off}-c_{off}-\varphi)F(z). \tag{34}$$

The second-order partial derivatives are:

$$\frac{\partial^2 EP_{off}}{\partial s^2}(s,z) = (p_{off}-c_{off}-p_{acq})D\frac{(p_{off}-p_{on})}{\overline{v}\alpha}\frac{\beta''(s)(\beta(s)-1)-2(\beta'(s))^2}{(\beta(s)-1)^3} - C''(s). \tag{35}$$

$$\frac{\partial^2 EP_{off}}{\partial s \partial z}(s,z) = 0. \tag{36}$$

$$\frac{\partial^2 EP_{off}}{\partial z \partial s}(s,z) = 0. \tag{37}$$

$$\frac{\partial^2 EP_{off}}{\partial z^2}(s,z) = -(p_{off}-c_{off}-\varphi)f(z), \tag{38}$$

then, the Hessian matrix is:

$$H(s,z) = \begin{pmatrix} \frac{\partial^2 EP_{off}}{\partial s^2} & \frac{\partial^2 EP_{off}}{\partial s \partial z} \\ \frac{\partial^2 EP_{off}}{\partial z \partial s} & \frac{\partial^2 EP_{off}}{\partial z^2} \end{pmatrix}. \tag{39}$$

Because $\beta''(s) < 0$, $\beta(s) - 1 \geq 0$ and $C''(s) > 0$, we have:

$$\frac{\partial^2 EP_{off}}{\partial s^2}(s, z) < 0 \tag{40}$$

and its determinant is:

$$|H(s,z)| = \left| \begin{matrix} (p_{off} - c_{off} - p_{acq}) D \dfrac{(p_{off} - p_{on})}{\bar{v}\alpha} \dfrac{\beta''(s)(\beta(s)-1) - 2(\beta'(s))^2}{(\beta(s)-1)^3} - C''(s) & 0 \\ 0 & -(p_{off} - c_{off} - \varphi) f(z) \end{matrix} \right| . \tag{41}$$

$$|H(s,z)| = \left[-(p_{off} - c_{off} - \varphi) f(z) \right] \times \left[(p_{off} - c_{off} - p_{acq}) D \frac{(p_{off} - p_{on})}{\bar{v}\alpha} \frac{\beta''(s)(\beta(s)-1) - 2(\beta'(s))^2}{(\beta(s)-1)^3} - C''(s) \right], \tag{42}$$

so,

$$|H(s,z)| > 0 . \tag{43}$$

Relations (40) and (43) imply that the differential of the second order is defined negatively, so the offline expected profit is a concave function. Therefore, we have proved the Proposition 3.