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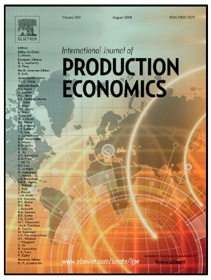

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A framework for evaluation of supply chain coordination by contracts under O2O environment

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Abstract

Over the past decade, a significant change has occurred in the way businesses progress, and that change is largely due to rapidly changing technology. The entire world depends on the online network that has radically changed our perspective of how business should be managed. The faster a company adapts, the more quickly that company can outpace its competitors, and a new approach that is attracting attention is called Online to Offline (O2O).

This paper establishes a comparison based on O2O approach; our model considers two types of demand under three coordination mechanisms (revenue-sharing, buy-back, and quantity flexibility contracts). We demonstrate that the best outcome and the highest profit is achieved with the O2O deterministic demand under the quantity flexibility agreement. However, the stochastic demand case attains the same result. This paper presents a fruitful introduction to this emerging topic, and future research might compare several coordination mechanisms using the Stackelberg game theory.

Keywords: Online to Offline (O2O); supply chain coordination; revenue-sharing contracts, buy-back contracts; quantity flexibility contracts

1. Introduction

In business, both manufacturers and retailers aim to maximize their own profits; in order for both sides to prosper, some coordination is necessary. A popular method to disperse risk among the members of the supply chain is the contracting mechanism (e.g. revenue-sharing, buy-back). If contracts are implemented in an efficient and effective way, they can improve the overall outcomes of the entire channel. Over the past decade, businesses have transformed because of technological advancements; therefore, coordination methods also need to adapt. One of the two most promising coordination methods is called Online to Offline (O2O). It is important to emphasize that O2O is considered a new and innovative approach that may cause major changes in numerous industries. Hence, the presented paper carries timely significance.

Ding and Jiang (2015) define O2O in this manner: "O2O, online to offline, means enterprises provide discount, information and services through internet to attract consumers' attention and make them effect payment online and enjoy services offline, which could enhance consumer satisfaction and meet personalized requirements" (Ding and Jiang, 2015). Implementing an O2O system is a complex matter, and a coordinated supply chain is required to do so properly. While the coordinated channel is required, it is useful to analyze a non-coordinated case as well to see how the profit functions differ from each other.

Current research has not yet formulated an O2O approach to coordinated and non-coordinated supply chains under the presented settings. Hence, this paper presents a significant contribution to the literature by incorporating an innovative O2O approach in three coordination mechanisms. To compare contracts under stochastic demand, we use a numerical example to obtain answers to our research questions. With the assistance of certain performance measures, we compare coordination mechanisms to a non-coordinated case including the O2O model. In the first part of the model, we investigate whether the non-coordinated case performs better under a stochastic demand or under a deterministic demand within an O2O framework. The second part of the model contains an assessment between several contracts under a stochastic demand, followed by a comparison of the same model under an O2O model under a deterministic demand.

The goal of the paper is to answer the following research questions:

- In a non-coordinated case, which types of demands allow the supply chain to gain the highest profit?

- Which of the three presented coordinated agreements achieves the best outcome in an O2O setting? Which contract grants the best results under a stochastic demand?
- How do the mentioned contracts perform in comparison to the non-coordinated case under both types of demands?

All the above problems need to be resolved urgently in order to achieve coordination within the firms' operations. To this end, this paper presents a model that addresses the significance of the online to offline (O2O) system and supply chain contracts. This work introduces a comparison among three coordinated contracts and offers a non-coordinated approach as well. A non-coordinated supply chain, as well as the presented coordinated contracts, reacts to two different types of demand especially under the O2O deterministic case. This situation could easily occur in various industries, because many businesses rely heavily on the online channels for sales or promoting their business. This framework maintains attention to the offline market, and thirdly, we consider certain performance measures applied in supply chains in order to determine profits.

This paper is structured as follows. Section 2 contains a literature review based on the various uses of the O2O framework, dual channels, various demand types, and a brief examination of the three types of contracts used in the model (revenue-sharing, buy-back, and quantity flexibility). Section 3 presents notations and assumptions. Section 4 includes the model's development and performance measures. It concentrates on profit functions formulated under a stochastic demand and it incorporates the O2O framework into the classic contracts. Section 5 contains responses and discussions to the research questions presented above. Section 6 provides managerial implications and Section 7 compiles a summary of the findings and considers future directions.

2. Literature review

The following literature review presents the importance of the O2O approach, the essence of dual channels, and the significance of various coordination mechanisms. The three subsections correspond to the ways in which they complement various supply chains and they identify a gap in the available literature resources.

2.1 Online to offline (O2O)

Both the term O2O and the idea of dual channels are receiving increased attention due to their importance in the fields of supply chain management and elsewhere. Huang and Swaminathan (2009) show that these concepts have become popular in the retail industry; companies such as Bloomingdale's, Barnes & Noble, Walmart, and others are applying the O2O strategy. Furthermore, the practice extends to the suppliers as well. Xiao and Shi (2016) suggest that successful companies such as IBM, Nike, and Estée Lauder are using the same approach. Other issues discussed later in the literature review are the implications of social media regarding information on clientele, the fight on global warming, pricing strategies, as well as the development of agricultural products with the help of E-commerce.

The purpose of a supply chain is to achieve an overall coordination and a balance of the power structure across the entire supply chain. Chen et al. (2015) explore three game theory approaches: a Stackelberg game with the retailer as the leader, a Nash equilibrium that favors neither member, and a Stackelberg game with the supplier as the leader. The overall supply chain is, therefore, a hybrid dual channel.

With an online-to-offline framework, a new type of competition is created with regard to the pricing policy between the online and offline channels. The pricing structure is similar to that explained by Bernstein et al. (2006). The study reveals that retailers prefer an integrated pricing framework over a decentralized model; in other words, retailers opt to determine the price for offline and online transactions at the same time. This choice is plausible because profits are greater in online sales. It is notable that the power structure has considerable influence over the entire channel implementation as well as over the pricing choices.

The member that controls the marketplace will achieve a higher profit, but the entire channel succeeds if both retailer and supplier can achieve an equilibrium. Chen et al. (2015) analyze the consequences of distinct power frameworks for both parties involved, and Dongchuan and Hong (2015) focus on a similar approach.

The O2O framework may be applied in several practical ways. One method is to relate O2O to the critical subject of fighting global warming through mechanisms such as the Carbon Emission Trading Scheme as proposed by the United Nations Framework Convention on Climate Change (UNFCCC). Satoh (2013) introduces a personal carbon transaction involving an online-to-offline framework with Radio Frequency Identification (RFID) barcodes or tags. The RFID system keeps records to track entitlements to carbon grants in order to permit consumers (or buyers) who purchase services with carbon payments to hold the allowances. The whole framework design is based on an authentic supply chain with actual carbon transactions and real clients. Furthermore, this system may embolden industries and households to lower their carbon gas emissions.

Satoh (2013) is currently the only author considering the RFID system as credentials for carbon allowances. The main challenge of Satoh's paper is to insert the RFID system as actual credentials for carbon allowances or carbon emission certificates and limits (known as "caps") in an O2O setting.

As mentioned before, the O2O approach has many uses in a variety of domains. Several studies examine the social effects of this model. Tsai et al. (2013) find that social media delivers new prospects with regard to the relationship between clients and manufacturers. They declare that "Social media has become the most convenient space to retrieve the tremendous consumers' experience" (Tsai et al., 2013). Hence, social media platforms, especially Facebook, could provide retailers and various industries with valuable information in an efficient way (Tsai et al., 2013).

Another approach related to O2O occurs alongside e-commerce platforms. Hong (2013) and Zhang (2015) have researched agricultural products. Hong (2013) suggests a business structure composed of an O2O main model alongside high-tech processors, which include an e-commerce platform for all parties. The purpose of this formulation is to create an efficient link between the companies handling product development and the upstream material providers. According to Zhang (2015), the advance of e-commerce in the agricultural industry denotes a vast achievement. In the 1970s the main method of communication was the telephone, and the 1990s brought computer platforms and satellite equipment. Hong (2013) also says that northern parts of the European Union have increased their percentage of e-commerce platforms in agricultural industries by 60%. E-commerce certainly influences a client's behavior because the number of online acquisitions continues to increase.

The changes mentioned above influence the Chinese market as well. Zhang (2015) uses the e-commerce platform to increase the effectiveness of agricultural channels in China. This model is developed through different frameworks such as the O2O Community and WeChat. The authors conclude that the suggested model is quite intricate, and in order to be feasible, coordination is necessary thorough the whole channel to implement a closed-loop structure which includes an O2O framework (Zhang, 2015).

Ding and Jiang (2015) suggest that the Chinese industry should modify its marketing strategies in order to adjust to changing customer demands. Changes in the consumption trend are occurring. In relation to mobile marketing, O2O generates new chances for industries to advance. The authors propose new ways to use the O2O marketing tactics in order to improve the existing systems, create an efficient supply chain, and improve the client's contentment (Ding and Jiang, 2015).

Pan et al. (2017) proposes a novel O2O service recommendation method based on multi-dimensional similarity measurements. The proposed model proves that using multiple similarity measures performs better than any one single similarity measure. Li et al. (2017) examine cooperative advertising strategies in a O2O supply chain using three different models, namely, Integration Model (I-Model), Unilateral co-op advertising model (U-Model), and Bilateral co-op advertising model (B-Model). Zhang et al. (2017) analyze the effect of government regulations on competition in two-sided markets that feature network externality under the O2O era. These authors suggest that proposing contracts between agents and platforms are worth discussion to improve the coordination issues. Choi et al. (2017) explore an online-offline model on the choice of franchising contracts and ordering time under four different scenarios. Gao and Su (2017) study the impact of the buy online and pick-up in store initiative on store operations; they employ the model where a retailer operates both online and offline channels.

Overall, the O2O approach is multifunctional; it can be efficiently applied to retailers as well as to suppliers. O2O aligns with a variety of game theory strategies, and it may also be successfully applied to fields such as e-commerce and social media.

2.2 Dual channels

Avery et al. (2012) create a structure in order to analyze the outcome of including a retail store in a current channel. Niu et al. (2012) analyze a combined pricing strategy in a monopoly market structure. Xiao and Shi (2016) analyze a dual channel formed of both a brick-and-mortar network and an online channel. Focusing on the pricing model, they settle on various game strategies in order to better analyze pricing strategy and coordination stages of the entire channel. The outcomes demonstrate that coordination in the entire channel can resolve the retailer's issues regarding the supply of goods. Similar to Xiao and Shi (2016), Rodriguez and Aydin (2015) examine pricing strategy as well as the various decisions regarding the cost of holding inventory in an entire channel. The results show that variants with a volatile demand expect a low wholesale cost. Another similar topic regarding pricing is approached by Huang and Swaminathan (2009); their focus is on developing an ideal pricing policy in online as well as offline channels. Four types of strategies are used in their paper, and they examine both monopoly and duopoly models. The results demonstrate that a supply chain consisting of two channels has the advantage of diversity that could lead to higher prices if they face pure competition.

Bernstein et al. (2008) study how a bricks-and-mortar method compares to a clicks-and-mortar framework. Their work, and a later publication by Xiao and Shi (2016), considers a different type of market structure from that of Huang and Swaminathan (2009). These models employ an oligopoly framework structure. The results show that the "clicks-and-mortar" strategy is considered to be the best option for the client (Bernstein et al., 2008).

Cai (2010) looks at supply chain coordination from two different views, including a classic channel and a dual channel, and his methods include two distinct types of Pareto improvements. The results show that in a classic channel, both parties are at an advantage if the supplier includes a new channel, but they also reveal that having numerous channels does not always outdo a more limited number of channels, a finding that is valid from the supplier's perspective.

Several authors expand the topic of dual channels in several ways. Cattani et al. (n.d.) describe the trend of equivalent pricing policies. Cao (2014) analyzes how to obtain a coordinated channel while developing a model under a stochastic demand. Teimoury et al. (2008) create a structure that implies both parties handle the stock. Dumrongsiri et al. (2008) and Ryan et al. (2013) use a classic newsvendor approach in order to focus on a framework managed by a manufacturer under a dual channel. Kevin Chiang et al. (2003) present ways to achieve coordination under a double channel with the help of a wholesale contract.

Dual channel supply chains also focus on the coordination relation regarding the pricing strategies in a distribution framework similar to O2O. The topic is discussed by several authors, including Rhee and Seong-Yong (2000), Chen et al. (2013), Hua et al. (2010), Yao and Liu (2005), and Chiang and Monahan (2005). These articles give a good overview of the vast industries in which O2O and dual channels may be used. Moreover, they present the topic from both sides, offering both the retailer's perspective and the vendor's perspective.
Dual channels are a frequently used framework in supply chains. They are considered especially relevant for both "bricks-and-mortar" and "clicks-and-mortar" strategies, and they offer suitable ways by which to analyze various pricing policies.

2.3 Coordination mechanisms

The coordination mechanisms that our model considers have been addressed several times before, but our research question bridges the gap regarding the incorporation of the O2O model with these models. Viswanathan and Wang (2003) demonstrate that coordination is possible due to a quantity discount framework. Qin et al. (2007) reveal that the same outcome is feasible due to franchise taxes. Braidea et al. (2012) use the same mechanism in order to coordinate a Vendor-Managed Inventory (VMI) system.

Meanwhile, according to Gerchak and Wang (2004a), revenue-sharing appears to achieve an optimal profit; revenue-sharing has been used in several businesses such as e-commerce and retailing. Chen and Bell (2011) investigate a buy-back agreement under a stochastic demand, which is set to be price dependent and able to achieve coordination in a study similar to that of Chiu et al. (2011). Cachon and Lariviere (2005) complete research under the same demand setting; they demonstrate that the buy-back contract and revenue-sharing agreement do not obtain the same outcome in a fixed price setting. Shin and Benton (2007) create a model relevant to the application of a contract involving a quantity discount under an overall coordination of the entire channel. The basis for the coordination mechanisms is the demand type used. For that reason, a brief review is required to assess properly the coordination mechanisms.

Several authors consider the two types of demand, which shall be further presented in the numerical example. The stochastic demand is considered to be more difficult to implement because its main characteristic is the randomness of its variables which may lead to an unknown output. The deterministic demand is more commonly found in research papers. Çetinkaya et al. (2008) employs a stochastic type of demand due to the randomness factor of the arrivals. This creates a setoff for obtaining an exact result related to the costs created. Ma et al. (2013) examine a decentralized channel under a stochastic demand. Mateen et al. (2015) analyze a channel under an uncertain demand. Further studies related to uncertain demands may be found in Nagarajan and Rajagopalan (2008), Ben-Daya et al. (2012), Song and Dinwoodie (2008), Salzarulo and Jacobs (2014), Zhang et al. (2007), and Çetinkaya et al. (2008).

Furthermore, the deterministic approach is the central focus of several papers due to its efficient implementation in numerical examples. This method of calculation is the basis for the model presented below. Lee et al. (2016) develop a model based on a (Q,r) inventory system that faces a deterministic demand. Chakraborty et al. (2015) analyze different coordination mechanisms under the same type of demand. Other authors using the same approach include Darwish and Odah (2010), Xu and Leung (2009), and Dong and Leung (2009). In order to achieve coordination in a supply chain, coordination mechanisms are frequently considered necessary to obtain an optimal result. For example, Viswanathan and Wang (2003) have shown that coordination is possible due to the implementation of a quantity discount structure. This work utilizes three contracts (specifically, revenue-sharing, buy-back, and quantity flexibility) which have been the focus of multiple scholarly studies; see Gerchak and Wang (2004), Chen and Bell (2011), Chiu et al. (2011), Cachon and Lariviere (2005), Braidea et al. (2012), and Viswanathan and Wang (2003). More detailed explanation about the contracts used in this paper can be found from the review article published by Govindan et al. (2013).

3. Notations and assumptions

Notations

α: base demand

θ: offline market share

$(1-\theta)$: online market share

γ: self-price sensitivity

β: cross-price sensitivity

p_1: price per unit offline

p_2: price per unit online

g_v,g_r: goodwill cost of the vendor, and the goodwill cost of the retailer

s_v,s_r: salvage costs

c_v,c_r: production cost of the vendor, and the marginal cost of the vendor/ retailer

w: wholesale price

q_b: optimal order quantity of the retailer in a non-coordinated supply chain

Q_{SC}^*: optimal order quantity of the supply chain in the coordinated channel

$S(q)$: expected sales

Notations related to the buy-back contract:

β': buy-back price paid by the vendor towards the retailer in the case of unsold items

Notations related to the revenue-sharing contract:

$w^{'}$: new wholesale price

φ: revenue-sharing fraction, $\varphi \in (0,1)$

Notations for the quantity flexibility contract:

δ: quantity flexibility fraction, $\varphi \in (0,1)$

$(1-\varphi)Q_{SC}^{*}$: the minimum quantity acquired by the retailer under the contract agreement

In order to obtain the results needed for the comparisons, the following notations have been used:

P_V: vendor's profit

SV_v: salvage rate

G_v: goodwill sustained

W_v: wholesale worth

MC_v: marginal costs sustained

P_b: retailer's profit

$R_{r,}$: generated revenue

SV_r: salvage rate

G_r: goodwill sustained

W_r: wholesale worth

MC_r: marginal cost sustained

The utilizations of the profit functions are presented below:

$P_V = f(SV_v, G_{v,}, W_v, MC_v)$

$P_b = f(R_{r,} SV_r, G_r, W_r, MC_r)$

3.2 Assumptions

The demand is a normal distribution under the assumed mean and standard deviation.

If the demand is not met, a goodwill fee is applied for the lost units.

At the end of the season, both parties can salvage the remaining units.

Under the buy-back agreement, if the retailer has a leftover inventory at the end of the season, the whole amount can be sold back to the vendor.

Under a revenue-sharing agreement, each party receives a part of the retailer's generated revenue.

In a quantity flexibility agreement, the retailer may order from the vendor only up to the optimum quantity of the entire channel.

Under the O2O model, the offline price is always considered higher than the online price ($p_1 > p_2$).

For the O2O model to function properly, a second condition must be met: the cross-price sensitivity must be higher than the self-price sensitivity ($\beta > \gamma$).

For the buy-back agreement to function properly, the buy-back price has to be lower than the wholesale price ($\beta' < w$).

As proven by (Chen et al. 2015), the integrated pricing scheme is considered more profitable compared to the decentralized pricing agreement, according to the retailer's profit. The following model will follow the integrated pricing scheme.

4. Model development

The model presented in this work contains a two-echelon supply chain formed of one vendor and one retailer. The structure is developed under a non-coordinated case as well as three coordinated models, which include a revenue-sharing contract, a buy-back contract, and a quantity flexibility contract. The base model is composed of two main models.

4.1 Description of the base model

The base model is composed of a stochastic demand following the methods used by Govindan et al. (2012). The second model is similar to Chen et al. (2015), Mukhopadhyay et al. (2008), and Chen et al. (2012); we presume that the deterministic demand in the offline channel is $d_1(p_1,p_2) = \theta\alpha - \beta p_1 + \gamma p_2$ and in the online channel $d_2(p_1,p_2) = (1-\theta)\alpha - \beta p_2$

$+ \gamma p_1$. The inspiration for non-coordination and coordination models is based on Govindan et al. (2012).

With the assistance of the profit functions and the performance measures, it is possible to gain the required information in order to answer the proposed research questions. The performance measures utilized to obtain the results for the retailer are the generated revenue, salvage realized, goodwill incurred, marginal cost incurred, and wholesale value incurred. Further, the measures used to obtain information from the supplier are the salvage realized, goodwill incurred, marginal cost incurred, wholesale value incurred, and the return costs. The developed graphs and tables present the inputs as well as the outputs and make it possible to visualize the achieved results.

4.2 Profit functions

In order to obtain the data required for analyzing the profit functions, the presented functions are developed under Govindan et al. (2012). The profit functions are established under the following elements:

4.2.1 Non-coordinated case

A supply chain under such a framework does not seek to optimize the outcome of the overall channel. The reason is because the retailer will solely focus on achieving his highest profit.
The profit functions are formed using the notations from section 3.1:
Non-coordinated case under a stochastic demand:

$$P_r(q) = pS(q) + s_r(q - S(q)) - g_r(D - S(q)) - c_r q - wq$$

$$P_v(q) = s_v(q - S(q)) - g_v(D - S(q)) - c_v q + wq$$

Non-coordinated case under a deterministic O2O demand:

$$P_r(q) = pS(q) + s_r(q - S(q)) - g_r\big(\alpha - (\beta - \gamma)(p_1 + p_2) - S(q)\big) - c_r q - wq$$

$$P_v(q) = s_v(q - S(q)) - g_v\big(\alpha - (\beta - \gamma)(p_1 + p_2) - S(q)\big) - c_v q + wq$$

In order to obtain the optimal order quantity for the non-coordinated cases, the profit function of the retailer is differentiated and the following formula is obtained:

$$F(q) = 1 - \frac{c_r + w - s_r}{p - s_r + g_r}$$

4.2.2 Coordination contracts

The three chosen contracts (specifically, revenue-sharing, buy-back, and quantity flexibility) have been the focus of multiple scholarly studies; see Gerchak and Wang (2004), Chen and Bell (2011), Chiu et al. (2011), Cachon and Lariviere (2005), Braidea et al. (2012), and Viswanathan and Wang (2003). A common focus of these studies pertains to issues regarding the coordination of the supply chain, but no study has yet compared different contracts regarding the O2O environment to see which one performs better under the mentioned assumptions.

A description of the coordination mechanisms used is as follows:

4.2.2.1 Revenue-sharing contract

This type of contract implies that the vendor will sell the goods to the retailer under a discounted price, but agrees to share a part of the gained revenue with the vendor at the end of the period.

Revenue-sharing agreement under a stochastic demand:

$$P_r\left(Q_{SC}^*\right) = \varphi\left[pS\left(Q_{SC}^*\right) + s_r\left(Q_{SC}^* - S\left(Q_{SC}^*\right)\right) - g_r\left(D - S\left(Q_{SC}^*\right)\right)\right] - c_r Q_{SC}^* - w' Q_{SC}^*$$

$$P_v\left(Q_{SC}^*\right) = - g_v\left(D - S\left(Q_{SC}^*\right)\right) - c_v Q_{SC}^* + w' Q_{SC}^* + (1-\varphi)[pS\left(Q_{SC}^*\right) + s_v\left(Q_{SC}^* - S\left(Q_{SC}^*\right)\right) - g_v\left(D - S\left(Q_{SC}^*\right)\right)]$$

Revenue-sharing agreement under a deterministic O2O demand:

$$P_r\left(Q_{SC}^*\right) = \varphi\left[pS\left(Q_{SC}^*\right) + s_r\left(Q_{SC}^* - S\left(Q_{SC}^*\right)\right) - g_r\left(\alpha - (\beta - \gamma)(p_1 + p_2) - S\left(Q_{SC}^*\right)\right)\right] - \mathrm{c}_r Q_{SC}^* - w' Q_{SC}^*$$

$$P_v\left(Q_{SC}^*\right) = - g_v\left(\alpha - (\beta - \gamma)(p_1 + p_2) - S\left(Q_{SC}^*\right)\right) - c_v Q_{SC}^* + w' Q_{SC}^* + (1-\varphi)[pS\left(Q_{SC}^*\right) + s_v\left(Q_{SC}^* - S\left(Q_{SC}^*\right)\right) - g_v\left(\alpha - (\beta - \gamma)(p_1 + p_2) - S\left(Q_{SC}^*\right)\right)]$$

4.2.2.2. Buy-back contract

Under a buy-back contract, the vendor commits to buy any unsold goods from the retailer at the end of the period. This transaction occurs under a specific pricing scheme, meaning that the buying price (β') has to be lower than the wholesale price (w).

Buy-back agreement under a stochastic demand:

$$P_r\left(Q_{SC}^*\right) = pS\left(Q_{SC}^*\right) + \beta\left(Q_{SC}^* - S\left(Q_{SC}^*\right)\right) - g_r\left(D - S\left(Q_{SC}^*\right)\right) - c_r Q_{SC}^* - wQ_{SC}^*$$

$$P_v\left(Q_{SC}^*\right) = \left(s_v - \beta\right)\left(Q_{SC}^* - S\left(Q_{SC}^*\right)\right) - g_v(\left(D - S\left(Q_{SC}^*\right)\right) - c_v Q_{SC}^* + wQ_{SC}^*$$

Buy-back agreement under a deterministic O2O demand:

$$P_r\left(Q_{SC}^*\right) = pS\left(Q_{SC}^*\right) + \beta\left(Q_{SC}^* - S\left(Q_{SC}^*\right)\right) - g_r\left(\alpha - (\beta - \gamma)(p_1 + p_2) - S\left(Q_{SC}^*\right)\right) - c_r Q_{SC}^* - wQ_{SC}^*$$

$$P_v\left(Q_{SC}^*\right) = \left(s_v - \beta\right)\left(Q_{SC}^* - S\left(Q_{SC}^*\right)\right) - g_v\left(\alpha - (\beta - \gamma)(p_1 + p_2) - S\left(Q_{SC}^*\right)\right) - c_v Q_{SC}^* + wQ_{SC}^*$$

For both buy-back contracts, the following statement has to apply:

$$\frac{(s_r + g_r - c_r - w)q - s_r S(q) + (c_r + w - g_r)Q_{SC}^*}{Q_{SC}^* - S\left(Q_{SC}^*\right)} \leq \beta \leq \frac{(g_v - c_s + w)Q_{SC}^* - (g_v - c_s + w)q + s_v(Q_{SC}^* - S\left(Q_{SC}^*\right))}{Q_{SC}^* - S\left(Q_{SC}^*\right)}$$

4.2.2.3. Quantity flexibility contract

Under such an agreement, the retailer agrees to acquire $(1 - \delta)Q_{SC}^*$ units with the option to restock during the season to optimum quantity points. The agreement constraint is δ, $\delta \epsilon\ [0,1]$. Due to the different demand levels, there are three separate cases:

Demand level is higher that the agreed upon quantity, under a stochastic demand:

$$D > (1 - \delta)Q_{SC}^*$$

$$P_r\left(Q_{SC}^*\right) = pS\left(Q_{SC}^*\right) + s_r\left((1 - \delta)Q_{SC}^* - D\right) - c_r\left((1 - \delta)Q_{SC}^*\right) - w((1 - \delta)Q_{SC}^*)$$

$$P_v\left(Q_{SC}^*\right) =- c_s(1 - \delta)Q_{SC}^* + w(1 - \delta)Q_{SC}^*$$

Demand level is higher that the agreed upon quantity, under a deterministic O2O demand:

$$\alpha - (\beta - \gamma)\left(p_1 + p_2\right) > (1 - \delta)Q_{SC}^*$$

$$P_r\left(Q_{SC}^*\right) = pS\left(Q_{SC}^*\right) + s_r\left((1 - \delta)Q_{SC}^* - \alpha - (\beta - \gamma)\left(p_1 + p_2\right)\right) - c_r\left((1 - \delta)Q_{SC}^*\right) - w((1 - \delta)Q_{SC}^*)$$

$$P_v\left(Q_{SC}^*\right) =- c_s(1 - \delta)Q_{SC}^* + w(1 - \delta)Q_{SC}^*$$

Demand level is higher that the agreed upon quantity but smaller than the optimal quantity, under a stochastic demand:

$(1-\delta)Q_{SC}^{*} < D < Q_{SC}^{*}$

$P_r\left(Q_{SC}^{*}\right) = pS\left(Q_{SC}^{*}\right) + w\left(Q_{SC}^{*} - D\right) - c_r Q_{SC}^{*} - wQ_{SC}^{*}$

$P_v\left(Q_{SC}^{*}\right) = \left(s_v - w\right)\left(Q_{SC}^{*} - D\right) - c_v Q_{SC}^{*} + wQ_{SC}^{*}$

Demand level is higher that the agreed upon quantity but smaller than the optimal quantity, under a deterministic O2O demand:

$(1-\delta)Q_{SC}^{*} < \alpha - (\beta - \gamma)\left(p_1 + p_2\right) < Q_{SC}^{*}$

$P_r\left(Q_{SC}^{*}\right) = pS\left(Q_{SC}^{*}\right) + w\left(Q_{SC}^{*} - \alpha - (\beta - \gamma)\left(p_1 + p_2\right)\right) - c_r Q_{SC}^{*} - wQ_{SC}^{*}$

$P_v\left(Q_{SC}^{*}\right) = \left(s_v - w\right)\left(Q_{SC}^{*} - \alpha - (\beta - \gamma)\left(p_1 + p_2\right)\right) - c_v Q_{SC}^{*} + wQ_{SC}^{*}$

Demand level is higher than the optimum quantity, under a stochastic demand:

$D > Q_{SC}^{*}$

$P_r\left(Q_{SC}^{*}\right) = pS\left(Q_{SC}^{*}\right) - g_r(D - S\left(Q_{SC}^{*}\right) - c_r Q_{SC}^{*} - wQ_{SC}^{*}$

$P_v\left(Q_{SC}^{*}\right) =- g_v\left(Q_{SC}^{*} - S\left(Q_{SC}^{*}\right)\right) - c_v Q_{SC}^{*} + wQ_{SC}^{*}$

Demand level is higher than the optimum quantity, under a deterministic O2O demand:

$\alpha - (\beta - \gamma)\left(p_1 + p_2\right) > Q_{SC}^{*}$

$P_r\left(Q_{SC}^{*}\right) = pS\left(\mathrm{Q}_{SC}^{*}\right) - g_r(\alpha - (\beta - \gamma)\left(p_1 + p_2\right) - S\left(Q_{SC}^{*}\right) - c_r Q_{SC}^{*} - wQ_{SC}^{*}$

$$P_v\left(Q_{SC}^{*}\right) =- g_v\left(Q_{SC}^{*} - S\left(Q_{SC}^{*}\right)\right) - c_v Q_{SC}^{*} + wQ_{SC}^{*}$$

4.3 Data and decisions variables

Table 1 identifies input data for the supplier and retailer, and it differentiates between stochastic and deterministic demands. The desired results are obtained using the data provided in Table 1 and Table 2 and the same is presented in Table 3.

Table 1: Input data

Supplier		Retailer		Stochastic Demand		Deterministic Demand	
Goodwill cost (Gs)	7	Goodwill cost (Gs)	12	Demand distribution	Normal	Base Demand (α)	120
Cost (Cs)	11	Cost (Cr)	3	Mean	100	Offline market share (Θ)	0.4
Salvage (Ss)	8	Salvage (Sr)	9	Standard deviation	30	Online market share (1-Θ)	0.6
Wholesale price (w)	18	Offline Price	53				
		Online Price	47				

The inputs used for obtaining the complete model are presented in the tables below, as well as the optimal order quantities.

Table 2: Decision variables and optimal order quantities

			Input			
		Optimal Q	β	w'	§	δ
Non-coordination	Offline	123.75				
	Online	121.19				
Revenue-sharing	Offline	142.28		9		0.66
	Online	140.65		9		0.66
Buy-back	Offline	142.28	9.9			
	Online	140.65	9.9			
Quantity Flexibility	Offline	142.28			0.185	
	Online	140.65			0.402	

In order to obtain the required results, the average of 100 computational runs have been calculated for each type of demand in Excel similar to Govindan et al. (2012) and Arshinder et al. (2009). The simulation results are presented in Table 3 and Table 4 for both presented cases.

Table 3: Profit outcomes and performance measures under a stochastic demand

Stochastic demand
Online + Offline

Retailer	Non-coordination	Revenue-sharing	Buy-back	Quantity Flexibility
Generated Revenue	5016.48	5170.22	5170.22	5170.22
Salvage realized	261.89	402.56	442.82	234.37
Goodwill incurred	24.26	10.07	10.07	57.79
Marginal cost incurred	371.25	426.84	426.84	370.78

Wholesale value incurred	2227.48	1280.53	2561.05	2224.66
Leftover inventory	29.10	44.73	44.73	26.04
Units short	2.02	0.84	0.84	4.82
Average sale	94.65	97.55	97.55	97.55
Supplier				
Salvage realized	0	0	402.56	127.20
Goodwill incurred	14.15	5.88	9.54	5.88
Marginal cost incurred	1361.24	1565.09	1493.57	1359.51
Wholesale value incurred	2227.48	1280.53	2444.03	2224.66
Return cost	0.00	0.00	442.82	65.83
Inventory level	0.00	0.00	44.73	26.04
Units short	2.02	0.84	1.36	0.84
Average sale	123.75	142.28	97.55	123.59

Table 4: Profit outcomes and performance measures under a deterministic demand

Deterministic demand
Online + Offline

Retailer	Non-coordination	Revenue-sharing	Buy-back	Quantity Flexibility
Generated Revenue	4671.17	4776.29	4776.29	5402.74
Salvage realized	1346.87	1963.59	1836.87	891.06
Goodwill incurred	0.00	393.66	0.00	0.00
Marginal cost incurred	734.81	848.79	848.79	600.20
Wholesale value incurred	4408.89	2546.36	5092.72	3621.55
Leftover inventory		185.54	185.54	103.81
Units short	0.00	32.80	0.00	0.25
Average sale	95.29	97.39	97.39	97.39
Supplier				
Salvage realized	0.00	0.00	1484.34	0.00
Goodwill incurred	0.00	0.00	0.00	1.77
Marginal cost incurred	2694.32	3112.22	3112.22	2213.17
Wholesale value incurred	4408.89	2546.36	5092.72	3024.88
Return cost	0.00	0.00	1836.87	0.00
Inventory level	0.00	0.00	185.54	102.93

Units short	0.00	0.00	0.00	0.25
Average sale	244.94	282.93	97.39	201.20

5. Results and discussion

5.1 Profit functions

In order to answer the research questions, this sub-section discusses the outcomes of the simulations regarding profit functions.

Table 5: Profit outcomes under a non-coordinated setting

Non-Coordinated	O2O	Stochastic demand
Retailer's profit	2684.49	2655.38
Supplier's profit	1686.41	852.09
Total Supply Chain	4370.90	3507.47

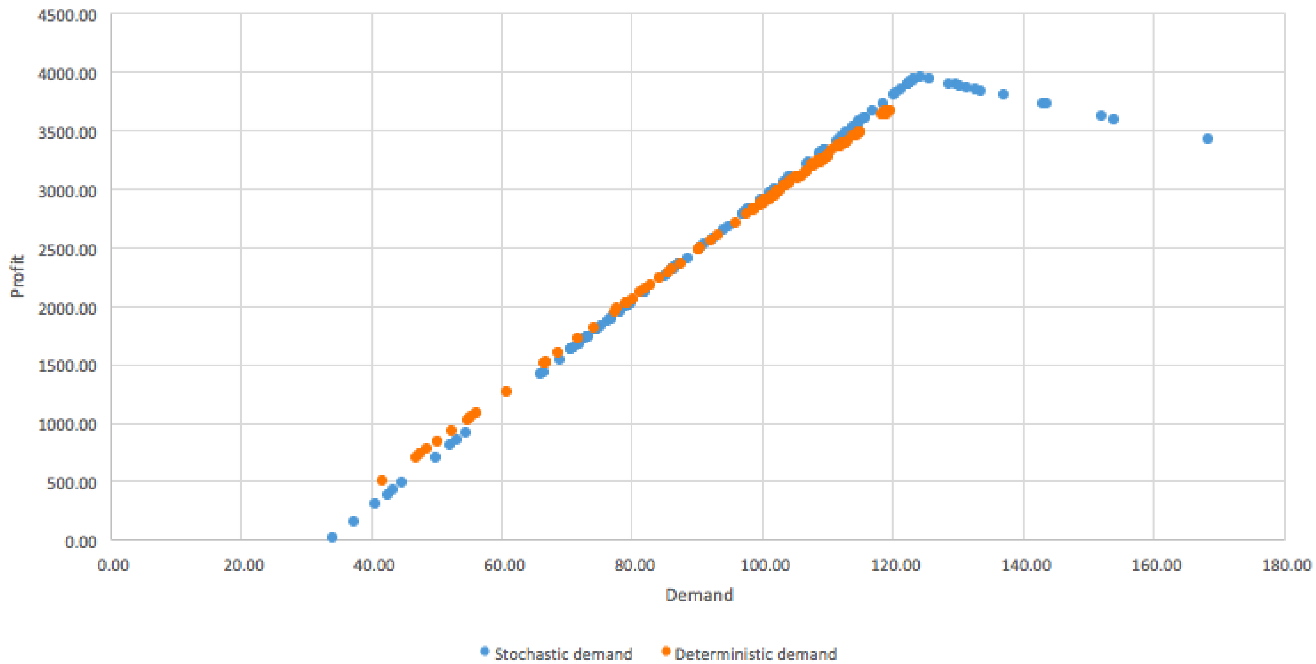

Figure 1: Profit of the retailer

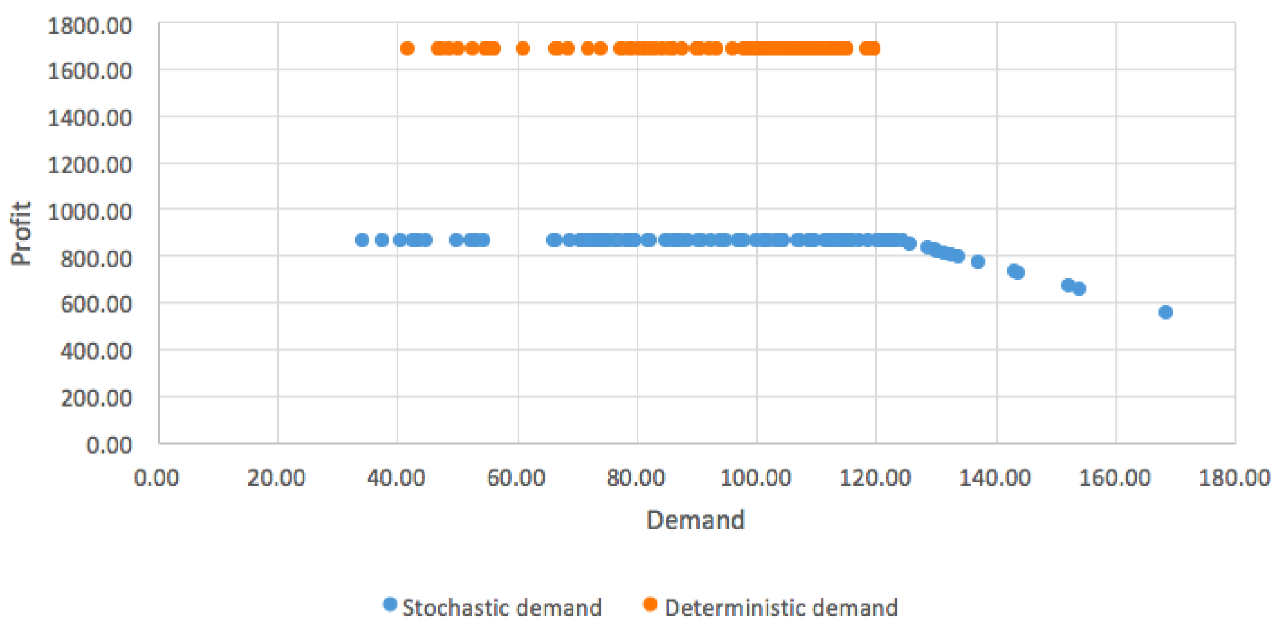

Figure 2: Profit of the supplier

1. The first comparison takes place in the non-coordinated setting. The aim is to see if the non-coordinated case performs better under an O2O dual channel or a classic supply chain. As seen in Figure 1, the retailer's profit in the deterministic case presents a slightly better outcome than in the stochastic case. This difference may occur due to the low cost involving the online channel and/or the overall gained profits of the dual channel. However, Figure 2 depicts a clear difference which is the supplier's profit function; one of the factors for this difference is the increased average sale and the high wholesale value achieved.
In this scenario, it can be concluded that the overall supply chain performs better under an O2O setting with a deterministic demand.

2. The second comparison takes place under three coordinated mechanisms, namely revenue-sharing, buy-back, and quantity-flexibility agreements. The basis of this assessment takes place under an O2O framework with a deterministic demand.

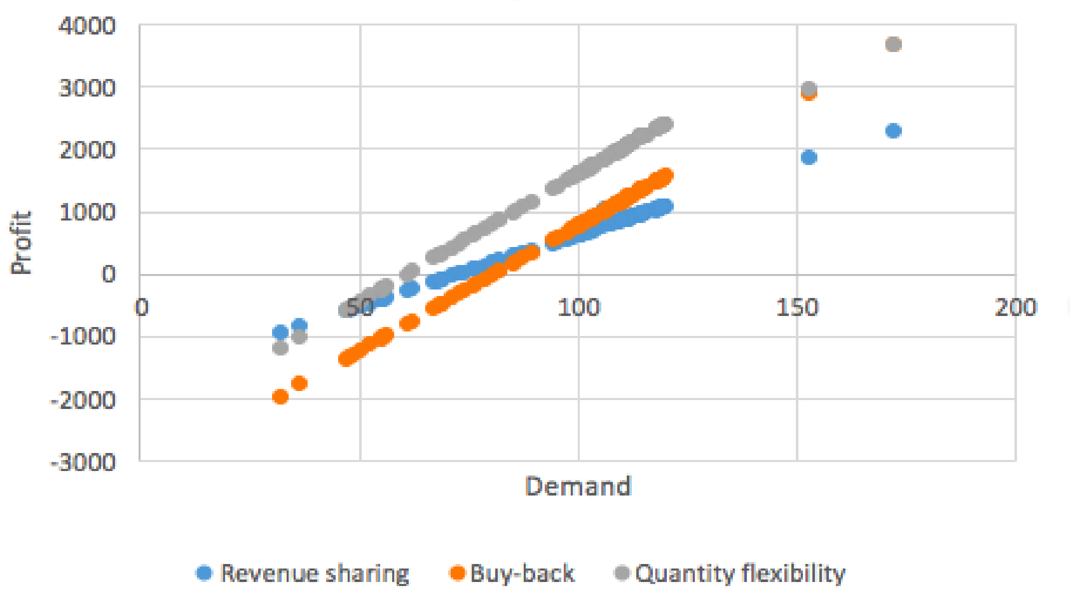

Figure 3: Profit of the retailer under a deterministic demand

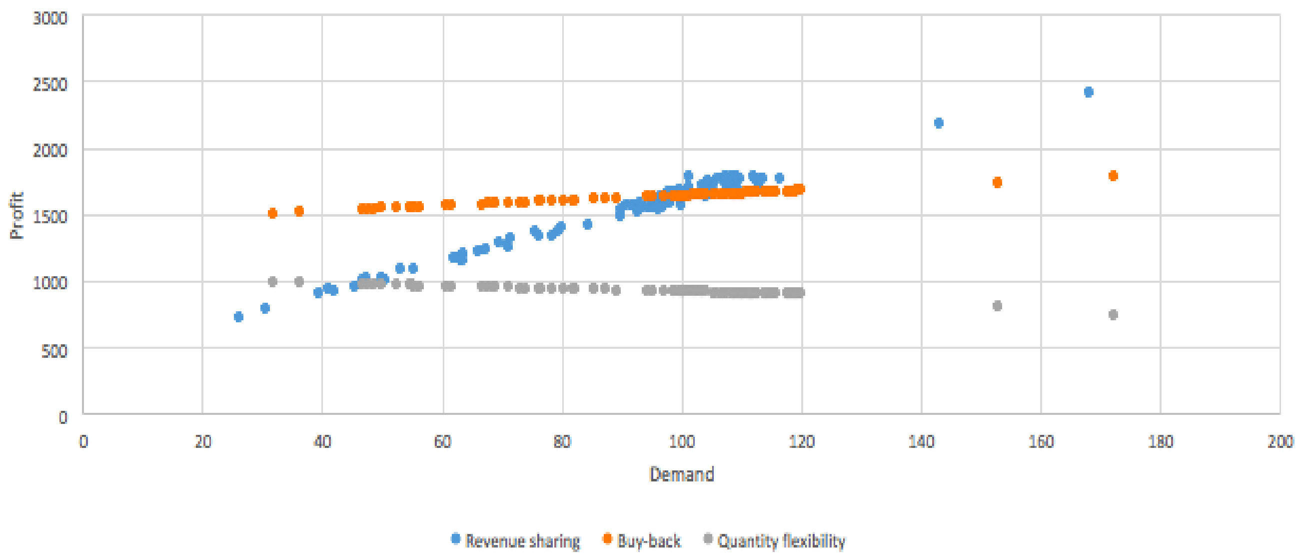

Figure 4: Profit of the supplier under a deterministic demand

Table 6: Profit outcomes under a deterministic demand

Deterministic Demand	Revenue-Sharing	Buy-Back	Quantity Flexibility
Retailer's profit	578.96	671.66	1482.41
Supplier's profit	1512.55	1627.97	912.62
Total Supply Chain	2091.52	2299.63	2395.03

As we can see from Figure 3 and Figure 4, the retailer's profit is generally lower compared to the non-coordinated case. This decrease may happen because the retailer is concerned with increasing the entire supply chain profit instead of focusing only on increasing his own profit. Of the three contracts, the quantity flexibility agreement has the best performance for the entire supply chain. The retailer obtains the highest profit from the quantity flexibility method among the three contracts. Due to the increased efficiency of the contract, the model presents the lowest leftover inventory and marginal cost followed by the buy-back contract and the revenue-sharing agreement.

3. The third comparison is developed under a stochastic demand, which is applied to the three coordination contracts.

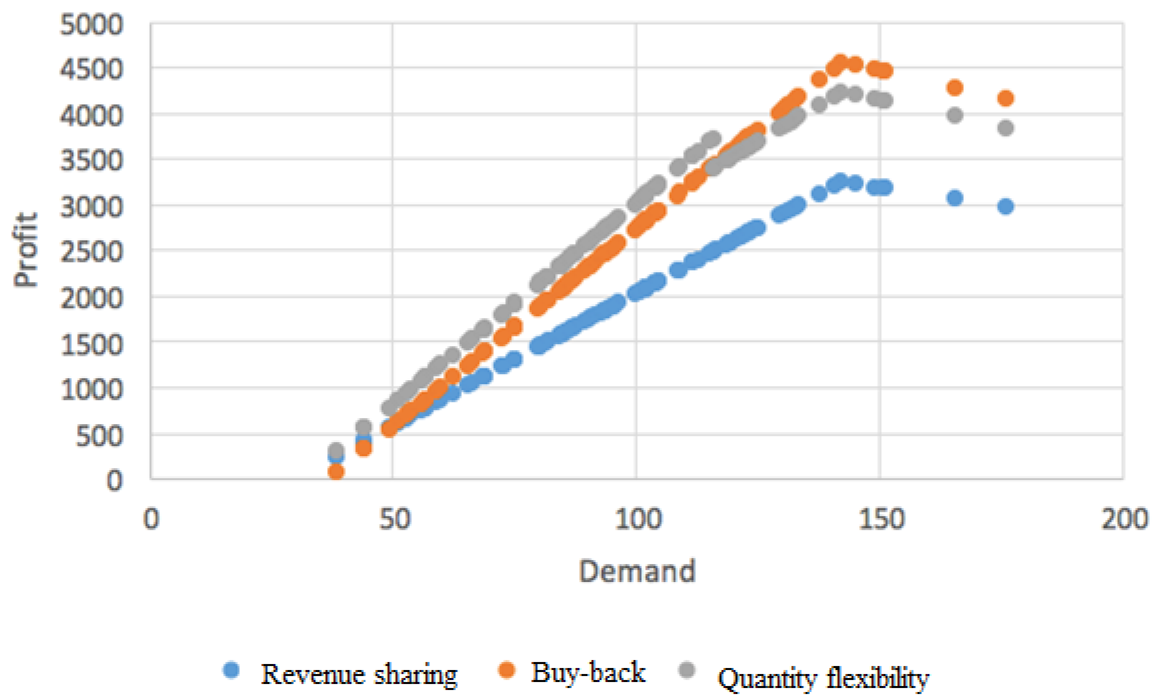

Figure 5: Profit of the retailer under a stochastic demand

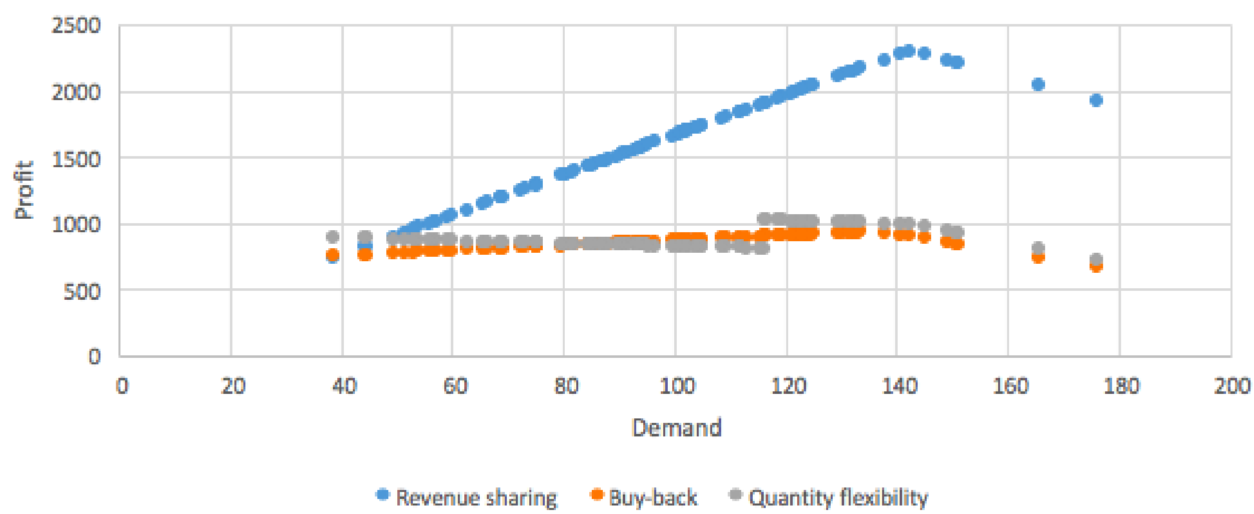

Figure 6: Profit of the supplier under a stochastic demand

Table 7: Profit outcomes under a stochastic demand

Stochastic	Revenue-sharing	Buy-back	Quantity

Demand			Flexibility
Retailer's profit	1945.13	2615.07	2751.36
Supplier's profit	1619.78	855.93	884.47
Total Supply Chain	3564.91	3471.00	3635.83

In the case of the stochastic demand, the quantity flexibility contract achieves the best outcome. This occurs due to the agreements settings in comparison to the other two contracts. The revenue-sharing agreement and the buy-back contracts may have a lower outcome compared to the quantity flexibility contract due to the high marginal costs incurred for both the vendor and the retailer and due to the higher leftover inventory in the retailer's case. The Buy-back contract achieves the lowest outcome out of the three due to the return costs considered in the contract.

5.2 The influence of the performance measures

In order to comprehend the influence of the coordination mechanisms on the supply chain, we need to review the implications of the performance methods. Profit functions are offered in comparison to the non-coordinated case, under an O2O model and under a stochastic demand.

Assessment of the performance measures under a deterministic O2O demand:

The results represented in Figure 7 and Figure 8 present the influence of the performance measures based on the calculations obtained from Table 8.

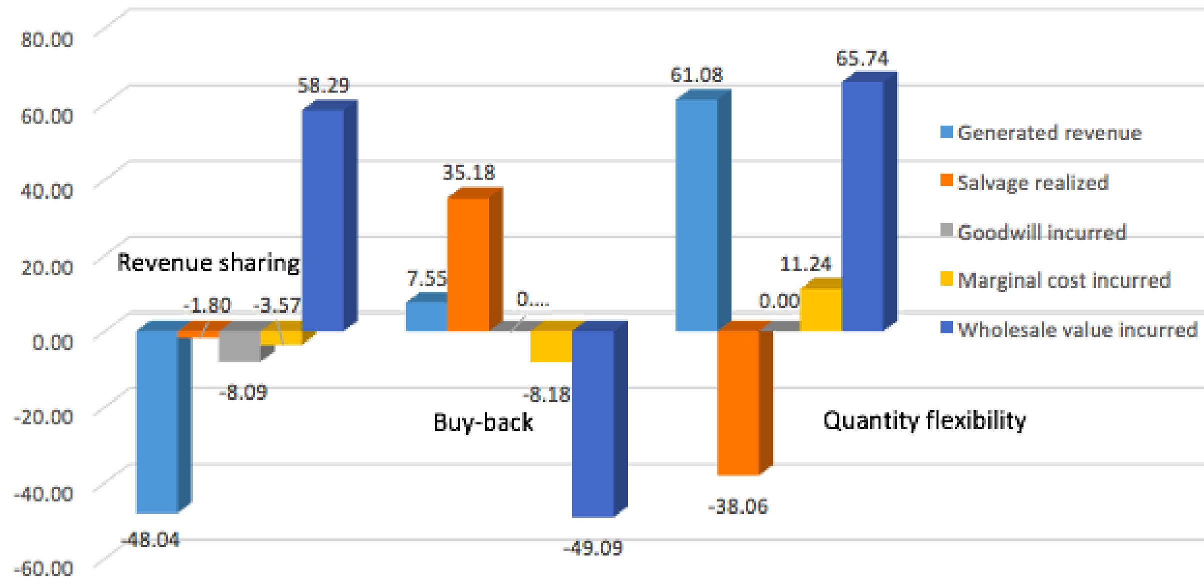

Figure 7: Assessment of the retailer's performance measures under a deterministic demand

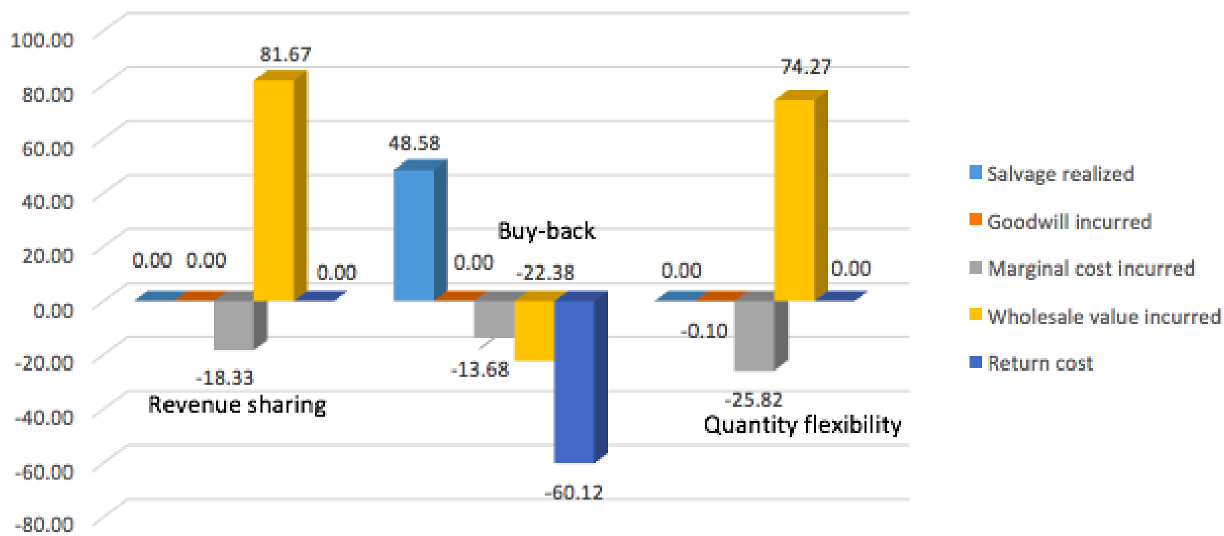

Figure 8: Assessment of the supplier's performance measures under a deterministic demand

Table 8: Performance measures under a deterministic demand - Online

Performance Measures
Deterministic Demand
Online

Retailer	Non-coordination	Revenue-sharing	Buy-back	Quantity Flexibility
Generated Revenue	2968.75	3017.11	3017.11	3388.93

Salvage realized	522.22	981.80	756.90	189.40
Goodwill incurred	0.00	0.00	0.00	0.00
Marginal cost incurred	363.57	421.94	421.94	252.32
Wholesale value incurred	2181.40	1265.83	2531.66	1534.29
Leftover inventory	58.02	76.45	76.45	21.04
Units short	0.00	0.00	0.00	0.25
Average sale	63.16	64.19	64.19	64.19
Supplier				
Salvage realized	0.00	0.00	611.63	0.00
Goodwill incurred	0.00	0.00	0.00	1.77
Marginal cost incurred	1333.08	1547.13	1547.13	937.62
Wholesale value incurred	2181.40	1265.83	2531.66	937.62
Return cost	0.00	0.00	756.90	0.00
Inventory level	0.00	0.00	76.45	20.17
Units short	0.00	0.00	0.00	0.25
Average sale	121.19	140.65	64.19	85.24

Retailer	Revenue-Sharing	Contribution (%)	Buy-back	Contribution (%)	Quantity flexibility	Contribution (%)
Generated Revenue	-1535.03	-48.04	105.13	7.55	731.57	61.08
Salvage realized	-57.57	-1.80	490.00	35.18	-455.81	-38.06
Goodwill incurred	-258.48	-8.09	0.00	0.00	0.00	0.00
Marginal cost incurred	-113.97	-3.57	-113.97	-8.18	134.62	11.24
Wholesale value incurred	1862.53	58.29	-683.83	-49.09	787.34	65.74
Total gain	1546.48	48.40	595.13	42.73	275.76	23.02
Total loss	-1649.01	-51.60	-797.80	-57.27	921.96	76.98
Total	3195.49	100.00	1392.93	100.00	1197.72	100.00
Supplier						
Salvage realized	0.00	0.00	1484.34	48.58	0.00	0.00
Goodwill incurred	0.00	0.00	0.00	0.00	-1.77	-0.10

Marginal cost incurred	-417.89	-18.33	-417.89	-13.68	-481.15	-25.82
Wholesale value incurred	1862.53	81.67	-683.83	-22.38	1384.01	74.27
Return cost	0.00	0.00	-1836.87	-60.12	0.00	0.00
Total gain	1862.53	81.67	800.51	26.20	1382.24	74.18
Total loss	-417.89	-18.33	-2254.77	-73.80	-481.15	-25.82
Total	2280.42	100.00	3055.28	100.00	1863.39	100.00

In the retailer's case, the quantity flexibility agreement achieves the best performance among the three contracts. This result arises from a surge in the generated revenue.

The buy-back agreement achieves less than the former, but still performs considerably better than the revenue-sharing agreement. This result transpires due to the increase in revenue and, most importantly, due to the salvage realized.

The quantity flexibility contract presents the best outcomes on the supplier's side as well, proving that it generates the best performance for the entire supply chain. It can be observed that the wholesale value incurred covers the marginal cost by a high margin. The revenue-sharing contract outperforms the buy-back contract due to its main advantage. The retailer is bound by the contract to share a fraction of the revenue with the supplier.

A balance between supply and demand can be achieved and still be profitable for both parties.

Assessment of the performance measures under a stochastic demand:

Figure 9 and Figure 10 depicts the influence of the performance measures, and the utilized performance measures can be seen in Table 9.

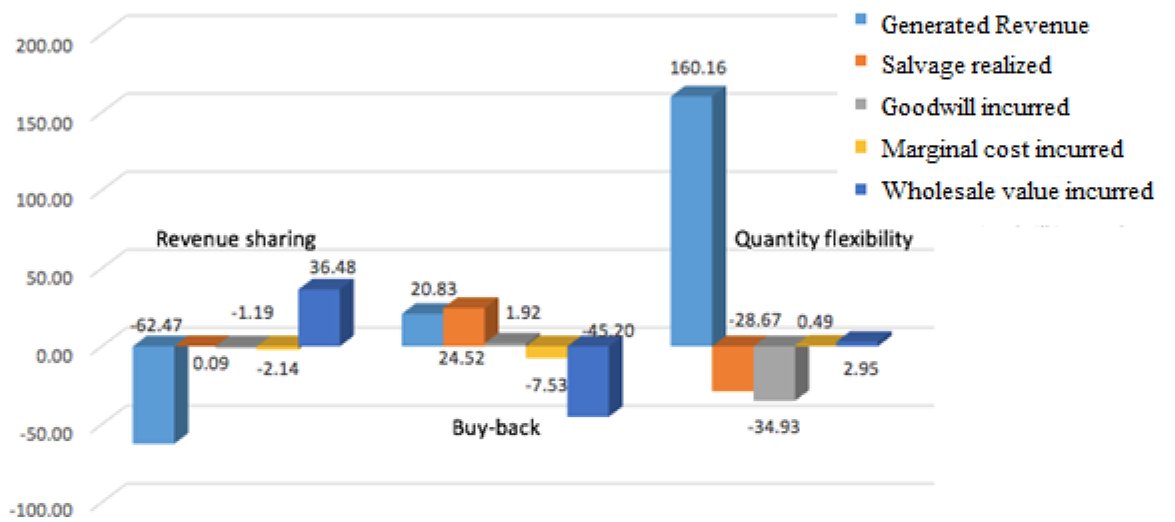

Figure 9: Assessment of the retailer's performance measures under a stochastic demand

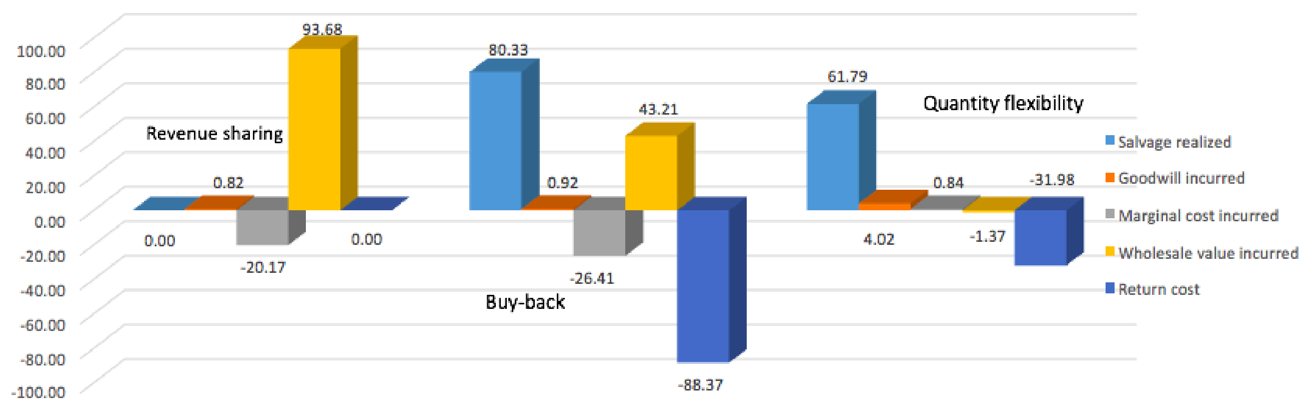

Figure 10: Assessment of the supplier's performance measures under a stochastic demand

Table 9: Performance measures under a stochastic demand

Performance Measures
Deterministic Demand

Offline				
Retailer	Non-coordination	Revenue-sharing	Buy-back	Quantity Flexibility
Generated Revenue	1702.42	1759.18	1759.18	2013.81
Salvage realized	824.65	981.80	1079.98	701.66
Goodwill incurred	0.00	393.66	0.00	0.00
Marginal cost incurred	371.25	426.84	426.84	347.88
Wholesale value incurred	2227.48	1280.53	2561.05	2087.26
Leftover inventory	91.63	109.09	109.09	82.77
Units short	0.00	32.80	0.00	0.00
Average sale	32.12	33.19	33.19	33.19
Supplier				
Salvage realized	0	0	872.71	0
Goodwill incurred	0	0	0.00	0
Marginal cost incurred	1361.24	1565.09	1565.09	1275.55
Wholesale value incurred	2227.48	1280.53	2561.05	2087.26
Return cost	0.00	0.00	1079.98	0.00
Inventory level	0.00	0.00	109.09	82.77
Units short	0.00	0.00	0.00	0.00
Average sale	123.75	142.28	33.19	115.96

Retailer	Revenue-sharing	Contribution (%)	Buy-back	Contribution (%)	Quantity flexibility	Contribution (%)
Generated Revenue	-1621.70	-62.47	153.74	20.83	153.74	160.16
Salvage realized	2.44	0.09	180.93	24.52	-27.52	-28.67
Goodwill incurred	-30.87	-1.19	14.19	1.92	-33.53	-34.93
Marginal cost incurred	-55.59	-2.14	-55.59	-7.53	0.47	0.49
Wholesale value incurred	946.96	36.48	-333.57	-45.20	2.83	2.95
Total gain	918.53	35.38	348.86	47.27	92.69	96.56
Total loss	-1677.29	-64.62	-389.16	-52.73	3.30	3.44
Total	2595.82	100.00	738.02	100.00	95.99	100.00
Supplier						
Salvage	0.00	0.00	402.56	80.33	127.20	61.79

realized						
Goodwill incurred	8.28	0.82	4.61	0.92	8.28	4.02
Marginal cost incurred	-203.85	-20.17	-132.33	-26.41	1.73	0.84
Wholesale value incurred	946.96	93.68	216.54	43.21	-2.83	-1.37
Return cost	0.00	0.00	-442.82	-88.37	-65.83	-31.98
Total gain	955.23	93.68	274.85	54.85	137.21	66.65
Total loss	-55.59	-18.33	-226.28	-45.15	-68.65	-33.35
Total	1010.83	-20.17	501.13	100.00	205.86	100.00

In the model developed under a stochastic demand, the retailer gains the same revenue for both the buy-back and quantity flexibility contracts. The buy-back contract has a considerable amount of salvage realized, so the quantity flexibility contract manages to outdo the former. The buy-back agreement (which is influenced by the salvage realized) presents better outcomes compared to the revenue-sharing contract.

In the vendor's case, the revenue-sharing agreement is at an advantage due to the shared fraction of the retailer's revenue; it reaches an increase of 93.7% while covering the marginal cost, and it is followed, respectively, by the quantity flexibility agreement and the buy-back contract.

As seen from the presented literature review, the O2O framework can be used in a variety of domains. Although this model is still near the beginning of its life cycle, the few papers related to this topic cover a vast area. For example, it can be applied in marketing departments because it can complement certain strategies regarding the clientele and acquire information about the customer's behavior via the online channel. Another promising domain is the development of agriculture under E-commerce in certain regions of China. An interesting approach is the application of personal carbon fees under an O2O model with the use of RFID technology. Furthermore, the topic is spreading to the retailer sectors as well; companies such as Bloomingdales, Barnes & Noble, Estée Lauder, and Nike are starting to implement the discussed model (Huang & Swaminathan 2009; Xiao & Shi 2016). While the

O2O framework is constantly being developed for a variety of applications, there is still a need for further research on this matter.

6. Managerial Implications

The scientific world has just started to become familiar with the O2O approach. The relevant articles regarding this topic have demonstrated so far that this method can be used in a variety of fields. However, the scientific world should consider potential theoretical approaches as well. Future research should be made upon the O2O structure with the involvement of the Stackelberg game to create a comparison between multiple coordination mechanisms. Presently, the vast majority of industries rely heavily on online services. This system brings a number of advantages, especially for major retail stores, but, at the same time, there are disadvantages for the other parties. Small- and medium-sized businesses are struggling to implement the O2O approach effectively. The main issues with small- and medium-sized businesses are that retailers are not able to fully comprehend if the marketing strategies are entirely effective for their policies. These matters are being evaluated by new technology companies which assist their customers with new and advanced tools regarding the implementation of O2O.

One of these approaches is provided by a company called Octalytics. The sole purpose of the company is to offer a cost-effective marketing strategy that manages to track the customer's behavior online as well as offline. Although the concept is formed for small and medium companies, major businesses could also benefit from such a strategy.

Creating an effective strategy could also increase competition among advertising companies. Start-ups are eager to create new and innovative strategies to implement the O2O approach effectively. Major companies have to adapt to these changes in order to keep up with their new competitors. In order to create an efficient and effective business environment as well as to ensure a correct implementation of the O2O model, companies must be able to adapt to the new concept surrounding this idea. As a new strategy, O2O could be adapted to fit a variety of fields from major retailer companies to small- and medium-sized companies.

7. Conclusion

Due to the vast speed at which technology is evolving, the scientific world has to adapt and adjust the well-known classic frameworks such as the coordination mechanism investigated in this study. One focus of this study is to fill the gap missing in the literature review and to answer the research questions presented earlier.

We first compare the three coordination mechanisms (revenue-sharing, buy-back and quantity flexibility contracts) under an O2O model constructed on a deterministic demand as seen in Chen et al. (2015). We also compare the three mentioned contracts calculated on the basis of the stochastic demand as defined by Govindan et al. (2012) and on the non-coordinated supply chain under two types of demand considered for the numerical example. Furthermore, this work focuses on how the coordination mechanisms react in comparison to the non-coordinated case under the O2O deterministic demand and the stochastic demand. The performance measures proposed by Govindan et al. (2012) form the basis of this section. The research questions have been answered with the help of the numerical examples computed in Excel. Under a non-coordinated case, the profit function of the entire channel achieves the best outcome under the O2O deterministic demand.

Based on the O2O framework under a deterministic demand, the highest profit is obtained by the quantity flexibility contract, followed by the buy-back and lastly the revenue-sharing agreement. However, in the case involving the deterministic demand, the quantity flexibility agreement gains the best outcome for the entire supply chain and the buy-back contract is surpassed by the revenue-sharing agreement. The same result is obtained for the performance measures under an O2O structure. However, under a stochastic demand, the revenue-sharing agreement presents an advantage for the supplier. Our overall analysis of the profit functions and the performance measures introduces a new approach regarding the present literature review. However, future research should consider a comparison between several coordination mechanisms which take into consideration the Stackelberg game as a basis for the models and a multi-echelon supply chain. The same model setup can be extended by considering environmental and sustainability aspects (Kannan, 2018).

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