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Coordination of promotional effort, corporate social responsibility and periodic review replenishment decisions in a two-echelon socially responsible supply chain

Seyyed-Mahdi Hosseini-Motlagh[1*], Mina Nouri[1], Parvin Pazari[1]

[1]*School of Industrial Engineering, Iran University of Science and Technology, Tehran, Iran*

motlagh@iust.ac.ir, p_pazari@ind.iust.ac.ir, mina_nouri@ind.iust.ac.ir

Abstract

In this paper, we explore the issue of coordination in a manufacturer-retailer supply chain where the manufacturer is socially responsible and invests in CSR activities. On the other hand, the retailer invests in promotional efforts and uses a periodic review order-up-to policy for replenishing items. First, the decentralized decision-making structure is modeled to calculate the minimum acceptable level for the members profit to accept coordination. Then, the centralized structure is formulated to obtain the benchmark solutions for the whole supply chain profitability. Afterwards, a cost-sharing (CS) contract is proposed to persuade the members to accept the centralized decision-making structure and to follow the benchmark solutions. The results of the sensitivity analyses demonstrated that the proposed coordination model is beneficial from three aspects, i. e. economic, environmental and social viewpoint, compared to the decentralized model. Furthermore, some outstanding managerial insights are provided which further illustrates the applicability of the proposed model.
Keywords: Supply chain coordination, corporate social responsibility, promotional efforts, periodic review order-up-to policy, cost-sharing contract

1- Introduction

In every supply chain, product demand is of paramount importance to the members of the chain and each member can have a significant role in increasing demand. Promotional efforts such as giving free gifts, advertising, in-store activities and so forth, which can be done by a retailer or a manufacturer, can be an example of the members' activities in enhancing demand. Creating a competitive advantage for the final product is one of the main objectives of supply chains (Beheshtinia et al. 2017a). By means of promotional efforts, the retailer can introduce the quality and services of the products that make it attract new customers or remind the previous customers. Moreover, a manufacturer's investment in corporate social responsibility can be pointed out as another way for increasing demand. Investing in social responsibilities can enhance companies' reputation and customer's fidelity to the company and thus can boost the company's market share. Either the promotional efforts, or the corporate social responsibility done by a supply chain member, impacts on the other member's profitability.

*Corresponding author
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Besides, the retailer’s decisions on its inventory replenishment system have a direct impact on supply chain stock-outs and lost sales. Thus, inappropriate decisions made by a supply chain member may have negative impact on the other members’ profitability. In traditional business environment, each SC member makes its decisions independently and aims to maximize its own profit without considering other members profitability. However, there are much interdependencies between members’ such decisions as promotional efforts, corporate social responsibility level and replenishment decisions and the members profitability. Therefore, it is of great significance to design a coordination plan which could provide enough incentives for the members to make such decisions, i. e., level of *promotional efforts*, *corporate social responsibility level* and *replenishment* decisions, under integrated decision-making structure.

Corporate Social Responsibility (CSR) is a way for promoting social and environmental superintendence by organizations. A definition of CSR is provided by (Van Marrewijk, 2003) as company’s voluntary activities that incorporate social and environmental concerns into their business performance and their communications with the shareholders. The corporations can absorb consumers' and clients' choices by demonstrating their responsibilities to a larger group of stakeholders, i. e. company’s staff, consumers, communities, etc. (Modak et al., 2014). In recent century, corporate social responsibility has become very important for many international companies because the social and environmental effects of industrial activities in supply chains are realized by the companies. Many prominent international brands, such as Nike, Walmart, Adidas and Gap have become interested to insert CSR in their supply chains (Modak et al., 2014). Nike Inc., follows environmental and social targets through sustainable innovations. For instance, the company has collected three billion plastic bottles since 2010 and has converted them into recycled polyester for some of its products. It also uses innovative technologies which reduce the waste and the amount of water consumed during the production process. Microsoft Corporation provides annual reports on corporate social responsibility. In its 2017 CSR report, the company claims that its business operation shows its commitment to impact positively on the world’s communities. They aim to build customer trust through commitment to some principles such as respecting to human rights, making privacy and data security and responsible sourcing. They also try to better leverage new technologies to transform the use of the world’s natural resources. In addition to CSR, *promotional effort* can help the corporations to increase their sales, because advertising further builds the brand’s image and attracts customers (Song et al., 2017). There are several ways to advertise. For example, making shelf space for particular items by A&F Clothiers to make the item be available for a longer period; the free trials which is often offered for some specific foods by Wal-Mart and Target to stimulate demand (Tsao and Sheen, 2012), could be named as kinds of promotional efforts. Such efforts made by an SC member impacts on the sales volume of the whole supply chain which in turn impacts on the other members’ profitability. Thus, it is worth finding the optimal level of efforts which is beneficial for all SC members.

Whenever managing supply chains with stochastic demand, there are two approaches for reviewing the inventory: continuous review and periodic review (Eynan and Kropp, 2007). The periodic review inventory models are more applicable in managing stock-outs and lost sales since higher level for the safety stock is considered in these models (Tagaras and Vlachos, 2014). However, if the retailer’s decision on the safety stock or more generally the retailer’s replenishment decisions are not coordinated, the understocking of the inventories not only will incur a loss for the retailer, but also will negatively impact on the profitability of the other supply chain members. On the other hand, overstocking causes a loss for the retailer. Thus, coordinating replenishment decisions in which all members’ profitability is considered will be of great importance.

The remainder of the paper is structured as follows. In the next section, the related literature is reviewed and the contributions of the paper are highlighted. In section 3, a complete description of the model is represented and the notations are introduced. In section 4, mathematical formulation and solution procedures under different structures are developed. In section 5, numerical experiments and sensitivity analyses are conducted and are discussed. Finally, section 6 represents the conclusion of the study and proposes future research.

2-Literature review

There are many studies about coordination in supply chain context. They assert that the benefit of applying supply chain coordination is much more than that of the decentralized conditions. A supply chain is a network composed of various enterprises and consequently coordination of those is of high importance (Beheshtinia and Nemati-Abozar, 2017b). In this regard, various coordination mechanisms as incentives for members to participate in the coordination model are developed in the coordination literature. One of the most widely used contracts is quantity discounts. Li and Liu (2006) studied coordination of ordering decisions in a two-echelon supply chain using quantity discount. Heydari and Norouzinasab (2015) used quantity discounts to coordinate pricing and ordering decisions in a supplier-retailer chain. In another study, Heydari and Norouzinasab (2016) investigated coordination of pricing, lead-time and replenishment decisions by applying wholesale price discount. Nie and Du (2017) coordinated a dual fairness supplier-retailer chain by using a combined contract of quantity discounts and fixed fees. Another contract which is applicable in practice and has gained attention by the researchers is delay in payments. Chaharsooghi and Heydari (2010) studied coordination of reorder point and order quantity decisions in a two-tier supply chain using credit period. Duan et al. (2012) investigated coordination policy in a supply chain with fixed lifetime products. They used delay in payments for coordination purpose. Gao et al. (2014) proposed a delay in payment contract for coordinating periodic review replenishment decisions in a supplier-retailer chain. Heydari (2015) considered a two-echelon supply chain in which the upstream member applies delay in payments contract to change the downstream member’s decision on reorder point and ordering quantity. Aljazzar et al. (2017) studied coordination in a three-layer supply chain and showed that delay in payments along with price discounts can effectively coordinate the SC. Heydari et al. (2017) applied delay in payments contract to achieve coordination of ordering and marketing decisions in a decentralized SC. Another contract which is used in the coordination literature, is buyback contract. Wu (2013) examined buyback strategy for achieving coordination for two competing supply chains. Zhang et al. (2014) proposed a two-level buyback policy to coordinate ordering decisions in news-vendor setting. Heydari et al. (2017) investigated coordination of ordering decisions and the rate of refund guarantee service in a supplier-retailer SC where the supplier offers buyback contract to the retailer. Some other studies have applied sales rebate for coordination purpose. For instance, Wong et al. (2009) applied sales rebate contract for coordinating a competitive supply chain. Chiu et al. (2011) demonstrated that target sales rebate contract can achieve coordination in a SC where the retailer is considered to be risk-averse. Heydari and Asl-Najafi (2016) proposed a sales rebate contract for coordinating a two-echelon SC and developed a new approach for calculating the contract parameters, i. e. target level and amount of rebate.

Despite the great significance of CSR activities from both theoretical and practical viewpoints, few studies have considered CSR in the supply chain coordination literature (Nematollahi et al., 2017a). a category of coordination papers pay attention to pricing decisions (Ye, 2016; Chakraborty, 2016; Zhang and Wang, 2018), some others study ordering decisions (Hu and Feng, 2017; Hu, 3013; Chen and Xiao, 2011) or study quality decisions (Wang and Shin, 2015 ; Mai, 2017), some of them check out promotional efforts (Ma et al., 2013; Pal et al., 2015; Bai et al., 2015 and 2016) and a few of them consider corporate social responsibility in their studies as in (Hseuh 2014; Nematollahi et al., 2017a and 2018). Ni et al. (2010) considered CSR in a two-echelon supply chain where the upstream member invests in the improvement of social responsibilities and shares its cost with the downstream member through the wholesale price. In this study, CSR investment is optimized by utilized game theory approach. Brand and Grothe (2013) tried to extend Goering’s work (2012) which was a study on a bilateral monopoly with channel coordination to investigate the effects of corporate social responsibility. They extend this analysis into a supply chain where both firms were socially concerned. Panda (2014) explored CSR activities of both SC members in coordinating a manufacturer–retailer chain. The channel was coordinated by revenue sharing contract and channel conflict was resolved by the retailer’s motivation for perfect welfare maximizing. Modak et al. (2014) studied a dual-channel supply chain model where the manufacturer wants to increase stakeholders' welfare by showing CSR. The SC is coordinated by applying all unit quantity discounts with a franchise fee and excess profit division. Hsueh (2014) aimed to incorporate CSR into supply chain coordination in a two-tier supply chain. The paper introduced a new revenue sharing contract which required the manufacturer to invest in CSR. Panda and Modak (2016) considered coordination of a three-echelon supply chain where the manufacturer exhibited CSR and a contract-bargaining strategy was proposed for coordination between members and for dividing profit. Nematollahi et al. (2017a) investigated a two-level supply chain and determined optimal order quantity and CSR investment. They showed that CSR performance level will be better through the collaborative model than other decision-making structures**.** Most of the abovementioned papers have considered the effect of CSR in the form of consumer surplus. Taking a different viewpoint, some have modeled CSR by considering the effect of investment in CSR directly on supply chain demand function as (Hsueh, 2014; Nematollahi et al., 2017a).

Research in the supply chain coordination literature has studied promotional efforts under different supply chain settings. Tsao and Sheen (2012) studied retailers' promotional efforts as well as replenishment decision in a two-echelon competitive supply chain. In their study, coordination is established by promotion cost sharing. Zhang et al. (2013) studied cooperative advertising in a supply chain by considering the effect of advertising on consumers' reference price. They calculated the optimal decisions under Stackelberg game and cooperative game. Zhou et al. (2016) considered a low-carbon manufacturer-retailer supply chain. They examined the capability of the co-op advertising contract and emission reduction cost sharing contracts to achieve coordination. Ebrahimi et al. (2017) coordinated a two-echelon periodic review inventory system under stochastic promotional effort dependent demand using a delay in payment contract. Johari and Hosseini-Motlagh (2018) coordinated cooperative promotional efforts with competing retailers using a promotion cost sharing contract. Song et al. (2017) considered a two-echelon SC with a manufacturer and a retailer and tried to integrate innovation and advertising decisions. The manufacturer pays a part of retailer's advertising cost for cooperation. Bai et al. (2017) investigated coordination in a sustainable supply chain where demand was dependent to promotional effort, product price, and sustainable level. They proposed a revenue-cost-sharing contract for coordination. Most of the above papers have studied cooperative advertising in which the manufacturer shares a part of the retailer's advertising cost. Moreover, they have used cost-sharing contract for coordination purpose.

Periodic review replenishment decisions are widely studied in the inventory management literature. In Eynan and Kropp (2007) paper, a periodic review inventory model is examined under stochastic demand. The cost function is approximated by using a Taylor series in order to obtain the optimal values for cycle length and the safety stock. Berman et al. (2012) considered a supply chain where the distribution centers were assumed to use periodic review inventory policy. They found the optimal value of the review period by using a Lagrangian method. Chang and Chou (2013) used a periodic review policy in a system including a supplier and one or more buyers. They found the optimal value of the time interval between two successive shipments. Zhang and Unnikrishnan (2016) considered a closed loop supply chain and managed the inventory in forward and reverse distribution systems using a periodic review inventory policy and determined the optimal value of the review interval which minimized costs. All of these studies and similar researches in the related literature, have investigated integrated decision-making structures and have neglected supply chain coordination. Nematollahi et al. (2017b) is the first study which has considered supply chain coordination in a periodic review inventory setting. They studied a two-level pharmaceutical supply chain in which the duration of the review period was determined by the pharma-distributor's visit interval. Hojati et al. (2017) coordinated a supplier-retailer chain under periodic review inventory system using a delay in payments contract. Afterwards, Johari et al (2017a) studied coordination of periodic review replenishment decisions in a manufacturer-retailer chain by using quantity discounts. In another study, Johari et al (2017b) proposed a model for simultaneous coordination of pricing and periodic review replenishment decisions. Johari et al. (2017c) coordinated a periodic review inventory system by developing a lead time reduction policy. Recently, Nematollahi et al. (2018) proposed a multi-objective collaboration model to achieve coordination of safety stock and visit interval under periodic review inventory setting.

Based on the above reviewed literature, the main contributions of the current study can be stated as follows: (1) To the best of our knowledge, this is the first study which considers simultaneous coordination of promotional efforts, CSR activities and replenishment decisions, (2) this study, together with Nematollahi et al. (2018) all study corporate social responsibility as well as replenishment decisions in a supply chain with periodic review inventory setting, however, Nematollahi et al. (2018) did not consider promotional efforts decisions which we aim to investigate. Moreover, in their study, CSR is evaluated by means of the firm's service level consideration whereas in the current study we evaluate direct effect of CSR level on the demand function and (3) a cost-sharing (CS) contract is developed to achieve simultaneous coordination of promotional efforts, CSR activities and replenishment decisions.

3- Problem definition

In this paper, we study coordination of a supply chain comprising of one retailer and one manufacturer with one type of product. The retailer applies promotional efforts to boost final demand of the product. On the other hand, the manufacturer is socially responsible and is concerned with social and environmental issues while producing the items. The manufacturer's such concerns, in turn, impacts on the purchasing behavior of the customers. Thus, both the retailer's promotion and the manufacturer's CSR activities are considered as factors affecting demand. In this supply chain, demand is stochastic and it is assumed to follow a normal distribution with a known mean and standard deviation. The retailer uses a periodic review order-up-to policy for replenishing the items. i. e., the inventory level is reviewed at intervals of equal length (T) and at each epoch, an order is placed according to the maximum desirable level for the inventory, (R). The orders are received by the retailer after a constant lead-time L which is deterministic and does not exceed the length of the review period (T). Besides, the manufacturer applies a lot-for-lot policy for replenishing the items with a constant production multiplier n which is deterministic. To be more precise, if the manufacturer receives an order with quantity DT from the retailer, he will produce nDT quantities at each setup process where the production rate (P) is finite. Shortages in the retailer side are considered to be fully backordered and there are no shortages in the manufacturer's end. Overall, in the considered supply chain, the retailer decides on the promotional efforts level, length of the review period and the order-up-to level and the manufacturer decides about the level of CSR activities. The demand function of the product can be represented by: $D = \alpha + \beta\, E + \delta\, S$ where α is the base market demand of the product E is the promotional efforts level and S is the CSR level. Coefficients β and δ represent the effectiveness ratio of promotional efforts and CSR activities on demand, respectively. In fact, δ is the level consumer's sensitivity to CSR issues. The more is δ, the more is consumers' inclinations to buy the product which is produced regarding CSR issues. Coefficient β represents the ratio of the consumers which are affected by promotional efforts. The more isβ, the more is the number of consumers which are effort sensitive. In other words, demand will be changed by promotional efforts and CSR activities in proportion with β andδ. Such demand function is considered in previous studies as (Ma et al., 2013; Bai et al., 2016; Basiri and Heydari, 2017). We aim to evaluate the optimal decisions of the members under different decision-making structures and to investigate the simultaneously effects of the abovementioned decisions on the supply chain performance. To this end, first, we model the decentralized decision-making structure, where each member decides independently without paying attention to the other member's profitability. The decentralized structure is modeled under the Stackelberg game with the retailer as the leader and the manufacturer as the follower of the game. Second, we consider the supply chain as a whole and calculate the optimal values with respect to the whole supply chain viewpoint. The centralized model is profitable for the whole supply chain but it may incur a loss for some members. Thus, to provide enough incentives for the members to make decisions on the promotional efforts, CSR activities and replenishment decisions under the centralized model, a cost-sharing (CS) contract is proposed. Moreover, the applicability of the model is evaluated by numerical examples and by a set of sensitivity analyses conducted in this study.
The notations which are used in this study are introduced in the followings.

Decision variables:

T: Length of the review period

R: Order-up-to-level

E: Promotional efforts level

S: Level of CSR activities

Parameters:

w: Wholesale price offered by the manufacturer

n: Manufacturer's production multiplier, a positive integer, deterministic

c: Production cost per unit for the manufacturer

S_m: Setup cost per setup for the manufacture

P: Production rate per year

r: Products selling price offered by the retailer

A_r: Ordering cost per order for the retailer

h_r: Inventory holding cost per unit for the retailer

h_m: Inventory holding cost per unit for the manufacturer

L : Length of the lead time, deterministic

σ: Standard deviation of the demand per unit time

I : Demand during the protection interval $(\mathrm{T}+\mathrm{L})$ with normal probability distribution function with finite mean $\mathrm{D}(\mathrm{T}+\mathrm{L})$ and standard deviation$\sigma\sqrt{\mathrm{T}+\mathrm{L}}$.

π: Shortages cost for the retailer

β: Promotional efforts elasticity coefficient of demand

δ : CSR activities elasticity coefficient of demand

4- Model formulation and solution procedures

In this section, mathematical models of different decision-making structures, i. e. the decentralized, the centralized and coordinated decision-making structures, are formulated and are solved.

4-1- Decentralized model

In decentralized decision-making model, each member aims to maximize its profit without considering other members' profitability. The retailer decides on promotional effort, review period and order-up-to-level variables. On the other side, the manufacturer decides about the level of CSR activities. Due to the dominant market power of the retailer, the interaction between the supply chain members under the decentralized structure, is modeled under the non-cooperative retailer-Stackelberg game. Accordingly, the retailer as the leader of the game moves first and determines promotional efforts level, review period and order-up-to level. The manufacturer as the follower determines the level of CSR activities with respect to the retailer's decisions. In order to find the equilibrium solution of the game, we use backward induction. i. e., the manufacturer's problem is solved first; with given values of retailer's decision variables. Thus, the primary decision of the manufacturer on CSR level is determined which his best response to the retailer's decision is. Second, the retailer finds the optimal values of his decisions based on the manufacturer's primary decisions. Finally, the manufacturer finds his optimal decision based on the retailer's optimal decisions. In what follows, the retailer-Stackelberg game is modeled and the optimal decisions of the members are calculated under the decentralized model.

4-1-1- Manufacturer model

As mentioned before, the manufacturer applies a lot-for-lot policy for replenishing the items with a constant production multiplier n which is deterministic. The manufacturer's problem under the decentralized model can be formulated as follows in which he decides on the level of CSR activities:

$$\pi_m(\mathrm{S}) = (\mathrm{w} - \mathrm{c})(\alpha + \beta\, E + \delta\, S\,) - \frac{S_m}{nT} - h_m \frac{(\alpha+\beta\, E+\delta\, S\,)T}{2}[\frac{(\alpha+\beta\, E+\delta\, S\,)}{P}(2-n) + (n-1)] - \frac{1}{2}\zeta S^2 \quad (1)$$

In the above equation, the first term is the revenue obtained for the manufacturer from wholesaling the products, the second term is the setup cost for the manufacturer per production run, the third term is the average inventory holding cost for the manufacturer which is calculated based on Joglekar (1988), in which the average inventory is represented by $\{\mathrm{nDT}[\frac{DT}{P} + (n-1)] - \frac{(nDT)^2}{2P} - \frac{D^2T^2}{D}[1 + 2 + \cdots + (n-1)]\}\frac{D}{nDT} = \frac{DT}{2}[\frac{D}{P}(2-n) + (n-1)]$ and the last term represents cost of manufacturer's investment in CSR activities.

The manufacturer's best response as his primary decision, can be obtained by optimizing the above equation with respect to CSR. Thus, we first need to prove the concavity of the manufacturer profit function with respect to CSR.

Proposition1. The manufacturer profit function is concave with respect to S, for a given E, T and K, under the condition $h_m T\delta^2(2-n) + P\zeta \geq 0$.

Proof. Calculating the second order derivative of the manufacturer profit function under the Stackelberg model, we have $\frac{\partial^2 \pi_m}{\partial S^2} = -\frac{h_m T\delta^2(2-n)+P\zeta}{P}$, thus it is concave with respect to S when $h_m T\delta^2(2-n) + P\zeta \geq 0$.

According to proposition 1, the primary value of CSR level, under the Stackelberg game can be obtained by the first order derivative rule, as follows:

$$S^{pr} = \frac{P\left((\mathrm{w}-\mathrm{c})\delta - \frac{\delta\, h_m\, T(\alpha+\beta\, E)}{P}(2-n) - \frac{h_m T\delta}{2}(n-1)\right)}{P\zeta + h_m T\delta^2(2-n)} \quad (2)$$

Now, the retailer determines the optimal value of his decision variables based on the manufacturer's primary response. The retailer model is investigated in the next section.

4-1-2- Retailer model

As mentioned before, the retailer uses a periodic review order-up-to level policy for replenishing the items and decides on length of the review period, the order-up-to level along with the level of promotional efforts. Considering the retailer's revenue and costs, the retailer profit function under the decentralized model can be formulated as follows:

$$\pi_r(\mathrm{E,R,T}) = (\mathrm{r} - \mathrm{w})(\alpha + \beta\, E + \delta S) - \frac{A_r}{T} - h_r\left[R - (\alpha + \beta\, E + \delta\, S)L - \frac{(\alpha+\beta\, E+\delta\, S)T}{2}\right] - \frac{1}{T}\,\pi\ \mathrm{E(I - R)^+} - \frac{1}{2T}\eta E^2 \quad (3)$$

In the above equation, the first term represents the retailer's revenue from selling the products, the second term is the ordering cost per year, the third and the forth terms are the expected holding cost and the expected shortages cost per year, respectively, which are obtained according to (Vijian and Kumaran, 2008) and the last term is cost of retailer's promotional efforts per year as in (Ma et al. 2013). Demand during the protection interval, follows a normal distribution with mean $D(T + L)$ and standard deviation $\sigma\sqrt{T + L}$ to better illustrate the uncertainty of demand. Thus, the order-up-to level which is sum of the protection interval demand and the safety stock is:

$$R = (\alpha + \beta\, E + \delta\, S)(T + L) + K\sigma\sqrt{T + L} \quad (4)$$

where K is the safety factor. An approximation of the expected shortages at the end of each period, $\mathrm{E(I-R)^+}$, is as the following (Ouyang and Chuang, 2000):

$$\mathrm{E(I-R)^+} = \int_R^{\infty}(I-R)f_i\,\mathrm{di} = \sigma\sqrt{T+L}\,\Psi\,(\mathrm{k}) > 0 \quad (5)$$

Where $\Psi\,(\mathrm{k}) = \varphi(\mathrm{k}) - \mathrm{k}[1-\Phi(\mathrm{k})]$ in which $\varphi(\mathrm{k})$ and $\Phi(\mathrm{k})$ are the standard normal probability and distribution functions, respectively.

Since the order-up-to level R is a function of the safety factor K, it could be considered as the retailer's decision variable instead of R. Thus, according to equations (4) and (5), the retailer profit function given by equation (3) can be written as follows:

$$\pi_r(\mathrm{E,K,T}) = (\mathrm{p-w})(\alpha+\beta\,E+\delta S) - \frac{A_r}{T} - h_r\left[\frac{(\alpha+\beta\,E+\delta\,S)T}{2} + K\sigma\sqrt{T+L}\right] - \frac{1}{T}\,\pi\,\sigma\sqrt{T+L}\,\Psi\,(\mathrm{k}) - \frac{1}{2T}\eta E^2 \quad (6)$$

Proposition2. Under the Stackelberg game, the retailer profit function is concave with respect to K and E, for a given T.

Proof. See Appendix A.

Therefore, the optimal values of the retailer decision variables under the Stackelberg game model can be obtained by the first-order derivatives of the retailer profit function with respect to K and E, for a given T:

$$E^* = \frac{BT}{\eta} \quad (7)$$

Where, $B = (r-w)\beta - \frac{h_r\beta T}{2} - \left(\left((\mathrm{r-w})\delta - h_r\frac{\delta T}{2}\right)\left(\frac{\delta h_m T\beta(2-n)}{P\zeta+h_m T\delta^2(2-n)}\right)\right)$.

$$k^* = 1 - \Phi^{-1}\left(\frac{h_r T}{\pi}\right) \quad (8)$$

To obtain the optimal value of the review period T under the decentralized model, the following solution algorithm is proposed:

Step1. Set T to be equal to the lowest possible answer ($T=\varepsilon$).
Step2. Calculate PE^* using equation (7).
Step3. Calculate K^* using equation (8).
Step4. Calculate the retailer profit using equation (6) for the values (PE^*, K^*, T) obtained in steps (2) and (3).
Step5. If $T > \frac{\pi}{h_r}$, stop the procedure; else set $T = T+\varepsilon$ and go to step2.
Step6. The set of values (PE^*, K^*, T) which results in the greatest profit for the retailer will be the optimal values for the retailer's decision variables under the decentralized model.

Since the manufacturer is the follower, by substituting the retailer's optimal decisions into manufacturer primary decision, the optimal value of the manufacturer CSR activities under the Stackelberg game, is:

$$S^* = \frac{P\left[(\mathrm{w-c})\delta - \frac{\delta\,h_m\,T(\alpha\eta+\beta\,BT)}{2P\eta}(2-n) - \frac{h_m T\delta}{2}(n-1)\right]}{P\zeta+h_m T\delta^2(2-n)} \quad (9)$$

The above optimal solutions for the members under the decentralized Stackelberg model are obtained from each member's viewpoint separately and may not lead to the optimal solution for the whole supply chain. Thus, in the next section, the centralized decision-making structure is modeled in which the optimal solutions are obtained from the whole supply chain viewpoint.

4-2- Centralized model

Under the centralized decision-making mode, the manager of the supply chain aims to maximize the entire SC profit. The profit function of the entire SC is equal to the sum of SC members profit functions and can be formulated as:

$$\pi_{sc}^{ce}(E,K,T,S) = \pi_r(\mathrm{E,K,T}) + \pi_m(\mathrm{S}) = (\mathrm{r-c})(\alpha + \beta\, E + \delta S) - \frac{A_r}{T} - h_r\left[\frac{(\alpha+\beta\, E+\delta\, S)T}{2} + K\sigma\sqrt{T+L}\right] - \frac{1}{T}\,\pi\,\sigma\sqrt{T+L}\,\Psi\,(\mathrm{k}) - \frac{1}{2T}\eta E^2 - \frac{S_m}{nT} - h_m\frac{(\alpha+\beta\, E+\delta\, S\,)T}{2}\left[\frac{(\alpha+\beta\, E+\delta\, S\,)}{P}(2-n) + (n-1)\right] - \frac{1}{2}\zeta S^2 \qquad (10)$$

Proposition 3. The centralized supply chain profit function is concave with respect to S, K and E, for a given T under the condition$\left(\frac{h_m\,T\delta^2}{P}(2-n)+\zeta\right)\times\left(\frac{\eta}{T}+\frac{h_mT\beta^2}{P}(2-n)\right)\geq\left(\frac{h_m\,T\delta\beta}{P}(2-n)\right)^2$.

Proof. See Appendix B.

Therefore, the optimal values of S, K and E, for a given T, can be obtained by taking the first-order derivatives of the supply chain profit function with respect to these decisions, as follows:

$$\frac{\pi_{sc}^{ce}(\mathrm{S,K,E})}{\partial \mathrm{S}} = 0$$

$$(\mathrm{r-c})\delta - \frac{h_r\delta T}{2} - \zeta S - h_m\frac{(\alpha+\beta\, E+\delta\, S\,)(2-n)\delta T}{P} - h_m\frac{\delta T(n-1)}{2} = 0 \qquad (11)$$

$$\frac{\pi_{sc}^{ce}(\mathrm{S,K,E})}{\partial \mathrm{E}} = 0$$

$$(\mathrm{r-c})\beta - \frac{h_r\beta T}{2} - \frac{\eta}{T}PE - h_m\frac{(\alpha+\beta\, E+\delta\, S\,)(2-n)\beta T}{P} - h_m\frac{\beta T(n-1)}{2} = 0 \qquad (12)$$

$$\frac{\pi_{sc}^{ce}(\mathrm{S,K,E})}{\partial \mathrm{K}} = 0$$

$$-h_r\sigma\sqrt{T+L} - \frac{1}{T}\,\pi\,\sigma\sqrt{T+L}(\Phi(\mathrm{K})-1) = 0 \qquad (13)$$

Solving the above equations simultaneously, results in the following optimal solutions for K, E and S, respectively, for a given T.

$$K^{**} = \Phi^{-1}\left(1-\frac{h_rT}{\pi}\right), \qquad (14)$$

$$E^{**} = \frac{(\mathrm{r-c})\beta - \frac{h_r\beta T}{2} - h_m\frac{(\alpha+\delta F_1\,)(2-n)\beta T}{P} - h_m\frac{\beta T(n-1)}{2}}{\frac{\eta}{T} + h_m\frac{\beta^2 T(2-n)}{P} + \frac{(\,h_m(2-n)\beta\delta T)^2}{P^2\zeta + P\,h_m\delta^2 T(2-n)}} \qquad (15)$$

$$S^{**} = \frac{(\mathrm{r-c})\delta - \frac{h_r\delta T}{2} - h_m\frac{(\alpha+\beta F_2\,)(2-n)\delta T}{P} - h_m\frac{\delta T(n-1)}{2}}{\zeta + h_m\frac{\delta^2 T(2-n)}{P} + \frac{(\,h_m(2-n)\beta\delta T)^2}{P^2\frac{\eta}{T} + P\,h_m\beta^2 T(2-n)}} \qquad (16)$$

where $F_1 = \frac{(\mathrm{r-c})\delta - \frac{h_r\delta T}{2} - h_m\frac{\alpha(2-n)\delta T}{P} - h_m\frac{\delta T(n-1)}{2}}{\zeta + h_m\frac{\delta^2 T(2-n)}{P}}$ and $F_2 = \frac{(\mathrm{r-c})\beta - \frac{h_r\beta T}{2} - h_m\frac{\alpha(2-n)\beta T}{P} - h_m\frac{\beta T(n-1)}{2}}{\frac{\eta}{T} + h_m\frac{\beta^2 T(2-n)}{P}}$.

To obtain the optimal value of the review period T under the centralized decision-making mode, the following solution algorithm is proposed similar to (Nematollahi et al., 2017b):

Step1. Set T to be equal to the lowest possible answer ($T = \varepsilon$).
Step2. Calculate K^{**} using equation (14).
Step3. Calculate E^{**} using equation (15).
Step4. Calculate S^{**} using equation (16).
Step5. Calculate the whole supply chain profit using equation (10) for the values ($E^{**}, K^{**}, T, S^{**}$) obtained in steps (2), (3) and (4).
Step6. If $T > \frac{\pi}{h_r}$, stop the procedure; else set $T = T + \varepsilon$ and go to step2.

Step7. The set of values $(E^{**}, K^{**}, T, S^{**})$ which results in the greatest supply chain profit will be the optimal values for decision variables under the centralized model.

The optimal solutions obtained under the centralized decision-making model, lead to the optimal performance for the whole supply chain but does not guarantee each member's profitability. Thus, the member who encounters profit loss under the centralized model does not accept the integrated decision-making. On the other hand, decisions made by members, impact the other member's profitability. Therefore, it is important to design a coordination plan to provide enough incentives for all supply chain members to accept integrated decision-making. In the next section, a coordination plan named a cost-sharing contract is developed.

4-3- Coordination model

For establishing any coordination, the model must be desirable for all supply chain members. Actually, the benefit of SC members under coordination model must be more than that under the decentralized conditions. We follow this aim by applying a cost sharing (CS) contract. In this contract, based on different scenarios which may occur for the supply chain members, the retailer shares γ_1 proportion of the manufacturer's CSR activities related costs and the manufacturer shares γ_2 proportion of the retailer's promotional efforts cost, as well. By doing so, the supply chain members can benefit from the reduction in their costs and therefore they will accept the integrated decisions on promotional efforts, level of CSR activities, review period and order-up-to-level. Accordingly, the retailer and the manufacturer profit functions under the coordination model can be represented by the following equations, respectively.

$$\pi_r^{co} = (\mathrm{r}-\mathrm{w})(\alpha+\beta E+\delta S) - \frac{A_r}{T} - h_r\left[\frac{(\alpha+\beta E+\delta S)T}{2} + K\sigma\sqrt{T+L}\right] - \frac{1}{T}\,\pi\,\sigma\sqrt{T+L}\,\Psi(\mathrm{k}) - (1-\gamma_2)\left(\frac{1}{2T}\eta E^2\right) - \gamma_1\left(\frac{1}{2}\zeta S^2\right) \quad (17)$$

$$\pi_m^{co} = (\mathrm{w}-\mathrm{c})(\alpha+\beta E+\delta S) - \frac{S_m}{nT} - h_m\frac{(\alpha+\beta E+\delta S)T}{2}\left[\frac{(\alpha+\beta E+\delta S)}{P}(2-n)+(n-1)\right] - (1-\gamma_1)\left(\frac{1}{2}\zeta S^2\right) - \gamma_2\left(\frac{1}{2T}\eta E^2\right) \quad (18)$$

The optimal level of the retailer's promotional efforts, which maximizes the retailer profit under the coordination contract, is as follows:

$$E^{co} = \frac{\left((r-w)\beta - \frac{h_r\beta T^{co}}{2}\right)T^{co}}{\eta(1-\gamma_2)} \quad (19)$$

Similarly, the optimal level of the manufacturer's CSR activities, which maximizes the manufacturer profit under the coordination contract, can be written as follows:

$$S^{co} = \frac{P\left[(\mathrm{w}-\mathrm{c})\delta - \frac{\delta h_m T^{co}(\alpha+\beta E^{co})}{P}(2-n) - \frac{h_m T^{co}\delta}{2}(n-1)\right]}{P\zeta(1-\gamma_1) + h_m T^{co}\delta^2(2-n)} \quad (20)$$

Since the aim of applying the CS contract in a decentralized supply chain, is to convince the retailer and the manufacturer to opt decisions of the centralized model, the following equalities must be satisfied: $E^{co} = E^{**}$, $T^{co} = T^{**}$, $k^{co} = k^{**}$and $S^{co} = S^{**}$. Accordingly, the exact value of coordination parameters γ_1 and γ_2, which is acceptable to all SC members, can be represented by the following equations.

$$\gamma_1 = 1 - \frac{P\left[(\mathrm{w}-\mathrm{c})\delta - \frac{\delta h_m T^{**}(\alpha+\beta E^{**})}{P}(2-n) - \frac{h_m T^{**}\delta}{2}(n-1)\right] - h_m T^{**}\delta^2(2-n)S^{**}}{P\zeta S^{**}} \tag{21}$$

$$\gamma_2 = 1 - \frac{\left((r-w)\beta - \frac{h_r \beta T^{**}}{2}\right)T^{**}}{\eta E^{**}} \tag{22}$$

By applying the above coordination parameters in the CS contract, the retailer and the manufacturer accept to participate in the integrated decision-making structure. Thus, the maximum profit will be made for the whole supply chain.

5- Numerical experiments and sensitivity analyses

Pharmaceutical supply chains are under pressure of their shareholders to invest in CSR activities since they have a great role in the healthcare system. “Tozi-Pakhsh-Daroo” is a pharmaceutical supply chain which produces drugs and cosmetics and distributes the items through its retailers. The company exhibits CSR by investing in technologies for producing the items, which are less harmful to the environment. To inform the consumers about its CSR activities, the company shares a part of retailer’s promotional efforts for its products. Moreover, it is important for the company to remain credible between the consumers by improving its service level. Since the retailer makes replenishment decisions, the service level provided by the company is affected by these decisions. Thus, the company provides enough incentive for the retailer to change its replenishment decisions towards the decisions which are profitable for the whole supply chain. Tozi-Pakhsh-Daroo considered the integrated decision-making and estimated at least a 10% increase in its profitability rather than the decentralized model. Such results motivated us to investigate coordination of CSR activities, promotional efforts and replenishment decisions in a consumer electronics supply chain where the manufacturing process produces high level of pollution to the environment and the items demand is highly affected by promotional efforts such as advertising. Consider a consumer electronics supply chain comprising of one manufacturer and one retailer. The manufacturer produces home-office printers and sells the items through a retailer which invests in promotional efforts to remain competitive in the market. The manufacturer itself, is a socially responsible firm which tries to produce printers that use less energy and meet the standards of quality. Since the retailer is the dominant power in the market, it acts as the leader and the manufacturer is the follower. Thus, they follow the Stackelberg behavior. For replenishment decisions, the retailer uses a periodic review order-up-to policy and decides on the length of the review period (T) at which he checks the inventory level, and decides on the maximum level which is desirable for the inventory, (R). At each period, he places an order to raise the inventory level up to R. Ordering and holding cost for the retailer are $A_r = 400\$/per\ unit$ and $h_r = 15\$/per\ unit$, respectively. The retailer’s orders are received after a constant lead-time $L = 2days$. Shortages in the retailer side are fully backordered and causes a cost of $\pi = 26\$/per\ unit$. On the other side, the manufacturer replenishes its stock in periods with a length that is a multiplier (n=1) of the retailer’s replenishment cycle. At each setup, the manufacturer produces items with a finite production rate $P = 1100unit$. The production and the setup cost for the manufacturer, are $c = 72\$$ and $S_m = 300\$$, respectively. Holding cost of inventories for the manufacturer is $h_m = 20\$/per\ unit$. The initial market demand for the retailer is $\alpha = 1000/printer$. The selling price for the retailer is $r = 90\$$ which he buys them with a wholesale price of $w = 80\$$. Investing one unit in promotional efforts, causes demand to be increased by a coefficient equal to $\beta = 50$. Each level of promotional efforts, PE, causes a cost with coefficient $\eta = 60$ for the retailer. On the other side, investing one unit in CSR activities by the manufacturer, leads to an increase in demand by coefficient$\delta = 30$. Each level of CSR activities conducted by the manufacturer causes a cost with coefficient $\zeta = 120$ for him. Accordingly, the market demand can be represented by $D = 1000 + 50E + 30S$.

By considering the above values of the model parameters, the performance of the proposed model under different decision-making structures, i. e. the decentralized, centralized and coordinated model, is evaluated. Results of running the model are represented in table (1) in which the optimal decisions of the members and their profitability are discussed and are compared.

Table. 1. Results of running the model under different decision-making structures

Supply chain structure	$T(days)$	K	E	S	π_r	π_m	π_{sc}
Decentralized	67	1.25	1.29	1.08	3628.73	5062.2	8690.93
Centralized	64	1.27	1.90	3.21	4106.56	4932.38	9038.94
Coordinated	64	1.27	1.90	3.21	3886	5152.95	9038.94

As can be seen in table (1), under the centralized model, the retailer should determine shorter periods for reviewing the inventories, hold more amount of safety stock and invest more in promotional efforts, rather than the decentralized model. Similarly, the manufacturer should invest more in CSR activities under the centralized model compared with the decentralized model. Based on the results obtained for the members profit in table (1), the centralized model is not profitable for the manufacturer but it is profitable for the retailer. Thus, the retailer suggests the manufacturer to make an agreement on sharing CSR and promotion costs with a rate of $\gamma_1 = 0.68\%$ and $\gamma_2 = 0.32\%$, respectively. By doing so, both members accept to make the centralized decisions and the supply chain profit reaches its optimal level of the centralized model which is 9038.94$. The total improvement in the demand level under the decentralized model is 9.69% while it is 19.13% under the coordinated model. Despite the more investment in promotion and CSR activities under the coordination model, the retailer and the manufacturer profit are improved by 7.08% and 1.79%, respectively, in comparison with their profit under the decentralized model. The result is outstanding from economic viewpoint. Moreover, investing more in CSR activities by the manufacturer enhances the supply chain credibility among the customers and results in a 9.63% improvement in the demand level. Thus, it is worth saying that the proposed cost-sharing contract is not only beneficial from economic viewpoint, but also is beneficial from social and environmental viewpoints since the manufacturer accepts to invest more in CSR activities.

Furthermore, a set of sensitivity analyses is conducted with respect to some important factors of the model to evaluate the optimal decisions of the supply chain members under different situations and to illustrate the benefits of the proposed model.

Due to the heightened consumer sensitivity to environmental and social issues, investing in CSR can be one of the major factors affecting the consumers' purchasing behavior. Accordingly, we have examined how the company's investment in CSR changes with respect to consumers' sensitivity to CSR activities, in the followings. Figure 1(a) shows the changes in the level of CSR activities with respect to increase in CSR elasticity coefficient of demand, δ, which we have considered as consumer sensitivity to CSR activities. As can be seen in this figure, the more is the consumer sensitivity to CSR activities, the more is the level of CSR, under all decision-making structures. This shows the sensitivity of the manufacturer's CSR activities to consumer's awareness of CSR issue. Moreover, the results show that under the coordination model the manufacturer invests more in CSR rather than the decentralized model. This implies that under the coordination model, more consumers will be satisfied and the credibility of the company will be increased.

Figure 1(b) shows the trends of the manufacturer profit with respect to δ, under different decision-making structures. According to this figure, the manufacturer profit under the coordination model is greater than that under the other decision-making structures while he invests more in CSR activities under the coordination model. In fact, under the centralized model, the manufacturer profit decreases with respect to increase in consumers' sensitivity to CSR. Thus, he does not accept the centralized decision on CSR level while this level of CSR is the optimal level for the whole supply chain profitability. Therefore, the retailer shares a part of the manufacturer cost of investment in CSR and convinces the manufacturer to make the centralized decisions. As can be seen in figure 1(a), the graph of the coordinated model coincides with that of the centralized model which implies that under the coordination model, the manufacturer accepts to make the centralized decisions on CSR.

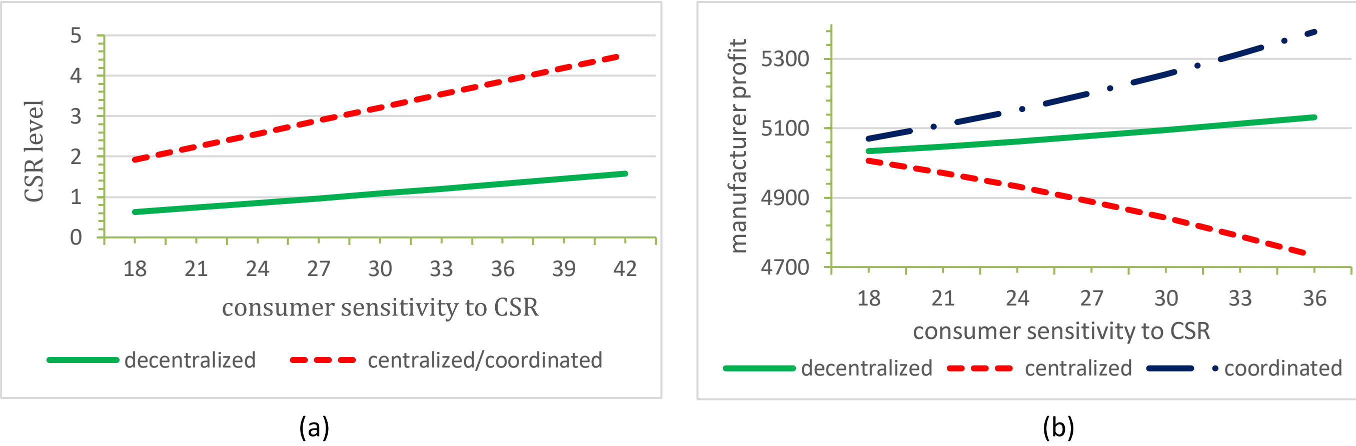

Fig 1. Effects of consumer sensitivity to CSR activities on: (a) The CSR level and (b) the manufacturer profit under different structures

Figure 2(a) examines the effect of consumer sensitivity to CSR activities on the level of promotional efforts. As can be seen, under all the three decision-making structures, the promotional efforts level has a decreasing trend with respect to consumer sensitivity to CSR. However, the retailer invests more in promotional efforts under the coordinated model rather than the decentralized model. Based on this observation, one can conclude that the retailer profit under the coordination model may be less than that under the decentralized model. However, according to figure 2(b), the retailer profit under the coordination model is greater than that under the decentralized model despite the retailer's more investment in promotional efforts under the former. Besides, it is noteworthy that the retailer profit under the centralized model is the greatest but as mentioned above, the centralized model is not acceptable for the manufacturer. Thus, the retailer shares a part of the manufacturer profit to convince him to take part in the coordinated model. By doing so, although under the coordination model the retailer profit may not be equal to that of the centralized model, it is more profitable for him rather than when he makes decisions independently.

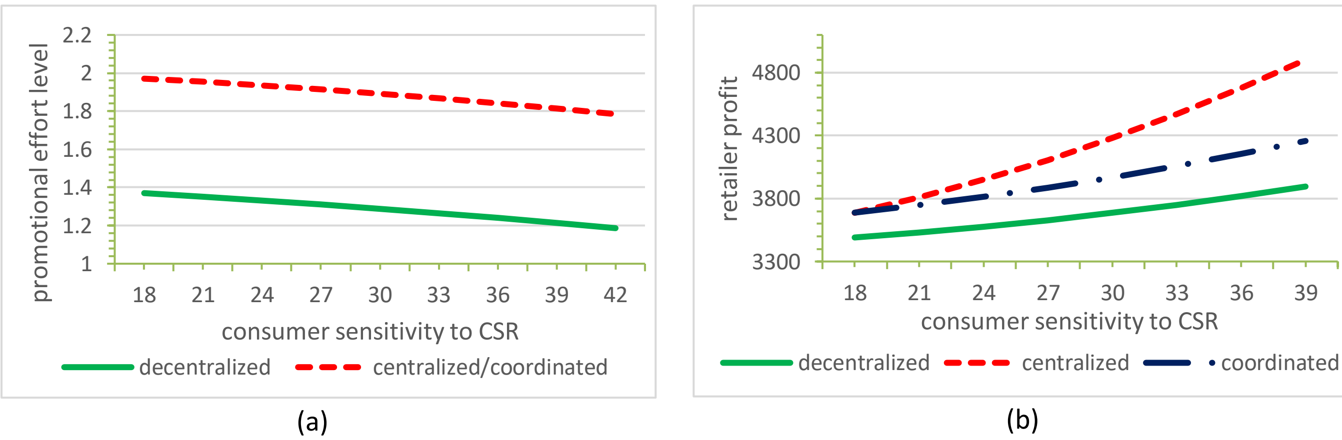

Fig 2. Effect of consumer sensitivity to CSR on: (a) the retailer's promotional effort level and (b) the retailer profit under different structures

Figure (3) demonstrates the trends of the supply chain profitability with respect to CSR elasticity coefficient of demand under different decision-making structures. As can be seen, the supply chain profit increases with respect to the changes in CSR elasticity coefficient of demand, under all structures. Moreover, it is worth saying that the graph of the centralized model coincides with that of the coordination model. This result demonstrates the capability of the proposed coordination model (the cost-sharing contract) which leads the supply chain profit reaches its optimal level i. e., its profit under the centralized model.

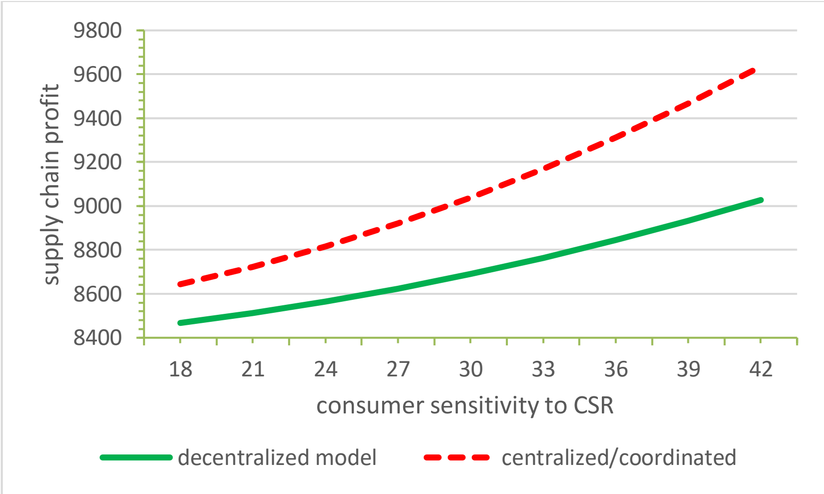

Fig 3. Trends of supply chain profit with respect to CSR elasticity coefficient of demand under different structures

Figure (4) shows the trends of supply chain members' and the whole supply chain profitability under different levels of demand uncertainty. As can be seen, by increasing the uncertainty level, both members' profit as well as the whole supply chain profit follows a decreasing trend. However, the centralized model leads to greater level of profit for the retailer rather than his profit under the other structures. On the other hand, the centralized model makes the manufacturer profit to be less than that under the other structures. Under the coordination model, both members make more profit rather than making decisions independently. In fact, under high levels of demand uncertainty, if the members have participated in the coordination model, they will lose less profit rather than making single decisions under the decentralized model. Accordingly, when facing with demand uncertainty, applying the proposed CS contract leads to more profit for the whole supply chain rather than the decentralized structure.

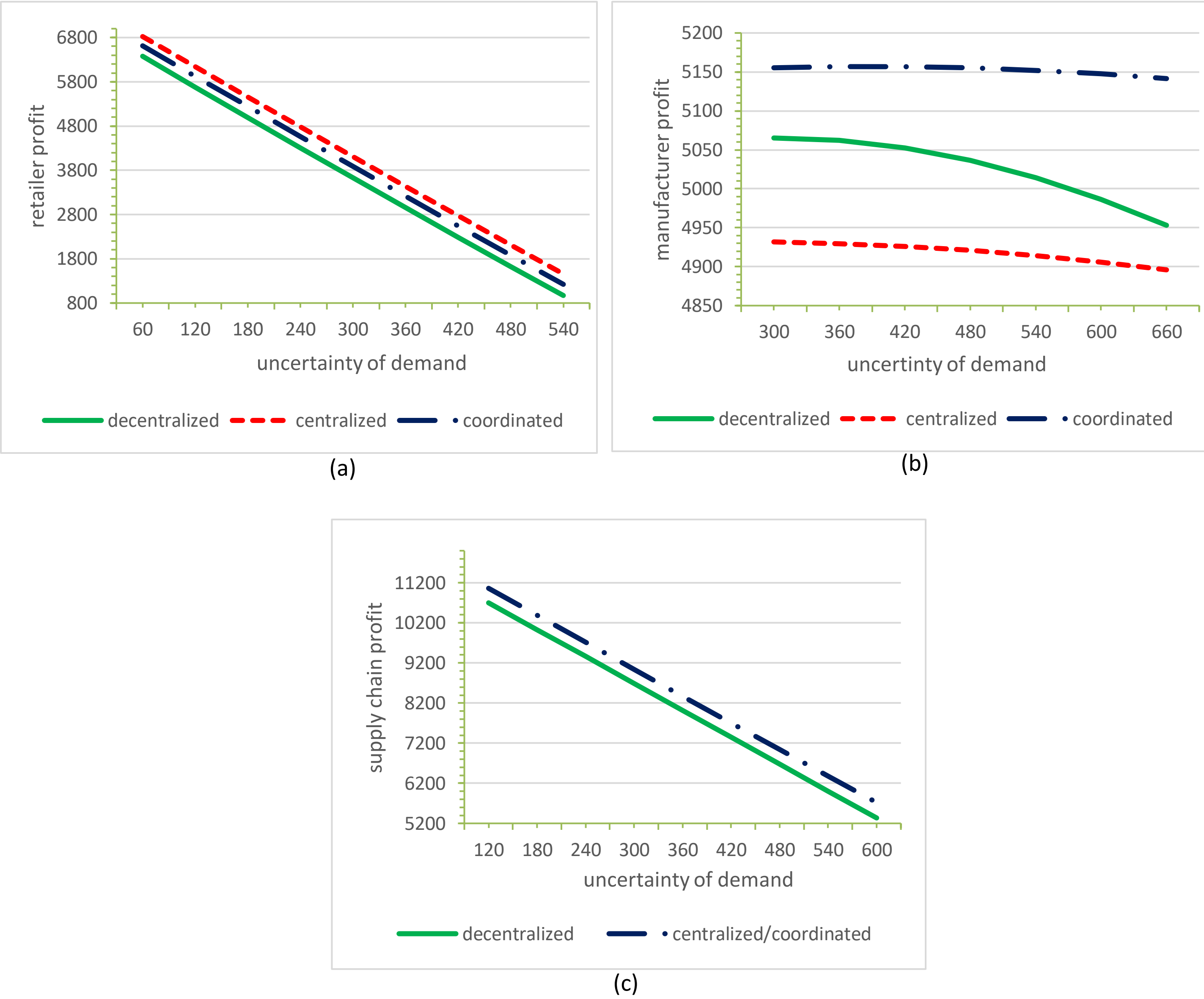

Fig 4. Effects of demand uncertainty on: (a) the retailer profitability, (b) the manufacturer profitability and (c) the whole supply chain profitability

Figure (5) shows the changes in the values of coordination parameters under different levels of demand uncertainty. According to this figure, the participation rate of the retailer in the manufacturer’s cost of investing in CSR, is greater than the manufacturer’s participation rate in the retailer’s promotion costs. As showed in figure (4), under different levels of demand uncertainty, the centralized model was profitable for the retailer while it was not acceptable for the manufacturer, in the case. This is why the retailer’s participation rate is greater than the manufacturer’s. As demand uncertainty level increases, the retailer’s participation rate decreases and the manufacturer’s rate increases and the rates may converge under high levels of demand uncertainty. In other words, with the convergence of the participation rates, the CS contract can be applied more easily in practice because the members agree to share the same amounts of the other’s costs.

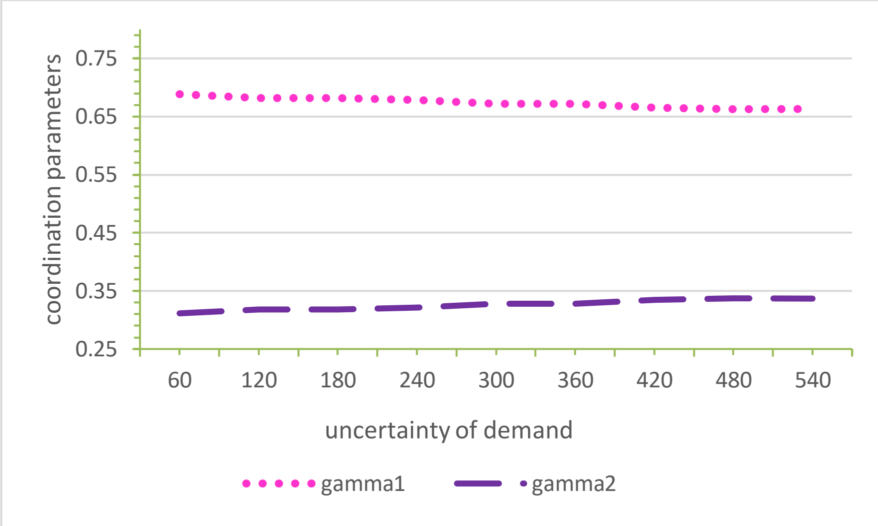

Fig 5. Coordination parameters under different levels of demand uncertainty

The effect of increasing shortages cost on the retailer's replenishment decisions is examined in Figure (6). Accordingly, when the shortages costs imposed to the retailer increases, the retailer holds more safety stock under all decision-making structures, which is anticipated (figure 6(a)). However, the amount of the safety stock under coordination model is greater than that under the decentralized model. On the other hand, he determines shorter periods for reviewing the inventory level and for making the orders, under all decision-making structures (figure 6(b)). The length of the review period under the coordination model is less than that under the decentralized model. Based on these results, i. e. more values of safety stock and shorter review periods, one can conclude that the retailer's profit under the coordination model is less than the profit he makes under the decentralized model. Unlike this thought, figure 6(c) shows that the coordination model results in more profitability for the retailer rather than the decentralized model.

To sum up, applying CS contract as a coordination scheme, not only is beneficial from the economic viewpoint, but also is beneficial from social viewpoint. In fact, by holding more safety stock, more rate of consumers demand will be met. In other words, the service level of the supply chain will be increased which results in more level of consumer satisfaction. Moreover, when the retailer determines shorter review periods, this will be beneficial for the manufacturer and he may share a greater part of the retailer's promotion costs if needed.

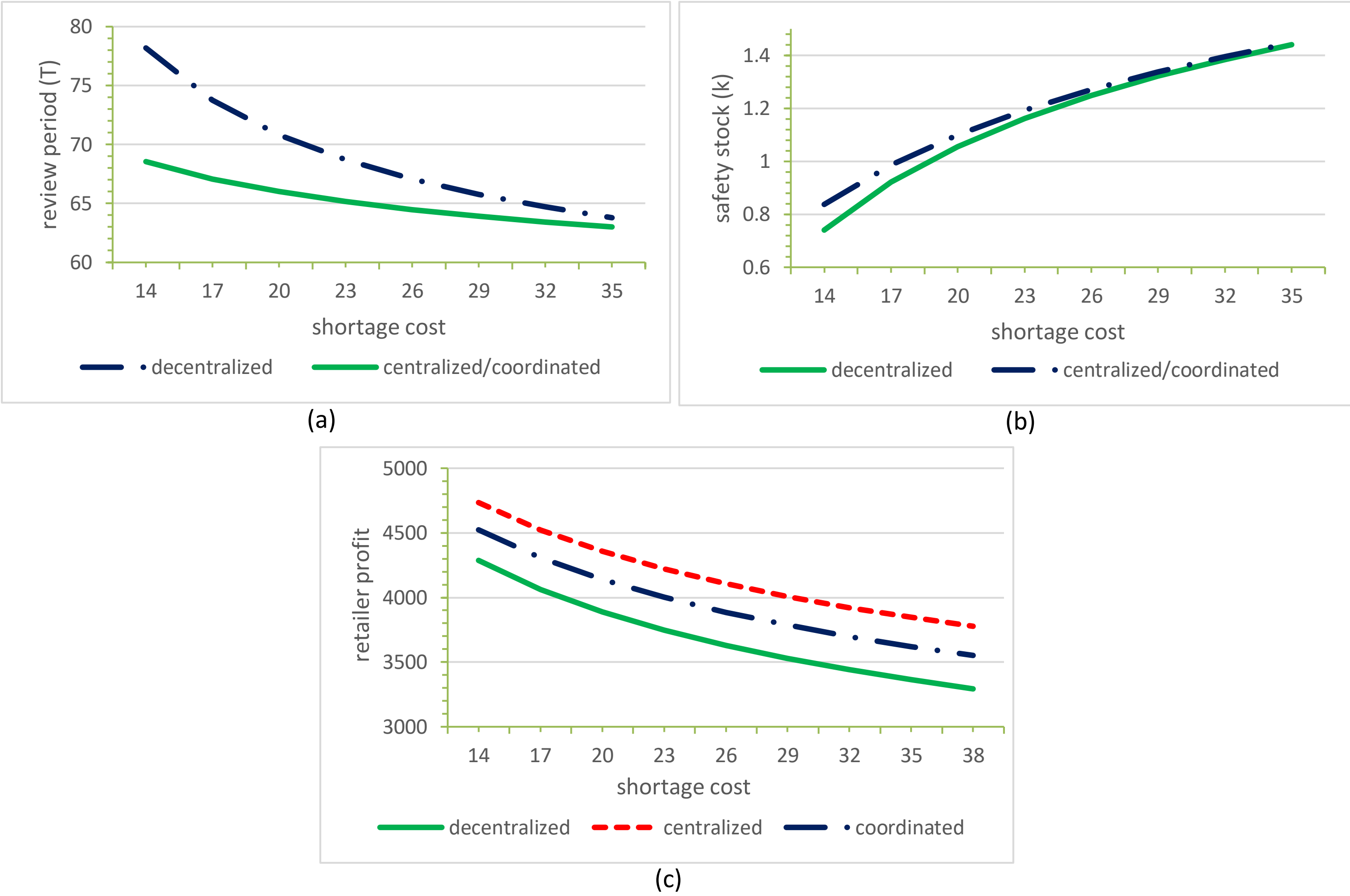

Fig 6. Effects of increasing the shortages cost on: (a) the amount of safety stock, (b) length of the review period and (c) the retailer's profit, under different structures

6- Conclusion

In today's marketplace, besides a company's promotional efforts which highly impact on consumer demand, the environmental and social issues are also the factors affecting demand. These could be thought of the results of the increase in consumer sensitivity to sustainability issues. Thus, finding the optimal level of promotional efforts and corporate social responsibility activities along with other decisions such as replenishment decisions is a challenging issue for the companies. In this study, the issue of coordination in a manufacturer-retailer supply chain is explored where the manufacturer is socially responsible and invests in corporate social responsibility activities and the retailer invests in promotional efforts. Besides, the retailer uses the periodic review order-up-to policy for replenishing inventories. Final demand is assumed to be a function of the retailer's promotional efforts and the manufacturer's CSR activities. In order to achieve the optimal performance of the whole supply chain as well as the members' optimal performance, a cost-sharing (CS) contract is proposed. The results showed that the proposed CS contract is capable of coordinating the promotional effort, CSR activities and periodic review replenishment decisions, simultaneously. Three different decision-making structures are investigated. First, the decentralized model is studied through Stackelberg game model where the retailer as the leader determines the level of promotional efforts and replenishment decisions, and then the manufacturer reacts by determining the level of CSR activities based on the retailer's decisions. Second, the centralized model is investigated and the benchmark solutions of the whole SC profitability are obtained. To persuade the members to opt benchmark solutions, the CS contract is proposed. To evaluate the effectiveness of the model, a set of sensitivity analyses is carried out with respect to the key parameters of the model. The results of the analyses provided some managerial implications which can be summarized as follows.

- Coordinating the retailer's promotional efforts and its replenishment decisions along with the manufacturer's CSR decisions, not only enhances the whole supply chain performance, but also enhances the individual members' performance. The enhancement is from three aspects: *economic*, *environmental* and *social* aspects. From *economic* viewpoint, since both the promotion and CSR highly impact on demand, coordinating these decisions, simultaneously, results in a great improvement percentage in the demand level. From *environmental* viewpoint, that the manufacturer invests more in CSR under the coordinated model, improves the environmental performance of the whole SC. From *social* viewpoint, the retailer's promotional effort can be aligned with the manufacturer's CSR activities, thus, promote the product reputation among the customers.
- Based on the results of the sensitivity analyses, in a socially responsible supply chain, the level of CSR activities is highly dependent on consumers' sensitivity to sustainability issues. In markets facing with such customers, the CSR member, here the manufacturer invests more in CSR activities to increase its market-share. But these activities are costly for the manufacturer and this may cause him to choose a lower level of activities than the optimal level. Thus, the manager of the supply chain could apply a cost-sharing coordination scheme to provide enough incentives for the manufacturer to opt the optimal level of CSR activities.
- From inventory management viewpoint, the CS contract would be beneficial for the supply chain. Whenever the shortages cost is high, the manager of the supply chain can apply the CS contract in order to encourage the retailer to hold more amount of safety stock and to determine shorter periods for the review intervals. By doing so, not only the economic benefits of the supply chain are preserved, but also the SC earns social benefits. In other words, in situations with high shortages cost, determining the safety stock and the review period under the CS contract makes more profit for the supply chain rather than its profit under the decentralized model. Moreover, holding more amount of the safety stock and determining shorter review periods under the CS contract, reduce the risk of shortages for the retailer and increases the supply chain service level. Thus, more amount of customer demands is satisfied which is a social advantage for the supply chain.
- The analyses showed that the cost sharing scheme works perfectly in coordinating the promotional efforts, CSR activities and replenishment decisions, simultaneously, even under high levels of demand uncertainty. Moreover, the CS contract is a flexible agreement between the members since they both can determine the acceptable rate to share another member's effort cost.

The current study has some limitations and could be extended from several aspects. Although the proposed coordination model persuades the members to opt the centralized decisions, the members' profitability is not guaranteed. In fact, there should be upper and lower bounds for the cost-sharing ratios which are obtained based on the member's condition for participation in the coordination model. One can derive conditions for the proposed CS contract or propose another contract which guarantees members' profitability under the coordination model. Moreover, in real life situations, the competition is prevalent among the members of the same echelon in supply chains, which we have neglected in this study because our focus was on studying the coordination of promotion, replenishment and CSR decisions. For instance, one can consider two retailers or multiple retailers instead of one retailer and study their competition on investing in promotional efforts. Furthermore, we have studied a two-echelon supply chain. An interesting topic for future study could be considering a three-echelon supply chain in which the interaction between a supplier, a manufacturer and a retailer is studied and the impacts of supplier's decisions on the manufacturer's CSR activities is examined.

References

Aljazzar, S. M., Jaber, M. Y., and Moussawi-Haidar, L. (2017). Coordination of a three-level supply chain (supplier–manufacturer–retailer) with permissible delay in payments and price discounts. *Applied Mathematical Modelling*, 48, 289-302.

Bai, Q., Chen, M., & Xu, L. (2017). Revenue and promotional cost-sharing contract versus two-part tariff contract in coordinating sustainable supply chain systems with deteriorating items. *International Journal of Production Economics*, 187, 85-101.

Bai, Q., Xu, X., Xu, J., & Wang, D. (2016). Coordinating a supply chain for deteriorating items with multi-factor-dependent demand over a finite planning horizon. *Applied Mathematical Modelling*, 40(21), 9342-9361.

Bai, Q.-G., Xu, X.-H., Chen, M.-Y., and Luo, Q. (2015). A two-echelon supply chain coordination for deteriorating item with a multi-variable continuous demand function. *International Journal of Systems Science: Operations and Logistics*, 2(1), 49–62.

Basiri, Z., & Heydari, J. (2017). A mathematical model for green supply chain coordination with substitutable products. *Journal of Cleaner Production*, 145, 232-249.

Beheshtinia, M. A., Ghasemi, A., & farokhnia, M. (2017a). Supply chain scheduling and routing in multi-site manufacturing system (case study: a drug manufacturing company). *Journal of Modelling in Management*. https://doi.org/10.1108/JM2-10-2016-0094

Beheshtinia, M. A., & Nemati-Abozar, V. (2017b). A Novel Hybrid Fuzzy Multi-Criteria Decision-Making Model for Supplier Selection Problem (A Case Study in Advertising industry). *Journal of Industrial and Systems Engineering*. 9(4), 65-79.

Berman, O., Krass, D., & Tajbakhsh, M. M. (2012). A coordinated location-inventory model. *European Journal of Operational Research*, 217(3), 500-508.

Brand, B., & Grothe, M. (2013). A note on 'Corporate Social Responsibility and Marketing Channel Coordination'. *Research in Economics*, 67(4), 324-327.

Chaharsooghi, S. K., and Heydari, J. (2010). Supply chain coordination for the joint determination of order quantity and reorder point using credit option. *European Journal of Operational Research*, 204(1), 86-95.

Chakraborty, A., & Chatterjee, A. K. (2016). A surcharge pricing scheme for supply chain coordination under JIT environment. *European Journal of Operational Research*, 253(1), 14-24.

Chang, C. T., & Chou, H. C. (2013). A coordination system for seasonal demand problems in the supply chain. *Applied Mathematical Modelling*, 37(6), 3674-3686.

Chen, K., & Xiao, T. (2011). Ordering policy and coordination of a supply chain with two-period *demand* uncertainty. *European Journal of Operational Research*, 215(2), 347-357.

Chiu, C. H., Choi, T. M., and Li, X. (2011). Supply chain coordination with risk sensitive retailer under target sales rebate. *Automatica*, 47(8), 1617-1625.

Corporate social responsibility. December 22, 2017 from Microsoft official website on the world wide web: https://www.microsoft.com/en-us/about/corporate-responsibility

Duan, Y., Huo, J., Zhang, Y., and Zhang, J. (2012). Two level supply chain coordination with delay in payments for fixed lifetime products. *Computers and Industrial Engineering*, 63(2), 456-463.

Ebrahimi, S., Hosseini-Motlagh, S. M., & Nematollahi, M. (2017). Proposing a delay in payment contract for coordinating a two-echelon periodic review supply chain with stochastic promotional effort dependent demand. *International Journal of Machine Learning and Cybernetics*. https://doi.org/10.1007/s13042-017-0781-6

Eynan, A., & Kropp, D. H. (2007). Effective and simple EOQ-like solutions for stochastic demand periodic review systems. *European Journal of Operational Research*, 180(3), 1135-1143.

Gao, D., Zhao, X., and Geng, W. (2014). A delay-in-payment contract for Pareto improvement of a supply chain with stochastic demand. *Omega*, 49, 60-68.

Goering, G. E. (2012). Corporate social responsibility and marketing channel coordination. *Research in Economics*, 66(2), 142-148.

Heydari, J., Choi, T. M., and Radkhah, S. (2017). Pareto improving supply chain coordination under a money-back guarantee service program. *Service Science*, 9(2), 91-105.

Heydari, J., Rastegar, M., and Glock, C. H. (2017). A two-level delay in payments contract for supply chain coordination: The case of credit-dependent demand. *International Journal of Production Economics*.

Heydari, J., and Asl-Najafi, J. (2016). Coordinating inventory decisions in a two-echelon supply chain through the target sales rebate contract. *International Journal of Inventory Research*, 3(1), 49-69.

Heydari, J., and Norouzinasab, Y. (2016). Coordination of pricing, ordering, and lead time decisions in a manufacturing supply chain. *Journal of Industrial and Systems Engineering*, 9, 1-16.

Heydari, J., and Norouzinasab, Y. (2015). A two-level discount model for coordinating a decentralized supply chain considering stochastic price-sensitive demand. *Journal of Industrial Engineering International*, 11(4), 531-542.

Heydari, J. (2015). Coordinating replenishment decisions in a two-stage supply chain by considering truckload limitation based on delay in payments. *International Journal of Systems Science*, 46(10), 1897-1908.

Hojati, S., Seyyedhosseini, S. M., Hosseini-Motlagh, S. M., & Nematollahi, M. (2017). Coordination and profit sharing in a two-level supply chain under periodic review inventory policy with delay in payments contract. J*ournal of Industrial and Systems Engineering*, 10, 109-131.

Hu, B., & Feng, Y. (2017). Optimization and coordination of supply chain with revenue sharing contracts and service requirement under supply and demand uncertainty. *International Journal of Production Economics*, 183, 185-193.

Hsueh, C. F. (2014). Improving corporate social responsibility in a supply chain through a new revenue sharing contract. *International Journal of Production Economics*, 151, 214-222.

Hu, F., Lim, C. C., & Lu, Z. (2013). Coordination of supply chains with a flexible ordering policy under yield and demand uncertainty. *International Journal of Production Economics*, 146(2), 686-693

Joglekar, P. (1988). Comments on a quantity discount pricing model to increase vendor profits. *Management science*, 34(11), 1391-1398.

Johari, M., Hosseini-Motlagh, S. M., & Nematollahi, M. (2017a). Simultaneous coordination of review period and order-up-to-level in a manufacturer-retailer chain. *Journal of Industrial and Systems Engineering*, 10, 1-17.

Johari, M., Hosseini-Motlagh, S. M., & Nematollahi, M. R. (2017b). Coordinating pricing and periodic review replenishment decisions in a two-echelon supply chain using quantity discount contract. *Journal of Industrial Engineering and Management Studies*, 3(2), 58-87.

Johari, M., Hosseini-Motlagh, S. M., & Nematollahi, M. (2017c). Supply Chain Coordination using Different Modes of Transportation Considering Stochastic Price-Dependent Demand and Periodic Review Replenishment Policy. *International Journal of Transportation Engineereing*, 5(2), 137-165.

Johari, M., & Hosseini-Motlagh, S. M. (2018). Coordination of cooperative promotion efforts with competing retailers in a manufacturer-retailer supply chain. *Uncertain Supply Chain Management*, 6(1), 25-48.

Li, J., and Liu, L. (2006). Supply chain coordination with quantity discount policy. *International Journal of Production Economics*, 101(1), 89-98.

Mai, D. T., Liu, T., Morris, M. D., & Sun, S. (2017). Quality coordination with extended warranty for store-brand products. *European Journal of Operational Research*, 256(2), 524-532.

Modak, N. M., Panda, S., Sana, S. S., & Basu, M. (2014). Corporate social responsibility, coordination and profit distribution in a dual-channel supply chain. *Pacific Science Review*, 16(4), 235-249.

Ma, P., Wang, H., and Shang, J. (2013). Contract design for two-stage supply chain coordination: Integrating manufacturer-quality and retailer-marketing efforts. *International Journal of Production Economics*, 146(2), 745–755.

Nematollahi, M., Hosseini-Motlagh, S. M., & Heydari, J. (2017a). Coordination of social responsibility and order quantity in a two-echelon supply chain: A collaborative decision-making perspective. *International Journal of Production Economics*, 184, 107-121.

Nematollahi, M., Hosseini-Motlagh, S. M., & Heydari, J. (2017b). Economic and social collaborative decision-making on visit interval and service level in a two-echelon pharmaceutical supply chain. *Journal of Cleaner Production*, 142, 3956-3969.

Nematollahi, M., Hosseini-Motlagh, S. M., Ignatius, J., Goh, M., & Nia, M. S. (2018). Coordinating a socially responsible pharmaceutical supply chain under periodic review replenishment policies. *Journal of Cleaner Production*, 172, 2876-2891.

Nie, T., and Du, S. (2017). Dual-fairness supply chain with quantity discount contracts. *European Journal of Operational Research*, 258(2), 491-500.

Ni, D., Li, K. W., & Tang, X. (2010). Social responsibility allocation in two-echelon supply chains: Insights from wholesale price contracts. *European Journal of Operational Research*, 207(3), 1269-1279.

Ouyang, L. Y., Chuang, B. R., 2000, A periodic review inventory model involving variable lead time with a service level constraint, *International Journal of Systems Science*, 31: 1209-1215.

Pal, B., Sana, S. S., & Chaudhuri, K. (2015). Coordination contracts for competitive two-echelon supply chain with price and promotional effort sensitive non-linear demand. *International Journal of Systems Science: Operations & Logistics*, 2(2), 113-124.

Panda, S. (2014). Coordination of a socially responsible supply chain using revenue sharing contract. *Transportation Research Part E: Logistics and Transportation Review*, 67, 92-104

Panda, S., & Modak, N. M. (2016). Exploring the effects of social responsibility on coordination and profit division in a supply chain. *Journal of Cleaner Production*, 139, 25-40.

Song, J., Li, F., Wu, D. D., Liang, L., & Dolgui, A. (2017). Supply chain coordination through integration of innovation effort and advertising support. *Applied Mathematical Modelling*, 49, 108-123

Tagaras, G., and Vlachos, D. (2001). A Periodic Review Inventory System with Emergency Replenishments. *Management Science*, 47(3), 415–429.

Top things to know about sustainable innovation at Nike. December 20, 2017 from Nike, Inc. on the world wide web: https://news.nike.com/news/sustainable-innovation

Tsao, Y. C., & Sheen, G. J. (2012). Effects of promotion cost sharing policy with the sales learning curve on supply chain coordination. *Computers & Operations Research*, 39(8), 1872-1878.

Van Marrewijk, M. (2003). Concepts and definitions of CSR and corporate sustainability: Between agency and communion. *Journal of business ethics*, 44(2), 95-105.

Wang, J., & Shin, H. (2015). The impact of contracts and competition on upstream innovation in a supply chain. *Production and Operations Management*, 24(1), 134-146.

Wong, W. K., Qi, J., and Leung, S. Y. S. (2009). Coordinating supply chains with sales rebate contracts and vendor-managed inventory. *International Journal of Production Economics*, 120(1), 151-161.

Wu, D. (2013). Coordination of competing supply chains with news-vendor and buyback contract. *International Journal of Production Economics*, 144(1), 1-13.

Ye, T., Sun, H., & Li, Z. (2016). Coordination of pricing and leadtime quotation under leadtime uncertainty. *Computers & Industrial Engineering*, 102, 147-159.

Zhang, F., & Wang, C. (2018). Dynamic pricing strategy and coordination in a dual-channel supply chain considering service value. *Applied Mathematical Modelling*, 54, 722-742

Zhang, Z. H., & Unnikrishnan, A. (2016). A coordinated location-inventory problem in closed-loop supply chain. *Transportation Research Part B: Methodological*, 89, 127-148.

Zhang, J., Gou, Q., Liang, L., & Huang, Z. (2013). Supply chain coordination through cooperative advertising with reference price effect. *Omega*, 41(2), 345-353.

Zhang, B., Lu, S., Zhang, D., and Wen, K. (2014). Supply chain coordination based on a buyback contract under fuzzy random variable demand. *Fuzzy Sets and Systems*, 255, 1-16.

Zhou, Y., Bao, M., Chen, X., & Xu, X. (2016). Co-op advertising and emission reduction cost sharing contracts and coordination in low-carbon supply chain based on fairness concerns. *Journal of Cleaner Production*, 133, 402-413.

Appendix A. Proof of the retailer profit function concavity under the Stackelberg game

The Hessian matrix of the retailer profit function under the Stackelberg model with respect to K and E, for a given T, is:

$$\mathrm{H}(\pi_r(\mathrm{K},\mathrm{E})) = \begin{bmatrix} \frac{\partial^2 \pi_r}{\partial K^2} & \frac{\partial^2 \pi_r}{\partial \mathrm{K}\, \partial \mathrm{E}} \\ \frac{\partial^2 \pi_r}{\partial \mathrm{E}\, \partial \mathrm{K}} & \frac{\partial^2 \pi_r}{\partial E^2} \end{bmatrix} \quad \text{(A1)}$$

If $H_{11} \leq 0$ and $H_{22} \geq 0$, then the retailer profit function is concave with respect to K and E, for a given T.

$$H_{11} = \frac{\partial^2 \pi_r}{\partial K^2} = -\frac{1}{T}\, \pi\, \sigma \sqrt{T+L}\, \varphi\,(\mathrm{k}) \leq 0$$
(A2)

$$H_{22} = \frac{\partial^2 \pi_r}{\partial K^2} \times \frac{\partial^2 \pi_r}{\partial E^2} - \frac{\partial^2 \pi_r}{\partial \mathrm{K}\, \partial \mathrm{E}} \times \frac{\partial^2 \pi_r}{\partial \mathrm{E}\, \partial \mathrm{K}} = \frac{1}{T}\, \pi\, \sigma \sqrt{T+L}\, \varphi\,(\mathrm{k}) \times \eta \geq 0$$
(A3)

based on the above equations, the first and the second principle minors satisfy the concavity conditions, thus the retailer profit function is concave with respect to K and E, for a given T.

Appendix B. Proof of the supply chain profit function concavity

The Hessian matrix of the supply chain profit function with respect to CRS, K and E, for a given T is:

$$H(\pi_{SC}^{ce}(S, \mathrm{K}, \mathrm{E}, \mathrm{T}) = \begin{bmatrix} \frac{\partial^2 \pi_{SC}}{\partial S^2} & \frac{\partial^2 \pi_{SC}}{\partial S\, \partial \mathrm{k}} & \frac{\partial^2 \pi_{SC}}{\partial S\, \partial \mathrm{E}} \\ \frac{\partial^2 \pi_{SC}}{\partial \mathrm{K}\, \partial S} & \frac{\partial^2 \pi_{SC}}{\partial K^2} & \frac{\partial^2 \pi_{SC}}{\partial \mathrm{K}\, \partial \mathrm{E}} \\ \frac{\partial^2 \pi_{SC}}{\partial \mathrm{E}\, \partial S} & \frac{\partial^2 \pi_{SC}}{\partial \mathrm{E}\, \partial \mathrm{K}} & \frac{\partial^2 \pi_{SC}}{\partial E^2} \end{bmatrix} \quad \text{(B1)}$$

If $H_{11} \leq 0$, $H_{22} \geq 0$ and $H_{33} \leq 0$, then the centralized profit function is concave with respect to S, K and E for a given T.

$$H_{11} = \frac{\partial^2 \pi_{SC}}{\partial S^2} = -\frac{2\delta\, h_m\, T\delta}{2P}(2-n) - \zeta \leq 0$$
(B2)

$$H_{22} = \frac{\partial^2 \pi_{SC}}{\partial S^2} \times \frac{\partial^2 \pi_{SC}}{\partial K^2} - \frac{\partial^2 \pi_{SC}}{\partial \mathrm{S}\, \partial \mathrm{k}} \times \frac{\partial^2 \pi_{SC}}{\partial \mathrm{K}\, \partial \mathrm{S}} = (\frac{\delta\, h_m\, T\delta}{P}(2-n) + \zeta) \times \left(\frac{1}{T}\, \pi\, \sigma \sqrt{T+L}\big(\varphi(\mathrm{k})\big)\right) \geq 0$$
(B3)

$$H_{22} = \frac{\partial^2 \pi_{SC}}{\partial S^2} \times \frac{\partial^2 \pi_{SC}}{\partial K^2} \times \frac{\partial^2 \pi_{SC}}{\partial E^2} - \frac{\partial^2 \pi_{SC}}{\partial \mathrm{S}\, \partial \mathrm{E}} \times \frac{\partial^2 \pi_{SC}}{\partial K^2} \times \frac{\partial^2 \pi_{SC}}{\partial \mathrm{E}\, \partial \mathrm{S}} = \left(-\frac{1}{T}\, \pi\, \sigma \sqrt{T+L}\big(\varphi(\mathrm{k})\big)\right)\left[\left(\frac{h_m\, T\delta^2}{P}(2-n) + \zeta\right) \times \left(\frac{\eta}{T} + \frac{h_m T\beta^2}{P}(2-n)\right) - \left(\frac{\delta\, h_m\, T\beta}{P}(2-n)\right)^2\right] \leq 0 \quad \text{(B4)}$$

Thus, the centralized profit function is concave with respect to S, K and E when the following condition is satisfied:

$$\left(\frac{\hbar_m T\delta^2}{P}(2-n)+\zeta\right)\times\left(\frac{\eta}{T}+\frac{\hbar_m T\beta^2}{P}(2-n)\right)\geq\left(\frac{\hbar_m T\delta\beta}{P}(2-n)\right)^2 \tag{B5}$$