ARTICLE IN PRESS

International Journal of Production Economics xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

International Journal of Production Economics

journal homepage: www.elsevier.com/locate/ijpe

Pricing strategies in the competitive reverse supply chains with traditional and e-channels: A game theoretic approach

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ARTICLE INFO

Keywords:
Reverse supply chain
Game theory
Channel competition
Pricing
E-channel
Sustainability

ABSTRACT

Increasing attention to sustainable development issues and competition between different supply chains are forcing the stakeholders to use different incentives to capture more market share. Collecting channels are one of the effective topics in the reverse competitive chains. Because of the importance of this issue, we consider two collecting reverse supply chains consist of a retailer and a manufacturer who compete together by proposing more rewards to the customers. One of these chains tries to facilitate the collecting process and obtain more market share by using the direct and traditional channels advantages. The other one uses only the traditional channel. Hence, the return rate of each channel not only depends on the self-reward but also is function of the cross-rewards suggested to the customer by the competitors in the other channels. The competitive environment in our model consists of internal and external competitions. Competition between two channels of one chain infers to internal competition, external competition that points out to competition among two supply chains. We apply three game theory structures to obtain the optimal channels rewards: Nash, Nash-Stackelberg-first supply chain, and Nash-Stackelberg-second supply chain. Finally, we comparing the results of decision variables and profit function of members under three structures through numerical analysis. Our numerical investigations show that e-channel because of less costly than traditional channel proposes more appropriate reward to customers, so this channel could obtain a more substantial share of the market. Moreover, the results reveal that highest return rate occurred under Nash scenario while Nash-Stackelberg-first supply chain and Nash-Stackelberg-second supply chain are the most economic scenarios for the first and the second supply chains, respectively.

1. Introduction

Increasing customer' attention to environmental issues has encouraged the industrialists and researchers to focus on sustainable products. Reverse and closed-loop supply chain are well adapted to the sustainability goals (Eskandarpour et al., 2015). Moreover, environmental legislation prescribes manufacturers to invest in recycling and remanufacturing process in order to decrease the need for earth' natural resources and also waste out of landfills (Qiang, 2015). For instance, Xerox Company could keep more than 145 million pounds of waste out through recycling process during two decades ago.[1] Moreover, employment growth, improving productivity, increasing competitive and economic advantages are the other results of implementing remanufacturing process which are considered as the important motivations for industrials (Eskandarpour et al., 2015; Rezapour et al., 2014; Golicic and Smith, 2013; Lee et al., 2011).

Many companies paid attention to implementing the recycling process, among the different products, computer and electronic goods are one of the successful industries in the remanufacturing process (Das and Chowdhury, 2012). Generally, reverse logistics consist of some operations like collecting the used products, transfer them from customers to the manufacturer and finally inspecting and remanufacturing. In today's competitive business environment, the companies should be trying to convince the customers to return their used products. The ways of collecting obsolete products are one of the important items in reverse logistics (RL) which have a significant impact on customer decisions and return rate.

Traditional channel, e-channel and dual channel are the most well-known distribution and collecting channels. In the traditional channel, the retailer appears in the role of an intermediary between manufacturer and customer. In other words, the used products return through the physical store. Therefore, the retailer inspects the returned product and proposes a reward to the customer for eligible devices. Converse, e-channel is a way which directly connects the customer to the

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[1] Source: https://www.xerox.com/about-xerox/recycling/enus.html.

https://doi.org/10.1016/j.ijpe.2018.06.011
Received 28 June 2016; Received in revised form 15 June 2018; Accepted 16 June 2018

manufacturer. In reverse SC, the customers aware of the manufacturer's suggested price through referring to company's website and registering the specification of their obsolete products. Finally, the customer can utilize the advantages of both channels in dual-channel structure. Despite the conflict that may occur between the channels on dual strategy, the firms can gain the economic and competitive advantages through considering hybrid collecting channels (Saha et al., 2016). Each of mentioned channels has its own advantages, therefore company according to their goals, kinds of customer, competitive environment etc. decides on selecting the suitable channel strategy. This strategy should be chosen and designed such that the customer sends back a used product at the lowest cost without any problems.

Despite the advantages mentioned above, there is no paper that considers competition between chains and channels with the different power structures, especially in a reverse supply chain. Whereas, according to studies by Cai (2010), there are numerous reasons that cause companies have different channel strategies. Although most of the previous literature on competition between SCs investigated the competitive chains with the same channel structure, we have some practical evidence that supports our argument on different channel structures. “For instance, Apple Company lets the customers recycle their obsolete devices at an Apple Store or online collection channel.[2]” Also, HP allows their customers to recycle their hardware of any brands through the retail collection and online channel. Other powerful companies in electronics industry like Dell recently has established offline stores for selling their products and only uses the online channel in order to collect the obsolete products. In addition, there are some competitors who prefer to use only the benefits of traditional channels like Sony that lets its customers recycle their old devices by going to the nearest recycling store.[3] Therefore, how to manage channel competition is one of the important issues for the members of competitive SCs in the real world.

The models are extended for competitive SCs, so companies can use them as a guideline for selecting their optimal strategies under different interactions which these models arise from different interactions in the real-world competition. For instance, the competitive companies with equal market power could use the advantage of the first scenario. Competition between Apple and Dell as two powerful companies with equal market power can be mentioned as a practical evidence that supports our argument on Nash game. Additionally, the second and the third scenarios stem from competition between chains which one of them is larger and more powerful than the other one like competition between brands with different market power such as National brand and Store brand. Competiton McDonald's against local fast food is one of the familiar competitors we can point them out. Moreover, the competition between powerful companies like Apple as a national brand company in electronic devices with GLX as an Iranian company in a cellphone is another instance of this issue.

Based on these observations and in order to fill this gap, in this paper, we consider two supply chains which compete with each other to collect obsolete products. Each chain includes one manufacturer and one retailer. One of these chains uses the direct and traditional channels and the other one uses only the traditional channel. The first manufacturer decides on the reward of e-channel, and the retailers decide on the rewards of their traditional channels. Competition between chains leads to that the selected policies by a member effect on the other members. Therefore, the demand's market of each chain is sensitive to the proposing rewards of different channels. Furthermore, the model investigates three different interactions between chains and channel by applying three scenario games: Nash, Nash-Stackelberg-first supply chain and Nash-Stackelberg-second supply chain.

[2] Source: http://www.apple.com/recycling.

[3] Source: http://www.sony.net/SonyInfo/csr/SonyEnvironment/spotlight/recycling_program/index.html.

The main research questions which this research answers them list as follows:

1. How can each chain increase the amount of returned products?
2. What is the optimal reward of each channel under different interaction between chains' members?
3. What is the impact of policies competitor on the profit of members?
4. Which strategies is the best, from the perspective of members, sustainability goals?
5. What is the effect of collecting channel on the competitor return rate?
6. Does refurbishing cost have a positive effect on the behavior of all members, always?

The main contributions of this research with respect to literature are threefold: first, the competition between chains with the different power structures in RLs is investigated. Second, we consider channels competition through defining interdependent return rates. Third, we modeled three different interactions between chain and channel by applying three scenario games. Finally, we analyzed the impact of the acceptance rate and refurbishing cost through the numerical example.

The rest of the study organized as follows: In Section 2 presented a brief overview of the relevant literature. Then we describe the model and review the used notation and assumption in Section 3. In the fourth section, we consider three cases for relevant between two supply chain members and according to each case we use appropriate game theory algorithms to solve the problem. A numerical example and sensitive analysis are presented in Section 5. In the last section, we give a summary of the paper, conclusion and provide some directions for future research.

2. Literature review

In this section, we review the pricing studies which are related to our research. We classify them into the two major categories: First, we present the pricing studies that focused on distributing/collecting channel and then examine the researches who considered the competition between chains.

Most of the studies on channel problems have only focused on the channel selection. For instance, Lal and Sarvary (1999) examined the impact of direct distribution channel on the competition and explored the positive effect of it on the members' profit for the first time. Savaskan et al. (2004); Savaskan and Van Wassenhove (2006) and Hong et al. (2015) investigated the profit of members in a reverse supply chain when there is only direct or indirect channel. Huang et al. (2013b) and Wang et al. (2016) further extended Savaskan et al.'s problem by analyzing the single- and dual-channels respectively, in a closed-loop and forward SCs. Taleizadeh et al. (2015) studied the effects of pricing and lot-sizing optimization in a direct SC in which unhealthy item is produced and inspection performed after regular production process and used the Stackelberg approach to solve the problem. Sane Zerang et al. (2018) developed a three-echelon closed-loop SC with advertising effort and price dependent market requirement rate. Taleizadeh and Noori-daryan (2016) developed an integrated lot-sizing, pricing and manufacturing policies in a SC of pharmacological item with reworking using game theoretic approaches to enhance the SC profit. Taleizadeh et al. (2017a, b) developed a competitive duopoly supply chain with parallel importation in which selling price and warranty period length are optimized such that the total profit of the chain is maximized. Saha et al. (2016) examined a closed-loop supply chain that could collect the used products through three different modes: direct, traditional or third-party collector and then compared these modes separately. However, they have disregarded the effects of competition among channels when the direct in parallel with indirect channels sell or collect products. Some studies have addressed the issue in forward logistics. For instance, Yan (2010) considered a market consists of a dual-channel that each channel sells products with different brands and prices and also they examined a horizontal competition between channels. Gan et al. (2017) investigated on a CLSC of short life-cycle products when the dual channels are used to sell products and only one channel are used to collect the obsolete products. Taleizadeh et al. (2018a,b) studied the influence of advertising efforts on a closed-loop SC when the new and refurbished products are sold through offline and online channel. Moreover (Ding et al., 2016; Li and Li, 2016; Shang and Yang, 2015; Huang et al., 2012, 2013a; Dan et al., 2012), are the other studies that investigated dual-channel competition, whereas hybrid channel is a new topic in reverse logistics. Taleizadeh et al. (2018a,b) and Hong et al. (2016) are rarest works in hybrid channel in a closed-loop supply chain. Taleizadeh et al. (2018a,b) compared two types of distribution-collecting channel consist of a channel to sell and dual-channel to collect products, dual-channel to sell and a single channel to collect. They used Stackelberg approach to determine the optimum values of prices, quality levels, and sales and collection. Hong et al. (2016) investigate three alternative collecting channels: through the retailer and manufacturer, retailer and third-party logistic, manufacturer and third party. Authors solved the problem by applying Stackelberg structure in which manufacturer acts as a leader. Generally, there is no similar study in the reverse logistics literature specially channel with different power (Taleizadeh et al., 2018; Moshtagh and Taleizadeh, 2017; Giri et al., 2017; Gao et al., 2016; Hong et al., 2016). In order to address this gap, we provide a pricing model consist of three competitive collecting channels in two reverse chains.

Another stream of the related literature to our work is competition between chains. To the best of our knowledge, there are few researches that examined this kind of competition in their problem especially in reverse or closed-loop supply chains (Taleizadeh et al., 2017a, b; Gao et al., 2016; Wei and Zhao, 2015). We can point out the following studies that addressed to chain-to-chain competition in the forward supply chain. McGuire and Staelin (1983) developed a model compose of two competition chains, in which, each chain coordinated SC through wholesale price contract. Trivedi (1998) analyzed the impact of competition on the price and profit of members. Xiao and Yang (2008) and Wu et al. (2009) examined this problem in their research while demand is uncertain. Moreover, Li and Li (2016) concentrated on a game model with two sustainable products of two chains which have competed on the sustainability level. Each chain interested in maximizing their profits by optimizing the wholesale price and sustainability level. The author solved the problem by applying Nash and Stackelberg game. Taleizadeh et al. (2016) addressed a pricing and ordering decisions problem in two competing SCs where both chains produce the same good with different brands which the retailer acts as a Stackelberg-leader in each channel. Yang et al. (2015) investigated competition between supply chains while they can use single channel or dual channel for selling products and they compared the effect of channel strategy on Nash equilibrium. Zhao et al. (2016), Wu (2016), Wu and Wu (2016) and Wu et al. (2015) are other related researches in forward logistic. Wei and Zhao (2015) is one of the rarest work in the chain-to-chain competition in the reverse supply chain, consist of two competing chains that one of these chains have forward SC and use the raw material and another one is a remanufacturing chain. They limited their contribution by considering the same structure for chains. Moreover, most of the studies in this area are assumed different power for the competitors and applying only Stackelberg game or sometimes only Nash, whereas these assumptions are incorrect in the real world. This paper considers two competitive chains with different structures. One of them uses the direct and traditional channel to collect the used product and the other uses only the independent retailer. We model three-game theory approaches: Nash, Nash-Stackelberg-first supply chain and Nash-Stackelberg-second supply chain. Table 1 presents the nearest related literature to our work.

According to the Table 1, there is no previous study considering simultaneously competition between chains and also among channels in reverse and forward logistics. Moreover, based on the best of knowledge, there are some papers that investigated different power structures in the forward supply chain (see Li and Li, 2016), whereas there is no paper proposes this problem in a reverse supply chain. Moreover, as Wu (2012) and Wei and Zhao (2015) pointed out, multi power structure between members and also the chains which are in competitive situations could be useful contributions for future research. In order to fill these gaps, we investigated chain-to-chain competition in reverse supply chain while one of these chains, through single collecting channel, competes with the other one who uses dual channel. Furthermore, we consider three different interaction between channels of chains by applying three scenario games.

3. Problem description

We consider two competitive reverse supply chains including one manufacturer and one retailer. Both of the chains compete in collecting and refurbishing the used products after their useful life. One of these chains collects the eligible obsolete products through the traditional and internet channel while his competitor uses only the traditional channel. When the manufacturer collects the obsolete products through e-channel, it means that the manufacturer directly tends to encourage the customers to return the obsolete devices by proposing a suitable reward of the e-channel. Moreover, in the traditional channel, the retailer proposes a reward to the customer for per unit return. In order to, the customers can choose a channel of these two chains as a way to return their obsolete products.

If the customers select the traditional channel, the returned products are inspected by the retailer. Then he transfers the suitable products to the manufacturer and receives the recycling fee for per unit of the returned product. In this step, in order to accurate identification of the damaged parts and estimate the amount of damage, the manufacturer inspects again and then refurbishes them by original components. Otherwise, if the customer chooses e-channel, the manufacturer inspects the products by using the internet equipment, then those products can no satisfy the related standards will be delivered to the refurbishing line for re-manufacturing. Finally, the recovered products are sold to the customers. The supply chains structure and the relation between their members are illustrated in Figure (1). Figure (2) shows the refurbishing process in a reverse supply chain.

Generally, the return rate of used products to each channel is a function of the self-reward and the cross-rewards suggested to the customer by the competitors in other channels. Therefore, the proposed rewards are the primary key factors which have a direct effect on return rate and as a result on the members' profitability.

In this paper, we are looking to adjust a suitable reward on each channel which not only maximizes the profit of members but also, encourages more customers to return the obsolete goods. We tried to investigate the different strategic interactions that might occur between the members of chains. In order to, we use Nash and Stackelberg game under different leaders and followers in our model. And finally, we analyzed the members' behaviors and policies under the different strategies.

It is evident that these models can help the managers in their decision-making process and companies can select each of the mentioned models depending on their goals and conditions. This fact occurs especially when the competitors have different collecting strategies. For instance, in competition between prominent manufacturers such as Apple or HP, who use offline-online collecting channel, and Sony or Dell, who only utilize one channel to collect the obsolete products.

In order to model the problem, the following notations are used.

Table 1
Summary of the related literature.

Article	The number of SC	The number of tiers	Supply chain			Kind of game Or Competition type		Channel		Competitive environment		
			Forward	RSC	CLSC	Nash	Stackelberg	Traditional	Internet	External Competition[a]	Internal Competition[b]	Channel Competition
Kurata et al. (2007)	2	2	✓			✓		✓	✓	✓	✓	✓
Yan (2010)	1	2	✓				✓	✓	✓		✓	✓
Dan et al. (2012)	1	2	✓				✓	✓	✓		✓	✓
Huang et al. (2012)	1	2	✓				✓	✓	✓		✓	✓
Wu (2012)	2	2	✓	✓			✓			✓	✓	
Huang et al. (2013b)	1	3			✓		✓	✓	✓		✓	✓
Hsieh et al. (2014)	1	2	✓			✓		✓	✓	✓		
Hong et al. (2015)	1	3–2			✓		✓	✓	✓	✓	✓	
Shang and Yang (2015)	1	2–3	✓					✓	✓		✓	✓
Wei et al. (2015)	1	2			✓		✓	✓			✓	
Yang et al. (2015)	2	2	✓					✓	✓	✓		✓
Zou and Ye (2015)	1	2			✓		✓	✓			✓	
Gan et al. (2017)	1	3			✓			✓	✓		✓	✓
Hong et al. (2016)	1	2–3			✓		✓	✓			✓	✓
Li and Li (2016)	2	2	✓			✓	✓	✓		✓		
Saha et al. (2016)	1	2–3			✓		✓	✓	✓		✓	
Sadigh et al. (2016)	1	3	✓			✓		✓			✓	
Taleizadeh et al. (2016)	2	2	✓				✓	✓		✓	✓	
Xie et al. (2017)	1	2	✓	✓			✓	✓	✓		✓	✓
Taleizadeh et al. (2018a,b)	1	2			✓		✓	✓			✓	✓
Current study	**2**	**2**			✓	✓	✓	✓	✓	✓	✓	✓

[a] External competition point out to competition between chains.
[b] Internal competition stem from the competition among the members of a supply chain.

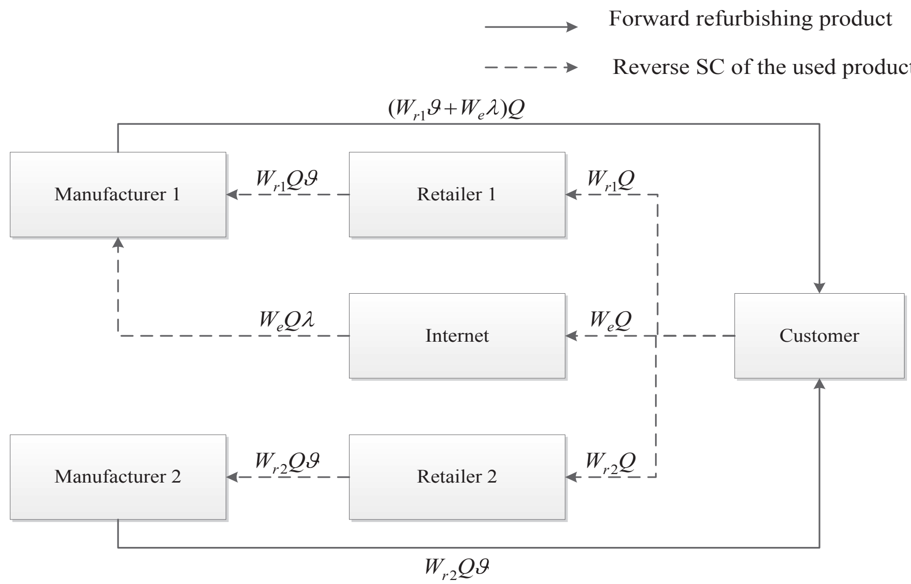

Fig. 1. The structure of the competitive supply chain.

Parameters

W_{Mi}	The recycling fee paid by the manufacturer i to the retailer i for each unit if the used products;
C_{ri}	Cost of inspection at the retailer site per item;
ϑ	The acceptance rate in the traditional channel (the percentage of products that from the retailer's view are eligible to enter the remanufacturing process);
λ	The acceptance rate in the e-channel;
C_{mie}	The unit cost of inspection for the product that returned through e-channel;
C_{mir}	The unit cost of inspection for the product that returned through the traditional channel;
Q	The quantities of new products that are sold in forward SC;
P	The selling price of refurbished products by the manufacturer;
C_{mf}	Remanufacturing cost for per item;
d_i^{max}	A level of offered reward to the customers in channel i which under it, all customers will return their obsolete product;

Independent decision variables

d_{ri}	The optimal reward that the retailer i offered to customers in exchange for each returned unit with remanufacturing value;
d_e	The optimal reward that the first manufacturer offered to customers in exchange for each returned unit with remanufacturing value;

Dependent variables and functions

W_{ri}	Customers' willingness to return the obsolete products to traditional channel i (a function of rewards offered to customers in different channels); a real number between 0 and 1;
W_e	Customers' willingness to return the obsolete products to the direct channel (a function of rewards offered to customers in different channels); a real number between 0 and 1;
π_{SCi}	The profit of supply chain in the chain i ;
π_{ri}	Retailer's profit in the chain i ;
π_{Mi}	Manufacture's expected profit in the chain i ;

Moreover, the assumptions that considered in the model are as follows:

- All items entered into the remanufacturing process will be refurbished and are sold in the market.
- The function of return rate in this paper is developed from a function

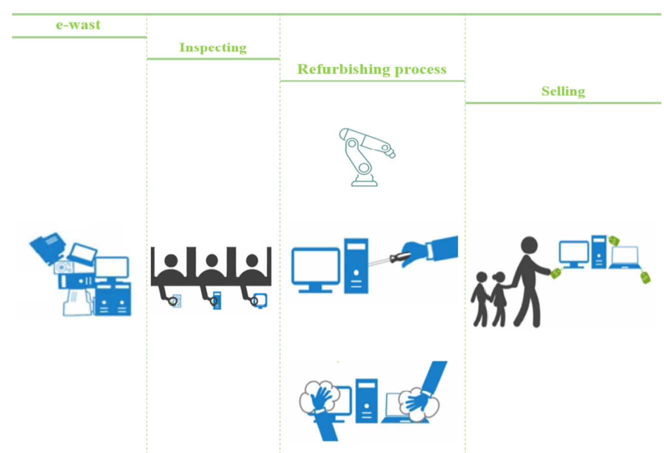

Fig. 2. The refurbishing process in a reverse supply chain.

that Bai (2009) and also Govindan and Popiuc (2014) defined in their studies. Our distinction is that they used their function for a single-channel structure while we extended it for multi-channel structure. Moreover like Hanssens et al. (2003); Kurata et al. (2007); Mukhopadhyay et al. (2008); Ghosh and Shah (2012); Xu et al. (2014); Chakraborty et al. (2015) and many others, we adopt a linear function for retune rate of each channel with self- and cross-rewards effects. In other words, the return rate of each channel not only depend on the self-reward but also is a function of the cross-rewards that are suggested to the customer by the competitors in the other channels, as follows:

$$W_{r1} = \frac{d_{r1}}{d_{r1}^{\max}} - \gamma_2 \frac{d_e}{d_e^{\max}} - \beta_2 \frac{d_{r2}}{d_{r2}^{\max}} = \alpha_1 d_{r1} - \gamma_2' d_e - \beta_2' d_{r2} \tag{1}$$

$$W_e = -\alpha_2 \frac{d_{r1}}{d_{r1}^{\max}} + \frac{d_e}{d_e^{\max}} - \beta_2 \frac{d_{r2}}{d_{r2}^{\max}} = -\alpha_2' d_{r1} + \gamma_1 d_e - \beta_2' d_{r2} \tag{2}$$

$$W_{r2} = -\alpha_2 \frac{d_{r1}}{d_{r1}^{\max}} - \gamma_2 \frac{d_e}{d_e^{\max}} + \frac{d_{r2}}{d_{r2}^{\max}} = -\alpha_2' d_{r1} - \gamma_2' d_e + \beta_1 d_{r2} \tag{3}$$

Where, the return rate of the first chain consists of traditional channel (W_{r1}), direct channel (W_e) and finally in the second chain, W_{r2} is the return rate of retail channel of this chain. Here, d_{r1}, d_e are, respectively, the proposing reward to customer in traditional and direct channel of the first chain and d_{r2} is the reward of the traditional channel of the second chain. α_1 and α_2, respectively, indicate the sensitivity of d_{r1} in the retail channel of the first chain and in the other competitive channels. Also, β_1 and β_2 measure the influence of d_{r2} on return rate of the second retailer channel and the competitive channels in the first chain, respectively. Similarly, γ_1 represents the impact of d_e on the return rate of e-channel (W_e), and γ_2 measures the influence of the proposing reward of the direct channel on the return rate of competitive channels (W_{r1} and W_{r2}).

- The impact of the reward of a channel on the return rate of his channel shall be greater than the cross-rewards that his competitors propose in the other channels, therefore we consider that: $\alpha_1 \geq \beta_2', \gamma_2'$ and $\beta_1 \geq \alpha_2', \beta_2'$ and also $\gamma_1 \geq \alpha_2', \gamma_2'$.
- The impact of offering reward of one channel on the return rate to his channel is greater than the effect of it on his competitor in the other channel, for this reason, we assume that: $\alpha_1 \geq \alpha_2', \beta_1 \geq \beta_2', \gamma_1 \geq \gamma_2'$ (Hanssens et al., 2003; Kurata et al., 2007; Mukhopadhyay et al., 2008; Ghosh and Shah, 2012; Xu et al., 2014; Chakraborty et al., 2015).
- Direct channel because of being equipped with precision equipment can have a more accurate estimation of a recyclable device, therefore, we assume that $\lambda > \vartheta$.

4. Modeling & solution method

In this section, the pricing models in two competitive chains under three different scenario games are presented. The manufacturer profit can be modeled as follows:

$$\pi_{M1} = Q\left[(P - C_{mf} - W_{M1} - C_{mir})\vartheta W_{r1} + \left(P - C_{mf} - d_e - \frac{C_{mie}}{\lambda}\right)\lambda W_e\right] \tag{4}$$

Where W_{r1} and W_e are the return rate of obsolete products which respectively enter to the first supply chain through direct and internet channel. As explained above, the returned product through traditional channel is purchased by the manufacturer at price W_{M1}. Then, the manufacturer inspects the returned product at unit cost C_{mir}. Moreover, the products that entered the chain through e-channel, at first will be checked online at cost C_{mie}, then the eligible items are purchased by the manufacturer at unit reward d_e. Afterward, the needed remanufacturing operations are done on the products that transfer to the refurbishing line at unit cost C_{mf}. Finally, it is sold on the market at price P. The expected profit function of the first retailer can be formulated as follows:

$$\pi_{r1} = W_{r1}\vartheta Q\left[W_{M1} - d_{r1} - \frac{C_{ri}}{\vartheta}\right] \tag{5}$$

Where the W_{M1} denotes the retailer's revenue from selling the returned products to the manufacturer, the remaining terms are the proposing reward to the customers and the costs of inspection, respectively.

We can formulate the manufacturer and retailer's profit of the second chain with considering this assumption that the second chain uses only the direct channel. As mentioned earlier, this chain has an exclusive the return rate, reward and recycling fee. Therefore, we have:

$$\pi_{M2} = W_{r2}\vartheta Q[P - W_{M2} - C_{mf} - C_{mir}] \tag{6}$$

$$\pi_{r2} = W_{r2}\vartheta Q\left[W_{M2} - d_{r2} - \frac{C_{ri}}{\vartheta}\right] \tag{7}$$

4.1. First scenario game: Nash

The first scenario arises in the market where both chains have equal power like the competition between Apple and Dell as two powerful companies with equal market power. Accordingly, the competitors act as players in a Nash game and choose their policies about the proposing reward on their channels at the same time.

Theorem 1. The retailer and manufacturer's profit function of the first and second supply chain are concave.

Proof. The second-order derivative of Eq. (5) respect to d_{r1} is $\partial^2\pi_{r1}/\partial d_{r1}^2 = -2\alpha_1 Q\vartheta < 0$. Moreover, π_{r2} and π_{M1} respect to d_{r2} and d_e are concave because $\partial^2\pi_{r2}/\partial d_{r2}^2 = -2\beta_1 Q\vartheta$ and $\partial^2\pi_{M1}/\partial d_e^2 = -2\gamma_1 Q\lambda$ are negative. The proof is complete.

Since members' profit function are concave, we obtain unique optimal values of d_{r1}, d_e and d_{r2} by solving the following equations simultaneously which respectively gain from deriving the first-order condition of Equation (5) respect to d_{r1}, Equation (4) respect to d_e and Equation. (7) respect to d_{r2}:

$$\frac{\partial\pi_{r1}}{\partial d_{r1}} = Q\vartheta\left(\alpha_1\left(W_{M1} - \frac{C_{ri}}{\vartheta}\right) - 2\alpha_1 d_{r1} + \gamma_2' d_e + \beta_2' d_{r2}\right) = 0 \tag{8}$$

$$\begin{aligned}\frac{\partial\pi_{M1}}{\partial d_e} &= Q((P - C_{mf})(\lambda\gamma_1 - \vartheta\gamma_2') + (W_{M1} + C_{mir})\vartheta\gamma_2' - C_{mie}\gamma_1 \\ &\quad + \lambda(\alpha_2' d_{r1} - 2\gamma_1 d_e + \beta_2' d_{r2})) = 0\end{aligned} \tag{9}$$

$$\frac{\partial\pi_{r2}}{\partial d_{r2}} = Q\vartheta\left(\beta_1\left(W_{M2} - \frac{C_{ri}}{\vartheta}\right) + \alpha_2' d_{r1} + \gamma_2' d_e - 2\beta_1 d_{r2}\right) = 0 \tag{10}$$

Hence, members of chains make their decisions simultaneously as follows:

$$d_{r1}^I = \frac{\left(\lambda\beta_2'\beta_1\left(W_{M2} - \frac{C_{ri}}{\vartheta}\right)(2\gamma_1 + \gamma_2') + \lambda\alpha_1\left(W_{M1} - \frac{C_{ri}}{\vartheta}\right)(4\beta_1\gamma_1 - \beta_2'\gamma_2') + ((P - C_{mf})(\lambda\gamma_1 - \vartheta\gamma_2') + (W_{M1} + C_{mir})\vartheta\gamma_2' - C_{mie}\gamma_1)\gamma_2'(2\beta_1 + \beta_2')\right)}{2\lambda[(4\gamma_1\beta_1 - \gamma_2'\beta_2')\alpha_1 - (\gamma_2'\beta_1 + \beta_2'(\gamma_1 + \gamma_2'))\alpha_2']}$$

$$d_e^I = \frac{\left(\lambda\beta_2'\beta_1\left(W_{M2} - \frac{C_{ri}}{\vartheta}\right)(2\alpha_1 + \alpha_2') + \left(W_{M1} - \frac{C_{ri}}{\vartheta}\right)\alpha_1\alpha_2'\lambda(2\beta_1 + \beta_2') + ((P - C_{mf})(\lambda\gamma_1 - \vartheta\gamma_2') + (W_{M1} + C_{mir})\vartheta\gamma_2' - C_{mie}\gamma_1)(4\alpha_1\beta_1 - \alpha_2'\beta_2')\right)}{2\lambda[(4\gamma_1\beta_1 - \gamma_2'\beta_2')\alpha_1 - (\gamma_2'\beta_1 + \beta_2'(\gamma_1 + \gamma_2'))\alpha_2']}$$

$$d_{r2}^I = \frac{\left(\lambda\beta_1\left(W_{M2} - \frac{C_{ri}}{\vartheta}\right)(4\alpha_1\gamma_1 - \alpha_2'\gamma_2') + \lambda\alpha_2'\left(W_{M1} - \frac{C_{ri}}{\vartheta}\right)(2\gamma_1 + \gamma_2') + ((P - C_{mf})(\lambda\gamma_1 - \vartheta\gamma_2') + (W_{M1} + C_{mir})\vartheta\gamma_2' - C_{mie}\gamma_1)\gamma_2'(2\alpha_1 + \alpha_2')\right)}{2\lambda[(4\gamma_1\beta_1 - \gamma_2'\beta_2')\alpha_1 - (\gamma_2'\beta_1 + \beta_2'(\gamma_1 + \gamma_2'))\alpha_2']}$$

Where d_{r1}^{I}, d_e^{I}, respectively, are unique optimal rewards of the traditional and direct channel of the first chain and d_{r2}^{I} is the unique optimal reward of the second supply chain, under the first scenario when two chains have equal power.

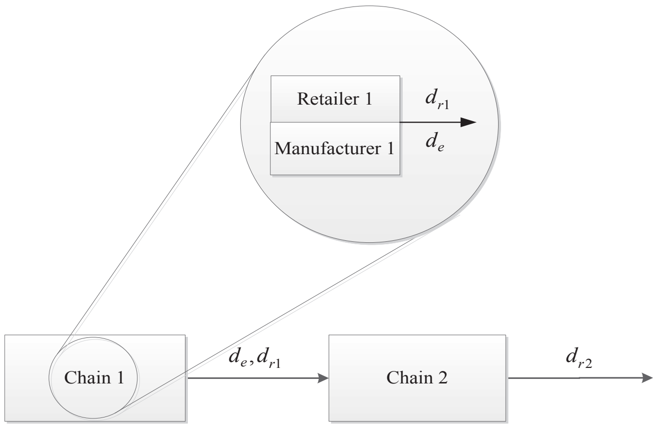

Fig. 3. Decision algorithm under second scenario game.

4.2. Second scenario game: Nash-Stackelberg-first supply chain

In this section, we integrate two games: Nash and Stackelberg. We apply the Stackelberg game between two competing chains where one of them is larger and more powerful than the other one and acts as a leader in the Stackelberg game. For example, competition among national brands and store brands, like Walmart with local retailers, or competition between Apple as a national brand company in electronic devices with GLX as an Iranian company in a cellphone. In this scenario, the first chain acts as a Stackelberg leader and his competitor (the other chain) is the follower. Meanwhile, the members of the first supply chain decide on their variables at the same time. It means that the retailer 2 makes his decision about the amount of d_{r2} as the best reaction to d_{r1} and d_e that the first retailer and the manufacturers are simultaneously determined by using Nash game rules (See Fig. 3).

As we showed in the previous scenario (Theorem 1), the profit of the retailer 2 is concave in d_{r2}. Therefore, the optimal reward of the second SC is calculated based on d_{r2} by solving Eq. (10) as follows:

$$d_{r2}^{II} = \frac{\beta_1\left(W_{M2} - \frac{C_{ri}}{\vartheta}\right) + \alpha_2' d_{r1} + \gamma_2' d_e}{2\beta_1} \tag{11}$$

We obtain the new value of W_{r1} and W_e by substituting Eq. (11) into Equations (1) and (2), as below:

$$W_{r1} = \left(\alpha_1 - \frac{\alpha_2'\beta_2'}{2\beta_1}\right)d_{r1} - \gamma_2'\left(1 + \frac{\beta_2'}{2\beta_1}\right)d_e - \frac{\beta_2'}{2}\left(W_{M2} - \frac{C_{ri}}{\vartheta}\right) \tag{12}$$

$$W_e = -\alpha_2'\left(1 + \frac{\beta_2'}{2\beta_1}\right)d_{r1} + \left(\gamma_1 - \frac{\gamma_2'\beta_2'}{2\beta_1}\right)d_e - \frac{\beta_2'}{2}\left(W_{M2} - \frac{C_{ri}}{\vartheta}\right) \tag{13}$$

Then by substituting Equations (12) and (13) into Eqs. (4) and (5) and taking the first derivative of them we have:

$$\frac{\partial \pi_{r1}}{\partial d_{r1}} = \vartheta Q\left(\left(W_{M1} - 2d_{r1} - \frac{C_{ri}}{\vartheta}\right)\left(\alpha_1 - \frac{\alpha_2'\beta_2'}{2\beta_1}\right) + \gamma_2'\left(1 + \frac{\beta_2'}{2\beta_1}\right)d_e + \frac{\beta_2'}{2}\left(W_{M2} - \frac{C_{ri}}{\vartheta}\right)\right) \tag{14}$$

$$\frac{\partial \pi_{M1}}{\partial d_e} = Q\left(-(P - C_{mf} - W_{M1} - C_{mir})\vartheta\gamma_2'\left(1 + \frac{\beta_2'}{2\beta_1}\right) + \left(P - C_{mf} - 2d_e - \frac{C_{mie}}{\lambda}\right)\lambda\left(\gamma_1 - \frac{\gamma_2'\beta_2'}{2\beta_1}\right) + \lambda\alpha_2'\left(1 + \frac{\beta_2'}{2\beta_1}\right)d_{r1} + \frac{\beta_2'\lambda}{2}\left(W_{M2} - \frac{C_{ri}}{\vartheta}\right)\right) \tag{15}$$

Theorem 2. The function of π_{r1} and π_{M1} are concave over d_{r1} and d_e, respectively.

Proof. For uniqueness of the optimal values, we check that the second order conditions π_{r1} and π_{M1} respect to d_{r1} and d_e, respectively. The concavity of π_{r1} respect to d_{r1} is assured since, as mentioned earlier, $\alpha_1 \geq \alpha_2'$, $\beta_1 \geq \beta_2'$ and all of the parameters are positive therefore $\partial^2\pi_{r1}/\partial d_{r1}^2 = -2Q\vartheta(\alpha_1 - \alpha_2'\beta_2'/2\beta_1) < 0$. In addition $\partial^2\pi_{M1}/\partial d_e^2 = -2Q\lambda(\gamma_1 - \gamma_2'\beta_2'/2\beta_1)$ is negative, since $\beta_1 \geq \beta_2'$ and $\gamma_1 \geq \gamma_2'$, hence π_{M1} is concave for all value of d_e. The proof is complete.

Since π_{M1} and π_{r1} is concave so we can obtain unique optimal values of d_{r1} and d_e by setting Eqs. (14) and (15) equal to 0. Therefore we have:

$$d_{r1}^{II} = \frac{\left(2\lambda\left(\gamma_1 - \frac{\gamma_2'\beta_2'}{2\beta_1}\right)\left(\left(W_{M1} - \frac{C_{ri}}{\vartheta}\right)\left(\alpha_1 - \frac{\alpha_2'\beta_2'}{2\beta_1}\right) + \frac{\beta_2'}{2}\left(W_{M2} - \frac{C_{ri}}{\vartheta}\right)\right) + \gamma_2'\left(1 + \frac{\beta_2'}{2\beta_1}\right)\left((P - C_{mf})\left(-\gamma_2'\left(1 + \frac{\beta_2'}{2\beta_1}\right)\vartheta + \left(\gamma_1 - \frac{\gamma_2'\beta_2'}{2\beta_1}\right)\lambda\right) - C_{mie}\left(\gamma_1 - \frac{\gamma_2'\beta_2'}{2\beta_1}\right) + (W_{M1} + C_{mir})\gamma_2'\left(1 + \frac{\beta_2'}{2\beta_1}\right)\vartheta + \frac{\beta_2'}{2}\lambda\left(W_{M2} - \frac{C_{ri}}{\vartheta}\right)\right)\right)}{4\lambda\left(\gamma_1 - \frac{\gamma_2'\beta_2'}{2\beta_1}\right)\left(\alpha_1 - \frac{\alpha_2'\beta_2'}{2\beta_1}\right) - \lambda\alpha_2'\gamma_2'\left(1 + \frac{\beta_2'}{2\beta_1}\right)^2} \tag{16}$$

$$d_e^{II} = \frac{\left(\lambda\alpha_2'\left(1 + \frac{\beta_2'}{2\beta_1}\right)\left(\left(W_{M1} - \frac{C_{ri}}{\vartheta}\right)\left(\alpha_1 - \frac{\alpha_2'\beta_2'}{2\beta_1}\right) + \frac{\beta_2'}{2}\left(W_{M2} - \frac{C_{ri}}{\vartheta}\right)\right) + 2\left(\alpha_1 - \frac{\alpha_2'\beta_2'}{2\beta_1}\right)\left((P - C_{mf})\left(-\gamma_2'\left(1 + \frac{\beta_2'}{2\beta_1}\right)\vartheta + \left(\gamma_1 - \frac{\gamma_2'\beta_2'}{2\beta_1}\right)\lambda\right) + (W_{M1} + C_{mir})\gamma_2'\left(1 + \frac{\beta_2'}{2\beta_1}\right)\vartheta - C_{mie}\left(\gamma_1 - \frac{\gamma_2'\beta_2'}{2\beta_1}\right) + \frac{\beta_2'\lambda}{2}\left(W_{M2} - \frac{C_{ri}}{\vartheta}\right)\right)\right)}{4\lambda\left(\gamma_1 - \frac{\gamma_2'\beta_2'}{2\beta_1}\right)\left(\alpha_1 - \frac{\alpha_2'\beta_2'}{2\beta_1}\right) - \lambda\alpha_2'\gamma_2'\left(1 + \frac{\beta_2'}{2\beta_1}\right)^2} \tag{17}$$

Then, by putting Eqs. (16) and (17) into (11), we find that the unique value of d_{r2} as follows:

$$d_{r2}^{II} = \frac{\left(W_{M2} - \frac{C_{ri}}{\vartheta}\right)}{2} + \frac{\left(\alpha_2'\lambda\left(2\left(\gamma_1 - \frac{\gamma_2'\beta_2'}{2\beta_1}\right) + \gamma_2'\left(1 + \frac{\beta_2'}{2\beta_1}\right)\right)\left(\left(W_{M1} - \frac{C_{ri}}{\vartheta}\right)\left(\alpha_1 - \frac{\alpha_2'\beta_2'}{2\beta_1}\right) + \frac{\beta_2'}{2}\left(W_{M2} - \frac{C_{ri}}{\vartheta}\right)\right) + \gamma_2'\left(2\left(\alpha_1 - \frac{\alpha_2'\beta_2'}{2\beta_1}\right) + \alpha_2'\left(1 + \frac{\beta_2'}{2\beta_1}\right)\right)\left((P - C_{mf})\left(-\gamma_2'\left(1 + \frac{\beta_2'}{2\beta_1}\right)\vartheta + \left(\gamma_1 - \frac{\gamma_2'\beta_2'}{2\beta_1}\right)\lambda\right) - C_{mie}\left(\gamma_1 - \frac{\gamma_2'\beta_2'}{2\beta_1}\right) + (W_{M1} + C_{mir})\gamma_2'\left(1 + \frac{\beta_2'}{2\beta_1}\right)\vartheta + \frac{\beta_2'\lambda}{2}\left(W_{M2} - \frac{C_{ri}}{\vartheta}\right)\right)\right)}{2\beta_1\left(4\lambda\left(\gamma_1 - \frac{\gamma_2'\beta_2'}{2\beta_1}\right)\left(\alpha_1 - \frac{\alpha_2'\beta_2'}{2\beta_1}\right) - \lambda\alpha_2'\gamma_2'\left(1 + \frac{\beta_2'}{2\beta_1}\right)^2\right)}$$

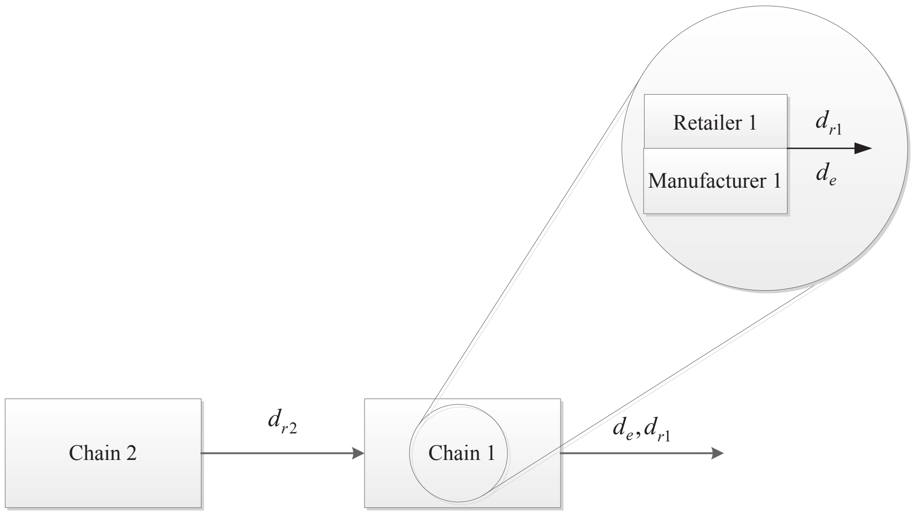

Fig. 4. Decision algorithm under the third scenario.

Therefore, d_{r1}^{II}, d_e^{II} and d_{r2}^{II} are unique optimal rewards of channels when there are two chain with different power and channel structures.

4.3. Third scenario game: Nash-Stackelberg-second supply chain

This model arises from the market with two competitors with different power like competition between Dell or Sony, which use a single collecting-channel, and electronic local-brands, which use dual collecting-channel and have lower power. Accordingly, in this section, we examine the other interaction between two competing chains while second supply chain announces his variable at first and then chain 1 determines their variables as the best reaction (Fig. 4). In order to, we use the Stackelberg game while the second supply chain is the leader and the first chain is the follower. Whereas the members of the first chain obtain the optimum rewards to the customer in traditional and internet channel through Nash game.

According to the rules of the Stackelberg game, at first, the problem solved from the perspective of the follower and then the leader calculates his variable. As mentioned in the Theorem 1, π_{M1} respect to d_e and π_{r1} respect to d_{r1} are concave. Therefore, we gain the optimum amount of reward of the internet and traditional channel as the best reaction to d_{r2} by solving Eqs. (8) and (9) simultaneously:

$$d_e^{III} = \frac{\lambda\alpha_2'\left(\left(W_{M1} - \frac{C_{ri}}{\vartheta}\right)\alpha_1 + \beta_2' d_{r2}\right) + 2\alpha_1\left((P - C_{mf})(\lambda\gamma_1 - \vartheta\gamma_2') + (W_{M1} + C_{mir})\vartheta\gamma_2' - C_{mie}\gamma_1 + \beta_2'\lambda d_{r2}\right)}{\lambda(4\alpha_1\gamma_1 - \alpha_2'\gamma_2')} \tag{18}$$

$$d_{r1}^{III} = \frac{2\lambda\gamma_1\alpha_1\left(W_{M1} - \frac{C_{ri}}{\vartheta}\right) + \gamma_2'\left((P - C_{mf})(\lambda\gamma_1 - \vartheta\gamma_2') + (W_{M1} + C_{mir})\vartheta\gamma_2' - C_{mie}\gamma_1\right) + \beta_2'\lambda d_{r2}(2\gamma_1 + \gamma_2')}{\lambda(4\alpha_1\gamma_1 - \alpha_2'\gamma_2')} \tag{19}$$

The customer willingness to return of the second SC changes as follows by substituting Eqs. (18) and (19) in Eq. (3):

$$W_{r2} = \beta_1 d_{r2} - \frac{\left(\lambda\alpha_2'(2\gamma_1 + \gamma_2')\left(\left(W_{M1} - \frac{C_{ri}}{\vartheta}\right)\alpha_1 + \beta_2' d_{r2}\right) + \gamma_2'(2\alpha_1 + \alpha_2')\left((P - C_{mf})(\lambda\gamma_1 - \vartheta\gamma_2') + (W_{M1} + C_{mir})\vartheta\gamma_2' - C_{mie}\gamma_1 + \beta_2'\lambda d_{r2}\right)\right)}{\lambda(4\alpha_1\gamma_1 - \alpha_2'\gamma_2')} \tag{20}$$

And the new value of W_{r2} applying into Eq. (7) then by taking the first-order condition of Eq. (7) with respect to d_{r2}, we have:

$$\frac{\partial\pi_{r2}}{\partial d_{r2}} = Q\vartheta\left(\left(\beta_1 - \beta_2'\frac{\alpha_2'(2\gamma_1 + \gamma_2') + \gamma_2'(2\alpha_1 + \alpha_2')}{(4\alpha_1\gamma_1 - \alpha_2'\gamma_2')}\right)\left(W_{M2} - 2d_{r2} - \frac{C_{ri}}{\vartheta}\right) + \frac{\left(\lambda\alpha_2'(2\gamma_1 + \gamma_2')\left(\left(W_{M1} - \frac{C_{ri}}{\vartheta}\right)\alpha_1\right) + \gamma_2'(2\alpha_1 + \alpha_2')\left((P - C_{mf})(\lambda\gamma_1 - \vartheta\gamma_2') + (W_{M1} + C_{mir})\vartheta\gamma_2' - C_{mie}\gamma_1\right)\right)}{\lambda(4\alpha_1\gamma_1 - \alpha_2'\gamma_2')}\right) \tag{21}$$

Theorem 3. The profit function of the retailer in the second supply chain is concave.

Proof. For uniqueness of the optimal value, we check that the second order condition π_{r2} respect to d_{r2}. We have the new function of the second retailer which is obtained by substituting Eq. (20) into Eq. (7) as follows:

$$\pi_{r2} = \vartheta Q\left(W_{M2} - d_{r2} - \frac{C_{ri}}{\vartheta}\right) - \frac{\left(\lambda\alpha_2'(2\gamma_1 + \gamma_2')\left(\left(W_{M1} - \frac{C_{ri}}{\vartheta}\right)\alpha_1 + \beta_2' d_{r2}\right) + \gamma_2'(2\alpha_1 + \alpha_2')((P - C_{mf})(\lambda\gamma_1 - \vartheta\gamma_2') + (W_{M1} + C_{mir})\vartheta\gamma_2' - C_{mie}\gamma_1 + \beta_2'\lambda d_{r2})\right)}{\lambda(4\alpha_1\gamma_1 - \alpha_2'\gamma_2')} + \beta_1 d_{r2}$$

As mentioned in hypotheses, $\alpha_1 \geq \alpha_2'$, $\beta_1 \geq \beta_2'$ and $\gamma_1 \geq \gamma_2'$, hence $\frac{\partial^2 \pi_{r2}}{\partial d_{r2}} = Q\vartheta\left(-2\beta_1 + \frac{\beta_2'(\alpha_2'(2\gamma_1 + \gamma_2') + \gamma_2'(2\alpha_1 + \alpha_2'))}{(4\alpha_1\gamma_1 - \alpha_2'\gamma_2')}\right)$ is negative and as a direct result π_{r2} for all value of d_{r2} is concave. The Proof is complete.

Since π_{r2} is concave, we obtain the independent value of d_{r2} by making Eq. (21) equal to 0:

In this condition, there are some ways which other members of the chain could convince the victim's member to change his strategy to the strategy which is the most economic for the entire of SC. All of the members in the second chain insist on deciding as a follower because of the more profitability of the second strategy. Therefore, the second strategy is the most economic interaction for the second SC.

$$d_{r2}^{III} = \frac{\left(W_{M2} - \frac{C_{ri}}{\vartheta}\right)}{2} + \frac{\left(\lambda\alpha_2'(2\gamma_1 + \gamma_2')\left(\left(W_{M1} - \frac{C_{ri}}{\vartheta}\right)\alpha_1\right) + \gamma_2'(2\alpha_1 + \alpha_2')((P - C_{mf})(\lambda\gamma_1 - \vartheta\gamma_2') + (W_{M1} + C_{mir})\vartheta\gamma_2' - C_{mie}\gamma_1)\right)}{2\lambda(4\alpha_1\gamma_1 - \alpha_2'\gamma_2')\left(\beta_1 - \beta_2'\frac{\alpha_2'(2\gamma_1 + \gamma_2') + \gamma_2'(2\alpha_1 + \alpha_2')}{(4\alpha_1\gamma_1 - \alpha_2'\gamma_2')}\right)} \tag{22}$$

Then, by putting Eq. (22) into (18) and (19), we have unique values of d_{r1} and d_e as follows:

Also, the optimal reward of each channel obtained based on relative equations that we mentioned earlier, is presented in Table 4. The results

$$d_e^{III} = \frac{\lambda\alpha_2'\alpha_1\left(W_{M1} - \frac{C_{ri}}{\vartheta}\right) + 2\alpha_1((P - C_{mf})(\lambda\gamma_1 - \vartheta\gamma_2') + (W_{M1} + C_{mir})\vartheta\gamma_2' - C_{mie}\gamma_1)}{\lambda(4\alpha_1\gamma_1 - \alpha_2'\gamma_2')}$$
$$+ \frac{\beta_2'(2\alpha_1 + \alpha_2')}{(4\alpha_1\gamma_1 - \alpha_2'\gamma_2')}\left(\frac{\left(W_{M2} - \frac{C_{ri}}{\vartheta}\right)}{2} + \frac{\left(\lambda\alpha_2'(2\gamma_1 + \gamma_2')\left(\left(W_{M1} - \frac{C_{ri}}{\vartheta}\right)\alpha_1\right) + \gamma_2'(2\alpha_1 + \alpha_2')((P - C_{mf})(\lambda\gamma_1 - \vartheta\gamma_2') + (W_{M1} + C_{mir})\vartheta\gamma_2' - C_{mie}\gamma_1)\right)}{2\lambda(4\alpha_1\gamma_1 - \alpha_2'\gamma_2')\left(\beta_1 - \beta_2'\frac{\alpha_2'(2\gamma_1 + \gamma_2') + \gamma_2'(2\alpha_1 + \alpha_2')}{(4\alpha_1\gamma_1 - \alpha_2'\gamma_2')}\right)}\right)$$

$$d_{r1}^{III} = \frac{2\lambda\gamma_1\left(\left(W_{M1} - \frac{C_{ri}}{\vartheta}\right)\alpha_1\right) + \gamma_2'((P - C_{mf})(\lambda\gamma_1 - \vartheta\gamma_2') + (W_{M1} + C_{mir})\vartheta\gamma_2' - C_{mie}\gamma_1)}{\lambda(4\alpha_1\gamma_1 - \alpha_2'\gamma_2')}$$
$$+ \frac{\beta_2'(\gamma_2' + 2\gamma_1)}{(4\alpha_1\gamma_1 - \alpha_2'\gamma_2')}\left(\frac{\left(W_{M2} - \frac{C_{ri}}{\vartheta}\right)}{2} + \frac{\left(\lambda\alpha_2'(2\gamma_1 + \gamma_2')\left(\left(W_{M1} - \frac{C_{ri}}{\vartheta}\right)\alpha_1\right) + \gamma_2'(2\alpha_1 + \alpha_2')((P - C_{mf})(\lambda\gamma_1 - \vartheta\gamma_2') + (W_{M1} + C_{mir})\vartheta\gamma_2' - C_{mie}\gamma_1)\right)}{2\lambda(4\alpha_1\gamma_1 - \alpha_2'\gamma_2')\left(\beta_1 - \beta_2'\frac{\alpha_2'(2\gamma_1 + \gamma_2') + \gamma_2'(2\alpha_1 + \alpha_2')}{(4\alpha_1\gamma_1 - \alpha_2'\gamma_2')}\right)}\right)$$

Therefore, d_{r1}^{III}, d_e^{III} and d_{r2}^{III} are unique optimal rewards of channels under the third scenario.

5. Computational and practical results

In this subsection, a numerical example and a set of sensitivity analyses are provided in order to illustrate the effectiveness of the proposed models. Moreover, the results of different scenario game are examined. The set of parameters that we used in the model, presented in Table 2. The data input in Table 2 is an estimation of the real data that Apple Company[4] presented for its refurbished products and Govindan and Popiuc (2014) used in their paper.

Table 3 shows the result of the members' profit function under scenario games. If we look at the problem from the perspective of retailers, we find that both retailers prefer that the first chain acts as a leader. But the first manufacturer tries to decide after the second chain, moreover, the first supply chain profit under the third strategy is more than the others.

show that when the members make decisions simultaneously, the proposing rewards to the customer are higher and as a result, the total willingness to return is greater than the other cases. Therefore, Nash strategy is the most economic interaction for customers.

Our investigations show that the acceptance rate plays an important role in the profit of supply chain members. Therefore, we examine and compare the impact of acceptance rate in the proposed model by a set of sensitivity analyses. We found that increasing acceptance rate (changing from 0.7 to 1) encourages the members to increase their proposing rewards and as a result the rate of return increases. Therefore, it is reasonable that increasing ϑ have a positive effect on the profit of all competitor members (Table 5). Accordingly, the manufacturers should motivate their retailers to invest in increasing acceptance rate by some approach like more detailed inspections. Refurbishing cost is the other important parameter in remanufacturing process, which have a considerable impact on the decision variables and profit functions under different scenarios. In order to examine the effect of C_{mf}, we change this parameter (from 200 to 260). Refurbishing cost is one of the most effectiveness parameters in the profit of the first manufacturer that increase in value of this parameter causes decrease in π_{M1} and as a direct result d_e intensify declining and finally this changing has a little negative effect on value of d_{r1} and d_{r2}. Accordingly, part of the customers

[4] http://www.apple.com/pr/library/2011/01/18Apple-Reports-First-Quarter-Results.html.

Table 2
Data input.

Parameter	P	W_{M1}	W_{M2}	C_{mie}	C_{mir}	C_{mf}	C_{ri}	Q	λ	ϑ	d_{r1}^{max}	d_e^{max}	d_{r2}^{max}	α_2	β_2	γ_2
Value	1000 ($/item)	300	280	150	200	260	20	1000	0.85	0.7	300	350	250	0.4	0.2	0.6

Table 3
Profit functions.

Scenario game	π_{r1}	π_{M1}	π_{r2}	π_{M2}	π_{SC1}	π_{SC2}
Nash	1762.8	96,559	926.52	13,243	98,322	14,169
Nash-Stackelberg-first chain	2395.4	95,957	1409.5	16,334	98,353	17,743
Nash-Stackelberg-second chain	1792.3	96,918	931.16	12,369	98,711	13,300

Table 4
Decision variables.

Scenario game	d_{r1}	d_e	d_{r2}	W_{r1}	W_e	W_{r2}	W_T
Nash	243.94	312.04	233.24	0.0916	0.3797	0.0728	0.544
Nash-Stackelberg-first chain	238.73	296.29	228.99	0.1046	0.3450	0.0897	0.539
Nash-Stackelberg-second chain	243.71	311.80	231.86	0.0916	0.3804	0.0680	0.541

in e-channel prefer to chang their collecting channel and choose retailers channel. Therefore, the return rates of traditional channels and direct channel, respectively, increases and decreases with increasing C_{mf}. Hence, the profit of retailers improving with increasing W_{r1} and W_{r2}; but the second manufacturer's behavior respect to chaining in C_{mf} is a little complicated.

We have an upward trend for the second manufacturer if increasing on W_{r2} could compensate for the rising on C_{mf}, like first and third senario, in the otherwise π_{M2} is reduced like second the senario (see Tables 6 and 7). Generally, the trend of members' profit due to change in C_{mf}, ϑ, at the same time, are represented in Fig. 5.

Environmental regulations, consumers' attention to these issues forces the manufacturer to focus on remanufacturing of products in order to reduce the need for earth's natural resources, the production of waste and also will likely increase the economic and competitive advantages of a business. To sum up, we obtain the following managerial insights in this paper:

1. This paper provides a framework to help the competitive SCs with different power structure using online and traditional retail channels to find an appropriate strategy and their decision variables. For instance HP, Apple use their stores and online channel to collect the eligible used products but usually, there are some competitors in the next to these powerful companies that use only the benefits of traditional channels like Dell and Sony use only the benefits of the internet and traditional channels, respectively.
2. Generally, these models can guide the managers in their decision-making process; in other words, companies can select each of the mentioned models depending on their goals and conditions. For instance, Nash scenario is one of the best choices for the public works in order to achieve their most important goals like less damage to natural resources. Accordingly, these kinds of companies for which the profit is the lowest priority, select the first scenario because the maximum return rate of obsolete products occurs under this scenario.
3. For the companies with economic goals would be better to select the second or the third scenarios depending on the circumstances because these structures are more beneficial for members of chains

Table 5
The sensitivity of profit functions due to change in acceptance rate under three strategy game.

ϑ		0.7	0.75	0.8	0.85	0.9	0.95	1
Retailer 1	Nash	1762.8	2180.6	2645.3	3158.5	3721.7	4336.5	5004.6
	Nash-Stackelberg-first chain	2395.4	2937.3	3538.7	4201.7	4928.5	5721.3	6582.2
	Nash-Stackelberg-second chain	1792.3	2218.2	2691.9	3215.1	3789.5	4416.5	5098.1
Manufacturer 1	Nash	96,559	97,653	98,823	100,060	101,350	102,700	104,100
	Nash-Stackelberg-first chain	95,957	96,866	97,839	98,865	99,937	101,050	102,200
	Nash-Stackelberg-second chain	96,918	98,060	99,278	100,560	101,910	103,310	104,750
Retailer 2	Nash	926.5	1209.8	1533.4	1898.9	2307.8	2761.8	3262.4
	Nash-Stackelberg-first chain	1409.5	1801.6	2246.1	2745.1	3300.7	3915.1	4590.5
	Nash-Stackelberg-second chain	931.2	1215.8	1541.1	1908.4	2319.4	2775.6	3278.7
Manufacturer 2	Nash	13,243	15,663	18,213	20,891	23,699	26,635	29,701
	Nash-Stackelberg-first chain	16,334	19,114	22,043	25,118	28,342	31,713	35,232
	Nash-Stackelberg-second chain	12,369	14,630	17,012	19,513	22,136	24,879	27,742
Supply chain 1	Nash	98,322	99,834	101,470	103,220	105,080	107,040	109,110
	Nash-Stackelberg-first chain	98,353	99,804	101,380	103,070	104,870	106,770	108,780
	Nash-Stackelberg-second chain	98,711	100,280	101,970	103,780	105,700	107,720	109,850
Supply chain 2	Nash	14,169	16,873	19,746	22,790	26,007	29,397	32,963
	Nash-Stackelberg-first chain	17,743	20,916	24,289	27,864	31,643	35,628	39,822
	Nash-Stackelberg-second chain	13,300	15,846	18,553	21,422	24,455	27,654	31,021

Table 6
The sensitivity of the decision variables due to change in refurbishing cost C_{mf}.

C_{mf}		200	210	220	230	240	250	260
d_{r1}	Nash	248.83	248.02	247.20	246.39	245.57	244.76	243.94
	Nash-Stackelberg-first chain	242.78	242.11	241.43	240.75	240.08	239.40	238.73
	Nash-Stackelberg-second chain	248.66	247.83	247.01	246.19	245.36	244.54	243.71
d_e	Nash	328.98	326.16	323.34	320.51	317.69	314.87	312.04
	Nash-Stackelberg-first chain	310.05	307.75	305.46	303.17	300.87	298.58	296.29
	Nash-Stackelberg-second chain	328.80	325.96	323.13	320.30	317.46	314.63	311.80
d_{r2}	Nash	237.68	236.94	236.20	235.46	234.72	233.98	233.24
	Nash-Stackelberg-first chain	232.62	232.01	231.41	230.80	230.20	229.60	228.99
	Nash-Stackelberg-second chain	236.64	235.84	235.04	234.25	233.45	232.65	231.86
W_{r1}	Nash	0.0753	0.0780	0.0808	0.0835	0.0862	0.0889	0.0916
	Nash-Stackelberg-first chain	0.0917	0.0938	0.0960	0.0982	0.1003	0.1025	0.1046
	Nash-Stackelberg-second chain	0.0638	0.0665	0.0693	0.0721	0.0748	0.0776	0.0803
W_e	Nash	0.4180	0.4116	0.4053	0.3989	0.3925	0.3861	0.3797
	Nash-Stackelberg-first chain	0.3760	0.3709	0.3657	0.3605	0.3554	0.3502	0.3450
	Nash-Stackelberg-second chain	0.4186	0.4122	0.4058	0.3995	0.3931	0.3868	0.3804
W_{r2}	Nash	0.0550	0.0579	0.0609	0.0639	0.0668	0.0698	0.0728
	Nash-Stackelberg-first chain	0.0752	0.0777	0.0801	0.0825	0.0849	0.0873	0.0897
	Nash-Stackelberg-second chain	0.0514	0.0541	0.0569	0.0597	0.0624	0.0652	0.0680
W_T	Nash	0.5483	0.5476	0.5469	0.5462	0.5455	0.5448	0.5441
	Nash-Stackelberg-first chain	0.5430	0.5424	0.5418	0.5412	0.5406	0.5400	0.5394
	Nash-Stackelberg-second chain	0.5458	0.5450	0.5441	0.5433	0.5424	0.5416	0.5408

than Nash.

4. Direct channel because of less costly than traditional channel proposes more appropriate reward to customers, so this channel could obtain more share of the market.
5. Furthermore, the competitive companies with equal power could use the advantages of the first scenario and determine their optimal decisions based on Nash game.
6. Moreover, the second and third scenarios are suitable for competition between brands with different power like National brand and Store brand.
7. Furthermore, the results indicate that the acceptance rate can have the significant positive effect on the member's profit and entire SC. Therefore, the manufacturers should give their retailers motivation to investment on increasing acceptance rate. Coordination contracts like Revenue or Cost sharing contract could convince the retailer to have an exact inspection in order to increase the acceptance rate of the traditional channel (See Heydari et al., 2018).
8. Moreover, the analysis carried out on C_{mf} show that this parameter has a considerable impact on the decision variables and profit functions under different scenarios. As mentioned above, increasing C_{mf} lead to decrease in the manufacturer's profit, accordingly, it is reasonable that the manufacturers invest in reducing this parameter through some ways like modular design components. On the other hand, the competitive environments which are faced with many changes in C_{mf}, it would be better to enter the impact of these variables by using an appropriate random function.

6. Conclusions and future research

In this paper, we investigate the competition problem between two reverse chains that each chain collects the used products through their collecting channels. Each chain consists of one manufacturer and one retailer. We examine three different interaction between members by applying three scenario games: Nash, Nash-Stackelberg-first supply chain and Nash-Stackelberg-second supply chain. Therefore, this paper provides a framework to help the competitive SCs with different power structures, so companies can use them as a guideline for selecting their appropriate strategies and their decision variables under different interactions. For instance, the second and the third scenarios are suitable for competition between brands with different market powers like National brand and Store brand. Competiton McDonald's against local fast foods are familiar competitors that we can point out. Moreover, the competition between powerful companies like Apple and Dell is another instance of this issue which turns back to competition between

Table 7
The sensitivity of the profit functions due to change in refurbishing cost C_{mf}.

C_{mf}		200	210	220	230	240	250	260
Retailer 1	Nash	1191.4	1278.9	1369.5	1463.1	1559.9	1659.8	1762.8
	Nash-Stackelberg-first chain	1838.3	1926.0	2015.8	2107.6	2201.5	2297.5	2395.4
	Nash-Stackelberg-second chain	1209.8	1298.9	1391.3	1486.8	1585.5	1687.3	1792.3
Manufacturer 1	Nash	120,480	116,390	112,350	108,340	104,370	100,450	96,559
	Nash-Stackelberg-first chain	119,450	115,440	111,470	107,540	103,640	99,780	95,957
	Nash-Stackelberg-second chain	120,800	116,720	112,680	108,680	104,720	100,800	96,918
Retailer 2	Nash	529.06	587.62	649.25	713.96	781.74	852.59	926.52
	Nash-Stackelberg-first chain	990.9	1055.6	1122.3	1191.0	1261.8	1334.7	1409.5
	Nash-Stackelberg-second chain	531.7	590.6	652.5	717.5	785.7	856.9	931.2
Manufacturer 2	Nash	12,316	12,574	12,791	12,966	13,100	13,192	13,243
	Nash-Stackelberg-first chain	16,856	16,853	16,817	16,747	16,643	16,505	16,334
	Nash-Stackelberg-second chain	11,504	11,745	11,947	12,111	12,236	12,322	12,369
Supply chain 1	Nash	121,670	117,670	113,710	109,800	105,930	102,110	98,322
	Nash-Stackelberg-first chain	121,290	117,370	113,490	109,640	105,840	102,080	98,353
	Nash-Stackelberg-second chain	122,010	118,020	114,070	110,170	106,310	102,490	98,711
Supply chain 2	Nash	12,845	13,162	13,440	13,680	13,882	14,045	14,169
	Nash-Stackelberg-first chain	17,847	17,909	17,939	17,938	17,905	17,840	17,743
	Nash-Stackelberg-second chain	12,036	12,336	12,600	12,829	13,022	13,179	13,300

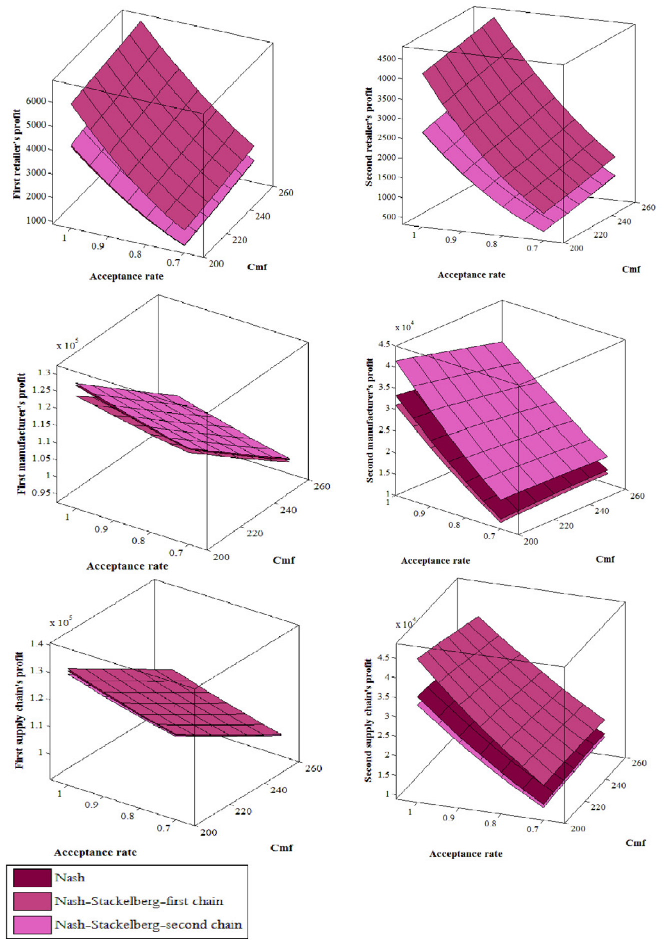

Fig. 5. Comparing the profit of each SC member under three scenario games by increasing C_{mf}, ϑ.

chains with different channel structures. Additionally, the competitive companies with equal market power could use the advantage of the first scenario like Apple, Sony, HP and so on.

Accordingly, we define a return rate function of each channel with considering this fact that each policy is chosen by a member impacts on the return rate of the others. In our models, the first manufacturer competes with the retailer of the first chain and also with the channel of his competitor in the other chain. We obtain the optimal value of proposing reward of these channels under the mentioned scenario games for the interactions that might occur between the members of competing chains. Finally, we analyzed the effect of acceptance rate and refurbishing cost on the decision variables and profit functions of members and found the following important managerial insights:

1. If we consider economic goals as the most important factor, the second or the third scenarios are more beneficial for members of chains than Nash.
2. Direct channel because of less costly than traditional channel proposes more appropriate reward to customers, so this channel could obtain more share of the market.
3. Furthermore, the competitive companies with equal power could use the advantages of the first scenario and determine their optimal decisions based on Nash game.
4. Moreover, the second and third scenarios are suitable for competition between companies with different power like National brand and Store brand.
5. Furthermore, the results indicate that the acceptance rate can have the significant positive effect on the member's profit, entire SC and decision variables.
6. Moreover, the analysis carried out on C_{mf} show that increasing this parameter leads to decrease and increase in the manufacturers' and retailers' profit, respectively.

The model is limited by some assumptions. We consider a linear and deterministic function for the return rate of each channel in a single period model. The model can be extended by considering uncertainty or non-linear function for return rate over the multi-period horizon (See Wu, 2015). On the other hand, we assume that the return rate is a function of the rewards in different channels while it would be interesting to investigate the impact of other items like recycling cost, advertising etc (See Wu et al., 2016) in the model. The quality of returned-obsolete products is another parameter is not considered in this paper while different quality level can lead to the appearance uncertainty in the other parameters such as the cost of remanufacturing and as a direct result on profit of members. In this paper, the effect of multi-channel strategy on customer's satisfaction and profits of the members are investigated, but considering other effective service factors and analyzing their impacts on the decision of members is another direction for future research. Furthermore, we can investigate the game results of the problem under asymmetric information. Coordination contract in reverse competitive supply chain can be one of the attractive issues for future research (See Heydari et al., 2018). Combining the scheduling problem and inventory decisions with the pricing model and incentive policies could be of interest (See Taleizadeh and Pentico, 2013; Taleizadeh et al., 2014; Taleizadeh, 2014).

Acknowledgments

The authors thank the anonymous reviewers for their helpful suggestions that have strongly enhanced this paper. The first author would like to thank the financial support from the University of Tehran for this research under grant number 30015-1-04.

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