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The impact of government intervention in competitive electronic closed-loop supply chain to support internal industry

Mohammad Reza Rezayat, Saeed Yaghoubi *, Atieh Fander

School of Industrial Engineering, Iran University of Science and Technology, Tehran, Iran

A R T I C L E I N F O

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A B S T R A C T

Due to the development of various industries, including electronic products industries, waste management of these products in order to reduce serious damages into the environment has been considered by human societies. On the other hand, due to the fact that a high percentage of the waste of these products have capability to use for production of new products, the management of these chains is more important to reduce production costs and consequently reduction the damage on the environment. There are competitive chains in which a variety of internal products are produced by a chain that competes with products produced by another chain abroad. In the proposed mathematical model, in addition to considering the waste management of these types of products, the government tries to intervene in a way that supports internal chain. Therefore, the first purpose of this study is to answer how waste management in the competitive chain (especially electronic products) and the second purpose is to answer how the government intervenes in this type of competitive chain to support domestic industry. These two cases will be examined by presenting a mathematical model. Due to the competitive demand function for both supply chains, the importance of pricing and quality determination is particularly evident. Optimal decision variables that impact on the demand functions are concluded by Stackelberg game using manufacturers leadership without and under government intervention. Numerical examples indicate reduction on using fresh raw materials for internal manufacturer and subsequently, reduction purchasing cost of fresh raw materials by government intervention. This leads to a reduction in production costs for the internal manufacturer, which in a way has led to a boom in the internal industry. Furthermore, government intervention leads to reduce in price of products for customers. Finally, in order to extract some management concepts, several sensitivity analyzes are performed on the main parameters.

1. Introduction

In many industries, due to the lack of appropriate mechanisms to prevent them from being released into the environment after being used by the end customer, humans and the environment suffer irreparable damage. Therefore, it has led human societies to minimize the damage reduction of such products into the environment by adopting appropriate trends. In the real world, there are companies where collects defective products from the customers to reduce the release into the environment. Owing to this, in addition to collecting products dumped in the environment, it reduces the use of raw materials for the production of new products, as it is sometimes possible to reuse these products disposed of in the environment.

The importance of this issue is more evident in the electronic wastes (e-wastes) released in the environment. According to the Environmental Protection Agency (EPA) report, 65,000 tons of e-wastes are produced annually, while the most valuable type of wastes among e-wastes are cell phones, because one million recycled cell phones is equivalent to reduce greenhouse gas effect on 33 cars! (treehugger.com [1]). Also, in a report that Apple announced at 2019, recycled aluminum has been used to produce Mac Mini Air and Mac Book without any altering the quality. In addition, 100% recycled tin, which has the same quality as freshly extracted tin, is used for soldering on the iPhone home screen. Also, in order to produce new batteries, cobalt used in iPhone batteries that are reusable is used (apple.com[2]).

Therefore, companies are seeking policies for reuse of reusable

* Corresponding author. School of Industrial Engineering, Iran University of Science and Technology, Tehran, 16846-13114, Iran.
E-mail addresses: m_rezayat@ind.iust.ac.ir (M.R. Rezayat), yaghoubi@iust.ac.ir (S. Yaghoubi), a_fander@ind.iust.ac.ir (A. Fander).

[1] https://www.treehugger.com/the-environmental-costs-and-benefits-of-our-cell-phones-4858551.

[2] https://esfahansteel.ir/newcms_en.

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products to address the side effects of abandonment at the environment and lower production costs. At year 2008, the EPA in coordination with manufacturers of cell phone such as LG, Samsung and Motorola and retailers, reached an agreement for the collection of defective cell phones. In the meantime, companies that were tasked with collecting defective cell phones have come forward to the collection of defective cell phones from the customer, so that this kind of organizations pay a fee to the customer as a reward for delivering defective phones. These devices are sold to other customers after thorough review by third parties where possible at a lower price and quality. If the cost of overhaul is high, they are sold to the manufacturers and then used to reproduce new products. According to above explanations, because of that companies such as LG, Samsung and Motorola are manufacturers, there need for retailers to sell their products to the customers. Based on the actual case introduced (LG, Samsung and Motorola), these manufacturers coordinate with a collector to collect defective goods. Therefore, it is a chain consisting of manufacture, collector and retailer (treehugger.com[1]). Given the above explanations, the importance of collecting some of the defective products released into the environment is increasing and the government adopts appropriate policies (tax collection or subsidies granted) as an effective entity to prevent expansion of this issue.

On the other hand, in industries especially electronic industries, in addition to the product being manufactured domestically by the internal manufacturer and the manufactured item being sold by the supplier itself (selling online) or by the retailer (selling offline) (Zhang et al., 2017; Jiaping et al., 2018; Modak and Kelle, 2019), another similar product is produced by a manufacturer at the foreign country. This means that the same product is manufactured by a foreign manufacturer at a price or even different quality from the internal product and is sold by another retailer in the internal market. However, there are two chains to produce products that are rival to each other. By adopting appropriate policies, the government will broad the internal product market in the country (e.g. subsidizing the internal manufacturer to encourage the production of goods) and in contrast, by obtaining tax and customs duties from retailers who sell foreign goods, it prevents more foreign goods from entering the country.

To deal with harmful pollutants arose from the release of this type of product to the environment and on the other hand, due to the high recyclability of these products in order to use for the reproduction, the importance of presenting a closed-loop supply chain (CLSC) model in this area is becoming more and more apparent.

In this paper, an electronic CLSC is considered, comprising two manufacturers, one collector and two retailers. At the forward movement, the internal manufacturer sells goods through both channels (The online and the offline channel), and the foreign manufacturer can sell its goods through another retailer in the destination country. At the backward flow, waste collection is the responsibility of the collector from customers. By reusing recycled products, the need for fresh raw materials is somewhat reduced and accordingly reduces environmental pollution caused by release them into the environment. For this purpose, two decision-making strategies have been created: manufacturers' leadership in the Stackelberg game without government intervention and considering chain with government intervention. By adopting appropriate policies, the government is trying to boost internal production, increase customer purchasing power and reduce the import of similar foreign goods into the country.

The main research questions that have to be answered are as follows:

1) How does the mathematical model show the competition between the supply chain of internal and foreign goods?
2) How does new and secondary goods are distinguished in the presented mathematical model?
3) How does the government reduce the entry of similar foreign goods into the country as a supervisory institution?
4) How does the threshold for accepting barriers, as well as the minimum level of acceptable incentive plan set by the government for members can be determined?

It is noteworthy that research has been done in this field in the past. However, differences in the new structure and application of the presented supply chain distinguish our research from others. To the best of our knowledge, mostly competitions assumed at green and non-green chains and has not been presented competition between internal and external chains. Lou and Ma (2018) and Hafezalkotob (2018), presented two chains where one of them produces a green output and the other works in the field of traditional non-green production. In some cases, the government, as a regulatory institution for some chains, has the task of reviewing and monitoring their performance. This monitoring has been studied in the literature in various ways. At the research of Hafezalkotob (2017), government intervention is considered in the competitive chain, which includes just green goods. Given that the competitive chains of various products, including internal production and imported products, have not been studied so far, the government's intervention in the field of customs duties on imported products has not been mentioned, which will be mentioned in this research. At this type of intervention, the government tries to influence the domestic industry in a competitive electronic supply chain and lead to the prosperity of the internal production chain. At this study, a competitive electronic supply chain means that one chain overseas sells its products in the under study country and another chain in the same country produces and sells its products. These two chains try to satisfy customers demand at a competitive space. Because of that customer's demand depends on the price and quality of both these chains and so on, these two chains try to attract customers to their products. At the literature, He et al. (2019a,b) examined a competitive collection and also Ranjbar et al. (2020) examined just a competitive recycling closed-loop supply chain channel. At the other investigation, Islam and Huda (2018) presented an article in which shows just reverse logistics at waste electrical closed-loop supply chain. But according to the explanations provided, an attempt is being made to examine competition in the closed-loop chain of electronic products in witch, the government in the under study country seeks to support the internal chain operating in its own country.

The framework of this research is based on the following. Sector 2 discuss the relevant literature at three subsections. Sector 3 describes model establishment and assumptions. At Segment 4 the suggested model formulation has been presented at two scenarios. Numerical results at three examples has been given in section 5. Sensitivity analyses are discussed in Section 6. Several sensitivity analyses on the main parameters are conducted at section 6 to extract managerial implications at section 7. Concluding directions for future investigations has been provided at section 8.

2. Literature review

According to the explanations provided for the objectives of the research, first, the research related to green management is reviewed in order to gain the necessary knowledge about dealing with pollution caused by the release of products into the environment. In the following, according to the second purpose of research on government intervention in order to manage the situation and also to support the internal industry, we will try to investigate government intervention and especially government intervention in green chains to gain the necessary knowledge about the types of government intervention. As a whole, there are two main categories in the literature which have discussed about this paper's subject: Green management, government intervention, and in particular government intervention at green chains. At the first, government intervention has been studied.

2.1. Government intervention

The effect of government intervention (GI) on the chain for both manufacturers and the collector being individually leaders was examined by Wang et al. (2015), and conclusions indicated decision variables in the collector's leadership were better. In a two-organ chain introduced by Heydari et al. (2017), by offering coordination contracts (quantity discount and increasing fee), they sought to increase consumers' motivation to return the used product. By providing some incentives such as tax exemption and subsidy, the government increased coordination among members. In a three-member chain consisted of two producers and one retailer, Wang et al. (2017) expressed that government intervention has reduced retail and wholesale prices and, in turn, increased the rate of collection of goods in a CLSC. It has also been shown that product substitution coefficient has an inverse correlation with profits of the chain members. At the article of Wang et al. (2017b), proved that the government intervention in the form of a reward-penalty have decreased the wholesale price for the manufacturer and the retail price for the retailer, in contrast to the cost of repurchasing the customer and the amount of defective goods returned. Similarly, in the literature of government intervention at the kind of reward-penalty in two period chain, Wang et al. (2018) checked out the effect of this intervention on the selling prices in each period and the collection rate by the collector. The results indicated the need for the government to impose reward-penalty by setting a specific collection rate to encourage manufacturer and collector. At a reverse chain presented by Guo et al. (2019), by adopting a subsidy policy, the government played a key role in recovering returned items. This policy has been adopted considering the dependence quality of returned goods to the cost of remanufacturing, return rate and buy back cost. The impact of government intervention on the Wan and Hong (2019) study considering subsidies granting has been investigated. By providing reproduction subsidies or recycling it has resulted in increase the consumption, the members' profits and recovery. Furthermore, in the e-supply chains, Wang et al. (2019)'s research has shown that the utilization rate of remanufacturing has straight relation compare to the benefit of regeneration and the amount of recycling compared to the marginal effect of the subsidy. He et al. (2019) further indicated that the government by adopting appropriate subsidies that encouraged the manufacturer to choose one of the three structures examined by him. When the saving cost from remanufacturing was very high or low, the policy of the manufacturer and the government to choose the optimal structure differed to each other. Recently, Kharaji Manouchehrabadi & Yaghoubi (2020) presented a three-echelon CLSC considering government role for solar cells. They presented that the price of return defective solar systems, environmental awareness, the 3 PL effort and the solar cells performance have impact on the return volume of defective solar systems.

2.2. Green management

To reduce the releasing of expired goods into the environment and subsequently, reduce the inspection, repair and remanufacturing cost, Chung and Wee (2008) suggested producing green products. To the reason that the consumer environmental awareness has been increased compared to the past, Zhang et al. (2015) mentioned that a chain consists of two members had to produce green product compatible to environment in addition to the traditional products. Due to the lack of proper methods to select best supplier, product design and modes of transportation, as well as adapt companies to the environment, Huang et al. (2016) used genetic algorithm to obtain the solution these unbeknownst. Follow-up to the articles related to the green management, Entezaminia et al. (2016) designed a production planning considering reverse logistics in order to balance economic and environmental performance using LP-metrics method. A game theorem approach at different modes (centralized and decentralized) has been considered by Zhu and He (2017) to conduct that how different competitions (price and greenness) at a supply chain with two members influenced to other one. Considering the importance of green degree that has important effect on the consumer attitude about the final product, the issue of advertising has been considered at the Liu and Yi (2017) investigation. The product's demand was extracted at a big data environment and the results authenticated that both sells prices for the manufacturer and the retailer have reverse relation to the level of advertising. In order to attain the tradeoff between lean and green practices at a green chain, Carvalho et al. (2017) introduced a model to illustrate this issue. To satisfy the economic and environmental constraints, there has to be a compromise between the behavior of different companies. At three scenarios, Sales effort and carbon emission effort have been studied separately at the paper of Lou and Ma (2018) at two parallel chains. In the following, they found that price adjustment could have much greater stability and profit than trying to sell and trying to reduce carbon emissions in all three scenarios. In order to show that factors such as reducing carbon emission, improvement the quality and return policy are key factors that influence the customer demand, two scenarios have been concluded (without third party and with third party presence) by Taleizadeh et al. (2019). They affirmed that chain benefit at the first scenario is less than the second one. Separating customers to traditional customers and green product aware customers, Sarkar and Bhadouriya (2020) presented a Cournot-Nash competition among one retailer and many manufacturers where they have competition in green supply chain to produce these two kinds of product. They have shown that increasing customer awareness of the environment improves green products over non-green ones. At the investigation of Rezayat et al. (2020), the collection of defective electronic products was examined in order to prevent release into the environment through the presentation of a hierarchical revenue sharing contract, but only one internal product chain within the country was mentioned, however, there is a variety of products in electronic products in which possible to import this product from abroad. Recently, a product life cycle approach including introduction, growth, maturity, and decline phases for sales effort of a closed-loop supply chain has been studied by Asl-Najafi and Yaghoubi (2021).

2.3. Government intervention especially in green supply chain

To specify that social welfare and supply chain profit under financial intervention adapted by government using taxation and subsidization has positive impact on these subjects, Sheu and Chen (2012) derived a Nash equilibrium solution. In the following of financial government intervention, Hafezalkotob (2015) created a price competition at a two-member chain consists of one retailer and one producer. They found that there are specific tariff limitations that guarantee the stability of a competitive market. In order to develop the green supply chain, three game models with government intervention have been considered by Yang and Xiao (2017). They found that considering the supply chain with retailer leadership is better than the other members' leadership. Interestingly, the retailer benefits from government subsidies that are provided to the manufacturer, and eventually becomes the main driver of green product development. At two competitive supply chain consist of one eco-friendly chain and the other non-green chain, Madani and Rasti-Barzoki (2017) considered government intervention to improve social welfare by subsidizing the green chain and taxing the non-green chain. In addition, at the research of Hafezalkotob (2017), government intervention is considered in the competitive chain, which includes just green goods. This intervention considered at competitive and coordinated situations. Considering the chain consisting of two layers in which the first one is the whole supply chain and the other is government, Sinayi and Rasti-Barzoki (2018) presented a model that surplus of the consumer is related to price and greening degree. In addition, they concluded that excess consumer demand increased with rising prices. Presenting green and non-green supply chain and two kind of government intervention (direct tariff and tradable permits) by Hafezalkotob (2018), this research has been formulated three-level non-linear programing to find that how these supply chains show reaction to these interventions. Due to the increase pressure of the government by applying some roles, and increase consumer's environmental awareness, Chen & 'Ulya (2019) researched on the behavior of the chain members to these roles. They found that by applying reward-penalty mechanism, rate of return and effort on greening level will be increased. In line with researches to increase social welfare, Zand et al. (2019) announced in which the government adjusts a limitation for the green level of products and the results have been shown that this threshold has positive impact to the amount of returned goods and subsequently, the social welfare. At the other assumption presented by Giri et al. (2019), it has been assumed that the net revenue for government consists of taxes attained by the retailer from costumer and penalties for the surplus carbon emission compared to the permissible level emitted by the manufacturer. To reduction the pollution of releasing goods to the environment, two coordination models (Licensing mechanisms and contract) have been presented by He et al. (2019). In the following, they announced that although retailer joining collection competition has decreased the remanufacturing cost, but it has not leads to improve the efficiency of recovery. Efficiency of recovery can be achieved to the best amount using the licensing mechanisms. Using two-part tariff, Zhang and Yousaf (2020) announced that high level government intervention cannot achieve to a high level green improvement and government shaved to change its policy from tax to subsidy at the high cost investment scenario of green investment. In the paper of Ghalehkhondabi et al. (2020), the government's intervention is aimed at increasing waste disposal facility responsibility for gas emissions. The main point of this article is to determine the price of disposal services and environmental improvement under Stackelberg game, Nash equilibrium and centralized scenario.

With sufficient insights from the above researches findings, it can be inferred that government intervention in different supply chains to improve social welfare levels and to have a positive impact on environmental issues is highly regarded. It is worth pointing out that in the real situation there are chains where there is competition between internal and external supply chains. These supply chains produce multi-products at different characters such as different price or quality level. In order to broad the country industries, the government will broad the internal product market in the country by providing motivational incentives for the internal supply chain and subsequently, by obtaining tax from the external supply chain, it prevents more foreign goods from entering the country.

At current paper, it has been considered two CLSC comprising two manufacturers, two retailers and one collector. Indeed, the collector is responsible for collecting and inspecting defective products from customers. By doing so, defective products will be inspected and some of them that cannot be refurbished and sell as secondary products, can be used by the manufacturers as returned materials to produce new products and it will be decreased fresh raw material. Demand function of each supply chain has been considered competitive and related to the retail price and quality level that are endogenous supply chains decision variables. Furthermore, based on the description presented at the introduction, presenting competition between the supply chain of internal and foreign goods and development of internal industry in the country by considering a new type of government intervention are basic innovations where have been investigated. The difference between current study and the existing studied articles are summarized at Table 1.

3. Model establishment and assumptions

At the first, all the notations that have been applied in this paper for the chain without considering GI are presented below and more explanations for the chain considering GI presented at 4.2.

Parameter	Definition
i	Product type index; n, s for the new and the secondary product
j	Product regional index; 1, 2 for the external and the internal product
A_{ij}	Total market of potential customers for product type i and product regional j
W_{n1}	The wholesale price of new external good
W_{sj}	The wholesale price of the secondary good regional j
C_{mnj}	The new product regional j production expenditure using fresh material
C_{ms2}	The production expenditure for new internal product using secondary material
C_{sj}	The secondary product regional j refurbish expenditure
Q_{n1}	The new external product quality level
Q_{sj}	The secondary product regional j quality level
b_j	The purchase price of product regional j from the customer
f_2	Unit secondary refurbishing license fee in which pay by collector to internal manufacturer for internal repaired products
g_j	The destroy expenditure in which pay by collector for non-refurbish able and non-remanufacture able product regional j
t_2	Amount in which pay by the internal manufacturer to the collector for remanufacture able internal products
α_1	Demand sensitivity to price for new products
α_2	Price transfer coefficient for new products
α_3	Demand sensitivity to price for secondary products
α_4	Price transfer coefficient for secondary products
β_1	Demand sensitivity to quality for new products
β_2	Quality transfer coefficient for new products
β_3	Demand sensitivity to quality for secondary products
β_4	Quality transfer coefficient for secondary products
θ_1	The amount of disposed returned external products in terms of percentage
θ_2	The amount of returned external products in terms of the percentage that can be renewed
θ_3	The amount of disposed returned internal products in terms of percentage
θ_4	The amount of returned internal products in terms of the percentage that can be renewed
k_j	Quality cost coefficient for new product regional j
X	Percentage of offline customer for internal product
Decision variable	**Definition**
W_{nf2}	The wholesale price of new internal product for online internal customers
P_{n1}	The new external good retail price
P_{nf2}	The new internal good retail price for offline internal costumer
P_{no2}	The new internal good retail price for online internal costumer
Q_{n2}	The new internal product quality level
P_{sj}	The secondary product regional j retail price

Two CLSC consist of two manufacturers, two retailers and one collector have been investigated. In the traditional supply chains, internal and external manufacturers produce one kind of product at different price and quality level. Due to international restrictions, the foreign manufacturer cannot directly sell its goods in the under study country

Table 1
Comparison of previous researches with this research.

Authors	Competitive issue		Variety of government intervention					Product variety		Dependent demand			Real issues		
	Competitive chain	Non-competitive chain	Tax collection	Subsidy granting	Others	Customs duties collection	Non-government intervention	Single product	Multi products	Price	Quality	Others	Competitive demand for internal and external product	Government intervention at competitive internal and external chain	Green management at competitive internal and external chain
Sheu and Chen (2012)	*		*	*				*		*					
Hafezalkotob (2015)	*		*	*					*	*		*			
Hafezalkotob (2017)	*		*	*					*	*		*			
Heydari et al. (2017)		*	*	*				*							
Madani and Rasti-Barzoki (2017)	*		*	*					*	*					
Wang et al. (2017b)		*			*			*		*					
Yang and Xiao (2017)	*			*				*		*		*			
Zhu and He (2017)	*						*	*		*		*			
Hafezalkotob (2018)	*		*	*					*	*					
Lou and Ma (2018)	*						*		*	*		*			
Wang et al. (2018)		*			*			*		*					
Giri et al. (2019)	*		*	*					*	*		*			
He et al. (2019)	*			*					*	*		*			
Wan and Hong (2019)	*			*				*		*					
Wang et al. (2019)		*		*				*		*		*			
Zand et al. (2019)		*			*			*		*		*			
Zhang and Yousaf (2020)		*	*	*				*		*		*			
Ghalehkhondabi et al. (2020)		*			*			*		*		*			
Rezayat et al. (2020)		*							*	*	*				
Sarkar and Bhadouriya (2020)	*						*		*	*		*			
This paper	*		*	*		*			*	*	*		*	*	*

market and this is only possible through a retailer. In other words, this retailer is the sales representative of the external manufacturer in the destination country. Vis-à-vis, internal manufacturer sells products via two channels (online and offline). Another retailer compared to the previous one, sells this manufacturer's products. Demand for these products have been considered competitive and depend to the quality and retail price. In the reverse chains, one collector collects defective products from the consumer using a motivation approach. The reason for this is to prevent releasing defective products in the environment as well as their high recyclability in order to reproduce. After inspecting collected items by the collector, numbers are not repairable and should be destroyed of. Some goods upgraded and the collector modernizes and sells any type of product as secondary product (internal or foreign products) to the retailer of the same product. The quality level and retail price of these two secondary product impacts on the demand of them. Due to the competitive market, both external and internal demand markets assumed to be competitive Due to the structure of some returned goods, it is possible to use them as raw material for the production of new goods. Because of that, it is not possible for the collector to return defective goods to a foreign manufacturer, the collector sells both kind of defective products to the internal manufacturer and uses them for the production of new output. Therefore, the need for fresh raw materials is somewhat reduced and accordingly saves on purchase costs.

The main assumptions of this investigation are shown as below. These assumptions are based on the description of the actual case (Apple) as well as the findings of previous research in the literature.

I. As it was introduced that the demand function has been considered competitive, demand for each type of five customers are as below. This kind of demand function has been presented in previous investigations (Liu et al., 2012; Zhang et al., 2015; Zhang and Ren, 2016):

$$D_{n1} = A_{n1} - \alpha_1.P_{n1} + \beta_1.Q_{n1} + \alpha_2.\left(P_{nf2} + P_{no2} - P_{n1}\right) - \beta_2.(Q_{n2} - Q_{n1}) \quad (1)$$

$$D_{nf2} = X.A_{n2} - \alpha_1.P_{nf2} + \beta_1.Q_{n2} + \alpha_2.\left(P_{n1} + P_{no2} - P_{nf2}\right) - \beta_2.(Q_{n1} - Q_{n2}) \quad (2)$$

$$D_{no2} = (1 - X).A_{n2} - \alpha_1.P_{no2} + \beta_1.Q_{n2} + \alpha_2.\left(P_{nf2} + P_{n1} - P_{no2}\right) - \beta_2.(Q_{n1} - Q_{n2}) \quad (3)$$

$$D_{s1} = A_{s1} - \alpha_3.P_{s1} + \beta_3.Q_{s1} + \alpha_4.(P_{s2} - P_{s1}) - \beta_4.(Q_{s2} - Q_{s1}) \quad (4)$$

$$D_{s2} = A_{s2} - \alpha_3.P_{s2} + \beta_3.Q_{s2} + \alpha_4.(P_{s1} - P_{s2}) - \beta_4.(Q_{s1} - Q_{s2}) \quad (5)$$

II. It has been assumed that the amount of returned external and internal new product and separately Y_{n1} and Y_{n2} (Rezayat et al., 2020). All the refurbished defective products sell through retailers. Due to these explanations, it can be shown that:

$$Y_{n1} = \frac{D_{s1}}{\theta_2} \quad (6)$$

$$Y_{n2} = \frac{D_{s2}}{\theta_4} \quad (7)$$

III. Based on the existing literature, it has been assumed that the specifications of the remanufactured goods and new ones are the same (Choi et al., 2013; Taleizadeh et al., 2018; Rezayat et al., 2020). According to previous explanations that both products with the ability to reproduce will be sold to internal producer, the reduced fresh raw material for internal manufacturer (F) is:

$$F = D_{no2} + D_{nf2} - (1 - \theta_1 - \theta_2).Y_{n1} - (1 - \theta_3 - \theta_4).Y_{n2}$$

IV. Unit secondary refurbishing license fee (f_2) in which pay by the collector to internal manufacturer, only affects products that are repaired by the collector (Rezayat et al., 2020).

V. Quality of new products individually increasing that it's up to manufacturers. This assumption was considered by (El Ouardighi, 2014; Basiri and Heydari, 2017; Gao et al., 2016; Hosseini-Motlagh et al., 2018). $\frac{k_1.(Q_{n1}{}^2)}{2}$ and $\frac{k_2.(Q_{n2}{}^2)}{2}$ indicates the new product quality level cost for both manufacturers.

VI. Given that new good producing cost from fresh raw material seems to be higher than recycled material, (Hosseini-Motlagh et al., 2018; Li et al., 2020), we establish that $C_{mn1} > C_{ms1}$ and $C_{mn2} > C_{ms2}$ to avoid an incorrect relationship. To considering no loss of profit for the collector from the purchase of defective goods from the customer, he/she must sell both non-recyclable goods to the internal manufacturer at a higher value compared to the amount pays to the customer ($t_2 > b_1$ and $t_2 > b_2$) (Jena et al., 2018).

VII. Given that the foreign manufacturer operates abroad and the chain does not have access to it, the wholesale price values and the product are assumed to be parameter.

VIII. All the returned inspected products that cannot be remanufactured have been sold to the internal manufacturer at value t_2 to use as raw material. It has been assumed that the collector cannot make a relation with the external manufacturer to return non-remanufacture-able external products. For this reason, it sells all returned products of both types to the internal manufacturer. With these explanations, the collector just pay f_2 for the internal products and the internal manufacturer has no right to get refurbishing license for the external product.

IX. At the section considering GI, income tax on sales is collected from internal manufacturer and collector. Also, granting of subsidies to internal manufacturer and the collector have been considered. Eventually, customs duties apply to imported goods on foreign product retailer.

4. The model formulation

At this section, the model formulation at different scenarios (manufacturers Stackelberg scenario (MSS) without government intervention and the second, considering the chain with government intervention (GI)) is presented to indicate the impact of GI to examine the objectives of the research.

4.1. Manufacturers stackelberg scenario (MSS)

At this scenario, a CLSC in which two manufacturers play as leaders and the internal one decides to determine the offline wholesale price, quality and online retail price of the new goods. The structure of the chain at this scenario presented at Fig. 1. At the forward flow, due to international constraints, external manufacturer has to sell products at the destination country through a retailer. Given that the external manufacturer operates abroad, it is obvious that its decision variables cannot be commented on. The internal manufacturer can sell goods at both online and offline channels. Both retailers decide on the new products retail price.

Due to the high re-use ability defective products and also to prevent their release into the environment by the consumer of the product, the collector buys these defective products from the end customer by paying b_1 and b_2 respectively for external and internal products as a motivation approach for customers to make them eager to return defective goods. After that the collector inspected the returned items, $\theta_1$and θ_3 $(0<\theta_1,\theta_3<1)$ (respectively for external and internal products) percent of the returned defective products are excreted and the collector pays $g_1$and g_2 (respectively for external and internal products) as disposal cost to dispose each unit of returned defective products. In the following, θ_2 and θ_4 $(0<\theta_2,\theta_4<1)$ percent of the defective products (respectively for external and internal products) could be refurbished, so after that the collector refurbished them, sells to both retailers as secondary goods. The collector sells those at the specific characters (Quality and wholesale price). In the following, the retailers sell them at the retail price. Eventually, the rest of returned items $(1-\theta_1-\theta_2\ (0<1-\theta_1-\theta_2<1)$ and $1-\theta_3-\theta_4\ (0<1-\theta_3-\theta_4<1)$ respectively for external and internal products) could not be refurbished, but as a raw material they are suitable for the production of new products. According to the assumptions, the internal manufacturer buys them by paying t_2 from the collector for all external and internal items and to procreate new product. It leads to reduce the fresh raw materials utilization. Furthermore, in order to refurbish the θ_4 percentage of internal defective goods that can be refurbished, the collector must pay a certain amount to the manufacturer as unit secondary refurbishing license fee. This is because the goods reproduced from the primary goods produced by the manufacturer are marketed as secondary goods. For the θ_2 percentage of external defective goods in which sells to the internal manufacturer, should not pay any unit secondary refurbishing license fee.

Let π_{m1}, π_{m2} , π_c, π_{r1} and π_{r2} indicate external manufacturer, internal manufacturer, the collector, external retailer and the internal retailer profits, respectively. Both manufacturer profit functions are as shown below:

$$\pi_{m1}=W_{n1}.\,D_{n1}-C_{mn1}.\,D_{n1}-\frac{k_1.(Q_{n1}{}^2)}{2} \tag{8}$$

$$\pi_{m2}(W_{nf2},P_{no2},Q_{n2})=(W_{nf2}.\,D_{nf2}+P_{no2}.\,D_{no2})-C_{mn2}.F-(C_{ms2}+t_2).\\((1-\theta_1-\theta_2).Y_{n1}+(1-\theta_3-\theta_4).Y_{n2})+f_2.D_{s2}-\frac{k_2.(Q_{n2}{}^2)}{2} \tag{9}$$

Revenue from the sale of new goods is shown in Eq. (9). Second section indicates the cost of production using fresh material. The third part indicates cost of production new good using the secondary returned products and the purchasing cost of the returned goods. The next section has been shown the revenue from the unit secondary refurbishing license fee has been gained by the internal manufacturer from the collector for the renovated goods and the last one shows the increasing cost product quality.

Proposition 1. *The internal manufacturer gain is concave in offline wholesale price, online retail price and quality. Thus, the optimal amount of decision variables can be calculating to optimize expected profit. These amounts for the internal manufacturers have been calculated as below, respectively.*

$$W_{nf2}=\left(\frac{1}{2(\alpha_1+\alpha_2)^2}\right)(\alpha_2.A_{n1}+\alpha_1.\alpha_2.(W_{n1}+2P_{no2}-P_{n1})+\alpha_2{}^2.\\(W_{n1}+3P_{no2}+P_{nf2}-P_{n1})+(\alpha_1+\alpha_2).(X.A_{n2}+\alpha_1.C_{mn2})\\+\beta_1.(\alpha_1.Q_{n2}+\alpha_2.Q_{n1}+\alpha_2.Q_{n2})+\alpha_1.\beta_2.(Q_{n2}-Q_{n1})) \tag{10}$$

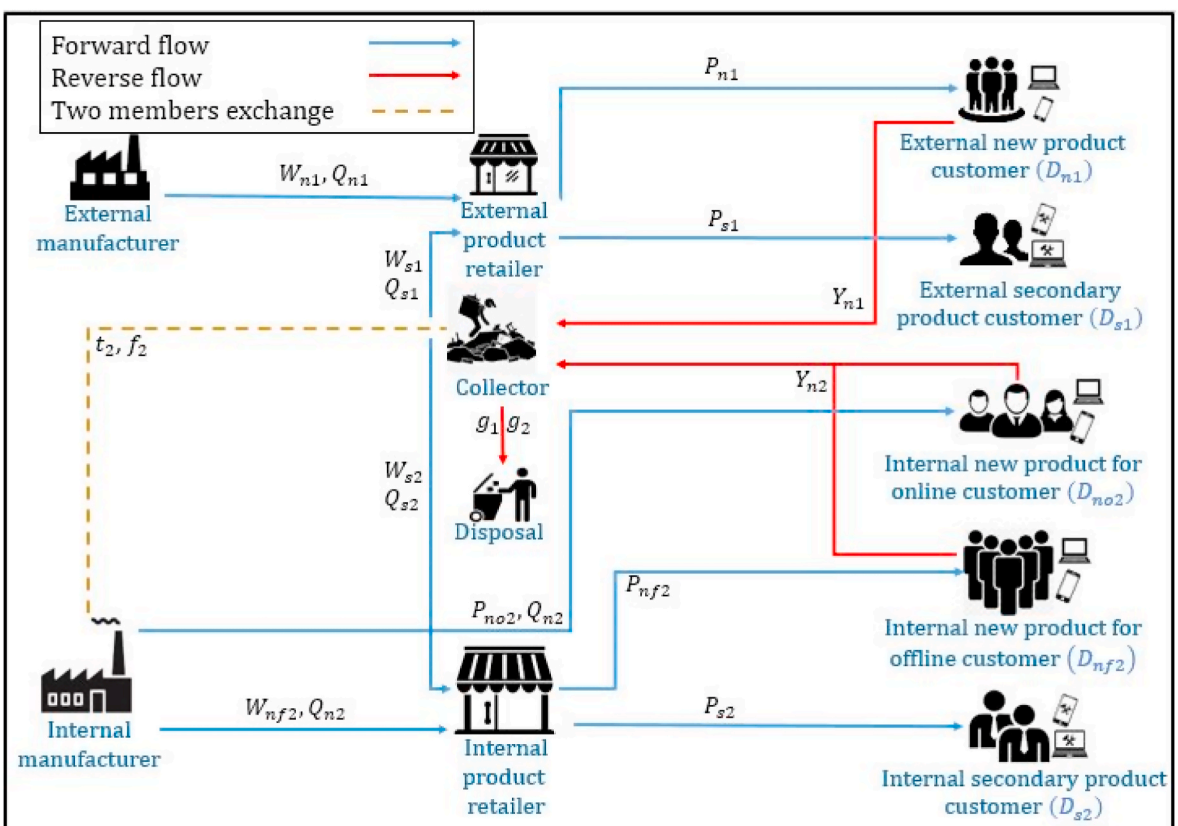


Fig. 1. The CLSC structure without GI.

$$P_{no2}=\left(\frac{1}{4\alpha_1.(\alpha_1+2\alpha_2)}\right)\Big(2\alpha_1.A_{n2}.(1-X)+\alpha_2.(A_{n1}+A_{n2}(2-X)) \\ +(\alpha_1.\alpha_2).(W_{n1}+2W_{nf2})+{\alpha_2}^2.(W_{n1}+3W_{nf2}+P_{nf2}+P_{n1}) \\ +(\alpha_1+2\alpha_2).(2\alpha_1-\alpha_2).C_{mn2}+\beta_1.(2\alpha_1.Q_{n2}+\alpha_2.Q_{n1}+3\alpha_2.Q_{n2}) \\ +2\beta_2.(\alpha_1+\alpha_2).(Q_{n2}-Q_{n1})\Big) \tag{11}$$

$$Q_{n2}=\left(\frac{1}{2k_2.(\alpha_1+\alpha_2)}\right)\Big(\alpha_2.(\beta_1.W_{nf2}+(3\beta_1+2\beta_2).P_{no2}-2(2\beta_1+\beta_2).C_{mn2}) \\ +\alpha_1.(\beta_1+\beta_2).(2P_{no2}+W_{nf2}-3C_{mn2})\Big) \tag{12}$$

Proof of this claim has been presented at Appendix A.

The collector profit function is presented below:

$$\pi_c=((W_{s1}-C_{s1}).D_{s1}+(W_{s2}-C_{s2}).D_{s2})+t_2.((1-\theta_1-\theta_2).Y_{n1} \\ +(1-\theta_3-\theta_4).Y_{n2})-(b_1.Y_{n1}+b_2.Y_{n2})-(g_1.\theta_1.Y_{n1}+g_2.\theta_3.Y_{n2})-f_2.D_{s2} \tag{13}$$

The first term indicates the sales profit from both secondary goods. The second section shows sales profit has been gained from selling remanufacture-able products for internal manufacturer. The next part is cost of buying defective products from consumers. The fourth part is disposal cost for both kind of defective products and the last term is secondary refurbishing license cost paid by collector to internal manufacturer for internal refurbished products.

Both retailers profit functions are as shown below:

$$\pi_{r1}(P_{n1},\ P_{s1})=(P_{n1}-\ W_{n1}).D_{n1}+(P_{s1}-\ W_{s1}).D_{s1} \tag{14}$$

$$\pi_{r2}(P_{nf2},\ P_{s2})=(P_{nf2}-\ W_{nf2}).D_{nf2}+(P_{s2}-\ W_{s2}).D_{s2} \tag{15}$$

The first terms indicate sales profits from new products for retailers and the second terms denote the sales profit from secondary products for retailers.

Proposition 2. *Both profit function for retailers are concave in new and secondary product retailing price. Thus, the optimal amount of these can be calculated to maximize both retailers expected profit. The optimal new and secondary product retailing price for both retailers are obtained as below, respectively.*

$$P_{n1}=\left(\frac{1}{2(\alpha_1+\alpha_2)}\right).(A_{n1}+\alpha_2.(P_{nf2}+\ P_{no2})+(\alpha_1+\alpha_2).\ W_{n1} \\ +(\beta_1+\beta_2).Q_{n1}-\beta_2.Q_{n2}) \tag{16}$$

$$P_{s1}=\left(\frac{1}{2(\alpha_3+\alpha_4)}\right).(A_{s1}+\alpha_4.P_{s2}+(\alpha_3+\alpha_4).\ W_{s1}+(\beta_3+\beta_4).Q_{s1}-\beta_4.Q_{s2}) \tag{17}$$

$$P_{nf2}=\left(\frac{1}{2(\alpha_1+\alpha_2)}\right).(X.A_{n2}+\alpha_2.(P_{n1}+\ P_{no2})+(\alpha_1+\alpha_2).\ W_{nf2} \\ +(\beta_1+\beta_2).Q_{n2}-\beta_2.Q_{n1}) \tag{18}$$

$$P_{s2}=\left(\frac{1}{2(\alpha_3+\alpha_4)}\right).(A_{s2}+\alpha_4.P_{s1}+(\alpha_3+\alpha_4).\ W_{s2}+(\beta_3+\beta_4).Q_{s2}-\beta_4.Q_{s1}) \tag{19}$$

Proof of this proposition has been presented at Appendix B.

After substituting Eqs. (1)–(5) at Eq. (14) and Eq. (15) and be derived from their variables; the first derivative of $\pi_{r1}\ (P_{n1}, P_{s1})$ *and* $\pi_{r2}\ (P_{nf2}, P_{s2})$ with respect to P_{n1}, P_{s1}, P_{nf2} and P_{s2} gives the unique P_{n1}, P_{s1}, P_{nf2} and P_{s2} as in Eqs. (16)–(19).

Due to that, the collector and external manufacturer have no decision variable, after getting the reaction from both retailers, retailers' decision variables (Eq. (16), (17), (18) *&* (19)) and also Eq. (6) *and* Eq. (7) should be replaced at internal manufacturer's profit functions (Eq. (9)) and be derived from its variables; the first derivative of $\pi_{m2}\ (W_{nf2}, P_{no2}, Q_{n2})$ respect to W_{nf2}, P_{no2} and Q_{n2} take to the unique W_{nf2}, P_{no2} and Q_{n2} as shown in Eqs. (10)–(12). After solving these Eqs. (10)–(12), (16)–(19), the

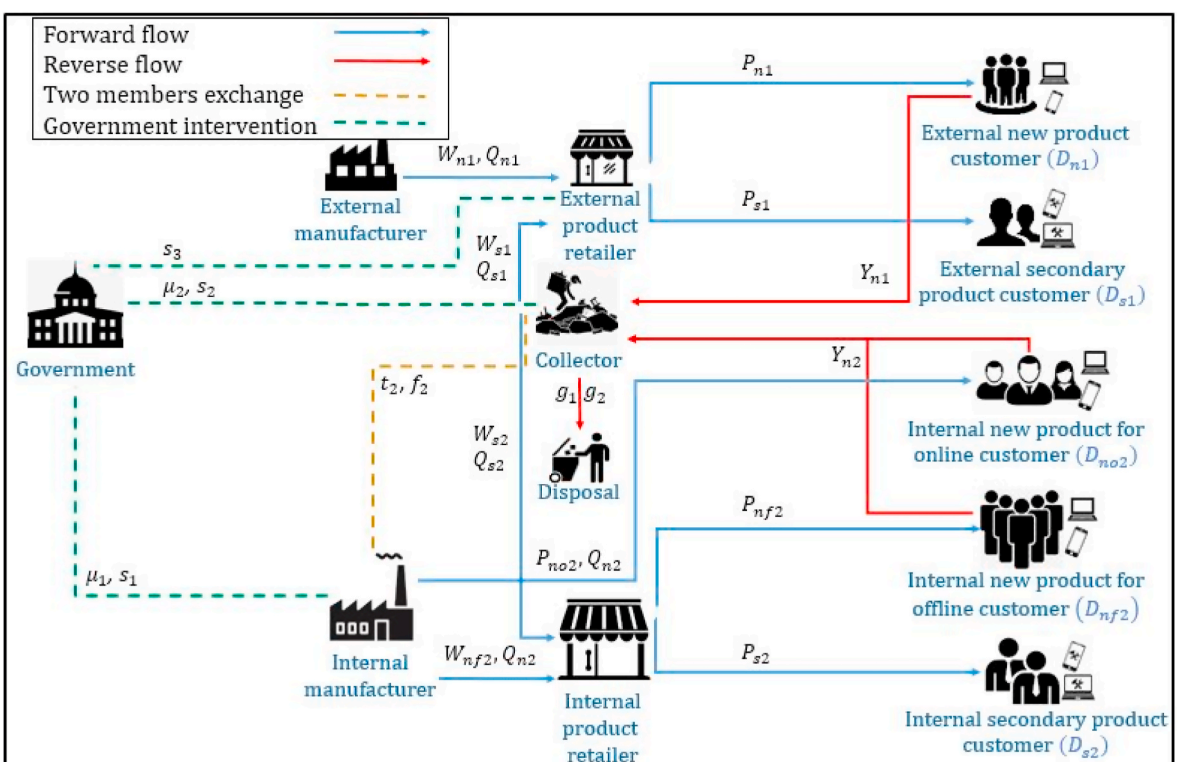


Fig. 2. The structure of the CLSC with considering GI.

pest value of these variables have been obtained. Using Wolfram Mathematica 11.3 software, these decision variables can be obtained.

4.2. Government intervention (GI)

Given that one of the objectives of this study is government support for internal industry (government is considered as a regulatory institution), government intervention should be considered more than subsidizing or taxing some members of the chain. Therefore, a new type of government intervention will be considered in this section. This scenario consists of two sub scenarios. At the first, government intervention considering tax collection and grant subsidies depending to the situation have been assumed (Sheu and Chen, 2012; Madani and Rasti-Barzoki, 2017). In addition, as a new type of government intervention, customs duties on retailer of foreign goods is included in the model. In this paper, this kind of intervention has been assumed as parameters and the impact of them on decision variables have been calculated. The structure of CLSC considering GI has been shown at Fig. 2. Given the competition for the sale of goods in the country under review, the government is trying to create a barrier to the entry of foreign goods into the country by collecting customs duties from retailers that import foreign goods.

At the second, the tolerance threshold of each member of the chain for taxes collected as well as the minimum amount of government subsidies paid to some members and maximum amount of acceptable customs duties for retailer of foreign goods has been calculated. The second sub scenario calculations are presented at section 5.

At the first sub scenario, income tax on sales is collected from internal manufacturer and collector. Given that the tax on domestically produced goods is collected from internal manufacturer, no tax is collected from internal retailer. μ_1 and μ_2 announce coefficients for tax collection from internal manufacturer and the collector respectively. In addition, the granting of subsidies to internal manufacturer is intended for the production of fresh raw materials, as well as the granting of subsidies to collector in order to collect defective goods from the customer. s_1 and s_2 represent granting subsidy coefficients for internal manufacturer and collector respectively. Furthermore, s_3 represents customs duties obtained from retailer of foreign goods by government. Eqs. (20)–(22) show new profit subordinates for the internal manufacturer, collector and the external product retailer sequentially. Further, Eq. (23) represents government profit function at this sub scenario. External manufacturer and internal retailer profit functions are as the same as Eq. (9) and Eq. (15).

$$\pi_{m2}(W_{nf2}, P_{no2}, Q_{n2}) = ((1-\mu_1).W_{nf2}.D_{nf2} + (1-\mu_1).P_{no2}.D_{no2}) - (C_{mn2} - s_1).(D_{nf2} + D_{no2} - (1-\theta_1-\theta_2).Y_{n1} - (1-\theta_3-\theta_4).Y_{n2}) - (C_{ms2} + t_2).((1-\theta_1-\theta_2).Y_{n1} + (1-\theta_3-\theta_4).Y_{n2}) + f_2.D_{s2} - \frac{k_2.(Q_{n2}^2)}{2} \quad (20)$$

$$\pi_c = (((1-\mu_2).W_{s1} + s_2 - C_{s1}).D_{s1} + ((1-\mu_2).W_{s2} + s_2 - C_{s2}).D_{s2}) + t_2.((1-\theta_1-\theta_2).Y_{n1} + (1-\theta_3-\theta_4).Y_{n2}) - (b_1.Y_{n1} + b_2.Y_{n2}) - (g_1.\theta_1.Y_{n1} + g_2.\theta_3.Y_{n2}) - f_2.D_{s2} \quad (21)$$

$$\pi_{r1}(P_{n1}, P_{s1}) = (P_{n1} - W_{n1} - s_3).D_{n1} + (P_{s1} - W_{s1}).D_{s1} \quad (22)$$

$$\pi_g = \mu_1.(W_{nf2}.D_{nf2} + P_{no2}.D_{no2}) + \mu_2.(W_{s1}.D_{s1} + W_{s2}.D_{s2}) + s_3.D_{n1} - s_1.((1-\theta_1-\theta_2).Y_{n1} + (1-\theta_3-\theta_4).Y_{n2}) - s_2.(D_{s1} + D_{s2}) \quad (23)$$

Proposition 3. *The internal manufacturer gain is concave in offline wholesale price, online retail price and quality. Thus, the optimal amount of decision variables can be calculating to optimize expected profit.*

Proof of this proposition has been presented at Appendix C.

Proposition 4. *The profit of external product retailer is concave in new and secondary product retailing price. Thus, the optimal amount of decision variables can be calculating to optimize expected profit. Proof of this claim has been presented at Appendix D.*

Due to the fact that the internal retailer profit function has not changed, so the Hessian matrix remains unchanged. With the same procedure at MSS, all decision variables' optimal value of can be calculated at GI.

Table 2
Parameters information.

Ex 1													
A_{n1}	A_{n2}	A_{s1}	A_{s2}	W_{n1}	W_{s1}	W_{s2}	C_{mn1}	C_{mn2}	C_{ms2}	C_{s1}	C_{s2}	Q_{n1}	Q_{s1}
1300	1100	200	400	1000	450	400	200	200	180	60	80	800	300
Q_{s2}	b_1	b_2	f_2	g_1	g_2	t_2	α_1	α_2	α_3	α_4	β_1	β_2	β_3
350	110	120	20	12	12	200	1.5	0.8	0.7	0.6	0.8	0.7	0.9
β_4	θ_1	θ_2	θ_3	θ_4	k_1	k_2	X	μ_1	μ_2	s_1	s_2	s_3	
0.8	0.02	0.08	0.1	0.15	0.5	1.5	0.4	0.07	0.1	40	30	60	
Ex 2													
A_{n1}	A_{n2}	A_{s1}	A_{s2}	W_{n1}	W_{s1}	W_{s2}	C_{mn1}	C_{mn2}	C_{ms2}	C_{s1}	C_{s2}	Q_{n1}	Q_{s1}
1000	1300	500	300	1100	450	350	300	250	160	80	70	1500	200
Q_{s2}	b_1	b_2	f_2	g_1	g_2	t_2	α_1	α_2	α_3	α_4	β_1	β_2	β_3
350	100	130	25	20	17	170	1.4	0.7	0.8	0.7	0.9	0.6	0.7
β_4	θ_1	θ_2	θ_3	θ_4	k_1	k_2	X	μ_1	μ_2	s_1	s_2	s_3	
0.6	0.1	0.15	0.05	0.1	0.2	1.5	0.3	0.09	0.09	50	40	70	
Ex 3													
A_{n1}	A_{n2}	A_{s1}	A_{s2}	W_{n1}	W_{s1}	W_{s2}	C_{mn1}	C_{mn2}	C_{ms2}	C_{s1}	C_{s2}	Q_{n1}	Q_{s1}
1500	1200	500	300	2000	700	500	400	250	100	80	70	1800	900
Q_{s2}	b_1	b_2	f_2	g_1	g_2	t_2	α_1	α_2	α_3	α_4	β_1	β_2	β_3
1200	140	120	25	15	13	200	1.6	0.9	1	0.7	1	0.6	1
β_4	θ_1	θ_2	θ_3	θ_4	k_1	k_2	X	μ_1	μ_2	s_1	s_2	s_3	
0.6	0.15	0.25	0.2	0.15	0.5	1.6	0.5	0.1	0.1	60	70	80	

5. Numerical study

In order to check model validity and assumptions, some examples are presented and then sensitivity analysis has been applied to key parameters. The parameters information for these three examples are presented in Table 2. All three numerical examples satisfy assumptions. In the following, the results for these example in modes MSS and GI have been presented in Table 3 and Table 4. Amounts of μ_1, μ_2, s_1, s_2, s_3 are just used for GI scenario.

At scenario GI, the optimal value for each member's profit, the tolerance threshold of internal manufacturer and collector for the tax imposed by the government, as well as the minimum acceptable amount paid by the government as a subsidy to the internal manufacturer and collector will be counted. Also, the maximum acceptable amount of customs duties for the retailer of foreign goods witch applied by the government is calculated. The process is as below: To calculate the threshold of each μ_1, μ_2 , s_1, $s_2$and s_3, we assume that the other four amounts are constant according to Table 2. By fixing other four amounts, the optimal value of the desired parameter is obtained. These calculations presented for three previous examples at Table 4.

Table 3
Profit of each member and decision variables.

Ex 1		MSS	GI
Decision variable	W_{nf2}	1519	1249
	P_{n1}	1341	1337
	P_{nf2}	1932	1585
	P_{no2}	1616	1334
	Q_{n2}	2100	1601
	P_{s1}	531	531
	P_{s2}	613	613
Profit function	π_g	–	181666
	π_{m1}	467675	350917
	π_{m2}	534871	203390
	π_c	270639	350093
	π_{r1}	276361	186049
	π_{r2}	452189	319158
Ex 2		**MSS**	**GI**
Decision variable	W_{nf2}	1889	1239
	P_{n1}	1682	1624
	P_{nf2}	2409	1555
	P_{no2}	2054	1377
	Q_{n2}	2695	1560
	P_{s1}	527	527
	P_{s2}	509	509
Profit function	π_g	–	280962
	π_{m1}	753859	538902
	π_{m2}	832460	231103
	π_c	156363	270845
	π_{r1}	721875	443140
	π_{r2}	604316	248897
Ex 3		**MSS**	**GI**
Decision variable	W_{nf2}	2838	1885
	P_{n1}	2568	2414
	P_{nf2}	3643	2406
	P_{no2}	2964	1967
	Q_{n2}	4139	2410
	P_{s1}	900	900
	P_{s2}	929	929
Profit function	π_g	–	391728
	π_{m1}	1464870	526430
	π_{m2}	3058010	1317070
	π_c	512395	888053
	π_{r1}	876723	347192
	π_{r2}	1935310	999461

Table 4
Maximum tax (%) and minimum subsidy and customs duties compared to GI.

Ex 1			μ_1	μ_2	s_1	s_2	s_3
Maximum acceptable loss compared to GI	π_{m2}	195000	7.175	–	19.96	–	–
	π_c	345000	–	13.2	–	28.39	–
	π_{r1}	180000	–	–	–	–	72.82
Ex 2			μ_1	μ_2	s_1	s_2	s_3
Maximum acceptable loss compared to GI	π_{m2}	225000	9.12	–	19.33	–	–
	π_c	265000	–	13.29	–	38.15	–
	π_{r1}	420000	–	–	–	–	104.72
Ex 3			μ_1	μ_2	s_1	s_2	s_3
Maximum acceptable loss compared to GI	π_{m2}	1280000	10.31	–	19.82	–	–
	π_c	850000	–	16.3	–	63.89	–
	π_{r1}	330000	–	–	–	–	114.25

6. Sensitivity analysis

At this part, in order to determine the model application, a comprehensive assessment of the main parameters of example 1 will be performed. The impact of variations α_1 and β_1 at MSS and GI have been presented respectively in Table 5 and Table 6. At the first, the impact of variation α_1 on decision variables and profit for each member at MSS and GI presented in Table 5.

Comparing the results of this table, it can be concluded that government intervention has reduced all decision variables except decision variables that are related to secondary goods. Because government intervention has not been applied to secondary goods, there should be no change in the amount of these variables. Table 5 shows that α_1 has no impact on the collector's benefit. It is because that there is no value of this coefficient at demand subordinate and consequently the collector profit subordinate.

The impact of variations α_1 on the profit of internal manufacture, external product retailer and the internal retailer at MSS and GI have been analyzed and conclusions have been shown in Fig. 3. Because of that α_1 has no impact on collector profit and also, external manufacture works abroad, we do not show the impact of variation α_1 for these members at Fig. 3. As α_1 increases, the retail price, demand volume as well as the profits of all members in MSS and GI should decrease. A larger amount of α_1 indicates consumers are seeking for lower priced

Table 5
The α_1 effect of changes on the MSS and GI profit.

MSS	**1.34**	**1.37**	**1.4**	**1.43**	**1.46**	**1.49**	**1.52**	**1.55**
W_{nf2}	7186	4227	2994	2318	1891	1598	1383	1220
P_{n1}	2440	1880	1641	1507	1420	1358	1310	1273
P_{nf2}	9298	5454	3851	2972	2417	2035	1756	1543
P_{no2}	7589	4470	3170	2458	2008	1699	1473	1301
Q_{n2}	11010	6358	4419	3356	2685	2223	1886	1630
P_{s1}	531	531	531	531	531	531	531	531
P_{s2}	613	613	613	613	613	613	613	613
π_{m1}	2305450	1367830	969849	746133	600418	496317	417031	353730
π_{m2}	12357200	4726600	2485180	1491810	951232	618397	395906	238216
π_c	270639	270639	270639	270639	270639	270639	270639	270639
π_{r1}	4446850	1689500	915362	584020	408490	302623	232964	184192
π_{r2}	9605610	3324240	1675180	1013230	683738	496706	380668	303898
GI								
W_{nf2}	3074	2414	1987	1688	1467	1297	1162	1053
P_{n1}	1762	1615	1517	1447	1393	1350	1314	1284
P_{nf2}	3947	3094	2541	2154	1868	1647	1473	1331
P_{no2}	3264	2566	2114	1798	1565	1385	1243	1128
Q_{n2}	4276	3309	2682	2244	1920	1671	1474	1314
P_{s1}	531	531	531	531	531	531	531	531
P_{s2}	613	613	613	613	613	613	613	613
π_g	1135230	696605	469425	336901	252952	196440	156573	127376
π_{m1}	1042930	804785	684008	530974	442602	371682	312807	262595
π_{m2}	2547670	1565470	1010360	659936	421447	250094	121842	22745
π_c	350093	350093	350093	350093	350093	350093	350093	350093
π_{r1}	1065260	674941	470113	343247	259772	201595	159271	127456
π_{r2}	1690550	1061800	734952	543724	422338	340543	282853	240671

Table 6
The β_1 effect of changes on the MSS and GI profit.

MSS	0.75	0.78	0.81	0.84	0.87	0.9
W_{nf2}	1161	1348	1625	2078	2952	5335
P_{n1}	1278	1312	1358	1431	1567	1930
P_{nf2}	1460	1707	2072	2670	3821	6963
P_{no2}	1241	1437	1727	2201	3114	5607
Q_{n2}	1484	1806	2282	3061	4561	8654
P_{s1}	531	531	531	531	531	531
P_{s2}	613	613	613	613	613	613
π_{m1}	353243	414231	500077	634399	884621	1551330
π_{m2}	204826	371841	640966	1136440	2286730	6734740
π_c	270639	270639	270639	270639	270639	270639
π_{r1}	187667	232724	304708	437431	750041	1998290
π_{r2}	265352	355496	519025	863234	1796370	6150250
GI						
W_{nf2}	1025	1146	1308	1535	1875	2441
P_{n1}	1293	1318	1348	1390	1449	1544
P_{nf2}	1290	1450	1663	1962	2410	3157
P_{no2}	1100	1227	1397	1634	1989	2582
Q_{n2}	1229	1431	1700	2076	2640	3579
P_{s1}	531	531	531	531	531	531
P_{s2}	613	613	613	613	613	613
π_g	122818	153091	199651	276922	419550	728928
π_{m1}	269856	314745	371500	447227	556127	731298
π_{m2}	12648	114258	256887	470262	820221	1483000
π_c	350093	350093	350093	350093	350093	350093
π_{r1}	134242	161828	200625	259207	357110	548396
π_{r2}	220749	271275	349340	479145	718667	1237110

goods, thereupon both retailers have to sell all types of goods at lower retail prices. Therefore, the internal manufacturer has to sell goods to the internal retailer at a lower wholesale price. Accordingly, the total profit in each scenario decreases.

At the second, the α_1 effect of changes on profit and decision variables for each member at MSS and GI presented in Table 6. Similar to Table 5, Table 6 shows that considering the chain with government intervention reduces amounts of all decision variables compare to MSS and consequently, member profits will be reduced. Because of that there is no β_1 at secondary products demand, Table 6 shows that β_1 has no effect on the collector's profit.

The impact of variations β_1 on the profit of internal manufacture, external product retailer and the internal retailer at MSS and GI has been investigated and the results presented in Fig. 4. For the same reasons stated in the previous figure, we don't show the impact of variation β_1 for these members at Fig. 4. As β_1 increases, the quality, demand volume as well as the profits of all members in MSS and GI should decrease. A larger value of β_1 indicates consumers are seeking for a product with high quality and is even incline to payment more for a product with high quality. In order to attract customer demand, the internal manufacturer have to improve the quality of its product (Because of that external manufacturing product quality level assumed as parameter, there is no change for it). Therefore, the internal manufacturer has to pay $\frac{k_1.(Q_{n1}{}^2)}{2}$ for the increasing quality level. Subsequently, internal manufacturer can increase the wholesale price. Accordingly, the total profit in each scenario increased.

In the following, the impact of parameters variation applied from government to internal manufacturer, the collector and the internal product retailer for example 1 has been examined. At the first, the impact of variations μ_1 and s_1 on the internal manufacturer profit function compare to MSS presented at Table 7 and Table 8 respectively.

We fixed the other four amounts constant according to Table 3. By fixing other four amounts, the minimum amount of μ_1 for the government is 1.7%. It means that if the amount of tax applied by government to the internal manufacturer is 1.7%, the government gain no profit. The maximum acceptable amount of μ_1 for the internal manufacturer compare to Table 4 is 7.1%. At the amount of 1.7%, internal manufacturer profit is equal to MSS.

By fixing other four amounts, the minimum amount of s_1 for the internal manufacturer considering Table 4 is 19.9. Furthermore, maximum amount of subsidy paid by government to internal manufacturer is 278.5. It means that if the amount of subsidy applied by government to the internal manufacturer is 278.5, the government gain no profit. This value does not satisfy the internal manufacturer profit compared to MSS. These explanations are shown in Fig. 5.

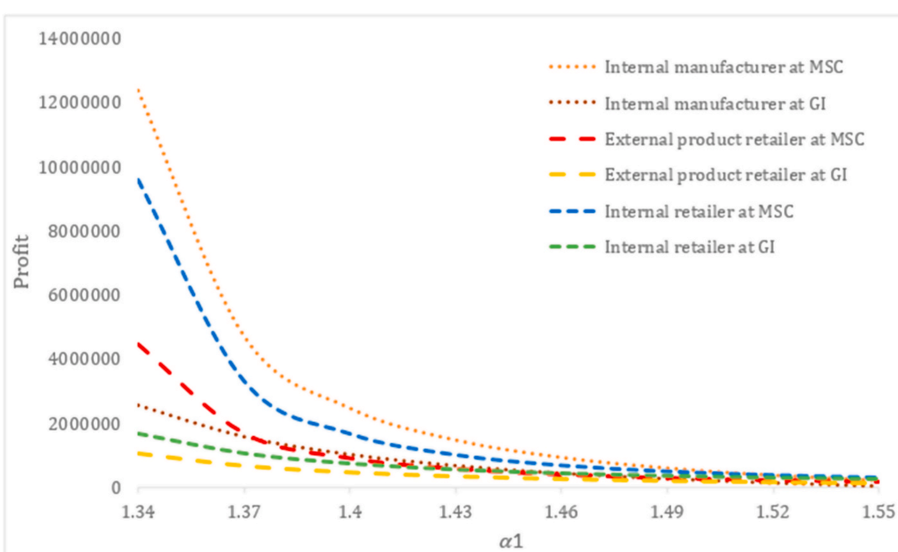


Fig. 3. The α_1 effect of changes on the MSS and GI profit.

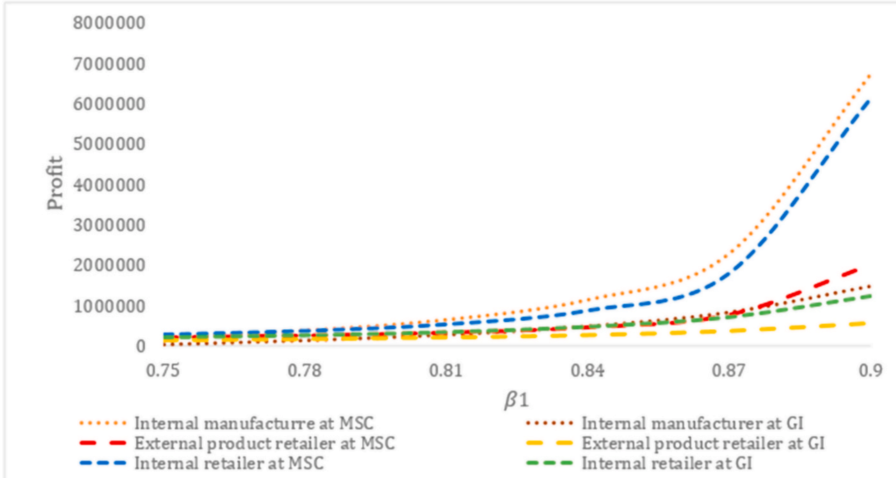


Fig. 4. The β_1 effect of changes on the MSS and GI profit.

Table 7
Impact of variation μ_1 at the GI compare to MSS.

	1.7	2.4	3.6	4.8	6	7.1
π_g	18898	51612	94403	130083	160003	185159
π_{m2}at GI	534871	474916	395235	319036	253610	195000
π_{m2} at MSS	534871	534871	534871	534871	534871	534871

At the second, the impact of variations μ_2 and s_2 on the collector profit function compare to MSS presented at Table 9 and Table 10 respectively.

By fixing other four amounts, the minimum value of μ_2 is equal to zero. At this amount, neither the government nor the collector make a negative profit. Maximum amount of tax paid by collector to the government is 60%. This amount satisfies profit of the collector at MSS.

By fixing other four amounts, the minimum acceptable amount of s_2 for the collector considering Table 3 is 4.9. Furthermore, maximum amount of subsidy paid by government to the collector is 87.1. It means that if the amount of subsidy applied by government to the collector is 87.1, the government gain no profit. This value satisfies the collector more profit compared to MSS. These explanations have been shown in Fig. 6.

At the end, the impact of variations s_3 on the external product retailer profit function compare to MSS presented at Table 11.

By fixing other four amounts, the minimum value of s_3 is equal to zero. At this amount, neither the government nor the external product retailer make a negative profit. Maximum amount of customs duties is 72.7 considering Table 4 paid by him/her to the government. These explanations presented at Fig. 7.

One of the most useful benefit of the structure of this paper is that the amount of fresh raw material for the internal manufacturer will be decreased. The collector returns non-refurbish-able both kind of products to the internal manufacturer. Because both types of recycled products are referred to the internal manufacturer by the collector, the amount of raw material will be greatly reduced. To the extent that it may not even need new raw materials in general and accumulate some for later production. This means that the costs of the raw material will become profitable for him. These explanations are more likely to be for GI scenario, as government intervention has led to a reduction in internal producer profits. The amount of fresh raw material needs for the internal manufacturer in the MSS compared to the GI have been presented at Table 12.

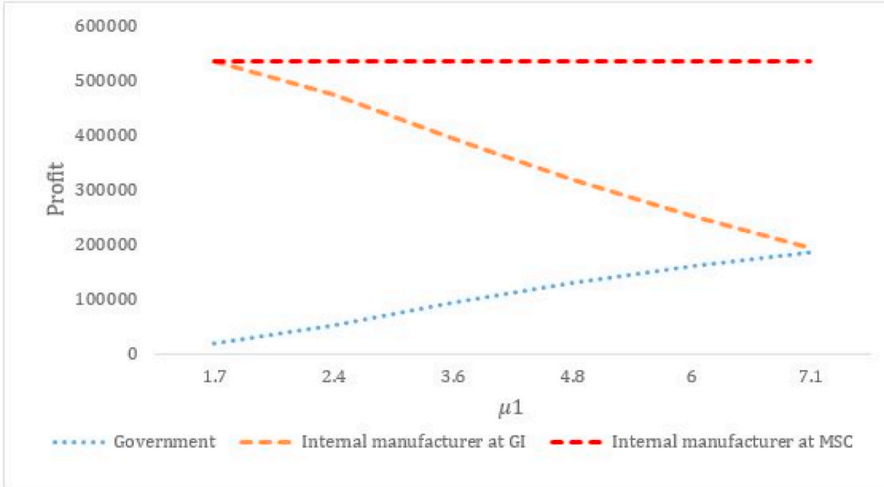
7. Managerial implications

With the necessary knowledge obtained from the sensitivity analysis of key parameters as well as the structure of the competitive chain, these managerial perspectives are presented:

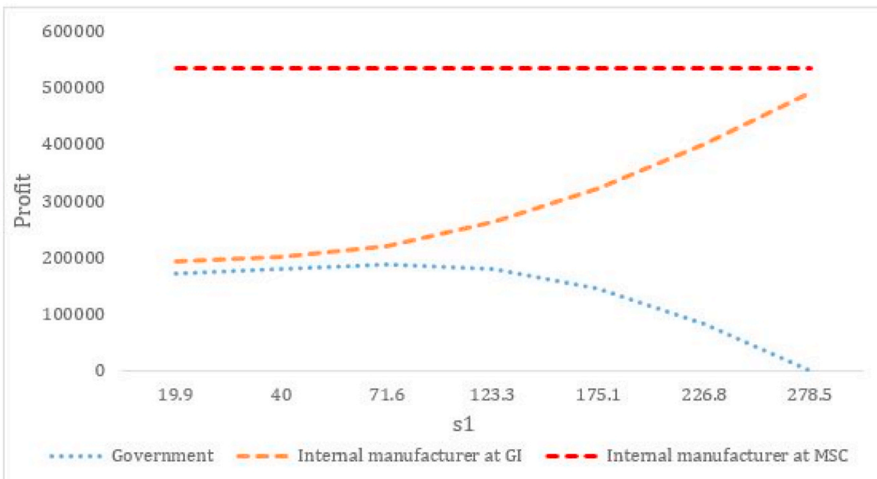
1) The effect that α_1 has on the profits of the members is greater than β_1. To make up for lost revenue when α_1 has been increased, offering time discounts in order to attract customers can be considered.
2) To deal with the costs of increasing the quality of the product due to the increase in β_1 that the internal manufacturer is aware of, products can be sold to the end customer at higher price, because the customer is quality oriented.
3) Based on the results on chapter 6, it is possible that government intervention leading to reduce profit for some members and also increase for the others. It means that the result of tax collection and subsidy granted is such that it leading to an enhancement in profit or a reduction compared to MSS. In other words, the government may not be able to regulate the amount of taxes and subsidies in which members do not harmed compared to MSS.
4) Given that the government's main goal in this intervention is not to make profit, it is better that the amount of tax received as well as the granting of subsidies be such that the members of the chain are not harmed compared to the decentralized state.

Table 8
Impact of variation s_1 at the GI compare to MSS.

	19.9	40	71.6	123.3	175.1	226.8	278.5
π_g	172165	181666	188862	179994	145561	85564	0
π_{m2} at GI	195000	203390	221683	264767	324252	400136	492423
π_{m2} at MSS	534871	534871	534871	534871	534871	534871	534871



a. Impact of variation μ_1 at the GI compare to MSS



b. Impact of variation s_1 at the GI compare to MSS

Fig. 5. The impact of variation μ_1 and s_1 at the GI compare to MSS.

Table 9
Impact of variation μ_2 at the GI compare to MSS.

	0	12	24	36	48	60
π_g	165793	184840	203887	222933	241980	261027
π_c at GI	365965	346919	327872	308826	289779	270639
π_c at MSS	270639	270639	270639	270639	270639	270639

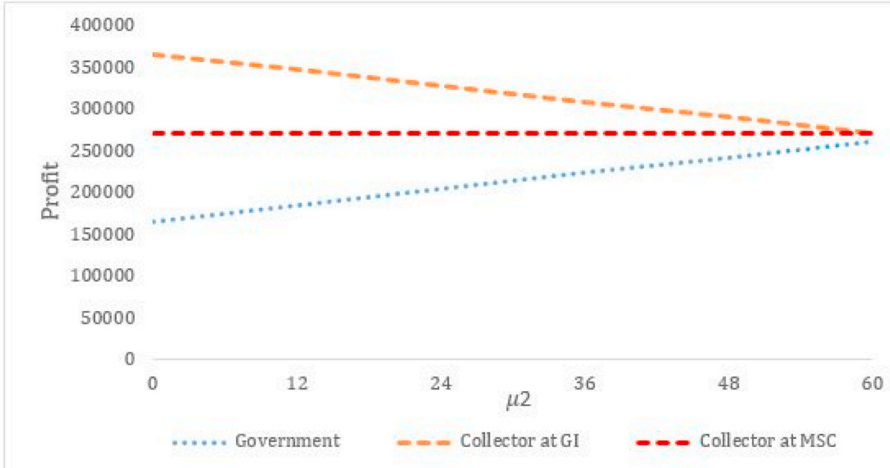
Table 10
Impact of variation s_2 at the GI compare to MSS.

	4.9	21.4	37.8	54.3	70.7	87.1
π_g	261120	208896	156672	104448	52224	0
π_c at GI	270639	322863	375087	427311	479535	531759
π_c at MSS	270639	270639	270639	270639	270639	270639

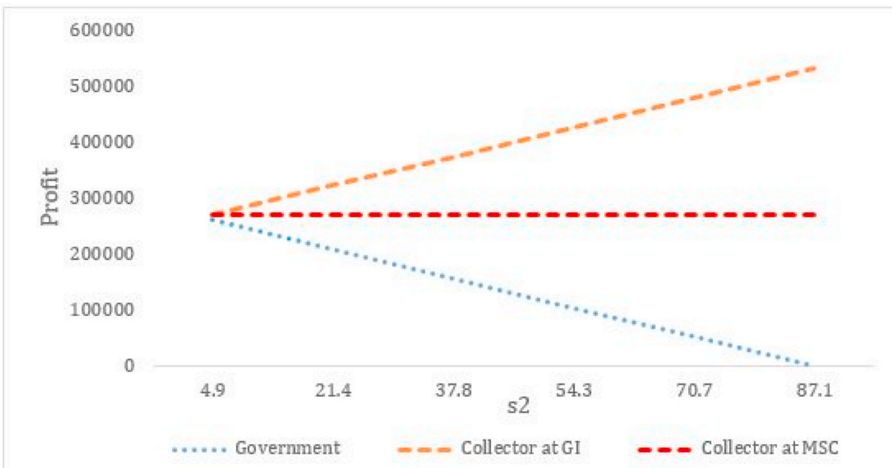
5) The ratio of declining retail profitability of foreign goods at GI is higher than MSS for example 1 and example 3 in Table 3 compared to internal retailer. This means that more space will be created for internal retailer, vis-a-vis, creating barriers to external product retailer will reduce her profit highly.
6) In order to boost production, it is better to reduce tax collection and increase subsidies on manufactured goods for internal manufacturer. If the subsidy is large enough that the manufacturer does not suffer compare to MSS, goods will be sold to end customers at lower price and also the internal manufacturer will not be harmed.

8. Conclusion

Due to the increase in the production of various products, including electrical products, which consequently leads to an increase in consumption as well as an increase in environmental release, human societies have been forced to deal with this issue. According to the research



c. Impact of variation μ_2 at the GI compare to MSS



b. Impact of variation s_2 at the GI compare to MSS

Fig. 6. The impact of variation μ_2 and s_2 at the GI compare to MSS.

gap studied in the literature, this issue presented in a competitive closed loop supply chain consisting of a production chain that enters the under study country from abroad and also a domestically production. The first main goal of this research is to reduce the need for fresh raw materials to produce products, especially electronic ones, and consequently reduce the harmful effects of the environment. In this competitive environment, the government as an effective member in monitoring prices, with items such as granting subsidies to some members is trying to reduce the product price for the end customer. A new type of government intervention in this competitive chain is presented to support the domestic industry. In addition to government intervention through subsidies or taxes mentioned in the literature, a new type of intervention has been introduced through the collection of customs duties from retailers importing foreign goods in which the government try to prevent the import of foreign goods to the country and thus the boom of domestic production. Given that many electrical products can be reused to

Table 11
Impact of variation s_3 at the GI compare to MSS.

	0	12.1	24.2	36.3	48.5	60.6	72.7
π_g	138648	147836	156774	165464	173906	182098	190068
π_{r1} *at GI*	215734	209547	203455	197456	191551	185740	180000
π_{r1} *at MSC*	276361	276361	276361	276361	276361	276361	276361

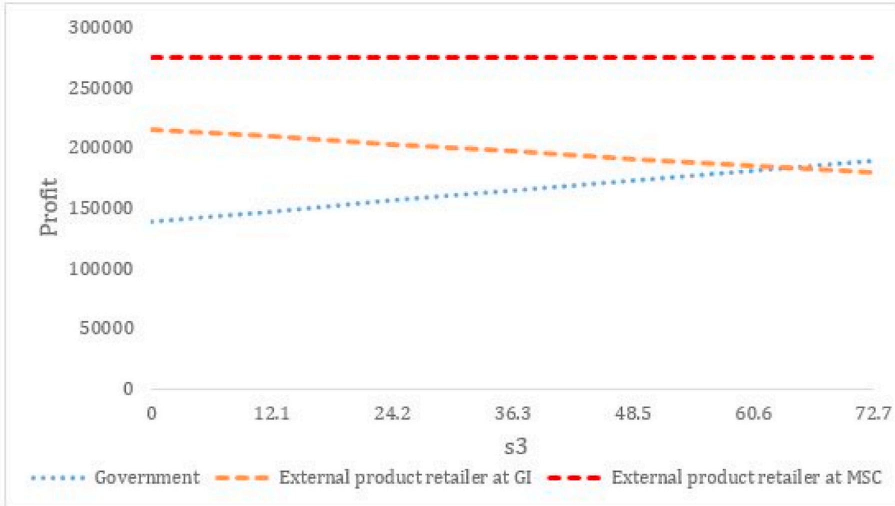


Fig. 7. The impact of variation s_3 at the GI compare to MSS.

Table 12
The amount of fresh raw material for the internal manufacturer in the MSS compared to the GI.

EX	MSS	GI
Ex1	520	−39
Ex2	1077	−265
Ex3	2355	119

produce a new product or a secondary product, considering different demand for both kind of new products (internal or external) and also for both kind of secondary products (internal or external) in which produced from defective goods collected by the collector from end customers, the importance of pricing and determine quality level is obvious. This type of government intervention in this type of competitive chain, according to the findings, indicates a reduction in the use of fresh raw materials for domestic producers. This has led to a reduction in environmental pollution as well as a reduction in domestic producer costs (support for domestic industry), both of which have achieved the main objectives of the research. Also, according to managerial implications, government intervention has led to a decrease in the profits of some members compared to MSS. Given that the government does not seek to make a profit from these type of interventions in the chains and mainly seeks to reduce prices in favor of the end customer, the amount of subsidies or taxes as well as customs duties should be such that members of the chain do not be harmed compared to MSS.

Considering competitive supply chain, subsequent researches could examine the impact of advertising and warranty period as two effective elements on demand function to purchase new goods. Furthermore, government intervention can also be considered as a way to enforce rules for the minimum product quality level or even the maximum product price. According to the explanations provided that it is better for the members of the internal chain not to be harmed in the GI compared to MSS, the optimal threshold of subsidies or taxes collected from members should be examined.

CRediT authorship contribution statement

Mohammad Reza Rezayat: Software, Validation, Investigation, Formal analysis, Resources, Data curation, Writing – original draft, Preparation. **Saeed Yaghoubi:** Conceptualization, Methodology, Formal analysis, Writing – review & editing, Visualization, Supervision, Project administration. **Atieh Fander:** Software, Validation, Formal analysis, Data curation, Writing – review & editing, Visualization.

Appendix A. Proving the first proposition

To assert the concavity of the internal manufacturer profit subordinate respect to his/her variables, the Hessian matrix has been showed below:

$$H_{m2}=\begin{pmatrix} \frac{\partial^2\pi_{m2}}{\partial {W_{nf2}}^2} & \frac{\partial^2\pi_{m2}}{\partial W_{nf2}\partial P_{no2}} & \frac{\partial^2\pi_{m2}}{\partial W_{nf2}\partial Q_{n2}} \\ \frac{\partial^2\pi_{m2}}{\partial P_{no2}\partial W_{nf2}} & \frac{\partial^2\pi_{m2}}{\partial {P_{no2}}^2} & \frac{\partial^2\pi_{m2}}{\partial P_{no2}\partial Q_{n2}} \\ \frac{\partial^2\pi_{m2}}{\partial Q_{n2}\partial W_{nf2}} & \frac{\partial^2\pi_{m2}}{\partial Q_{n2}\partial P_{no2}} & \frac{\partial^2\pi_{m2}}{\partial {Q_{n2}}^2} \end{pmatrix}=\begin{pmatrix} -(\alpha_1+\alpha_2) & \frac{\alpha_2(2\alpha_1+3\alpha_2)}{2(\alpha_1+\alpha_2)} & \frac{1}{2}.\left(\beta_1+\frac{\alpha_1.\beta_2}{\alpha_1+\alpha_2}\right) \\ \frac{\alpha_2(2\alpha_1+3\alpha_2)}{2(\alpha_1+\alpha_2)} & -\frac{2\alpha_1.(\alpha_1+2\alpha_2)}{\alpha_1+\alpha_2} & \beta_2+\frac{\beta_1.(2\alpha_1+3\alpha_2)}{2(\alpha_1+\alpha_2)}-k_2 \\ \frac{1}{2}.\left(\beta_1+\frac{\alpha_1.\beta_2}{\alpha_1+\alpha_2}\right) & \beta_2+\frac{\beta_1.(2\alpha_1+3\alpha_2)}{2(\alpha_1+\alpha_2)} & \end{pmatrix}$$

It should be noted that the first minor is negative $(-(\alpha_1+\alpha_2))<0$ or $\left(-\frac{2\alpha_1.(\alpha_1+2\alpha_2)}{\alpha_1+\alpha_2}\right)<0$ or also $(-\ k_2)<0$, the second one is positive $\left(\frac{8{\alpha_1}^4+32{\alpha_1}^3.\alpha_2+36{\alpha_1}^2.{\alpha_2}^2+4\alpha_1.{\alpha_2}^3-9{\alpha_2}^4}{4(\alpha_1+\alpha_2)^2}>0\right)$ if $(8{\alpha_1}^4+32{\alpha_1}^3.\alpha_2+36{\alpha_1}^2.{\alpha_2}^2+4\alpha_1.{\alpha_2}^3>9{\alpha_2}^4)$ and the third minor is negative [fx]. Because of that parameters meet the mentioned conditions, the optimal values of W_{nf2}, P_{no2} and Q_{n2} can be obtained.

Appendix B. Proving the second proposition

To assert the concavity of the external retailer profit subordinate respect to his/her variables, the Hessian matrix has been showed below:

$$H_{r1} = \begin{pmatrix} \frac{\partial^2 \pi_{r1}}{\partial {P_{n1}}^2} & \frac{\partial^2 \pi_{r1}}{\partial P_{n1} \partial P_{s1}} \\ \frac{\partial^2 \pi_{r1}}{\partial P_{s1} \partial P_{n1}} & \frac{\partial^2 \pi_{r1}}{\partial {P_{s1}}^2} \end{pmatrix} = \begin{pmatrix} -2(\alpha_1 + \alpha_2) & 0 \\ 0 & -2(\alpha_3 + \alpha_4) \end{pmatrix}$$

It should be noted that the first minor is negative $(-2(\alpha_1 + \alpha_2) < 0)$ or also $(-2(\alpha_3 + \alpha_4) < 0)$ and the second one is positive $(4(\alpha_1 + \alpha_2).(\alpha_3 + \alpha_4) > 0)$. Because of that parameters meet the mentioned conditions, optimized values of P_{n1} and P_{s1} is obtained.

To assert the concavity of the internal retailer profit subordinate to his/her variables, the Hessian matrix is:

$$H_{r2} = \begin{pmatrix} \frac{\partial^2 \pi_{r2}}{\partial {P_{nf2}}^2} & \frac{\partial^2 \pi_{r2}}{\partial P_{nf2} \partial P_{s2}} \\ \frac{\partial^2 \pi_{r2}}{\partial P_{s2} \partial P_{nf2}} & \frac{\partial^2 \pi_{r2}}{\partial {P_{s2}}^2} \end{pmatrix} = \begin{pmatrix} -2(\alpha_1 + \alpha_2) & 0 \\ 0 & -2(\alpha_3 + \alpha_4) \end{pmatrix}$$

It should be noted that the first minor is negative $(-2(\alpha_1 + \alpha_2) < 0)$ or also $(-2(\alpha_3 + \alpha_4) < 0)$ and the second one is positive $(4(\alpha_1 + \alpha_2).(\alpha_3 + \alpha_4) > 0)$. Because of that parameters meet the mentioned conditions, optimized values of P_{nf2} and P_{s2} is obtained.

Appendix C. Proving the third proposition

To assert the concavity of the internal manufacturer profit subordinate respect to his/her variables, the Hessian matrix has been showed below:

$$H_{m2} = \begin{pmatrix} \frac{\partial^2 \pi_{m2}}{\partial {W_{nf2}}^2} & \frac{\partial^2 \pi_{m2}}{\partial W_{nf2} \partial P_{no2}} & \frac{\partial^2 \pi_{m2}}{\partial W_{nf2} \partial Q_{n2}} \\ \frac{\partial^2 \pi_{m2}}{\partial P_{no2} \partial W_{nf2}} & \frac{\partial^2 \pi_{m2}}{\partial {P_{no2}}^2} & \frac{\partial^2 \pi_{m2}}{\partial P_{no2} \partial Q_{n2}} \\ \frac{\partial^2 \pi_{m2}}{\partial Q_{n2} \partial W_{nf2}} & \frac{\partial^2 \pi_{m2}}{\partial Q_{n2} \partial P_{no2}} & \frac{\partial^2 \pi_{m2}}{\partial {Q_{n2}}^2} \end{pmatrix}$$

$$H_{m2} = (1-\mu_1).\begin{pmatrix} -(\alpha_1 + \alpha_2) & \frac{\alpha_2(2\alpha_1 + 3\alpha_2)}{2(\alpha_1 + \alpha_2)} & \frac{1}{2}.\left(\beta_1 + \frac{\alpha_1.\beta_2}{\alpha_1 + \alpha_2}\right) \\ \frac{\alpha_2(2\alpha_1 + 3\alpha_2)}{2(\alpha_1 + \alpha_2)} & -\frac{2\alpha_1.(\alpha_1 + 2\alpha_2)}{\alpha_1 + \alpha_2} & \left(\beta_2 + \frac{\beta_1.(2\alpha_1 + 3\alpha_2)}{2(\alpha_1 + \alpha_2)}\right) - k_2 \\ \frac{1}{2}.\left(\beta_1 + \frac{\alpha_1.\beta_2}{\alpha_1 + \alpha_2}\right) & \left(\beta_2 + \frac{\beta_1.(2\alpha_1 + 3\alpha_2)}{2(\alpha_1 + \alpha_2)}\right) & \end{pmatrix}$$

It should be noted that the first minor is negative $(-(\alpha_1 + \alpha_2).(1-\mu_1)) < 0$ or $\left(-\frac{2\alpha_1.(\alpha_1+2\alpha_2).(1-\mu_1)}{\alpha_1+\alpha_2}\right) < 0$ or also $(-k_2) < 0$ if $\mu_1 > 0$. Given that μ_1 is the tax rate, it can't get the amount more than 1, so $(-(\alpha_1 + \alpha_2).(1-\mu_1)) < 0$ or $\left(-\frac{2\alpha_1.(\alpha_1+2\alpha_2).(1-\mu_1)}{\alpha_1+\alpha_2}\right) < 0$ or also $(-k_2) < 0$ if $0 < \mu_1 < 1$. The second one is positive $\left(\frac{(8{\alpha_1}^4+32{\alpha_1}^3.\alpha_2+36{\alpha_1}^2.{\alpha_2}^2+4\alpha_1.{\alpha_2}^3-9{\alpha_2}^4).(1-\mu_1)^2}{4(\alpha_1+\alpha_2)^2} > 0\right)$ if $\mu_1 > 0$. Whit the previous explanation, $\left(\frac{(8{\alpha_1}^4+32{\alpha_1}^3.\alpha_2+36{\alpha_1}^2.{\alpha_2}^2+4\alpha_1.{\alpha_2}^3-9{\alpha_2}^4).(1-\mu_1)^2}{4(\alpha_1+\alpha_2)^2} > 0\right)$ if $0 < \mu_1 < 1$ and the third minor is negative [fx]. Because of that parameters meet the mentioned conditions, the optimal values of W_{nf2}, P_{no2} and Q_{n2} with considering GI can be obtained.

Appendix D. Proof of Proposition 4

To assert the concavity of the external retailer profit function respect to his/her variables, the Hessian matrix has been showed below:

$$H_{r1} = \begin{pmatrix} \frac{\partial^2 \pi_{r1}}{\partial {P_{n1}}^2} & \frac{\partial^2 \pi_{r1}}{\partial P_{n1} \partial P_{s1}} \\ \frac{\partial^2 \pi_{r1}}{\partial P_{s1} \partial P_{n1}} & \frac{\partial^2 \pi_{r1}}{\partial {P_{s1}}^2} \end{pmatrix} = \begin{pmatrix} -2(\alpha_1 + \alpha_2) & 0 \\ 0 & -2(\alpha_3 + \alpha_4) \end{pmatrix}$$

It should be noted that the first minor is negative $(-2(\alpha_1 + \alpha_2) < 0)$ or also $(-2(\alpha_3 + \alpha_4) < 0)$ and the second one is positive $(4(\alpha_1 + \alpha_2).(\alpha_3 + \alpha_4) > 0)$. Because of that parameters meet the mentioned conditions, the optimized values of P_{n1} and P_{s1} is obtained.

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