Research Article

A Game Theoretical Approach to Optimize Policies of Government Under the Cartel of Two Green and Non-Green Supply Chains

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Abstract

In this research, firms aim at maximizing two purposes of social welfare (environment) and profitability in the supply chain system. It is assumed that there are two supply chains, a green and an ordinary, each consists of a manufacturer and a supplier; in which the manufacturer generates profit through franchises. The green and the ordinary manufacturers form a cartel on the market of a certain product with the goal of increasing their mutual profits and maintaining a certain level of social welfare, while the government, as a leader, intervene financially using tax rates and incentives. We formulate the problem as a Stackelberg game model seeking the equilibrium solutions. A numerical example is presented and a sensitivity analysis is carried out. The results show that the investment's encouraging tax rate in green technology has no impact on the optimal production of the green and ordinary manufacturers. Therefore, it is not an affective variable on the product market, but it is an important variable for the state utility function. Another highlight is that if tax rates are not equal for green and ordinary goods, then either the green or the ordinary producer will be withdrawn from the market. The most important result of this study is that if the government wants to maximize its utility function when the final product's market is facing with a cartel and the price collusion between the green and ordinary producer, it should realize the equality between the ordinary and green tax rate and there is no difference between these two parameters of the government's decision. If the government is willing to keep the green producer in the market, the optimal and absolute tax rate of green chain is obtained by assuming zero profit of the green manufacturer.

Keywords: Green supply chain management; Stackelberg game; Social responsibility; Tax rate.

1. Introduction

One of the most important responsibilities of government is to achieve a sustainable development with a view to preserving the environment. For example, governments in Europe and North America or Japan mostly take advantage of green laws and financial instruments for their own environmental policy (Robeson et al., 1992). Some states impose green tax on producers and the directly and indirectly subsidize to recycling industries to encourage environmental protection activities (Luke, 2005). The present study is conducted on how supply chain management reacts state policies in this field.

In the opening section of this study, relevant literature is investigated to identify factors contributing to the adoption of green supply chain management. In the next section, these studies will be the basis for making the analytical model of the study. In the end, the results of the study are raised to ease the awareness of the concept of the investigation and the relative importance of each of the contributing factors in the adoption and implementation of green supply chain management will be discussed.

Green supply chain management is defined as a series of supply chain management policies that all its activities and communications are for response to concerns related to environmental issues and includes sections such as design, production, distribution, use, reuse and tails of products and services of firms (Zsidisin and Siferd, 2001). Srivastava (2007) defined green supply chain as taking into account environmental issues in supply chain management including product design, selection and sourcing of materials, manufacturing process, delivering the final product to the customer and product management after taking over its useful life.

Although the concepts of sustainable supply chain management and green supply chain management are often used instead of each other in the supply chain literature, the two concepts differ little from one another. Sustainable supply chain management includes economic and social sustainability and environmental dimensions. Hence, the concept of sustainable supply chain management is more comprehensive than green supply chain management and green supply chain management is part of sustainable supply chain management (Farahani et al., 2009).

The rest of the paper is organized as follows. Section 2 describes the related literatures. Section 3 presents the assumptions and develops the mathematical sub-models of the supplier and manufacturer in green supply chain as well as the ordinary supply chain. Section 4 exhibits a numerical example and performs a sensitivity analysis on

the main parameters. Section 5 concludes the paper and remarks directions for future research.

2. Literature Review

Supply chain management is a cross-functional approach that includes managing the flow of goods involves the movement and storage of raw materials, work-in-process inventory, and of finished goods from point of origin to point of consumption (Simchi-Levi et al., 2000, Chopra and Meindle, 2007).

This paper is related to green supply chain management (GSCM) considering the concept of competition and cartel formation between supply chains. There are few recent researches that regard the competition and cooperation among supply chains or supply chain members in the area of green supply chain management (Debabrata and Janat, 2015, Du et al., 2015, Li et al., 2016, Zhu and He, 2017). Angappa et al., 2015 made a good review on green supply chain collaboration and discussed the trends and future research directions in this area.

Zsidisin and Siferd (2001) investigated a set of supply chain management policies that all of its existing activities and communications are intended to respond to concerns related to environmental issues and to include areas such as designing, producing, distributing, using, reusing and disposing of enterprise products and services. Governments are often motivated to take interventionist policies to create positive and negative foreign effects on firms. Therefore, Sheu (2011) and Murphy (2000) investigated the effects of government policy on green supply chain management (GSCM) performance in various aspects. They discussed that green regulations imposed by government increases the supporting technical innovative incentives of the environment. Similarly, Tsireme et al. (2012) showed that, in some environmental legislation cases, market-based instruments and internal control incentives play a significant role in matching management decisions with GSCM. Some studies benefited from the analytical framework of game theory to study the effects of government policies on GSCM. Mitra and Webster (2008) designed a two-stage game model between ordinary producers and recoverable product manufacturer and conclude that an ordinary producer can change into a recoverable product manufacturer only if the government imposes a reasonable level of subsidies. Sheu (2011) proposed a Nash bargaining model to analyze the interaction between producers and suppliers (raw recoverable materials) in terms of financial involvement of the government. He indicated that the supporting environmental financial laws levied by the state increase the bargaining power of producers in a green SCs structure. Jin and Mei (2012) developed a theoretical game model for government strategies and suppliers in a green SCs.

Sheu and Chen (2012) evaluated state financial interventions in a SCs competition system. Their analysis was based on a three-stage game model and showed that the SCs forward and backward focus can become more efficient by government's regulatory intervention. Zhao et al. (2012) used the game theory model to analyze the strategies employed for producers which reduce the risk of environmental hazards and examined the government's policy of punishment and rewards in this context. Zhou et al. (2014) used the theoretical model of game theory to analyze the interaction between government and green supply chain in a particular industry.

Hafezalkotob (2015) examined how government engages in fiscal policy (tax) on an oligopoly market structure. The basic premise of the article was that the decision-making structure of environmentally friendly commodity producers and ordinary goods follow Stackelberg's decision-making model. In addition, he also added retailer businesses to his theoretical model and then derived the optimal government's tax rates for each scenario in six scenarios (different government objectives and various concentrated and decentralized market structure between manufacturers and retailers).

Hafezalkotob and Hadi (2015) modeled the competition of two closed-loop and ordinary supply chains considering the effects of persuasive and punitive governmental plans. Optimal retail and wholesale prices of the products are achieved using a game theory approach.

Hafezalkotob (2017a) considered competition, cooperation, and coopetition between two green supply chains given the financial interventions of the government while optimizing the wholesale price and energy-savings level for each manufacturer as well as the retail price for each retailer. In the proposed model the government plays the role of the leader and sets tariffs on the products of the supply chains under different policies including energy-saving, revenue-seeking, social welfare, and sustainable development.

Hafezalkotob (2017b) studied the equilibrium between green and non-green product types under different government intervention schemas. To this end, we establish production competition models of a set of green and non-green supply chains (GSCs and NGSCs, respectively). GSCs and NGSCs are two-echelon supply chains (SCs) that present green and non-green types of a product to a market, respectively. We consider two schemas of governmental intervention: direct tariffs (DTs) and tradable permits (TPs), both with and without baselines. This research seeks to evaluate how the GSCs and NGSCs respond to the DT or TP schemas. To establish the best SC response strategies, we formulate three-level non-linear programming problems for four possible governmental intervention scenarios. We find that this problem is multidimensional with different system stakeholders including the government, SCs, consumers, and the environment.

As discussed above, few studies have been conducted on the optimal strategies for government's policy to create a green supply chain. The important implicit assumption in such studies has been the formation of competitive market between the green producer and the ordinary producer while it is possible that these two producers form a cartel by colluding with one another. Then, the question is

whether we can build a model that extracts the optimal government strategy considering the optimized interaction between suppliers and producers in the multiple market structures? The government can immediately and easily turn a high tariffs non-environmentally friendly producer to an eco-friendly manufacturer. Thus, the other very important topic is modeling the other condition of the product market in time of markets' multiple structures between producers and suppliers and eventually the new proposed model will be more adapted to the realities and explains a wider scope of the phenomenon.

In this study, the best behavioral strategy uses financial and tax policies for a green and environmentally-friendly product and market system as well as an optimal government strategy when the market structure of a product approaches a complete monopoly market structure (due to the formation of a cartel) is proposed.

3. Model Description

In this study, a static model is formulated. Therefore, the non-recurring game is considered (as the game has one period). In most supply chains, one or two members are usually more powerful than others and it is possible that a manufacturer is exclusive. Hence, it is not possible that all firms in the supply chain take simultaneous decisions with stronger businesses and act. In this case, Stackelberg' game system is used for analysis.

Firms in the supply chain system should maximize two target functions of social welfare (environment) and profitability. Our goal is to increase the profits of both players by maintaining a certain level of social welfare function.

3.1. Model assumptions

Some assumptions are considered to model the problem:

Market inverse demand function $P^M(q_t) = a - bq_t$ is determined as the retail price by demand. To avoid losing firms' market share, the manufacturer board controls wholesale prices to avoid re-pricing (retail). The franchise right or a two-part tariff is a clear procedure to achieve this goal. We assume that the manufacturer generates its profits by getting the right franchise (f).

Supply chain network is decentralized. All manufacturers and suppliers are assumed to have equal power and are symmetrical. As we want to simplify the model, only one manufacturer and one supplier are considered in each supply chain.

The model of this study assumes that there are five important players in the market: 1. Green supplier, 2. Green manufacturer, 3. Ordinary supplier, 4. Ordinary manufacturer, and 5. Government. Green supplier and manufacturer are in one chain and ordinary supplier and manufacturer are in the other chain competing with each other. A cartel may be formed between the two manufacturers in green and ordinary supply chain. The government as a leader tries to increase his benefit including tax revenue and social welfare. Figure 1 illustrates a schematic view of the model.
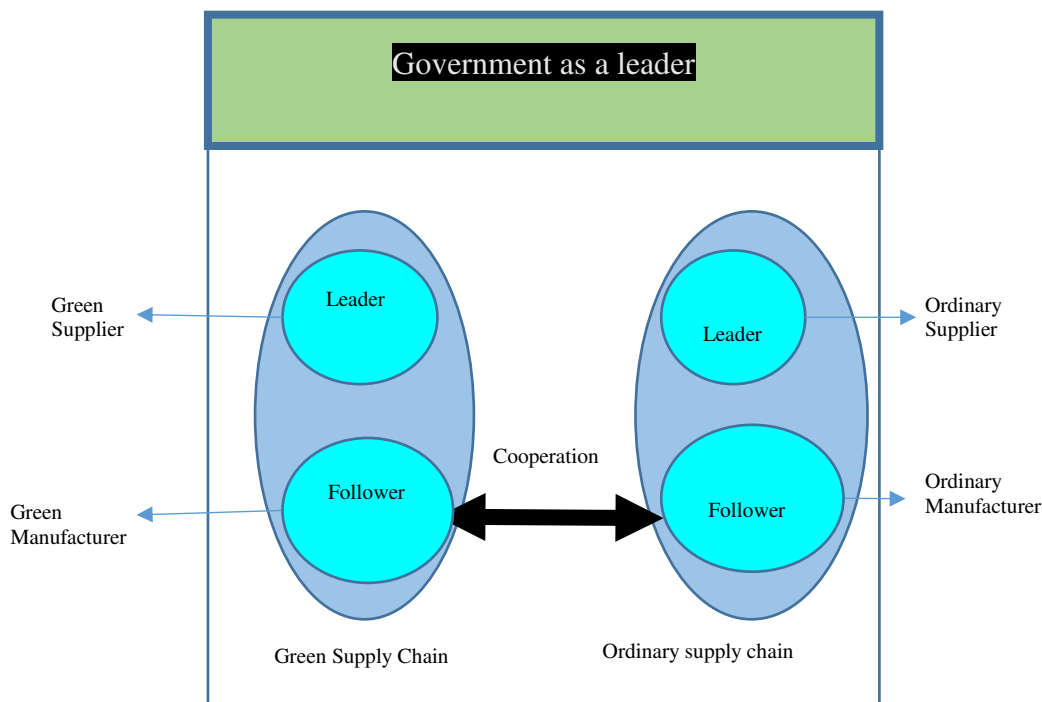

Fig.1. Schematic view of the model

The main different hypothesis of this study is that green and ordinary manufactured goods are perfectly homogeneous in the market and have an equal demand function. Following Sheu (2011), the manufacturer wholesale price can be defined as Eq. (1):

$$P = a - bQ - f \tag{1}$$

In which Q denotes the demand quantity and can be obtained as Eq. (2):

$$Q = r + g \tag{2}$$

where r is the production quantity of ordinary supply chain and g is the production quantity of ordinary supply chain. P is the market price. a is the market potential demand. b is the coefficient that shows the sensitivity of price to the supply quantity. f defines the cost of franchise.

All types of social reaction are assumed to be expressed by a ratio of the players' investments in the green chain. The social welfare function can be specified as Eq. (3):

$$E = \beta_1 x_1 + \beta_2 x_2 \tag{3}$$

in which β_1 and β_1 are the conversion ratios of the green supplier and green manufacturer investments to the social welfare, and, x_1 and x_2 are the amount of investments for the green supplier and green manufacturer, respectively.
Since investment of firms on green technology involves their private interests in addition to external interests and affect their profitability, B1 and B2 are defined equal to the private interests' level of the supplier and manufacturer firm and can be formulated as Eq. (4):

$$B_1 = \rho_1 E \quad , \quad B_2 = \rho_2 E \tag{4}$$

where ρ is the conversion coefficient of social welfare to firms' private interests.
Government requires agencies to keep a certain level of social welfare through policies or laws but also encourages them to higher levels. The following functions T1 and T2 determine the value of tax returns for the supplier and manufacturer (Feibel, 2003) and can be defined as Eq. (5).

$$T_1 = \kappa x_1 \big(1 + \theta(x_1 + x_2)\big) \tag{5}$$

$$T_2 = \kappa x_2 \big(1 + \theta(x_1 + x_2)\big)$$

where κ is the tax rate of return for the green supplier and manufacturer, and θ is the incentive tax rate of the entire supply chain. A certain percentage of investment is paid by the supplier and manufacturer in different ways. For example, the manufacturer pays more for eco-friendly raw materials.
The main objective of both the manufacturer and supplier is maximizing profits through their production decisions. In this study, a Stackelberg game model is used in two different scenarios supplier-leader and manufacturer-

leader to make a comparison. The supplier determines the quality and type of raw materials as well as the separation level of products. It can be as powerful as the manufacturer in the allocation of investment in welfare and social responsibility. We model a condition that the supplier is the leader of the chain.

3.2. The objective function and constraints

In this model, the supplier's utility function is defined by Eq. (6) (Sheu, 2011).

$$F_1 = (1 - \kappa)wg - cg + B_1 + T_1 - x_1 + dx_2 \tag{6}$$

where w is the production costs of the supplier which is sold to the manufacturer. d is the conversion coefficient of the manufacturer's investment in green supply chain to the interests of the supplier. c is the unit cost of production.

On the other side, the profit function of the manufacturer can be defined as Eq. (7).

$$F_2 = (1 - \kappa)Pg - cg + B_2 + T_2 - x_2 \tag{7}$$

3.3. The optimal amount of investment in green supply chain

To calculate the optimal amount of investment in green supply chain for the manufacturer and supplier, we first assume that the supplier plays the role of the leader due to its effective role and the manufacturer plays as the follower. Therefore, we use the reverse strategy to solve the Stackelberg equilibrium and extract the optimal amount of investment in the supply chain.

$$\frac{\partial F_2}{\partial x_2} = 0 \rightarrow x_2 = \frac{-\kappa + \rho_2 \beta_2 + \kappa \theta x_1 - 1}{2\kappa\theta} \tag{8}$$

So, the supplier's optimal amount of investment in green supply chain can be obtained by replacing it in the supplier's utility function, and making its derivative equal to zero:

$$x_1 = \frac{d - 2\rho_1 \beta_1 + \rho_1 \beta_2 + \rho_2 \beta_2 + 1}{2\kappa\theta} \tag{9}$$

After calculating the optimal amount of investment in green supply chain, we can determine the green manufacturer profit by placing the green supply chain investment and determine the new manufacturer profit which involves the balanced and optimized investment in green supply chain.

3.4. The optimal production level of green and ordinary manufacturers

Following Hafezalkotob (2015), to determine the optimal production level of both green and ordinary manufacturers in the market, the utility functions of ordinary manufacturer and ordinary supplier are defined as Eq. (10).

$$F_3 = (1 - v)wr - cr \tag{10}$$

$$F_4 = (1 - v)Pr - wr$$

3.5. Ordinary supply chain business tax rate

At this stage, based on the assumption of the first section, we assume that the two firms of manufacturer and supplier form a cartel. Thus, the optimized production level of each firm is obtained by initially embedding the derived zero sum gain functions of ordinary and green manufacturer:

$$\frac{d(F_2 + F_4)}{dg} = 0$$

$$g^* = \frac{a - f + w - av + fv}{\kappa b - bv}$$

$$r^* = \frac{f - a + \frac{b(a - f + w - av + fv)}{\kappa b - bv}}{b} \tag{11}$$

3.5. The objective function of the government

In this section, we define the objective function of the government by dividing it into two main parts: tax revenue and social welfare resulting from green production.

Government tax revenue is the total tax revenue of green and ordinary manufacturers and suppliers which is obtained as Eq. (12):

$$GNR = \kappa wg + \kappa Pg + vwr + vPr \tag{12}$$

Following Hafezalkotob (2015), state utility function is defined by a combination of income and environmental considerations (social welfare) and formulated as Eq. (13):

$$U = GNR + \mu E \tag{13}$$

in which μ is the conversion coefficient of social welfare to state welfare.

Finally, the green supply chain's optimal tax rate can be calculated by replacing the optimal values of other variables in the state utility functions and differentiating the state utility function regarding to κ. Thus the optimal value of κ can be calculated as Eq. (14).

$$\kappa = \frac{\beta_1 + \frac{\beta_2}{2} - 2\rho_1\beta_1^2 - \frac{\rho_1\beta_2^2}{2} - \frac{3\rho_2\beta_2^2}{2} + \sqrt{\frac{-(2\beta_1 + \beta_2 - 4\rho_1\beta_1^2 - \rho_1\beta_2^2 - 3\rho_2\beta_2^2 + 2d\beta_1 - d\beta_2 + 4\rho_1\beta_1\beta_2 + 2\rho_2\beta_1\beta_2)(4\rho_1\beta_1^2 - \beta_2 - 2\beta_1 + \rho_1\beta_2^2 + 3\rho_2\beta_2^2 + 8\theta\beta_1 + 4\theta\beta_2 - 2d\beta_1 + d\beta_2 - 4\rho_1\beta_1\beta_2 - 2\rho_2\beta_1\beta_2)}{2}}}{2\beta_1 + \beta_2} \tag{14}$$

4. Numerical solution and sensitivity analysis

To show the model capabilities, here we use a numerical example. The parameters used in the example are summarized in Table 1.
To study the sensitivity of the level of production in green and ordinary supply chain to tax rate (κ), we first consider that κ varies in the range [0,1] and map the level of the dependent variables r and g, assuming that the two green and ordinary manufacturers form a cartel and collude in setting prices. Figure 2 shows the variation of the production level in green supply chain as well as ordinary supply chain regarding to the tax rate (κ).

Table 1
The parameters of the numarical example

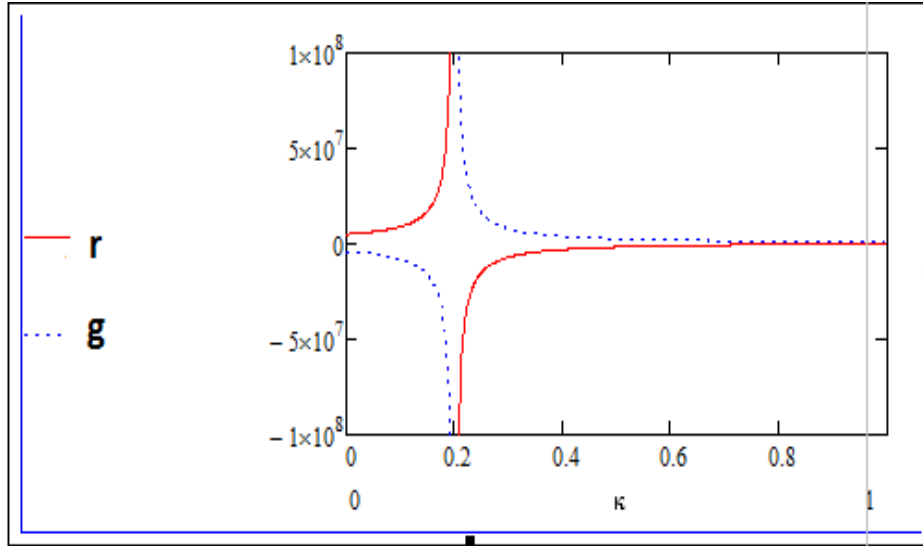| Parameter	numerical value	Parameter	numerical value
f	1	$\rho 1$	0.1
w	4	$\rho 2$	0.15
b	0.04	$\beta 1$	0.5
v	02	$\beta 2$	04
a	1000	d	0.05

Fig. 2. The sensitivity of the level of production in green and ordinary supply chain to tax rate (κ)

As seen in figure 2, the important observation is that the parameter θ has no effect on the green and ordinary manufacturers' production level. Therefore, it is not an affecting variable in the product market. However, it is an important variable of the state utility function. The explanation for this result is that the government's incentive rate of investment for green technology has no impact on the marginal cost of production for the manufacturer and supplier. Consequently, it does not have an impact on the efficient production level of the green and ordinary supply chains. By looking at figure 1, we realize that if the green supply chain tax rate is higher than the ordinary chain tax rate, the ordinary manufacturer will be phased out of the market, but the optimal production of green products is reduced by increasing the green supply chain tax rate and moves toward zero. Also, if the green supply chain tax rate is lower than the

ordinary chain tax rate, the green manufacturer will be phased out of the market. However, the optimal production ordinary good reaches its maximum value equal to the market potential demand (a), by increasing tax rate for green supply chain. Another important point is that if tax rates are not equal for green and ordinary good, one of the green or ordinary manufacturers will be certainly phased out of the market. These results will leads to the formation of cartel between the green and ordinary manufacturer.

To assess the relationship between the tax rate levels and the government's utility, it is assumed that both the ordinary and green manufacturers form cartels and the government tends to maximize its utility of social welfare and tax revenue. Figure 3 illustrates the variation of the government's utility function regarding to the tax rates.
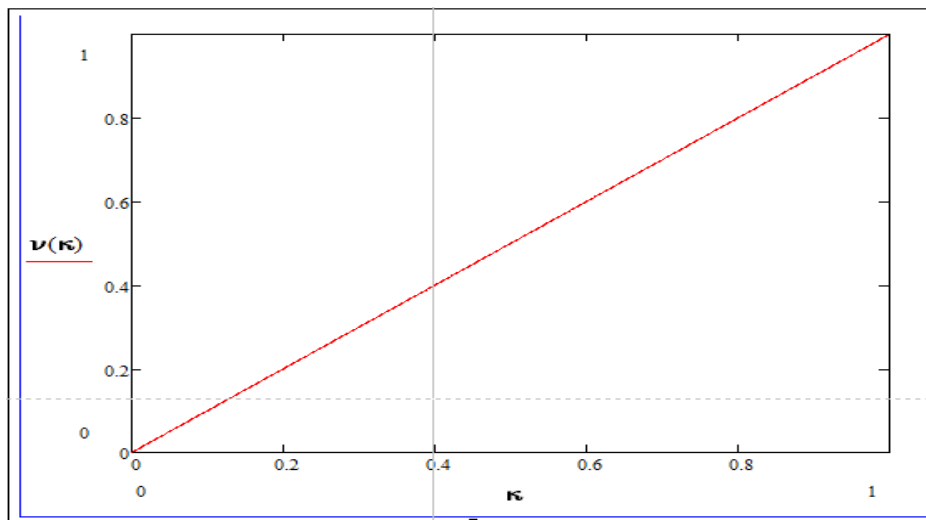

Fig. 3. The relationship between the tax levels and the optimal route of the government utility

The main observation in Figure 3 is that if the government wants to maximize his utility in the event that the market is facing a cartel and collusion between the green and ordinary manufacturers, the equality between the green and ordinary tax rates should be realized. The green and ordinary tax rate unification policy results in phasing out of the green or ordinary manufacturer with respect to the results of Figure 2. To answer the question that in which optimal rates these two firms will be phasing out of the market, we need to investigate the relationship between green chain tax rate and green technology incentive rate.

Figure 4 depicts the relationship between the green chain tax rate and the green technology incentive rate. The relationship between the two variables is represented well in blue when if the lower tax rates of 0.5 are accepted. As can be seen in figure 4, there is actually no significant relationship between green chain tax rate and green technology incentive rate. In fact, there are two different values of green chain tax rate while symmetrically maximizing the government utility function for each value of green technology incentive rate. Figure 5 shows this relationship in the form of a bargaining function. Figure 5 implies that the government has to increase green good tax rates with higher growth than green technology incentive rates to maximize it utility function.
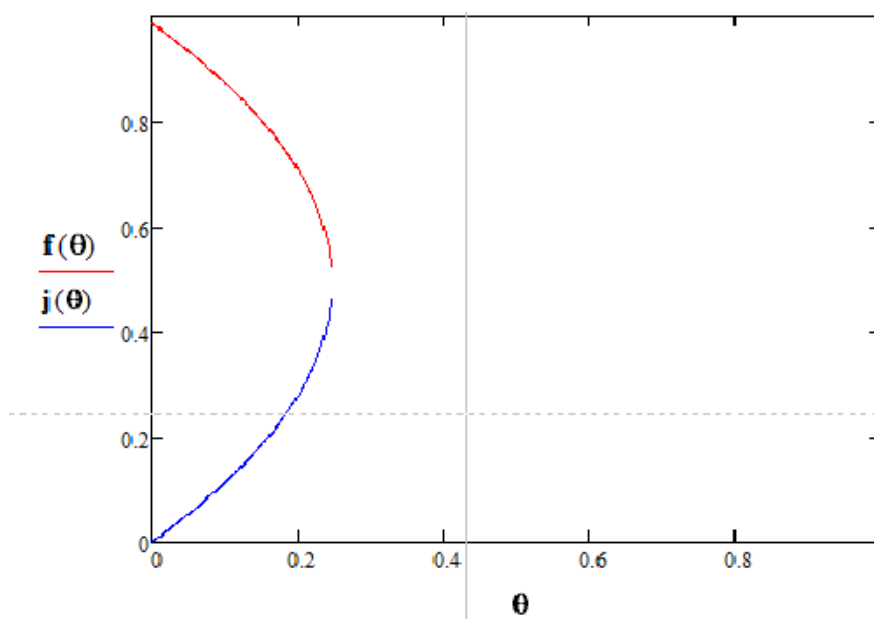

Fig. 4. The relationship between green chain tax rate and green technology incentive rate

Determining the optimal amount of green and ordinary chain tax rate:

As mentioned in section 4.3, the government should choose equal tax rates for the green an ordinary supply chain to maximize the amount of tax revenue and social welfare if there is a cartel between the green and ordinary manufacturers. In that case, either the green or the ordinary manufacturer will certainly be phased out of the market. Hence, if the government is willing to keep the green manufacturer in the market, the relationship between the green and ordinary tax rates should be achieved by keeping the green manufacturer profit function equal to zero (as in a competitive market). By embedding Figure 4, the optimal amount of the green and ordinary tax rate is obtained, as seen in Figure 5. This unique value is obtained based on a numerical approximation. Thus the optimal solution depends on the numerical values given for the parameters.
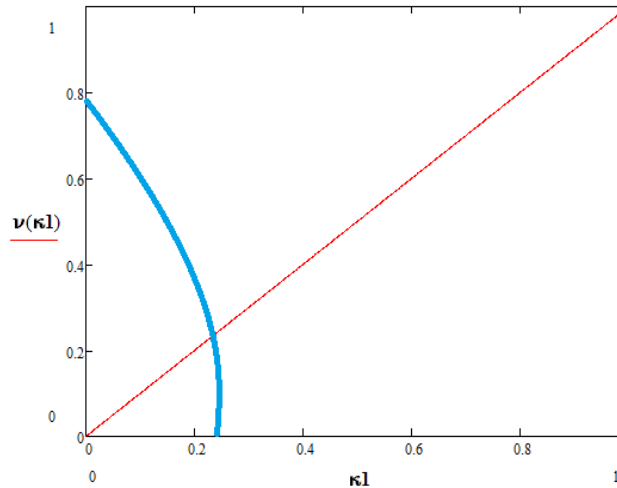
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Fig. 5. Investment sensitivity of green technology suppliers to supplier's social benefits

5. Conclusion

Through defining the four key players: green supplier, green manufacturer, ordinary supplier, ordinary manufacturer, the present study made an attempt to propose an economic model to optimize the government decision variables with the goal of maximizing the utility function of state tax revenue and environmental considerations under the assumption of forming a cartel between the green and ordinary manufacturers.

The analytical results of the study show that the investment's incentive tax rates in green technology θ has no impact on the optimal production of the green manufacturer. Therefore, it is not an affecting variable on the product market; rather, it is an important variable for the government utility function. Another important point that if tax rates are not equal for green and ordinary good, either the green or the ordinary manufacturer will certainly be phased out of the market.

The important result of this study is that if the government wants to maximize its utility function when the final product's market is facing with a cartel and there is a price collusion between the green and ordinary manufacturer, it should realize the equality between the ordinary and green tax rate.

Finally, determination of the unique optimal tax rate requires an extra assumption. In other words, if we assume that the government wants to maximize its utility function on the condition that the green firm stay on the market, we need to assume that the firm's profit becomes zero like in a competitive market. Then, the unique and optimal green and ordinary tax rate can be obtained by a numerical study. After determining the optimal green tax rate, the optimal amount of green technology incentive rate can be also calculated and it is slightly lower than the green chain tax rate.

For future research, one can assume the end-product market as a full competitive market or an oligopolistic market.

Another implicit extension is to consider the final product and raw materials pricing problem. In this case, simultaneous modeling of the two final and mediating markets can be done with the indigenizing this variable and providing market for intermediate goods. This will certainly be more consistent with the real world, though more complex equations and functions will also be achieved.

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