Auto Manufacturers and Applying Green Practices in the Presence of Rivals (The Case of End of Life Vehicles)

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Abstract

Fulfilling the legislation pertinent to end-of-life (EOL) products, in addition to sustainability of manufacturers, or license to operation can lead to brands added value and reputation. The competitive advantages of performing the EOL directives need to be assessed in the market framework and the presence of interaction among players. Complying with EOL legislation is necessary for activity in some markets (auto manufacturers of Member States need to meet the requirements of European Union's EOL Vehicle Directives), however, for the other markets can be a strategic choice (for example, US auto manufacturers in the absence of national regulation for automobile disposal and waste). In this study, we developed a model in order to analyze the strategic choice of auto manufacturers in response to EOL directives as the result of interaction of competitors in the market. We used evolutionary game theory for modeling the game between automakers.

Keywords
EOL vehicle legislation, Auto manufacturers, evolutionary game theory, competition

1. Introduction
After experiencing a period of crisis in the automobile industry in US, this industry will return to their high pre-crisis levels. (Heymann, 2012) believes that in the longer term, an even higher sales volume is plausible. The author mentions the growing population figures (another 50 million people by 2030) and the primary importance of cars for US consumers as the main drivers for this growth rate. Vehicles affect the environment over their entire life cycle. Some of these effects occur at the end of their lives such as hazardous substance emissions, and disposals (Kanari et al., 2003).Addressing the environmental issues for End of life Vehicle (ELVs) raises a number of serious challenges for the industry. In the USA, there is no specific legislation regarding the management of ELVs. With respect to the broad landfill spaces with lower costs of waste disposal and lack of standard waste legislation for whole states, recycling industry has received much less interest (Konz, 2009). Automotive industry has an essential role in the recycling industries in US and auto manufacturers participate in the programs for improvement recycling management process. For example, Ford has purchased more than 25 vehicle recycling operations in the US, with more expected and has an experimental dismantling center in Germany (Staudinger and Keoleian, 2001). In the absence of the identical legislation in auto recycling, automotive manufacturers follow different practices in a variety range from changes in design to issue a guideline or standards. Each of these practices has also different impacts on the other players and even can change economic sustainability of ELVs business (Kumar & Sutherland, 2008). Moreover, automakers choice of applying eco design practices which improves the recycling rate of ELVs needs to be considered in the context of the market and interaction of other competitors. Hence for automakers there

is two essential sources of uncertainty including market forces and future directives. Considering incomplete information and possibility of irrationality of players, it's difficult for players to make sure that their choice of strategy is the best. Therefore, the evolutionary game theory is appropriate for analysis of the situation with these conditions. We used sensitivity analysis in order to show that how the type of eco design practices considering its costs and market forces such as the elasticity of demand to price can affect the stability of the game. The rest of this paper is organized as follows: Section 2 provides a literature review. Section 3 introduces the model and formulation. Section 4 presents a numerical example, the results and the sensitivity analysis and finally in Section 5 we conclude with some remarks and insights for future researches.

2. Literature Review

2.1 Auto manufacturers and Eco practices

Design for environment (DFE) or Eco design strategy is one of manufacturer's efforts in order to integrate the environmental considerations into product and process design. There are different techniques and practices which can be used by manufacturers in DFE context. Material substitution, design for disassembly, design for recyclability and design for reusability are some of these practices. Each practice may have impacts on one or more stages of product life cycle as well as different effects on stakeholders and value creation framework. The motivations for designing align with environment come from different sources and pressures. The customer pressure, competitive forces and legislation are important reasons for companies in involvement in environmental efforts especially Eco efficiency design (Rose, 2000). The key drivers for Eco design practices and their effects on the manufacturer's behaviour can be shown as Figure 1.

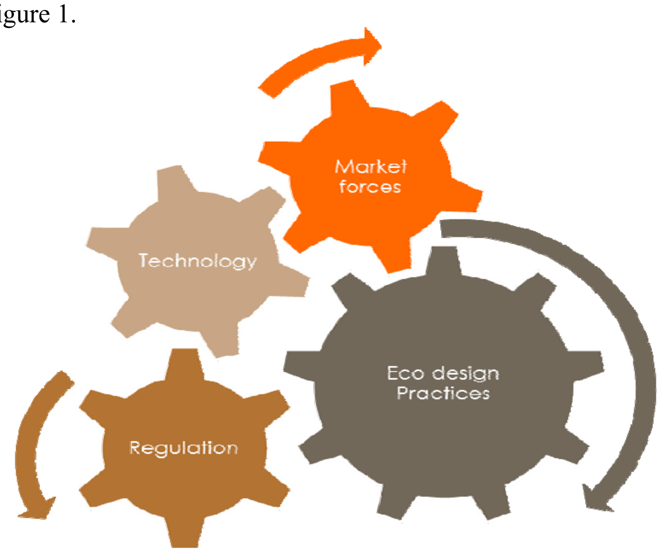


Figure 1: The key drivers for Eco design practices

Waste management is crucial as landfills close and populations grow (Pohlen & Farris, 1992). Therefore, reducing landfilled material, maximizing recycling, and controlling hazardous materials are important challenges in the end of life treatment. Products with different characteristics experience distinct end-of-life strategies. Now, end-of-life treatment systems are developed by industry volunteers or as a reaction to legislation (Rose, 2000). One product which has considerable effect on the environment at the end of life is vehicle. Numerous voluntary programmes have been performed by car manufacturers. However, almost none of these programs meet the recovery percentages proposed by European directives (Gerrard & Kandlikar, 2007).

(Gerrard & Kandlikar, 2007) present an evaluation framework based on anticipated changes that could result from the ELV directives. These changes relate to three areas: (a) vehicle design, (b) level of ELV recovery, and (c) information provision. The authors brought the evidences from different automakers in applying different strategies regarding ELVs recycling. Why the different automakers apply the variety of strategies and what are the advantages and disadvantages of different strategies are questions, which should be addressed via an appropriate model, in order to understand the behavior of automakers. Different strategies, which may be applied by an automaker related to ELVs, have been shown in Figure 2.

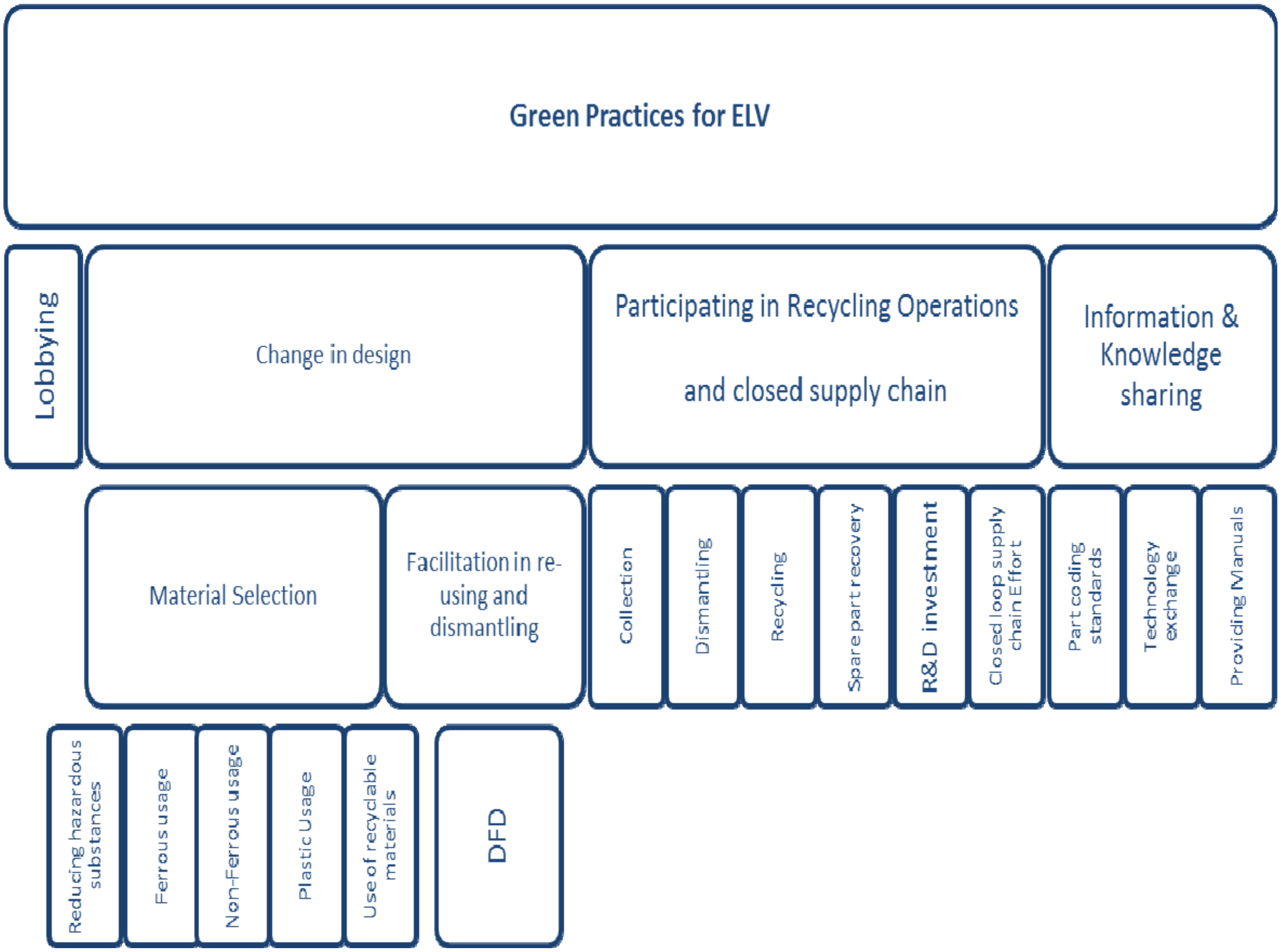


Figure 2: Different strategies which can be applied by automakers

2.2 ELV in USA and regulations

Government policies regarding addressing different phases of ELVs recycling process especially those in improving recycling rate can affect new technologies, market share of automotive manufacturers, the profit of dismantlers and shredders and even the sustainability of the overall business. Technical requirements for car design and minimum reuse and recovery rates for end-of-life vehicles are recent European Union directive on ELVs (Ferrao et al., 2006). In order to meet this directive, more changes are needed in recycling infrastructures and manufacturers actions. Hence complying with this directive raises some challenges for the automaker and other key players in recycling infrastructures. The requirements of EU directive on ELV are reducing total waste, organizing waste collection and treatment, meeting the target of re-use and recovery (85 % no later than 1 January 2006 and 95 % no later than 1 January 2015), and facilitating dismantling process via providing manuals and information and evaluation of progress through reports. Around 15 million cars and trucks reach the end of their useful life in the United States each year (Ferrao et al., 2006). Konz (2009) with studying the success and criticism of EU directives and current directives in US, proposed a framework for future directives in relation to ELVs in US. According to this reference in USA, no national regulation exists for the disposal of automotive waste and Individual States are free to adopt inconsistent regulations, or waive regulation completely. While the EU ELV Directive has a number of shortages, it can be considered as an initial model for uniform, federally mandated ELV legislation in USA. Three areas for future regulation in US can be explained as shown in Figure 3.

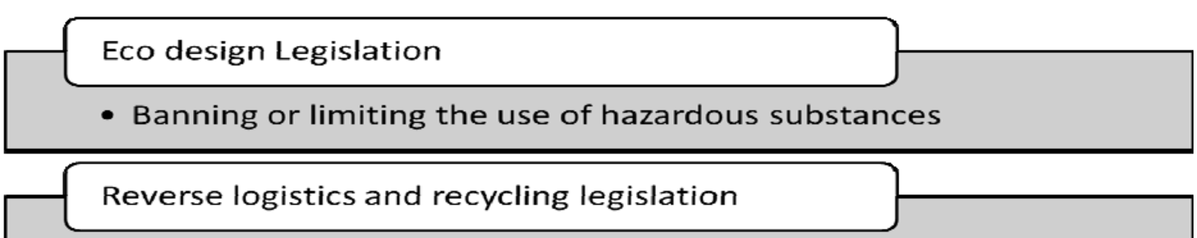


Figure 3: Three areas for future regulations in USA

2.3 Evolutionary game theory

In conventional game theory, there are three assumptions: (1) rational behavior of all the agents, (2) complete sharing of empirical information, (3) all the agents have common knowledge of these assumptions (Barari et al., 2012). As in the real world, considering these assumptions is difficult or even impossible, applying evolutionary game theory can bring the most advantages for modeling the behaviors of players. In Evolutionary game theory instead of directly calculating properties of a game, populations of players using different strategies are simulated, and a process similar to natural selection is used to determine how the population evolves. Varying degrees of complexity are required to represent populations in multi-agent games with differing strategy spaces. Zhu & Dou (2007) used evolutionary game theory in order to investigate the games between governments and core enterprises in greening supply chains. Barari et al. (2012) applied evolutionary game for analyzing the game between the producer and the retailer to adjudicate their strategies to trigger green practices with the focus on maximizing economic profits. Considering incomplete information and possibility of irrationality of game players, it is difficult for players to make sure that their choice of strategies is the best. Hence the evolutionary game theory is appropriate for analysis of the situation with these conditions. We used an extensive form of evolutionary game theory for modeling the game among automakers in performing the ELVs strategies.

3. Modeling Game between Automakers

For analysis of the game among automakers, we considered two groups of players. First group is dominant automakers in US automotive industry (Such as Big Three: Ford, General Motors, and Chrysler) the second group of player is non-dominant (fringe) automakers in US automotive market. Geçkil & Anderson (2009) also used the classification of domestic automakers and non-domestic automakers with concentration on light trucks, non-domestic automakers with concentration on passenger cars for analysing the game among government and automakers in for regulations regarding CAFÉ (corporate average fuel economy) standards in US.

There are two general strategies in this game; cooperation and competition. Cooperation for dominant automakers means accepting the associated costs of applying ELVs eco practices with no change in their price. Competition for this group of automakers means increasing the price and profiting from raising rivals cost. Salop and Scheffman (1983) explained in their study a novel concept named «raising rivals' costs". The authors showed that firms could gain market power by conducting this strategy. They brought a formal analysis which illustrates how applying this strategy for a dominant firm can lead to profitability. On the other side, cooperation for non-dominant automakers are applying one of ELVs strategies and competition means not following ELVs strategies. We assumed that there is not any regulation with respect to ELV in the market and applying ELV practices is not obliged. The structures of the game and payoff matrix have been shown in Figure 4 and table 1 respectively. First we need to address the pure strategies for two players. Table 1 illustrates this list.

Automaker B

Table 1: Pure strategies for two players

Automaker A	Automaker B
SA1: Cooperation	SB1: If Automaker A selects Cooperation: Cooperation; If Automaker A selects Competition: Cooperation
SA2: Competition	SB2: If Automaker A selects Cooperation: Cooperation; If Automaker A selects Competition: Competition
	SB3: If Automaker A selects Cooperation: Competition; If Automaker A selects Competition: Cooperation
	SB4: If Automaker A selects Cooperation: Competition; If Automaker A selects Competition: Competition

(Salop and Scheffman, 1983) explain that advertising expenditure and R&D races can be used to raise rivals' costs. The natures of eco practices particularity in the design category are like R&D investments in term of uncertainty, the essential role of technology and market effects. Applying one eco design practices can increase the average cost of manufacturer. This expenditure as performed by an efficient firm (we supposed that dominant firms are cost efficient) is tolerable, and it must be matched in effective intensity by less efficient rivals (fringe firm). In this case, no matter that applying the eco design practice can lead to the direct benefit for the dominant firm (consumer satisfaction, image benefit or etc.), the dominant firm can advantage from the consequence of this strategy. Disadvantage competitors can provide a benefit that goes beyond its costs if the strategy permits the dominant firm to increase the price or market share. For analyzing the game, we used the basis of formal analyzing provided by Salop and Scheffman (1983). We changed some assumptions and made some changes in order to adapt it with the game of automakers in this study.

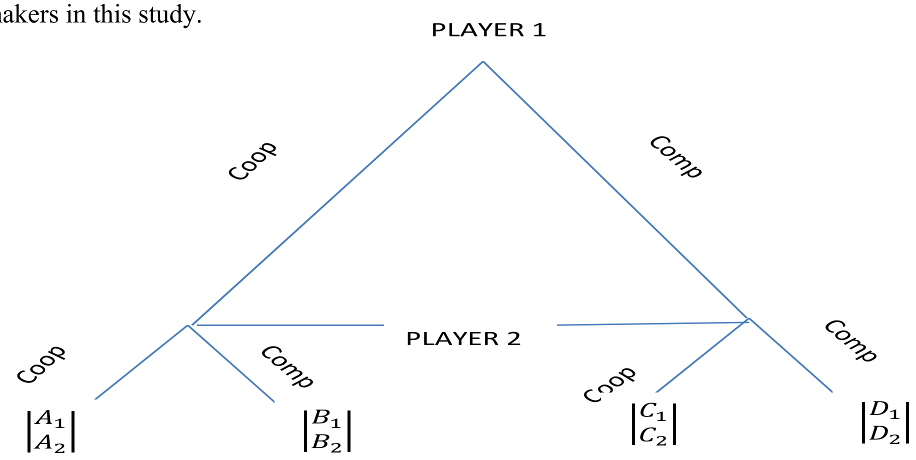


Figure 4: The structure of Game

		Coop/ Coop	Coop/Comp	Comp/ Coop	Comp/Comp
Automaker A	Cooperation	(A1, A2)	(A1, A2)	(B1, B2)	(B1, B2)
	Competition	(C1, C2)	(D1, D2)	(C1, C2)	(D1, D2)

Table 2: The pay-offs of the players

Table 3: The variables definition

Variables	Definition
$C(\alpha)$	The cost for applying strategy α
CA	The cost of Automaker A
CB	The cost of Automaker B
$R(\alpha)$	The direct revenue from applying strategy α
$\varepsilon_{D,P}$	The elasticity of demand to price
$\varepsilon_{S_B,P}$	The elasticity of supply of automaker B
S_B	The supply of automaker B
S_BN	The new supply of automaker B
x y	The market share of automaker A The market share of automaker B
P	The price
Δy	The change in supply by automaker B
D	The demand of market
DN	The new demand of market
Δp	The change in price by automaker A

In this model, the automakers A act as a price leader. The demand of the market is D and SB is supply of automakers B, which follows by collectively setting output y. The dominant firm produces at the point x on the residual demand curve R which is equal to (D- SB). For calculation of pay-off of each population of player and market share, we used the principle of dominate firm model. According to the definition of the dominant firm model in oligopoly context, the dominant firm sets prices which are taken by the fringe firms in defining their profit maximizing levels of production. The demand curve for the dominant firm is determined by subtracting the supply curves of all the small firms from the industry demand curve. After estimating net demand curve, the dominant firm maximizes profits by following the typical rule of producing, where marginal revenue equals marginal costs. The small firms maximize profits by acting as perfectly competitive firms equating price to marginal costs (Samuelson, & Marks, 2003).

The formulation of the problem has been shown via equations 1-21. Equation 1 and 2 represent the continuous replicator dynamic of the game. The fitness of an individual playing strategy SAi will be $(Ay\vec{y})i$. The average fitness of the first population will be $x\vec{x}^T Ay\vec{y}$. Similarly the fitness of strategy SBi will be $(By\vec{y})i$, and the average fitness for the second population will be $x\vec{x}^T Ay\vec{y}$. The pay-off matrices are written as 3 and 4. The pure strategies for two populations are presented as 5 and 6. We used the standard Jacobian Matrix (J) for evaluating the stability of an equilibrium strategy pair and obtain the evolutionary stable strategy (ESS) values. Equation 8 shows the trace of J matrix and conditions for finding ESS.

$$\dot{xx}_i = xx_i\left((A\vec{yy})_i - \vec{xx}^T A\, yy\right) \quad (1)$$

$$\dot{yy}_i = yy_i\left((B\vec{xx})_i - \vec{yy}^T B\, xx\right) \quad (2)$$

$$A = \begin{pmatrix} A_1 & A_1 & B_1 & B_1 \\ C_1 & D_1 & C_1 & D_1 \end{pmatrix} \quad (3)$$

$$B = \begin{pmatrix} A_2 & C_2 \\ A_2 & D_2 \\ B_2 & C_2 \\ B_2 & D_2 \end{pmatrix} \quad (4)$$

$$x = \begin{pmatrix} xx \\ 1 - xx \end{pmatrix} \quad (5)$$

$$yy = \begin{pmatrix} yy_1 \\ yy_2 \\ yy_3 \\ 1 - (yy_1 + yy_2 + yy_3) \end{pmatrix} \quad (6)$$

$$= \begin{bmatrix} \frac{\partial \dot{xx}}{\partial xx} & \frac{\partial \dot{xx}}{\partial yy_1} & \frac{\partial \dot{xx}}{\partial yy_2} & \frac{\partial \dot{xx}}{\partial yy_3} \\ \frac{\partial \dot{yy}_1}{\partial xx} & \frac{\partial \dot{yy}_1}{\partial yy_1} & \frac{\partial \dot{yy}_1}{\partial yy_2} & \frac{\partial \dot{yy}_1}{\partial yy_3} \\ \frac{\partial \dot{yy}_2}{\partial xx} & \frac{\partial \dot{yy}_2}{\partial yy_1} & \frac{\partial \dot{yy}_2}{\partial yy_2} & \frac{\partial \dot{yy}_2}{\partial yy_3} \\ \frac{\partial \dot{yy}_3}{\partial xx} & \frac{\partial \dot{yy}_3}{\partial yy_1} & \frac{\partial \dot{yy}_3}{\partial yy_2} & \frac{\partial \dot{yy}_3}{\partial yy_3} \end{bmatrix} \quad (7)$$

$$tr(J) = \left[\frac{\partial \dot{xx}}{\partial xx} + \frac{\partial \dot{yy}_1}{\partial yy_1} + \frac{\partial \dot{yy}_2}{\partial yy_2} + \frac{\partial \dot{yy}_3}{\partial yy_3}\right] \quad (8)$$

$\text{If } \det(J) > 0,\ tr(J) < 0, \text{ the soloution is ESS of the Game}$

Equations 9-32 show the pay-off matrices elements and the used variables are defined in table 3.
The first term in equation 9, 10, 13, 14,17,18,25 and 26 is the profit of the automaker without applying practice. The second term (if any) shows the profit as the result of applying one ELV practice which cal strategy α. The equation 11 presents market share of automakers B, which is derived from price to marginal Equation 12 shows the market share of population A which is obtained from residual demand curve. In this ca assumed two players select cooperation. Equation 15 and 16 shows the market share of each player when A s cooperation and B selects competition. When A select competition and B select cooperation, benefits from r rivals costs with increasing the price. In this case, the market share of B will be decreased. Equations 19 a show these changes. As the price will be changed, it is necessary to consider the effect of demand elasticit supply elasticity of B as the result of this increasing in price. The equations 21 and 22 represent new market de and supply of B respectively. The market share of two players has shown in equations 23 and 24. When two g of population select the competition as a strategy, the changes in price, demand, supply of B and their market s are presented in equations 27-32. It should be noted that, for simplicity, we assumed the linearity for su marginal cost and marginal revenue curves. However the formulas can be modified according to the real c which suggests for future studies.

$$A_1 = (P - C_A)x + \{R_A(\alpha) - C_A(\alpha)\} \quad (9)$$

$$B_1 = (P - C_B)y + \{R_B(\alpha) - C_B(\alpha)\} \quad (10)$$

$$y = \left\{\frac{C_B(\alpha)}{P - C_B}\right\} \quad (11)$$

$$x = \{D - (y)\} \quad (12)$$

$$A_2 = (P - C_A)x + \{R_A(\alpha) - C_A(\alpha)\} \quad (13)$$

$$B_2 = (P - C_B)y \quad (14)$$

$$y = \{S_B\} \quad (15)$$

$$x = \{D - (y)\} \quad (16)$$

$$A_3 = ((P + \Delta P) - C_A)x + \{R_A(\alpha) - C_A(\alpha)\} \quad (17)$$

$$B_3 = ((P + \Delta P) - C_B)y + \{R_B(\alpha) - C_B(\alpha)\} \quad (18)$$

$$\Delta P = \frac{C_A(\alpha)}{(D - S_B)} \quad (19)$$

$$\Delta y = \frac{C_B(\alpha)}{P - C_B} \quad (20)$$

$$DN = D - \varepsilon_{DP}\Delta P \quad (21)$$

$$S_BN = S_B - \varepsilon_{SBP}\Delta y \quad (22)$$

$$y = \{S_BN - \Delta y\} \quad (23)$$

$$x = \{DN - y\} \quad (24)$$

$$A_4 = ((P + \Delta P) - C_A)x + \{R_A(\alpha) - C_A(\alpha)\} \quad (25)$$

$$B_4 = ((P + \Delta P) - C_B)y \quad (26)$$

$$\Delta P = \frac{C_A(\alpha)}{(D - S_B)} \quad (27)$$

$$DN = D - \varepsilon_{DP}\Delta P \quad (28)$$

$$S_B N = S_B - \varepsilon_{S_B,P} \Delta p \quad (29)$$

$$\Delta p = S_B N \left(\frac{\Delta P}{P}\right) \quad (30)$$

$$y = (S_B N - \Delta p) \quad (31)$$

$$x = (DN - y) \quad (32)$$

4. Numerical Example and Discussion

In this section, we represent a numerical study and some scenarios discussion to provide managerial insights for decision makers. The used value for each variable in the numerical example is shown in table 4. We assumed that two populations of players (automakers A and B) produce a certain product in one segment, which can be comparable. Mathematical evaluation of ESS is done to identify the optimal strategy set that conveys the maximum economic benefit. This formulation has been coded in Matlab. The result is shown in Table 5. Automakers A plays 0.15% of time cooperation strategy and 0.85% of time competitive strategy while Automakers B always play S_B1 which means "If Automaker A selects Cooperation; Cooperation; If Automaker A selects Competition, Cooperation".

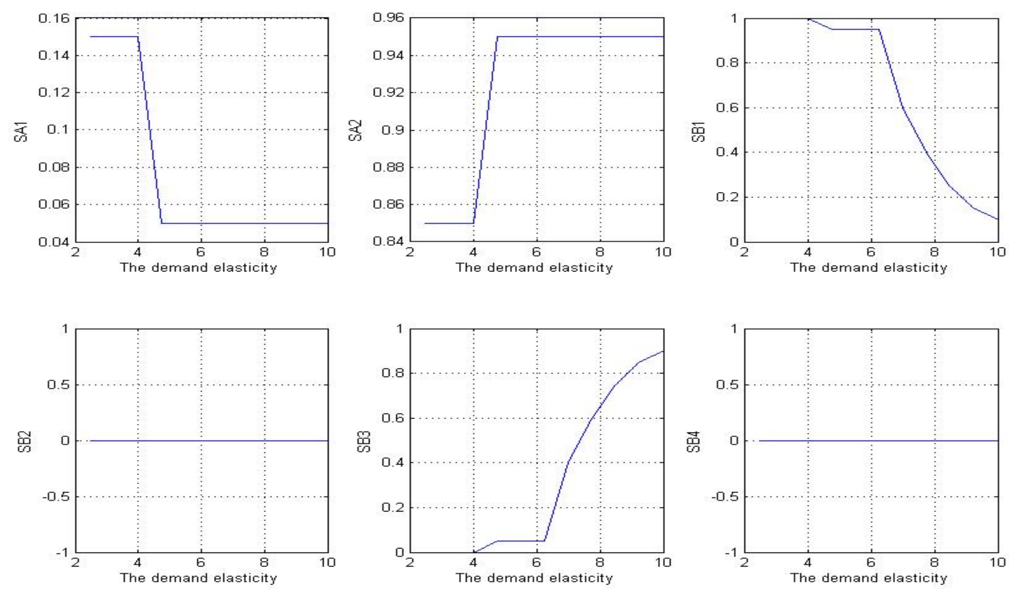
Table 4: The values for numerical example

Variables	Value
$C(n)$	25 for A and 30 for B
CA	4
CB	6
$R(n)$	40 for A and 35 for B
$\varepsilon_{D,P}$	5
$\varepsilon_{S_B,P}$	3
S_B	20
P	20
D	100

Table 5: The ESS of players

S_A1	S_A2	S_B1	S_B2	S_B3	S_B4
0.15	0.85	1	0	0	0

As we discussed in the previous section, when automaker A selects competition strategy, it benefits from raising rival costs with increasing the price and market share. The change in the residual demand curve depends on the elasticity of demand as well as the elasticity and shift of the fringe supply curve. As demand elasticity decreases, a given reduction in fringe supply causes a larger price rise. At the other side, if demand is perfectly elastic, residual demand does not increase at all (Salop and Scheffman, 1983). Hence assessing the effect of demand elasticity and supply elasticity of population B on strategies of players is essential. With this sensitivity analysis, we can observe the effect of market forces. As shown in Figure 5, 6 with increasing in demand elasticity and supply elasticity for player B, the player A prefer to play competition rather than cooperation and the willingness of player B for playing cooperation after competition will be decreased. As well as the willingness of player B for playing competition after cooperation and cooperation after competition will be increased. Figure 7 shows these changes in 3D plot obviously. (Kuhn, 2005) introduces environmental orientation of the market as the key parameter in assessing the green market context. He defined the environmental orientation of the market as the ratio of environmental elasticity of demand to price elasticity. The author concludes that high quality dominance with respect to both profit and market share implies an environmental orientation of the market which is sound relative to the cost of environmental performance (p.161) In this case, it means that when environmental orientation of the market is strong then consumers can pay for cars with a high rate of recycling and less EOL effect on the environment. In other extreme, in the market which consumers do not care the green performance of their choices, the translated eco practices costs in the price of car, leads to decreasing the demand and consequently market share of manufacturers. In order to analyze the different choice of manufacturers in term of which eco practices needs to be selected, we focused on associated costs and direct benefit of applying different eco practices as a measure. Figure 8, 9 shows the change in stable strategy of players based upon the change in direct revenue and the costs associated of implementing eco practices. When the cost of applying the ELV practices increases the willingness of player A for playing cooperation strategy decreases slightly but, obviously with these changes, player B prefers to play competition and not applying ELV. For fringe firms, the associated cost of eco practices particularly those, which need more investing in R&D and human resources, are not tolerable. So they prefer to apply the practices with less cost such as preparation of manuals or other information provisions.



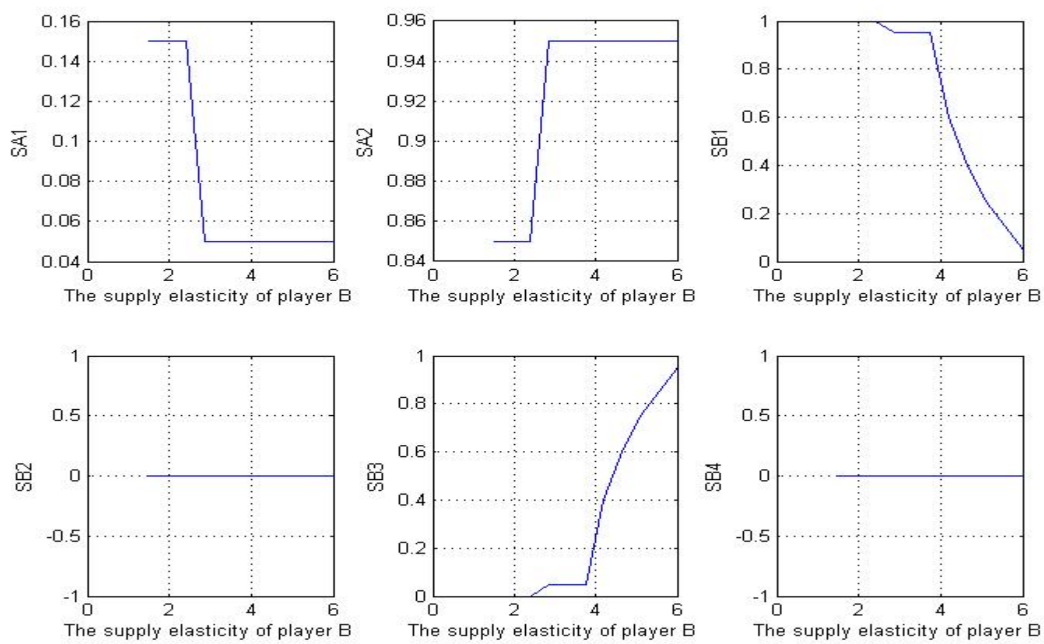


Figure 6: The change in ESS of players based upon the change in supply elasticity

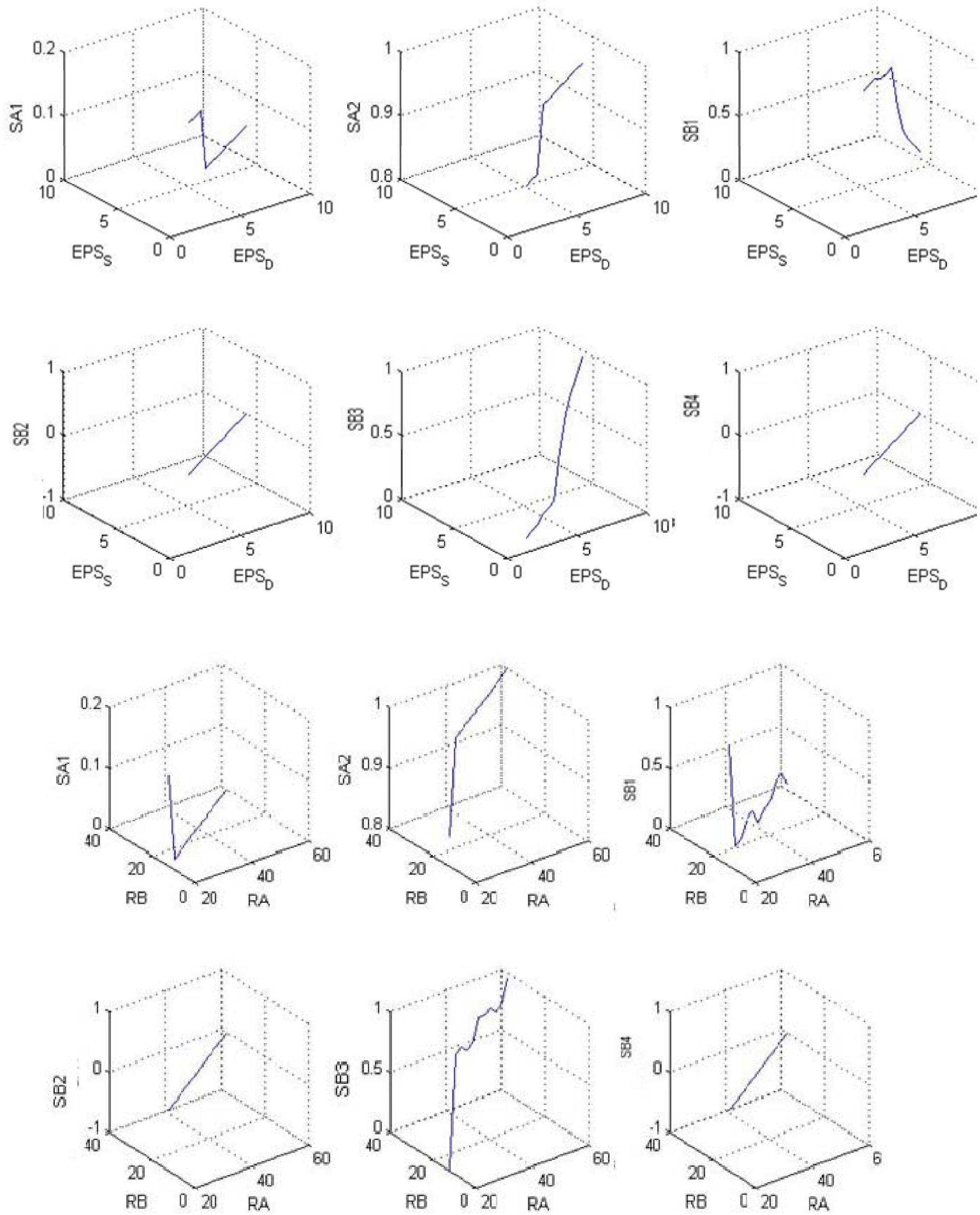


Figure 8: The change in strategy of players based upon the change of direct revenue from applying the eco practices

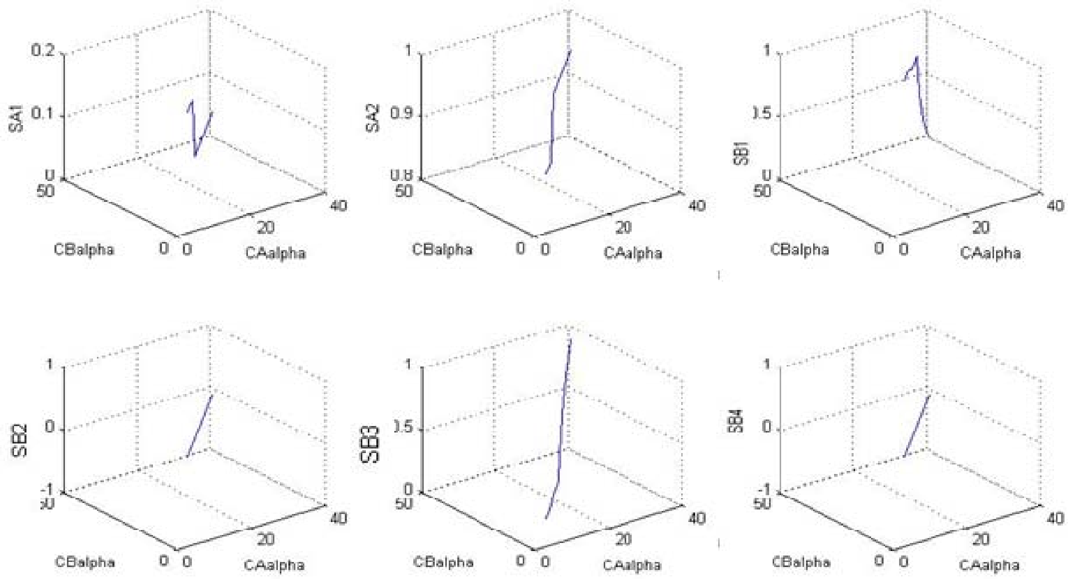


Figure 9: The change in strategy of players based upon the change of costs of applying the eco practices

5. Conclusion and future research

This paper proposed an evolutionary game model in order to analyze the behavior of automakers in applying the eco practices in the presence of competition. The result shows that when we have two populations of players including dominant firms and fringe firms; the market elements such as demand elasticity and supply elasticity are important parameters in stable strategy of the game. Furthermore, the choice of eco practices with respect to direct revenue and associated costs are considerable. We assumed a market with no regulation regarding ELV in order to predict the behavior of players; however the different scenarios of future regulations can be addressed in a separate study. Moreover in analyzing the market forces, we did not consider the effect of loyalty of consumers, taste of consumer and other factors in market. We propose considering these uncertain factors as further study. The influence of technology, which can change the cost and revenue of implementing the eco practices, also can be assessed in future studies.

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Biography

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