

# Defining Future Directions of Strategic Policy Decisions by Evolutionary Game Theory

Şule ERYÜRÜK<sup>1</sup>, Ichiro KOSHIIJIMA<sup>2</sup>

*Abstract*—Policy decision making for sustainability is a challenge for all industries, countries, and international directives. Governments and international regulations have been taking several imperative actions and pressure on automobile manufacturers to find innovative and effective solutions to deal with environmental centered sustainability problem. In Japan, government has regulations that support electric cars and a special type of vehicle in Japan named keijidousha (kei car) which are light and eco-friendly category of mini sized vehicles. This paper aimed to define the possible future directions of government's policies and international directives' related to the mini car strategies of auto industry. Objective of this research is expressing strategic interaction between government, international directives and industry that depends on all agents' choices. These interactions create many conditions and each of them makes a significant impact on auto industry's future strategies related to the mini car regulations. As a solution methodology, evolutionary game theory is applied.

*Keywords*—evolutionary game theory, international directives, government, industry, mini car, policy, sustainability, policy making

## I. INTRODUCTION

### A. Background

ENVIRONMENTALcentred sustainability is a major topic as in global-scale. While keeping the ongoing basis of the development with the balance of social and economic outputs, protecting the environment from all kind of pollutions is a great challenge for all policy making stakeholders. International directives are one of the major drivers to define macro level environmental standards as regulations. These regulations effect the decisions of government; which is second major driver on the process of policy making in their national strategies (Fig 1.). Every government has their own aims to be able to be competitive; however, because of the commercial trades with other countries, international directives become an affecting part of national strategic decisions. They require several enforcements to maintain international trades. This creates a conflict in policy decision making process of governments. Governments need to define a development path by their own action plans and at the same time there should be a negotiation process between the global scale strategies including the environmental centered sustainability topic[1].

Governments should response the changes taken place in global world on time and with a competitive strategy. Furthermore, government is directly related to the industries' policies as well. So, it is said that a nation's strategies can lead firms to be successful or fail. National regulations and market dynamics may push many companies to consolidate, divest, or exit from some geographies or businesses sometimes. In Japan, automobile industry is one of the main drivers of the economy. So, automotive companies may have to recheck their product portfolio, manufacturing systems, management styles and supply chain strategies to remain competitive in the complex and changing global regulatory environment [2][14][15].

Governments and international regulations have been taking several imperative actions and pressure on automobile manufacturers to find innovative and effective solutions to deal with environmental centered sustainability problem. However, only creating technology policies are not enough to contribute drastic solution of environmental problems caused by automotive sector. Transportation policies can be one of the major problems in the solution of environmental problems. These policies may help transformations in the transportation demand and these changes are very essential for policy makers to define future scenarios. In considering such policies, it is necessary to consider that transportation demand is dependent on local characteristic. Hereby, it is the crucial point that preparing and applying appropriate transportation policies with due consideration of national characteristics and international directives' expectations, while monitoring the technological industrial innovations [3][14].

In Japan, there are three main classification of automobiles based on body size (Fig 2.). Government has regulations that support a type of vehicle named keijidousha (Kei car) which is light and eco-friendly category of mini size vehicles and electric cars. The main purpose of the Japanese government's policy may be relevant to the aims of CO<sub>2</sub> reduction strategy of automobile sector in view of technological innovation and travel demand change. Travel demand change is related to the trends behind vehicle use. Vehicle preference indicates that mini cars are preferable by a great percentage of society. [4]. Not only technological innovation, but also minimizing the car engine size and decreasing the gasoline usage may be a future option to seize the environmental burdens of international directives and the government's future strategies.

Şule ERYÜRÜK<sup>1</sup> is with the Nagoya Institute of Technology, Graduate School of Engineering, Nagoya, Japan, 465-8555 (corresponding author's phone: +818045453882 ; e-mail:cir18505@stn.nitech.ac.jp ).

Ichiro KOSHIIJIMA<sup>2</sup>, is now with the Nagoya Institute of Technology Graduate School of Engineering, Department of Civil Engineering, Architecture and System Management, Nagoya, Japan, 466-8555 (e-mail:koshijima.ichiro@stn.nitech.ac.jp ).

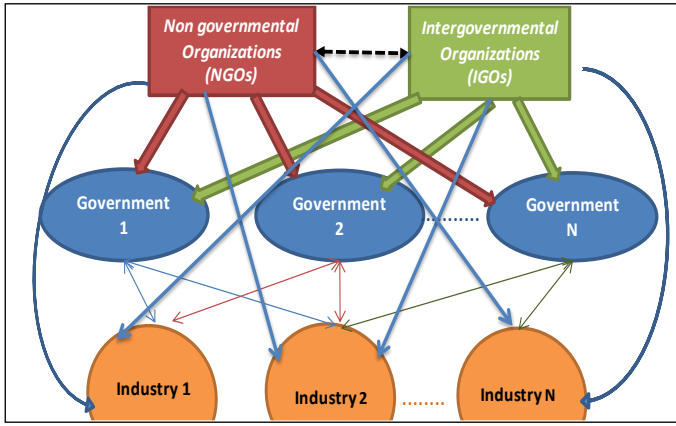


Fig 1: Influential key stakeholders in policy decision making and their relations (reproduced from [13] p.5).

This paper aimed to define the possible future directions of government's policies and international directives' related to the mini car strategies of auto industry considering Japan case. Objective of this research is expressing strategic interaction between government, international directives and industry that depends on all agents' choices. These interactions create many conditions and each of them makes a significant impact on auto industry's future strategies related to the mini car regulations. As a solution methodology, evolutionary game theory is applied.

#### B. Regulations History OF Mini cars in Japan - Kei cars

There are three main eras related to the policies of mini cars in Japan. Name of these eras can be defined by the upper limit of the engine size of the mini cars allowed by national policies. First era is 360 cc engine sizes, second era is 550 cc engine sizes and the final one is 660 cc engine sizes. After World War II., in order to support the development of automobile industry, as well as to offer an alternative delivery method to small business and shop owners, policies of mini car were created [5][12]. Engine mini cars originally limited to 150 cc in 1949, dimensions and engine size limitations were gradually increased in 1950, 1951, and 1955. In 1955, the Japanese Ministry of International Trade and Industry set several policies to manufacture a "national car" that was larger than kei cars produced at the time. Stricter emissions standards which were introduced in 1975 as part of a program of cleaning the air proved problems for kei car manufacturers. In the end, the Japanese legislature relented, increasing the overall length and width restrictions by 200 mm and 100 mm respectively. Engine size was increased to 550 cc, taking effect from January 1, 1976. In March 1990, new standards were introduced. An extra 110 cc were now allowed in a slightly larger (100 mm longer) body shell. The regulation of horsepower has been suggested due to the fitment of turbochargers and superchargers to these tiny engines during the late 1980s in order to cope with the lack of horsepower and torque.

#### C. Regulations History OF Mini cars in Japan – Electric cars

Environmental challenges, political problems and economic strategies is a concerning topic for all countries that may

significantly affect the future scenarios related to the transportation demands and gasoline vehicles.

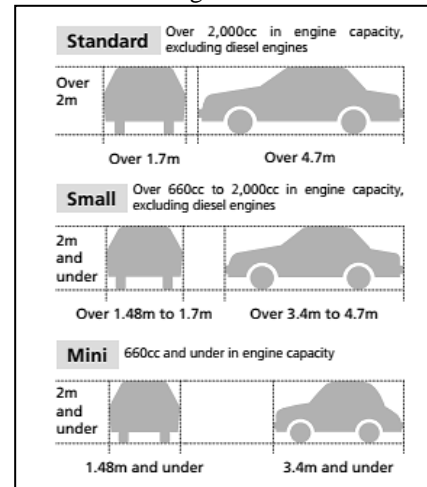


Fig. 2: Classification of automobiles based on body size and engine size in Japan [17]

So, there has been significant attention for electric vehicle. During 1930s, oil situation of Japan became serious. So, government of Japan has realized that they should not rely on imports of oil from abroad only for their sustainability, as many other oil-poor countries. [6] In recent years, the government has made a significant push in promoting eco-friendly vehicles through subsidies and tax incentives. The policy offered to buyers a subsidy for new eco-friendly cars. The policy was introduced in April 2009 and is effective for 12 months; In addition, there are varying degrees of automobile purchase and tonnage tax reduction on qualifying new vehicles, depending on their level of fuel efficiency and emission. At this point, the most remarkable part is "next-generation cars" such as electric and hybrids have fully exemption of several taxes. Used cars are also eligible for tax and/or price reduction, provided they meet the standards. Nonetheless, it should be noted that unlike other developed nations such as the United States, Japan has not yet implemented funding programs or direct subsidies to the OEMs to promote the growth of eco-friendly cars [2].

Finally, there is another problem is that electric cars are a part of the countermeasures for the emission control regulations. Japan followed the US clean air act for both economic and the environmental motivations, because US is a key market for the Japanese automobile industry.[7]

## II. PROBLEM STATEMENT

Government and international directives has a great impact on automotive industry to make a decision for future strategies related to mini cars (Fig. 3). In this situation, there are three main policy decision-makers which have interact with one another which are government, international directives and industry. The specific goal of each decision maker is different but however, they are dependent on each other to balance the satisfaction for the application of environmental centered sustainability expectations. Each of the strategic decisions is affected by how their behavior interacts with that of others [14]. So, all of the interaction has an impact on current and future conditions of their situations. Sometimes international directive

can be dominant or government can be dominant. Especially in developed countries like Japan, generally industry has a power and one of the major social and economic drivers but recently, it is so relevant to the environmental problems, too. Hence, here is the solution methodology which is appropriate for this problem: Evolutionary Game Theory (Fig ). Game theory is concerned with situations in which decision-makers interact with one another, and in which the happiness of each participant with the outcome depends not just on his or her own decisions but on the decisions made by everyone. The key insight of evolutionary game theory is that many behaviors involve the *interaction* of multiple organisms in a population, and the success of any one of these organisms depends on how its behavior interacts with that of others. So the fitness of an individual organism can't be measured in isolation; rather it has to be evaluated in the context of the full population in which it lives [8].

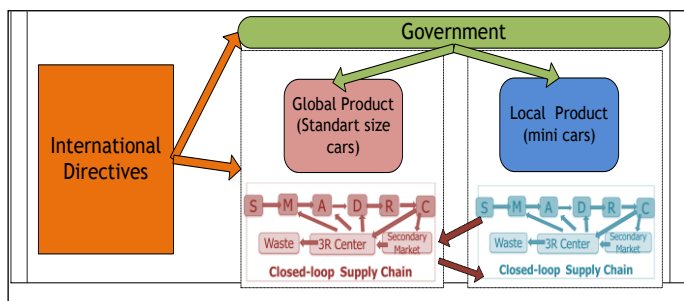


Fig. 3: Policy Making and Automobile Industry

### III. METHODOLOGY

#### A. Evolutionary Game Theory

In general, game theory was primarily focused on cooperative game theory, which analyzes optimal strategies assuming that individuals stick to previous agreements. In the 1950's, the focus shifted to non-cooperative games in which individuals act selfish to get the most out of an interaction. At that time, game theory had matured from a theoretical concept to a scientific field influencing political decision making, mainly in the context of the arms race of the cold war [9]. Evolutionary games are the bandwidth choice game can be given a different interpretation where it applies to a large *population* of identical players. Equilibrium can then be viewed as the outcome of a *dynamic process* rather than of conscious rational analysis.<sup>1</sup> Evolutionary game theory can be adapted to the policy decision making model to set up future strategies because this method may support the distribution of each player's selection over time with a payoff matrix. The players are the international directives, government and the industry. In this research, we considered the future situation and the current situation of these three players for their dominance cases. To be a dominant

<sup>1</sup> Please check 'Stochastic evolutionary game dynamics' by Arne Traulsen and Christoph Hauert in "Reviews of Nonlinear Dynamics and Complexity" Vol. II, Wiley-VCH, 2009, edited by H.-G. Schuster for the equations and mathematical expressions to calculate the evaluations expressed by pay off matrixes in evolutionary game theory.

player in a strategic game means that a strategy dominates another strategy of all player if it always gives a better payoff to that player, even not considering what the other players do (Fig. 5).

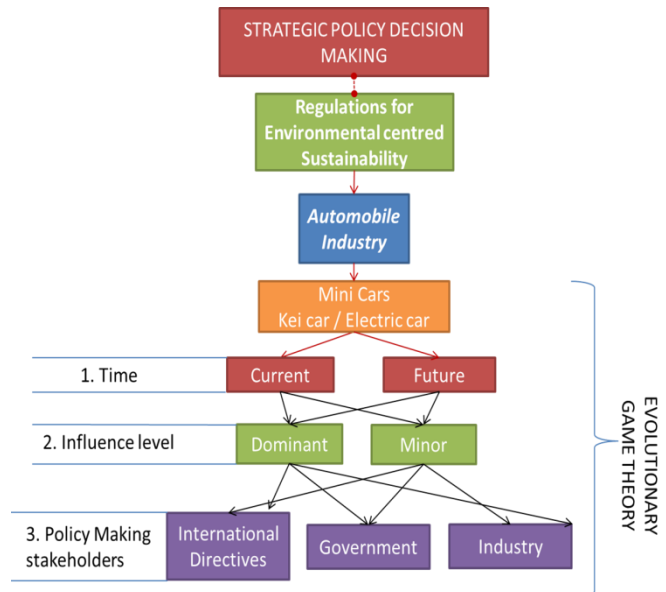


Fig. 5: Defining Future Strategies with Strategic Policy Making

In dominance cases, one strategy is always a better choice, despite the action of the opponent. Either international directives dominates government ( $d1 > g1$  and  $d2 > g2$ ) or government dominates international directives ( $d1 < g1$  and  $d2 < g2$ ), and either government dominates industry ( $g1 > i1$  and  $g2 > i2$ ) or industry dominates government ( $g1 < i1$  and  $g2 < i2$ ) and as a third case, either international directives dominates industry ( $d1 > i1$  and  $d2 > i2$ ) or industry dominates international directives ( $d1 < i1$  and  $d2 < i2$ ) (Fig. 4). However, the final case (industry dominates international directives) has almost any possibility to realize this strategy in real world.

	Directives	Government	Industry
Directives	$d1$	$d2$	$d3$
Government	$g1$	$g2$	$g3$
Industry	$i1$	$i2$	$i3$

Fig 4: Three strategies 3 x 3 pay off matrix

#### IV. ILLUSTRATIVE EXAMPLE

In order to express the interaction mechanism in policy making process by evolutionary game theory, dominance strategies of the player 'directives' on government's future and current situation for developing regulations related to the mini car and industry's future and current situation for seizing the regulations related to the mini car strategy is presented (Fig 5). There are three different cases based on the consideration of the player in the intersection of four triangle is always dominant. In Fig. 6 each triangle is the interactions and the influences of these elements' on each player's acts. In this example, an assumption is the international directives are the dominant element in all games. For instance, in combination 1,

international directives are always considering the best strategy and become dominant to define the expressions and affect the decisions of government and industry in a sharp way. To be clearer, for example, international directives may have some drastic changes in their expectations from governments related to the environmental centered sustainability enforcement. Governments should define a path to meet the demands of these directives to stay competitive. Accordingly, government can see the path to follow according to the strength of the strategic dominance of international directives showed as pay off s in the game by evolutionary game theory. Finally, industry may have a chance to follow status of dominance for both of the other strategic policy decisions and create a countermeasure plan as a scenario path in time to seize the government's and international directives' aim sequentially.

In Table 1, there are eight combinations for three policy decision makers' game strategies considering the current time and the future. The aim of these combinations is to show all strategic games which have an influence on the time schedule of the players.

As an example; the current strategy of international directives may have a dominant impact on the future decisions of government and the result of the method 'evolutionary game theory' may show us the way of path of strategies. Based on a common utility function which is usually the payoff from the game that individuals maximize, the actions of others can be predicted and the optimal strategy can be chosen.

TABLE 1  
POSSIBLE CASES EXPRESSING THE INTERACTION OF CURRENT AND THE FUTURE SITUATION OF THREE MAIN POLICY DECISION MAKING PLAYERS

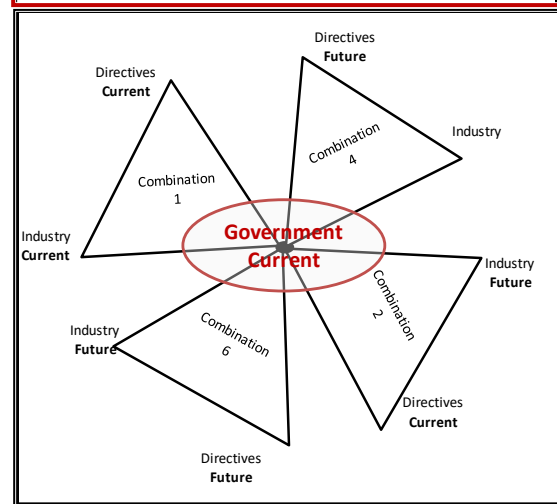
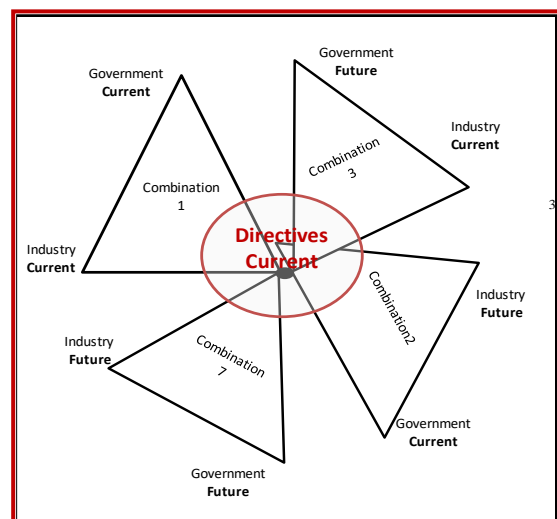
	CASES		
	Directive	Government	Industry
1	Current	Current	Current
2	Current	Current	Future
3	Current	Future	Current
4	Future	Current	Current
5	Future	Future	Current
6	Future	Current	Future
7	Current	Future	Future
8	Future	Future	Future

In evaluation step of evolutionary game theory, the payoff matrix should be created. Table 2 is the explanation of the status of being dominant in the game for all players. If the international directives are the main dominance player to define the strategy, then the evaluation value should be greater than the other two players. According to the Likert scale, we can use the evaluation values as 9,7,5,3 and 1. 9 is the highest point that shows the most dominant strategy is being held [14]. 1 is the lowest point which explains the less dominant strategy is being made by the player. For example, if the government has 9 degree dominance in a new policy definition game, the path of the future strategy is almost defined by government dominant regulations and there is less chance to create a different path for industry to follow the regulations.

TABLE 2:  
THE MAGNITUDE ORDER OF EVALUATIONS TO DEFINE MOST DOMINANT PLAYER IN PAY OFF MATRIX

DOMINANT STAKEHOLDER		
Directives	$d1 > g1 \geq i1$	$d1 > i1 \geq g1$
	$d2 > g2 \geq i2$	$d2 > i2 \geq g2$
	$d3 > g3 \geq i3$	$d3 > i3 \geq g3$
Government	$g1 > d1 \geq i1$	$g1 > i1 \geq d1$
	$g2 > d2 \geq i2$	$g2 > i2 \geq d2$
	$g3 > d3 \geq i3$	$g3 > i3 \geq d3$
Industry	$i1 > g1 \geq d1$	$i1 > d1 \geq g1$
	$i2 > g2 \geq d2$	$i2 > d2 \geq g2$
	$i3 > g3 \geq d3$	$i3 > d3 \geq g3$

The visualization of the all combinations in Fig. 5 indicates the dominance status of each policy decision makers and the relation of the future condition and current condition of all players at the same time in strategic state. Strategic state is the explanation of the results of this evolutionary game in evolutionary game theory.





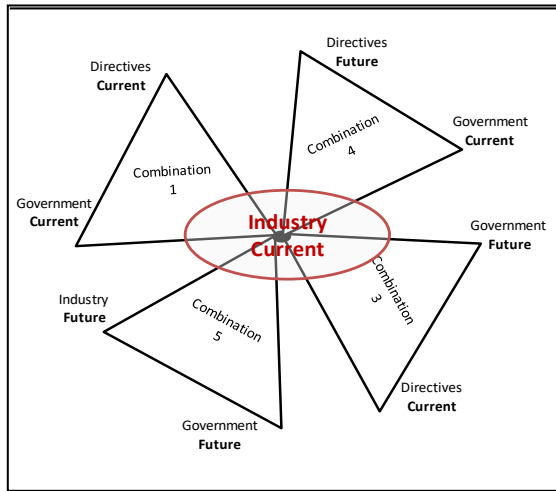


Fig. 6: Possible cases with the dominant players' current and future situation and interactions of each other

Considering the mini car strategies, current actions of each player have a decision but, they still interact another and this create a interaction that create a new dilemma such as the future strategies conflict of the each player.

In mini car strategies, industry is almost dependent on the consumer preferences and the government decision. If we consider that the consumer expectations are the key influencing issue for industry, they should keep an eye on their consumer relations strategies. However, only consumer preferences are not the only one issue to cope with. Government and accordingly international directives ask for some changes that makes them dominant in current situation and future situation related to the decision making process.

These paths are described according to the payoff matrixes. Strategic state is given to specify the payoff value concretely. Dominance status of international directives and the current / future considerations of all players are main evaluation criteria. The path to strategic state is described with Dynamo notebooks [10], created in Mathematica, -the mathematical software [11]. The arrows in Fig. 6 mean that the movement amount per unit time. Colors mean the movement speed of the catching the strategy of the opposite player. The speed becomes faster when the color of the area gets red. The speed gets slower through the blue area. Black dots are showing the dominance status which is the stable fixed points and white dots are the unstable fixed points which is bistable or no dominance of the player. Arrows generally express the decision making path whether short term or long term with direction of the strategy selection.

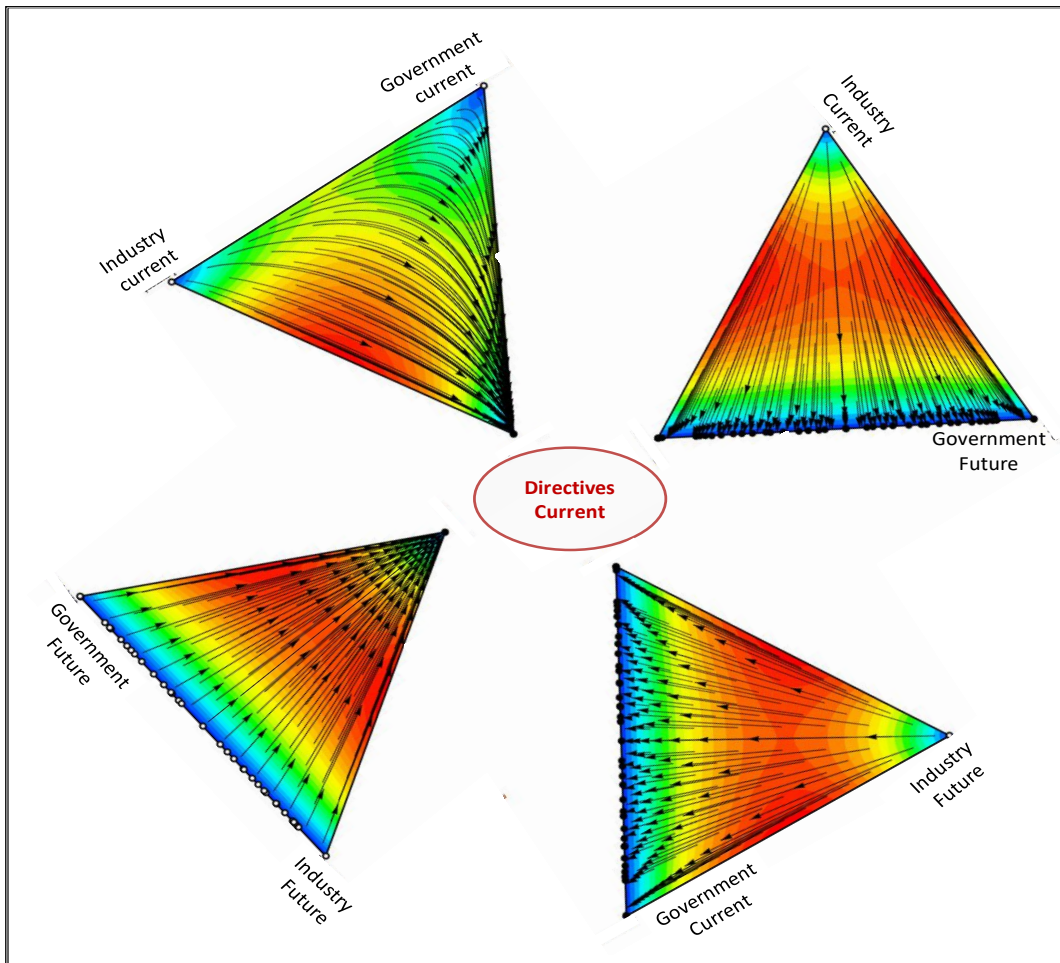


Fig. 6: Illustrative example for the dominance situation for international directives for four combinations

In combination 1, the evaluation in pay off matrix is expressed in Fig 7. Based on the Likert scale, 9 indicates the dominance of directives' strategy in current situation in pay off matrix.

$d1 > g1 > i1$ $d2 > g2 > i2$ $d3 > g3 > i3$			
	Directives	Government	Industry
Directives	9	9	9
Government	7	7	7
Industry	5	5	5

Fig. 7: An example of the payoff matrix and magnitude order of evaluations for Combination 1 in Illustrative Example

In this example, government's strategy in current time is less dominant than directives' strategies in current situation. Minor influent here is the industry's strategies for current situation. The black dot is on the exact coordinate of the international directives at current status. That shows that it is at the dominance status which is the stable fixed point. Hence, red area near industries presents that it should be faster than government to catch up the international directives' strategic actions. Government is safer to be able to apply the strategies parallel to international directives.

In combination 3, the evaluation in pay off matrix is shown in Fig 8.

$d1 = g1 > i1$ $d2 = g2 > i2$ $d3 = g3 > i3$			
	Directives	Government	Industry
Directives	9	9	9
Government	9	9	9
Industry	5	5	5

Fig. 8: An example of the payoff matrix and magnitude order of evaluations for Combination 3 in Illustrative Example

In this example, government's future plans are equally dominant with directives' current plans. Minor influent here is the industry's plans for current situation. The black dots are on the line between the international directives at current status and government future status. That shows that they are both at the dominance status and the stable fixed points are closer to them. Hence, red area near the center of triangle presents that industry can start to its strategies slower at the beginning but according to the time, mid-term decision making made them take fast actions to catch up the both international directives' strategic actions and government's actions. Government is safer to be able to apply the strategies parallel to international directives in this combination for near future and long term decision. Industry current is at the longest strategic path under these circumstances.

In combination 2, the evaluation in pay off matrix is shown in Fig 9.

$d1 = g1 > i1$ $d2 = g2 > i2$ $d3 = g3 > i3$			
	Directives	Government	Industry
Directives	9	9	9
Government	9	9	9
Industry	7	7	7

Fig. 9: An example of the payoff matrix and magnitude order of evaluations for Combination 2 in Illustrative Example

In this example, government's current strategies and the directives' current strategies is equally dominate on industry's future situation. Minor influent here is the industry for future situation. The dots and the speed explanations are similar to combination 3 but only difference is the arrows. As said before, the arrows express the direction of the strategy selection. Here, direction is from industry future to the line between international directives current and government current. The similar strategies of government and international directives at current status made the industry at future status need more time to take the correct step; meaning it will need a long term decision making process to catch up with the main powerful policy making stakeholders.

In combination 7, the evaluation in pay off matrix is expressed in Fig 10.

$d1 > g1 = i1$ $d2 > g2 = i2$ $d3 > g3 = i3$			
	Directives	Government	Industry
Directives	9	9	9
Government	7	7	7
Industry	7	7	7

Fig. 10: An example of the payoff matrix and magnitude order of evaluations for Combination 7 in Illustrative Example

In this example, government's future strategies and industry's future strategies are both less dominant than the directives' current situation. The black dot is on the exact coordinate of the international directives at current status. That shows that it is at the dominance status which is the stable fixed point. Hence, red area in the middle of the triangle presents that both government and industry at future status should start acts a little slower but in mid-term of the process, they need speed to act. All parallel arrows indicate that any strategy requires the similar direction of strategy decisions.

## V. CONCLUSION

In this research, the authors aimed to express strategic interaction between government, international directives and industry that depends on all agents' choices. These interactions create many conditions and each of them makes a significant

impact on auto industry's future strategies related to the mini car regulations. As a solution methodology, evolutionary game theory is applied.

Results of the illustrative example and the literature reviews showed that these three stakeholders all have their aims but at the same time, they have mutual interaction which is not easy to explain with rationalization or pure math only. Game theory fits the explain multi aim problems in the political strategic making both the optimum outputs for any players.

Illustrative example is only a little part to see the complexity and the difficulty to clearly explain of these interactions in big picture, however, that examples indicated that the international directives, government and industry are not the separate parts of policy making but they have together have a significant impact to create future strategies.

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