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Environment and Development of Oil and Gas Fields in Iran: Using Game Theory to Pathology and Gradation of the National Iranian Oil Company's Performance in Environmental Protection

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Abstract: On the path of development of Iran, Oil industry is like a two-edge razor. It has earned revenue for the country, but on the other hand, it leads undeniable damage to the environment. Undoubtedly, the pollution of the environment imposes additional cost to the country and the inclusion of these costs in the development of oil and gas fields is inevitable. The issue of preserving the environment is addressed in the Iranian constitution explicitly and the government is responsible for implementing this law, while this law has been neglected in the oil industry. This study tries to answer this question why the performance of the National Iran Oil Company as a representative of the government on the subject of environmental issue was not suitable? Game theory as an analytical tool has been used to answer this question and the methods to improve the performance of the NIOC in the environmental issue. The method including the ways of formulating an oil contract and educational and investment policies.

Keywords: Game Theory, Environment, Imperfect Information Game, Oil/Gas Field Development, Nash Equilibrium.

I. Introduction

On the path of development of Iran, Oil industry is like a two-edge razor. It has earned revenue for the country, but on the other hand, it leads undeniable damage to the environment. From Hur-Alazim in Khuzestan to the pollution of the Persian Gulf in the south and the leakage of gases in Turkaman desert, all show that the environment has neglected from the exploration and development of oil and gas fields in Iran. Quick glance at the public complaints regarding damages caused by the exploration and development of oil and gas fields to the underground water, livestock and agricultural land, is all about malfunctioning by the National oil corporation in protecting the environment. Undoubtedly, the pollution of the environment imposes additional cost to the country and the inclusion of these costs in the development of oil and gas fields is inevitable. The issue of preserving the environment as a national capital is addressed in the Iranian constitution explicitly and the government responsibility for implementing this law has been clarified. However, the National Oil Company as the representative of the government has not been acting properly on the environmental issues, why? Perhaps it would be better to put the above question in a different way: Why has the performance of the National Iranian Oil Company's observers in environmental issues not been proper?

Obviously, analyzing the issues in which human actions are effective is very complicated, therefore, scientists have tried to find a reliable way to predict human behavior. Game theory as a successful attempt which has undeniable effects on the subjects such as economics, politics, sociology and psychology is devised (Osborne and Rubinstein 1994).

The use of game theory in environmental problems has increased over time. Game theory offers a powerful tool to understand strategic interactions between diverse agents in the economy that face environmental problems, i.e., pollution, climate change, and biodiversity loss, among others.

In the scholarly literature, Anthony Currant in 1838 solved a monopoly problem with nearly game theory approach. Subsequently, Emile Bornel in 1921 was officially introduced game theory (Neumann 1928). Eventually, by publishing the “Game theory and economic behavior” by Von Neumann and Oscar Morgenstern in 1944 the concept of the game theory as a new topic in science is opened up (Von Neumann and Morgenstern 1945). John Nash introduced the concept of Nash Equilibrium in 1950 which was considered as a focal point in the game analysis (Nash 1950). After 1970, game theory not only revolutionized economics but also sociologists,

psychologists and biologists also used this theory (Alt, Calvert et al. 1988). After all, John Nash, John Harsney, and Reinhard Stelten were own a Nobel prize in economics in 1994 for game theory. After that, the application of game theory in the tenders and auctions led to billions of dollars in communication industry to be saved (Binmore 2007). The economic success of game theory has led engineer to take advantages of this approach in optimizing the design of engineering equipment (Annamdas and Rao 2009). For instance, Kemper Lewis and Farrokh Mistree have used game theory to regulate the relationships of forces in an aircraft company in order to optimize an aircraft design (Lewis and Mistree 1998, Xiao, Shao et al. 2015). In the simulation of human relationships, many games have been defined. The most important of these games are perfect information games, imperfect information games, cooperative games and non-cooperative games (Osborne and Rubinstein 1994). The contract has been signed between employers and contractors in the development of oil and gas fields correspond to the games with imperfect information (Wiggins and Libecap 1985). Since cooperation to reduce environmental damage always costs the contractor, thus the issue of cooperation between the parties on environmental issues can be ruled out.

In this paper, we have tried to use game theory to devise a model that simulates the interaction of supervisor of employer and the contractors. In addition, it provides the possibility of pathology monitoring of environmental issues and provides a solution to improve the performance of the National Iranian Oil Company.

II. Overview of Game Theory Literature

In game theory, the basic concept is that there are two or more decision makers known as players, each of which has a choice of ways of acting (Colman, 1995). In mathematical applications of game theory, it also has to be possible to quantify the preferences for decision outcome of each player in order to analyse the different possible outcomes.

Different decision-making contexts are represented by different games which are played by players who are making rational decisions typically based on self-interest. The types of games are determined by the types (and number) of players and the types of decisions that have to be made. Moreover, the games are classified based on the decision timing which could be simultaneous or sequential (Poundstone, 1992).

Game theory provides a useful theoretical framework to examine the decision process operating in the context of environmental assessment, and to examine the rationality and legitimacy of decision-making subject to Environmental Assessment (EA).

The regulations for Environment was approved based on a technical-rational model which argues that better information will lead to better decisions. This follows the logic that decision-makers taking the decision, based on the evidence available. Applying game theory to environmental assessment decision contexts is a novel means of investigating and evaluating practice from the viewpoint of rationality and legitimacy.

III. Modelling the Game of Environmental Issues

A lot of environmental problems also involve interactive decision making and hence game theory can be easily applied to model, analyse and solve, at least theoretically, these problems. For example, a pollutant emitted by a firm (or a country) pollutes the global atmosphere; hence, the decisions of several firms (countries) about their emission levels can easily be modelled as a game.

In most situations, decision makers (players) make decisions (play the game) only for themselves without any form of cooperation among themselves. Such games are called non-cooperative games. Some of these games are played simultaneously in which the players make decisions simultaneously. Some games however are played over time. The most popular concept is Nash equilibrium. A Nash equilibrium is a strategy profile consisting of one strategy for each player, such that no player has any incentive to deviate unilaterally from the profile; it is therefore a profile in which everyone is doing their best given others.

Let briefly review an environmental issue was modeled using game theory. Consider two (or a few) neighboring countries who are emitting a pollutant. The pollutant obviously affects the global atmosphere. Suppose now the countries are thinking of reducing the level of emission. A reduction in the emission level would reduce the global pollution and hence both countries would benefit. However, such an abatement also involves a cost. Thus reducing emission reduces the environmental damage cost but increases the abatement cost. So the countries have to consider the total cost of their emissions. This is a classic environmental problem which can easily be treated as a game between these countries and therefore game theoretic solution concepts can be applied to analyse this problem (Endres and Finus, 1998).

The environment of Iran is constantly changing in recent years and this issue cannot be ignored. Of the critical environmental crisis should refer to global warming, overcrowding, decreasing natural resources, garbage disposal, ozon layer destruction, deforestation, rainfalls, water pollution, public health issues, and genetic engineering. Men around the Iran are experiencing new and challenging environmental problems daily. Some of these problems are likely to affect the health of the ecosystem, but somehow they change the recent landscapes.

Environmental problems in Iran also make human beings vulnerable to natural disasters occur currently and in the future, as well. So due to the growing problems of the environment in Iran, this is an emergency situation. Therefore, the current environmental situation greatly needs urgent considerations and many factors to be addressed.

Oil and gas exploration and production operations have the potential for a variety of impacts on the environment. These 'impacts' depend upon the stage of the process, the size and complexity of the project, the nature and sensitivity of the surrounding environment and the effectiveness of planning, pollution prevention, mitigation and control techniques.

The game of environmental issues in the development contracts for oil and gas fields can be considered in accordance with Figure 1:

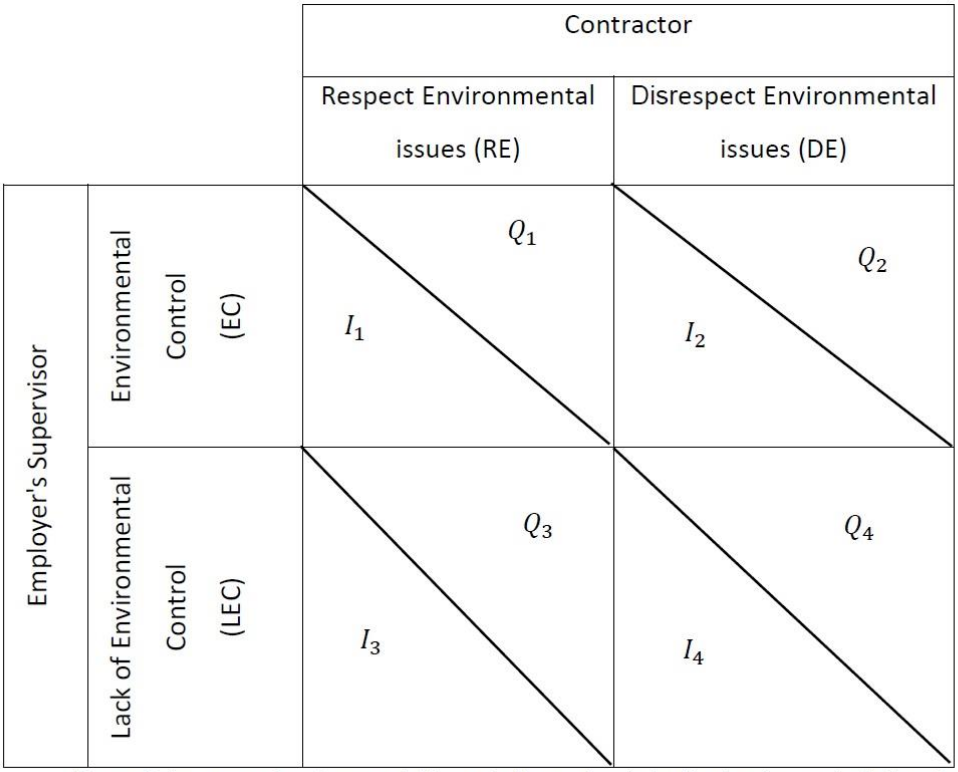

Figure 1 The game of environmental issues in the contracts for the development of oil and gas fields

I_1: Profit of the employer's supervisor, when he controls environmental issues and the contractor also has respected the environmental issues (Cell1)
Q_1: Profit of the contractor, when he respects the environmental issues and the employer's supervisor also has controlled the environmental issues (Cell1)
I_2: Profit of the employer's supervisor, when he controls environmental issues while the contractor has disrespected the environmental issues (Cell2)
Q_2: Profit of the contractor, when he disrespects the environmental issues and the employer's supervisor has controlled the environmental issues (Cell2)
I_3: Profit of the employer's supervisor, when he doesn't control the environmental issues, while the contractor has respected the environmental issues (Cell3)
Q_2: Profit of the contractor, when he respects the environmental issues and the employer's supervisor has not controlled the environmental issues (Cell3)
I_4: Profit of the employer's supervisor, when he doesn't control the environmental issues while the contractor also has disrespected the environmental issues (Cell4)
Q_4: Profit of the contractor, when he disrespects the environmental issues and the employer's supervisor also has not controlled the environmental issues (Cell4)
In the game shown in Figure 1, the contractor's profit in each scenario can be considered as follows:

$$Q_1 = p - l - \alpha' * f \quad (1)$$
$$Q_2 = p - \beta * f \quad (2)$$
$$Q_3 = p - l \quad (3)$$
$$Q_4 = p \quad (4)$$

Where p is the most probable profit of the contractor in the absence of any environment costs, l is the technical costs required to respect environmental issues, f is the maximum penalty set for the contractor when he does not respect the environmental issues α' is the probability that the contractor would be fined due to environmental control by the employer's supervisor in the event that the contractor respects the environmental issues, $\boldsymbol{\beta}$ is the probability that the contractor would be fined due to environmental control by the employer's supervisor in the event that the contractor disrespects the environmental issues.

With the assumption of imperfect information in the game, the expected profit of the contractor for choosing respect the environmental issue (Q'_1) and choosing disrespect the environmental issue (Q'_2) will be as follows:

$$Q'_1 = a \times (p - l - \alpha' \times f) + (1 - a) \times (p - l) = p - l - a \times \alpha' \times f \quad (5)$$
$$Q'_2 = a \times (p - \beta \times f) + (1 - a) \times p = p - a \times \beta \times f \quad (6)$$

On the above equations, a is the possibility of controlling environmental issue by the employer's supervisor from the contractor's point of view.

Regards to the profit of the employer's supervisor in each scenario of the game in Figure 1, the following equations can be written.

$$I_1 = m - \gamma_1 \times x \quad (7)$$
$$I_2 = m - \gamma_2 \times x \quad (8)$$
$$I_3 = m - \gamma_3 \times x \quad (9)$$
$$I_4 = m - \gamma_4 \times x \quad (10)$$

On the above equations, m is the supervisor's salary, x is the maximum penalty applied for supervisor in case of damage to the environment, γ_i the probability of penalizing the supervisor in each scenario.

Again, it is assumed that the it is a game with imperfect information, thus, the expected profit of the employer's supervisor in the choice of environmental control (I'_1) and the choice of lack of environmental control (I'_2) could be written as:

$$I'_1 = b \times (m - \gamma_1 \times x) + (1 - b) \times (m - \gamma_2 \times x) = m - (1 - b) \times \gamma_2 \times x - b \times \gamma_1 \times x \quad (11)$$
$$I'_2 = b \times (m - \gamma_3 \times x) + (1 - b) \times (m - \gamma_4 \times x) = m - (1 - b) \times \gamma_4 \times x - b \times \gamma_3 \times x \quad (12)$$

On equations 11 and 12, b is the employer's supervisor's view about the probability of respecting environmental issues by the contractor.

IV. Analysis the Results

Regarding the devised model, whenever the government calls for environmental protection, the following relationship has to be established:

$$Q'_1 > Q'_2 \quad (13)$$

With replacing equation 5 and 6 into equation13:

$$a \times f \times (\beta - a') > l \quad (14)$$

Equation 14 shows that preserving the environment has a direct relationship with parameters f, a, β and indirect relationship with parameters a', l, in which accordance with the definition of the parameters:

1. If the considered penalty (f) in the contract is not large enough, then the contractor would not respect the environmental issues.
2. If the contractor feels that in the case of disrespecting the environmental issues and supervisor's report, the probability of being penalized (β) is less than a certain amount, then the contractor would not respect the environmental issues.

3. If the technical costs of respecting the environmental issues (l) would be greater than a certain amount, then the contractor would not respect the environmental issues.
4. If the contractor feels that despite respect the environmental issues, the probability that he will be penalized (a') because of supervising the employer's supervisor is greater than a certain amount, this leads to disrespect the environmental issues by the contractor.
5. If from the contractor point of view, the probability of true supervision by the employer's supervision (a) is less than a certain amount, then the contractor disrespects the environmental issues.

In the contracts related to the development of Iranian oil and gas fields, the rate of penalty due to the damage to the environment (f) is usually considered very low (maximum 10% of the contract amount). The inability of the regulatory organization such as environmental organization to supervise the activities of National Oil Company has led to increase the level of corruption in the relations between the employer's supervisor and the contractor which significantly reduce the probability of the contractors are being penalized (β) by a report of employer's supervisors. On the other hand, this corruption leads to that from the contractor point of view the probability of being penalized (a') is too high even after respecting the environmental issues. International sanctions and lack of domestic investment on the waste management have led that the technical costs of respecting environmental issues (l) have got higher in comparison with the other countries. Migration of technician due to lack of bright vision form future and job corrupt has led the NOC have lost all the experienced and committed observers and using the non-specialized forces in advisory posts also has led the corruption expands in the relationship between contractors and employer's supervisor. From the contractor's view, all of these factors have made the supervisory capability of the employer's supervisor (a) in the low level. Therefore, it is obviously clear that the performance of National Oil Company in the environmental issue is not proper. How does these situation change?

1. The rate of penalties caused by the environmental damages (f) in the contracts of developing oil and gas fields needs to be reviewed and increased to the reasonable level. In this path, the approach used in the developed countries could be a good method.
2. The role of the supervisory organization such as environment organization in the development of oil and gas fields should be bolder by the legislation. In addition, by

clarifying the responsibilities of supervisors and educating the supervisors the possibility of penalizing contractors (β) is increased.

3. Reduce the corruption by legislating (as mentioned above) and increase the right of the contractor to defend its legal right by reviewing the contract in order to decrease the probable penalty of the contractor (a') because of supervisor's corruption.
4. Provide a situation where the technical costs of respecting environmental issues are decreased with the investment and legislation.
5. In order to increase the creditability of supervisors (a), prove a situation where the job promotion in NOC is based on the meritocracy and prevent the loss of expert forces as far as possible. Moreover, in order to increase the enthusiasm of the supervisors, the supervisors should be penalized for violation and their punishment needs to be broadcasted in the media.

As stated, whenever the contractors feel that the supervisors are keen in controlling the environmental issues, they respect the environmental issues properly. However, how policymakers can create a situation in which the supervisors are intend to control environmental issues. This means, designing a game in which its Nash Equilibrium is controlling the environmental issues as a choice of supervisors and respect the environmental issues is a choice of contractors. If the supervisors always intend on choosing the control environmental issue then:

$$I'_1 > I'_2 \qquad (15)$$

By replacing equations 11 and 12 into equation 15:

$$\frac{b}{1-b} \times (\gamma_3 - \gamma_1) > (\gamma_2 - \gamma_4) \qquad (16)$$

The above equation shows that the supervisors would not intend to control environmental issues as no penalties are imposed on the contract due to the environmental damage ($(\gamma_3 - \gamma_1) = (\gamma_2 - \gamma_4) = 0$) or due to the corruption in the relationship between contractors and supervisors, the report of supervisor from the contractor's violations will not be tracked. It should be noted that the fundamental education in relation to the value of the environment is very important from the childhood. Besides, when the supervisors feel that the contractor cares about the respecting the environmental issues then they will more intense to control the performance of the contractors and this means the parameter a has been increased. Also, the policymakers need to consider the penalty for the environmental damage on the contract. NIOC considers the penalty

issue in the contract of the official forces, while most of them do not know this issue. As it was said, the level of corruption in the relationship between the supervisors and the contractor in the National Iranian Oil Company is high, which can lead to a misconception for the supervisors which put them in the trouble if they report a contractor violation.

V. Conclusion

The interaction between supervisors and contractor in the field of respecting environmental issues is simulated by the game theory as a non-cooperative and imperfect information game. To ensure the Nash Equilibrium of the game is to control the environmental issues by the supervisors and to respect the environmental issues by the contractor, the following are inevitable:

1. If the amount of considered penalty in the contract is not large enough, the contractors would not respect the environmental issues.
2. If the probability of penalizing the contractor due to damage to the environment and reporting this violation by the supervisors is less than a certain amount, then the contractor will not respect the environmental issues.
3. If the technical costs of respecting environmental issues are higher than a certain amount, then the contractor will not respect the environmental issues.
4. Whenever, the probable of penalizing is greater than a certain amount even in the case of respecting environmental issues by the contractor, the contractor will not respect the environmental issues.
5. From the contractor point of view, whenever the probability of true supervision by the supervisors is less than a certain amount, the contractor will not respect the environmental issues.
6. Not considering a penalty due to the environmental damage in the contract between supervisor and contractor leads the contractor to disrespect the environmental issues.
7. Fundamental education related to the environmental issue from the childhood is equal to the setting a penalty for the working forces.
8. The existence of corruption in the relationship between the contractor and the supervisor leads to the disrespecting of the environmental issues.
9. The severity of the contractor to respect the environmental issue forces the supervisor to control the performance of the contractor with more care.

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