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| **GE 2256**  **Application Of Game Theory To Business**    **Group Project: Case Study On OPEC Strategies** |

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**Case study on OPEC strategies**

**1. Introduction**

Since the formation of the OPEC (Organization of Petroleum Exporting Countries) in 1960, the organization has seen its rise and fall in terms of economical-political influences, profitability from oil extraction and export, as well as the domestic well-being of the member countries themselves throughout the decades. From the perspective of strategic interaction, the action of forming an alliance has favored the OPEC countries by large: it has successfully manipulated the price level of crude oil and increased the bargaining power of OPEC countries in the international level, such as causing disruption among western countries in the 1973 oil embargo. However, there have been countless incidents where conflicts within OPEC causes misalignment of oil production level among countries, and the rapid development of crude oil substitutes such as shale gas, natural gas, coal, renewable energy has caused considerable impact on OPEC interests. This case study aims to explain the phenomenon of conflicts within OPEC and against other non-OPEC oil exporting countries using game theory, and to offer possible solutions to forging a stronger, more long-lasting relationship among the member countries by balancing their interests as much as possible.

1.1 **Theory Introduction**

With the dilemma that all OPEC members are facing: gain more profit by cheating or gain less by cooperating, prisoner’s dilemma can be applied. Prisoner dilemma is model stating that cooperation can bring the highest profit yet players will choose to fink to protect their self-interest. Here is an example illustrating a scenario where two prisoners are being locked into different places and being asked by the police.They can choose to fink or stay quiet. They are facing the following dilemma :

1. If both of them fink, both of them have to go to jail for 5 years.
2. If only one of them fink, he will be free and the other one goes to jail for 10 years.
3. If both of them stay quiet, they will both go to jail with shorter time, 2 years.

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|  | **Quiet** | **Fink** |
| **Quiet** | (2, 2) | (10, 0) |
| **Fink** | (0, 10) | (-5, -5) |

From the theory we can see staying quiet is the best choice for both of them. However, given that no communication is allowed, prisoners will choose to fink as to protect themselves from being jailed. In this case, the final outcome will be (Fink, Fink) which is the worst result of all.

Although the above theory is in an assumption that no communication between players, the model can still portrait the OPEC case since countries are looking for their own self-interest. They will stay quiet in order to gain more profit by producing more oil than other countries.

**2. The innate conflict of interest among OPEC members**

OPEC is an international organization focus on monitoring and controlling the oil supply of its members. In this section, we are going to apply the framework of prisoner’s dilemma to analyze the actions of the member countries.

We classify two players, which are a member country of OPEC (player 1), and other member countries of OPEC (player 2), in the game of prisoner’s dilemma. Although there are other non-OPEC countries involved in oil production activities, they are not included in this game of prisoner’s dilemma. The reason is since they are non-OPEC countries, their actions will not be considered as cheating despite of their oil production level.

The rationale of OPEC is based on law of supply, by increasing (reducing) oil supply, they can decrease(increase) the oil market price. As a result, OPEC can increase their overall revenue and profit (payoff) by reducing the oil supply.

For individual member country of OPEC, its payoff depends on three elements: selling price per unit of oil, sales volume of oil, and production cost per unit of oil. Its benefit can be enhanced by selling more oil as its sales revenue is increased.

From above discussion, a conflict of interest if observed between OPEC and its individual member country. We are curious on whether member countries of OPEC have incentive to cheat on the production level of oil.

Two assumptions are made when the framework of prisoner’s dilemma is applied:

1. The production cost per unit of oil always below the selling price per unit of oil, therefore, the seller of oil always make profit from the selling of oil.

2. No matter the volume of oil is selling, there are always a buyer(s) of oil existed in the market.

Player 1 is the row player while player 2 is the column player.

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|  | **Do not cheat** | **Cheat** |
| **Do not cheat** | (1000, 14000) | (800, 15000) |
| **Cheat** | (1500, 12500) | (900, 13500) |

4 situations are observed from the above framework.

**Analysis:**

If both player 1 and player 2 do not cheat, their payoff will be 1000 and 14000 respectively.

By cheating, player 1’s payoff will be increased to 1500 when player 2 does not cheat. Therefore, if player 2 does not cheat, the best response for player 1 is cheating as its payoff can be increased as a result.

If player 2 cheats while player 1 does not cheat, player 2’s payoff can be increased to 15000. Therefore, if player 1 does not cheat, the best response for player 2 is cheating as its payoff can be increased as a result.

If player 1 or player 2 cheats, the best response of the other player is cheating as it can reduce the loss by involving in the cheating activities.

Given that no matter the other player cheat or not, cheat is always the best response for a player. Under this scenario, (cheat, cheat) will be the Nash equilibrium for both players.

**Conclusion:**

From the analysis based on framework of prisoner’s dilemma, it is found that the best response for OPEC member countries is cheating on production level of oil in order to maximize their payoff. From the economic perspective, no matter OPEC existed or not, OPEC is hard to influence the oil market by controlling and monitoring the oil production level of its members.

The possible reason of OPEC still exist and maintain great influence on the oil market is OPEC is a political and economic entity instead of just a pure economic organization.

Saudi Arabia, which often considered as the strongest country and leader of OPEC, used to reduce their oil production level in order to balance the effect caused by the cheating activities of other OPEC effect[1]. Assume Saudi Arabia is player 1, from the viewpoint of OPEC, the response of Saudi Arabia (does not cheat, cheat) minimize the loss from cheating and helps OPEC operated efficiently.

However, given that the increasing popularity of clean energy source and a relatively unstable international environment, the effectiveness of OPEC and its price controlling strategy is questionable.

**3. The Game between OPEC and Non-OPEC countries on Oil Supply**

**1.Introduction:**   
The oil market is a complicated system, where OPEC and non-OPEC play the various game strategies with complex rules and multiple interactions. The balance between oil supply and oil demand is likely to be broken resulted from the eager for the higher payoffs. Therefore, our study on the oil supply is significant because we could relatively keep the balance of the oil market and make OPEC and non-OPEC more cooperative if they adapt the following subgame-perfect Nash equilibrium (SPE) to stabilize the payoffs at a high level. In the model part, we aim to provide a solution on the oil supply to increase the profits both for OPEC and for non-OPEC.

**2.Model: Stackelberg Model**

Assumptions:

* It is a sequential quantity-setting model, where non-OPEC choose its production in the first period and OPEC choose the quantity to produce after observing the non-OPEC’s production.
* Each producer is rational and maximizing the expected payoffs.
* OPEC and non-OPEC have the common knowledge that the price of the oil is settled by the quantity they produce together.
* OPEC and non-OPEC have the homogeneous good and compete in the quantities.
* OPEC and non-OPEC have the constant marginal cost of producing each unit of oil .
* Suppose the following market demand curve: , where is the quantity produced by non-OPEC and is the quantity produced by OPEC.
* The profits of the non-OPEC:
* The profits of the OPEC:

The solutions for the Subgame-perfect Nash equilibrium (SPE):

* Apply the backward induction for non-OPEC:

OPEC can observe the production of non-OPEC and then choose the production to maximize the payoffs to make the optimal behaviour to satisfy the requirements of SPE

The first order condition (FOC):

The best response of OPEC after observing the production of the non-OPEC is:

Therefore, the strategy for OPEC is

* Non-OPEC realizes that OPEC is rational and will apply the strategy , then non-OPEC simplify its payoffs from to

Non-OPEC wants to maximize its payoffs. FOC:

The production of non-OPEC is

* Apply the production of non-OPEC into the strategy of OPEC: =
* SPE strategy: non-OPEC choose to produce the quantity of the oil is. OPEC choose to produce the quantity of the oil is
* SPE outcome path: non-OPEC choose to produce the quantity of the oil is . OPEC choose to produce the quantity of the oil is
* SPE payoffs: (, ).

3.**Discussion:**

According to the model that we study, the production of non-OPEC should be twice larger than the production of non-OPEC, which is similar to the table 1 below. However, the SPE might be rejected resulted from the reasons below. Firstly, the oil resource is not inexhaustible, so the oil-producing countries want to reduce the oil supply and increase the oil price to maximize the profits. The OPEC are likely to reduce the quantity of the oil they produce in order to reserve the oil resources for future use. In addition, the win-win strategy for the oil-producing countries is to maintain the low supply and raise the oil price, but they are motivated to increase the oil supply to make more profits when the oil price is high. Although the action of increasing the oil supply may result in the decrease in the oil price, some oil-producing countries merely think that the instant interest is the main priority, regardless of the cut-throat competition which might be resulted in. According to the table 2, we can observe that the oil supply is almost correspondent to the oil demand, which means that compromise and concession might exist during the production of the oil.

**4. Possible Solution to Better Cooperation within OPEC**

**4.1) Solving Saudi Arabia’s Dominance**

Saudi Arabia has always been the leading participating country of OPEC, in both terms of crude oil reserves and oil production level, since the establishment of the organization. The mid-east country once occupied almost 30% of the global proven oil reserves in 2005, double of its immediate follower Iran. Currently it accounts for 13.24% of the global oil production, around 35% within the OPEC.

In an OPEC decision making process where prisoner’s dilemma could be applied (diner’s dilemma in precision since it is an n-th players game), how can the influence of great bargaining power be illustrated?

Recalling the prisoner’s dilemma situation, where two players {*P1, P2*} are able to choose between action of {*Cooperate, Not Cooperate*}. Let *p* be the profits of *P1* when both players cooperate, *q* be the profits of *P1* when *P1* choose not to cooperate and *P2* cooperates, and *r* be the profits of *P1* when both players choose not to cooperate. Under the dilemma, *q* > *p* > *r*, and assuming that no strategic moves (commitment, promise, etc.) involved, *P1* will always choose not to cooperate in a finite game as a characteristic of the dilemma.

Now, assuming that the game is infinite. Players’ payoff discounts with the game repeating through by a discount factor δ 𝜖 (0,1), which is higher when the player has higher level of patience. The “Trigger Strategy” will also be used by players in infinite games, which is to always play “Cooperate” unless someone has ever not to cooperate. Do not cooperate forever if someone did so in the past.

Considering *P1*, if *P2*adopts the trigger strategy and he follows, he will get

if he does not follow and choose not to cooperate instead, the game will be (*Not cooperate, Cooperate*) once and (*Not Cooperate, Not Cooperate*) forever. Therefore, he will obtain

=

*P1* will be justified to keep cooperate if , i.e.

Now, let take *p* and *r* as constants and differentiate the formula above in terms of *q*:

Since the range of both and > 0, , which means that the value of required is strictly increasing when *q* increases.

This illustrates that for OPEC member, cooperation requires higher level of patiences if its profits from cheating is greater. For dominant member country like Saudi Arabia, the profits of deviating is enormous because of its capability to operate oil trading independently, notwithstanding lack of assistance by OPEC. It would require lots of patience for it to cooperate within OPEC, which leads to hardship in coordination inside the organization.

While Saudi Arabia presence is important for OPEC’s overall productivity, one of the way to solve the issue that its dominance brings is to increase the profits under cooperation within OPEC. This could be done by increasing the external influence of OPEC as a unit, e.g. adding member countries.

**4.2) Use of strategic moves between OPEC members**

Communication and support play a significant role in real-life strategic interactions. In many game theory models, assumptions of prohibiting communication between players are made in order to exclude factors that may influence the outcome of a simulated game (in prisoner’s dilemma, cooperation would be much more achievable than fink if communication is possible since players can know and ensure their counterpart’s action). However, in reality, strategic moves involving communication can be a gamechanger in various situations.

In the case of OPEC countries, commitment and promise can be used to guide countries unwilling to compromise towards a more favorable outcome than to cheat each other.

Take the example presented in part 2. It has been concluded that (cheat, cheat) is the strictly dominant option for OPEC member countries since the payoff of cheating, which is to produce more when agreed to cut production, is strictly higher than the other option regardless of whether the other members would cooperate or cheat.

However, if one of the dominant, credible countries makes a commitment that it will play “cooperate”, it would be much more reasonable for the other player to cooperate as well since playing fink for once would compromise all trust among the players and cause the double-cheat outcome to occur again, and in the long term all players can achieve a better payoff predicted by (cooperate,cooperate) outcome in the game. In a similar sense,

Another strategic action that can be made to induce the situation to a favorable outcome is to make a credible threat. For example, if Saudi Arabia makes a statement about cancelling the OPEC Fund for International Development(OFID) support for countries that do not cooperate on oil production target, the other member countries may reconsider about their action, thus possibly acting in favor of Saudi Arabia. Such strategy can be useful for countries with sufficient bargaining power economically and politically against the other ones.

**5. Conclusion**

As depicted by the models aforementioned, while the formation of OPEC facilitated the member countries’ control on oil price level, there is innate conflict of interest among the members and the risk of disbandment have always persisted: Qatar has recently announced its departure from OPEC amidst political tension with nearby countries such as Saudi Arabia, and it has been reported that Qatar’s change of focus from crude oil to liquified gas extraction and export was also one of the reasons for their exit call. On the other hand, the competition between OPEC and non-OPEC energy sources is not in favor of OPEC since the plan of oversupplying crude oil in order to gain advantage in pricing over the alternative energy like natural gas and shale gas is not as effective as before. The situation of OPEC and the suitable strategies to be formed are not simple constants; they are dynamic and complicated, involving not only quantifiable statistics but also balance between political contest, well-being of citizens, environmental concerns.

On a higher level, Game Theory analysis can involve complex mathematical modelling, where a decision support system is developed using Artificial Neural Network with Game Theory underlying as working principles. This machine learning approach of system building has achieved astonishing results, where the predicted path of oil price level movement given a certain time period in the past has matched the real price movement history with a level of accuracy and similarity of around 80% ~ 90% (Navidi *et al*., 2012). This tool is certainly valuable for the decision makers in OPEC or other countries in search for the “optimal production point” for maximal profitability, yet there are much more analysis to be conducted and non-quantifiable factors to be taken into consideration before a sustainable decision making system can be put into use for forging a rational and healthy environment for further competition.

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**Appendix**



