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Game Theory Approach for Economic Cooperation and Sustainable Development: Optimization South Pars – North Dome Field between Iran and Qatar

Podejście oparte na teorii gier w ekonomicznej współpracy dla zrównoważonego rozwoju: optymizacja South Pars – North Dome Field pomiędzy Iranem a Katarem

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Abstract
Collaboration between countries in the exploitation of common natural resources such as oil and gas contribute to resource optimization, prevention of unsustainable extraction, promotion of long-term resource sustainability, strengthening diplomatic relations, enhancing peace, and fostering economic growth and development based on the 17 Sustainable Development Goals of the United Nations. This cooperation plays a significant role in the economy. This research presents a modeling of the extraction of interested countries from a common resource using triangular distribution and game theory approach. The modeling is designed based on the share of the parties in the common resource and the extraction capability (in terms of the sanction factor). The results indicate that the extraction level of each country from the common resource depends on both the share of the interested parties and the level of sanction imposed on them. Moreover, if a sanction is imposed on one or both countries, a portion of the resources will not be extracted. Among the most important results, we can point out that only if the amount of sanctions is very severe, then the extraction of resources for Iran has no economic justification.

Key words: game theory, common natural resource, sanctions, triangular distribution

Streszczenie
Współpraca między krajami w zakresie eksploatacji wspólnych zasobów naturalnych, takich jak ropa naftowa i gaz, przyczynia się do optymalizacji zasobów, zapobiegania niezrównoważonemu wydobyciu, promowania długoterminowej stabilności zasobów, wzmacniania stosunków dyplomatycznych, wzmacniania pokoju oraz wspierania wzrostu i rozwoju gospodarczego w oparciu o 17 Celów Zrównoważonego Rozwoju ONZ. Współpraca ta odgrywa znaczącą rolę w gospodarce. W badaniu przedstawiono model wydobywania zainteresowanych krajów ze wspólnego zasobu przy użyciu rozkładu trójkątnego i podejścia teorii gier. Modelowanie projektuje się w oparciu o udział stron we wspólnych zasobach i możliwościach wydobycia. Wyniki wskazują, że poziom wydobycia każdego kraju ze wspólnego zasobu zależy zarówno od udziału zainteresowanych stron, jak i od poziomu nałożonych na nich sankcji. Co więcej, w przypadku nałożenia sankcji na jeden lub oba kraje część zasobów nie zostanie wydobyta. Wśród najważniejszych wyników możemy wskazać, że tylko w przypadku bardzo dotkliwych sankcji wydobywanie surowców dla Iranu nie ma ekonomicznego uzasadnienia.

Słowa kluczowe: teoria gier, wspólne zasoby naturalne, sankcje, rozkład trójkątny

1. Introduction

Energy resources, including oil and gas reserves, play a foundational role in the economic life of industrial societies, particularly in developing countries. Oil and gas, as a strategic commodity, have a significant impact on the income levels and the economic situation of countries possessing these resources. Projections indicate that hydrocarbon resources will remain the primary source of energy supply in the world until the year 2050. The oil shocks of the 1970s doubled the importance of energy resources, leading all countries to recognize the importance of efficient management and consumption of energy resources (Markusen, 1975). In most oil exporting countries in the Third World, the foreign exchange earnings from the sale of oil and gas constitute a significant portion of the country's foreign exchange receipts or government revenues, providing the groundwork for the country's development. Therefore, in the eyes of most economic experts, it is considered the primary factor in the economic performance of countries (Asamoah et al., 2019). The income derived from the sale of energy resources has a direct relationship with the social standard of living in the community, as the level of economic activity, quality of life, supply of goods and services, and ultimately the social welfare of individuals in that community have a strong dependency on the income derived from the sale of these resources (Salimian & Shahbazi, 2017- Pazouki & Zhu, 2022).

The indiscriminate consumption of energy resources has led to a drastic reduction in these reserves and poses the risk of depletion or exhaustion of these resources. Even with the emergence of new energy sources and the continuous development of such energy, the importance and value of fossil fuels (especially oil and gas) have not diminished. However, the significance of this issue is twofold concerning shared energy resources, as the priority lies in the extraction of such shared resources. The reason for this is that each party involved seeks to increase its own national interests (Lebillon, 2003). Exploitation of natural resources such as oil and gas without prudence and adherence to principles leads to risks such as environmental threats, air pollution, and ultimately climate change. Therefore, effective cooperation and coordination between countries for sustainable exploitation of natural resources, including shared natural resources, are necessary and essential. This issue is one of the important goals of the economic and social development of the United Nations.

Participation in the fair division of common resources involves balancing conflicting interests and ensuring that no country is unfairly deprived of the right to benefit from common resources. Therefore, sustainable energy resource management requires cooperation among users with conflicting interests to optimize resources, prevent overexploitation, promote long-term resource sustainability, strengthen diplomatic relations, and promote peace (Nguyen & Nghiem, 2021). A mechanism for the fair allocation of common resources among stakeholders depends on factors such as historical rights, geographical proximity, socio-economic conditions, and intergenerational equity principles (Lee, 2020). The concept of transboundary natural resources includes any natural resources that, in their natural state and without human intervention, are capable of crossing the political boundaries of a country, and shared oil and gas fields are prominent examples of these resources due to their geographical extent, fluid nature, and ownership by more than one country (Beyene & Wadley, 2004). The issue of shared oil and gas resources is crucial for countries like Iran, whose economy significantly relies on oil revenues (Salimian et al., 2023). According to the international statistics announced in 2021 by BP, the Persian Gulf region, due to its geoeconomic significance and holding 48% of the world's oil and 40% of gas reserves, is recognized as the principal energy supply center globally. This indicates that the management of oil and gas reserves in the Persian Gulf is crucial due to the very high importance of this region. On the other hand, among the OPEC members, the long-term reduction of OPEC members to these six countries including Saudi Arabia, Iran, Iraq, Kuwait, the United Arab Emirates, and Qatar, will collectively possess about 50% of the world's proven oil reserves and will impact global oil strategies (Forneth, 2004).

The South Pars/North Dome Field is the world's largest gas field, located on the maritime border between Iran and Qatar. Approximately 25% of this field belongs to Iran, while 75% belongs to Qatar. This joint gas field, situated on the maritime border between the two countries, has intensified the strategic decision-making for the exploitation of oil and gas resources by Iran and Qatar. Being the world's largest gas resource, the anticipated increase in demand for natural gas in the years ahead and the shared nature of this field with Qatar, along with the government's budget dependence on the foreign exchange revenues from the sale of oil and gas resources, underscore the high importance of this gas field. On the other hand, due to the inability to delineate a border for shared fields, if any of the stakeholders in the joint field fails to extract, the opposing country can easily extract the remaining share. So, these two countries should cooperate to find sustainable solutions to prevent political and military confrontation. In fact, strengthening the rule of law, adherence to mutual rights, and ensuring the participation of stakeholders in a common natural resource are the key elements of a process that ultimately leads to establishing comprehensive peace and justice. This is a fundamental prerequisite for social and economic development.

In other words, if Iran, for any reason (including sanctions, outdated equipment, mismanagement of resource exploitation, etc.), cannot increase and develop its share of the South Pars field, this national wealth will easily fall into Qatar's hands. In general, the obstacles and problems facing Iran in the exploitation of the South Pars/North Dome joint field include: Qatar's threefold share compared to Iran, international sanctions against Iran, including those after the JCPOA, Iran's use of weak technology for resource exploitation, the 20% slope of the field towards Qatar, and the higher extraction costs by Iran.

In addition to Qatar's threefold share in the joint field, the most important barrier to Iran's exploitation of its natural resources is the imposition of international sanctions against the country. Sanctions restrict countries' access to advanced technology and hinder the cooperation of leading global companies with the sanctioned country. Additionally, the cost of extraction from the joint field is not the same for both parties. For example, the cost of extracting each barrel of oil in Iran is 1.5 to 2 times higher than in the countries of the southern Persian Gulf. On the other hand, the imposition of sanctions against a country, which leads to a reduction in its extraction capability, increases the costs of extracting natural resources (Salimian et al., 2023).

Game theory is a powerful tool for resolving various disputes among stakeholders who pursue their own interests. It seeks to mathematically express the strategic behavior of individuals in relation to the behavior of others and in decision-making situations. This method is widely applicable in various issues, including management and the exploitation of common natural resources. Therefore, this research considers the asymmetric share of the parties in the common resource, the imposition of sanctions, and the cost-increasing factors in resource extraction (in the event of sanctions) to model a more realistic approach based on logical assumptions regarding the extraction of common natural resources between countries.

Given that in the mutual relations between countries in the extraction and exploitation of common resources, there are conflicting interests, the main issue of this research is to investigate how the strategic behaviors between these countries (Iran and Qatar) in exploiting this common field are. And which strategy (cooperation or non-cooperation) is optimal for the players in exploiting this common resource? Also, how does the factor of sanctions and the unequal share of the parties affect the exploitation of this common gas field? So, the way countries benefit from common natural resources must be in line with principles 8 (economic growth of countries), 13 (addressing the global challenge of climate change), and 16 (establishing global peace and justice) of the 17 Sustainable Development Goals of the United Nations.

This article is organized into five sections. After the introduction, the second section discusses the research background. The third section outlines the research methodology, which includes two subsections: game theory and research modeling. Lastly, the final section is dedicated to drawing conclusions on the subject matter.

2. Research Background

The strategy of countries in the oil and gas sector is of great importance for both oil-rich countries and importing countries. The importance of these resources for developing countries is twofold, as the government budget is heavily dependent on the revenues from the sale of oil and gas.

Studies in the field of exploitation of common resources have generally adopted three approaches:

1. Studies that have examined the optimal strategy for parties through legal and political policies
2. The text mentions that studies conducted through the use of matrix game form and the application of game theory such as Prisoner's Dilemma, Chicken Game, Stag Hunt, War and Peace Game, and simple modeling have examined the optimal strategy for the parties involved.
3. The studies that have used modeling to examine the situation of shared fields between and to determine the optimal strategy for both parties have been very limited, although the number of articles adopting such an approach is very low.

2.1. First Approach: Political and Legal Policies

Basiri et al. (2015), in their research on the opportunities and challenges of utilizing shared oil and gas resources in Iran's relations with Persian Gulf countries, aimed to investigate the applicability of the theories of convergence and neo-functionalism put forth by Ernst Haas. They posited that the most significant opportunities include collaboration in the exploitation of joint fields, refining, and the transportation of these resources to global markets, while the main challenge lies in the lack of regionalism and economic convergence among these countries. They employed a descriptive-analytical research method in their study. The results indicated that countries with shared resources, through cooperation and the implementation of a suitable legal framework and extraction mechanism, can achieve increased economic collaboration, leading to reduced tensions, sustainable peace, development, prosperity, etc.

In Ghafari and Taklif's (2015) research, they focused on the application of rational model in strategic decision-making for sustainable production from the shared Pars South-North Dome field, with emphasis on legal requirements. In their study, for the joint management of these resources and to achieve sustainable production and make joint decisions by both countries, they utilized the rational model in decision-making. The results indicated that Iran's and Qatar's performance in exploiting the shared oil and gas resources reflects a type of aggressive policy or lack of cooperation in extracting from the fields without considering sustainability. They also demonstrated that increasing the level of production and extraction by each country causes serious damages to the field, while commitment to sustainable production in the long run leads to significant economic benefits for these countries.

Hayashi (2012), in a research titled *The 2008 Agreement between Japan and China on Cooperation for the Development of Shared Resources in the East China Sea*, the focus was on examining the differences between the two countries regarding the exploitation and development of hydrocarbon resources in the East China Sea. The most important issue in this regard that needs to be resolved is the definition of the common area for exploitation and development, and the entire disputed area should be considered as the continental shelf of both countries. The results showed that the Japanese must participate in the development of resources in accordance with Chinese laws.

Kharismawan and Wisanjaya (2022), delved into the examination of hydrocarbon resources between Indonesia and Malaysia in the Ambalat Sea region. They pursued a legal approach with the aim of finding a solution for the joint exploitation of resources, seeking peaceful utilization by both parties based on procedures and international law, while recognizing the differences between countries in delineating borders based on each country's legal and political interpretation and the economic value of these resources.

2.2. Second Approach: the matrix game form

Khatami and Shakibaie (2017), delved into the evolutionary game theory of Iran and Saudi Arabia within the framework of genetic algorithms. They simulated the competition between Iran and Saudi Arabia in the OPEC oil coalition using 12 types of strategies in the prisoner's dilemma game to articulate the best strategy with the aim of maximizing the profit and benefit of each player and minimizing the rival's benefit. Their results indicated that the *tit-for-tat* strategy is the best strategy for both parties, followed by the *majority agreement* strategy, *grim trigger strategy*, and *tit-for-tat after two mutual defections.* Additionally, theun-cooperative strategy resulted in the least benefit and profitability for both parties.

Bayati et al. (2019), in a research titled *Iran-Qatar Cooperation in Exploiting the Joint Gas Reserves of South Pars - North Dome emphasizing on Game Theory*, investigated cooperative andun-cooperative games between Iran and Qatar to achieve the optimal economic strategy for Iran. Their results indicated that by designing aun-cooperative game and using dominant strategy equilibrium (eliminating dominated strategies) and Nash equilibrium, the choice ofun-cooperation strategy is optimal for both countries and brings greater economic benefits for Iran. They also demonstrated that both countries adopt aun-cooperation policy for the exploitation of their joint resources to increase the current net value of the two countries.

Rostamzadeh et al. (2021), conducted a study investigating the global effects of international oil sanctions against Iran using game theory. The results of the game tree analysis between the parties involved in this game (the United States, Europe, and Iran) indicate that the imposition of sanctions affects the interests of all countries involved, but a Nash equilibrium is achieved when the United States and Europe impose weaker sanctions against Iran. Another finding of their research is the inability of the United States to completely zero out Iran's oil exports due to incomplete agreement between the US and Europe, as well as Iran's efforts to bypass the sanctions.

Esmaeili et al. (2015), in a study titled *Using Game Theory Approach to Interpret Sustainable Policies of Joint Oil and Gas Resources Dispute between Iran, Iraq, and Qatar*, designed and modeled Iran's oil strategies in exploiting shared fields with Iraq and Qatar. Their results showed how countries heavily reliant on oil and gas revenues strategically approach exploiting their shared resources.

Salimian et al. (2023), investigated the modeling of gas extraction from a common resource between Iran and Qatar using 4 static games. In their modeling, they considered the asymmetric share and the factor of sanctions. Their results indicated that the commitment to cooperation orun-commitment of the parties depends on the share of each country as well as the level of sanctions imposed against the counterpart.

2.3. Third Approach: Modeling Optimal Strategies

Salimian and Shahbazi (2017), conducted a study to examine Iran's strategy in exploiting shared oil and gas resources from a game theory perspective. In their research, they analyzed Iran's best strategy against other partners in shared fields, both in cases of cooperation andun-cooperation. Their findings indicated that in the case of cooperation among countries, the same level of resources could be extracted with less effort, and if more countries are involved in a shared field, the individual efforts of each country would be less, but the total effort of these countries together would be greater, resulting in inefficiency. Ultimately, they suggested that countries involved in a shared resource should engage in mutual cooperation to extract from the shared fields with less activity, thus extracting the same amount of shared resources with a lower level of effort.

Toufighi et al. (2020), investigated and articulated Iran's issues in production and exploitation of the joint Forouzan oil field using cooperative game theory. In their study, they designed a game model to optimize Iran's production and exploitation of the joint field with Saudi Arabia (Forouzan field) utilizing descriptive data. Their findings indicated that the best strategy for Iran is cooperation in exploiting this joint field while Saudi Arabia's equilibrium lies inun-cooperation.

Most studies conducted in the field of Iran's strategies in shared reservoirs with neighboring countries have examined the political and legal policies. In other words, most studies in the field of how to exploit shared natural resources are qualitative studies. Some studies have also focused on determining optimal strategies for extracting shared resources through game theory and limited studies through modeling. It can be almost said that all of these studies have focused on determining optimal strategies, taking into account the same and symmetrical conditions for both parties, while the conditions of the two parties (two countries involved in a shared reservoir) are not the same. Another noteworthy point about the reviewed studies and other reviewed studies in the field of resource economics is not paying attention to the 17 goals of the United Nations regarding sustainable development. Sustainable development includes *correct and efficient management and exploitation of basic resources, natural resources, financial resources and human resources to achieve the optimal consumption pattern, along with the use of technical facilities and appropriate structures and organizations to meet the needs of today's and future generations continuously and satisfactorily*. In this research, from the definition of sustainable development the topic of common natural resources and its correct and efficient use has been discussed.

In this study, we attempt to obtain the optimal strategy for Iran and Qatar in extracting from the shared gas reserves of South Pars – North Dome by utilizing the triangular distribution and the theoretical game theory method, considering the asymmetric conditions of the parties (varying extraction costs for the parties, unequal shares of this common field, international sanctions against Iran, etc).

3. Methodology

In this study, a model for the exploitation of common natural resources is constructed considering three factors: the share of each country from the common resource, the extraction capacity (based on the factor of sanctions), and the additional cost of resource extraction in case sanctions are imposed against a country. Since the modeling of this game is based on the approach of game theory, general concepts of game theory will be explained further.

3.1. Game Theory

Although sustainable development is completely considered as a new paradigm and the study of sustainability is very important, evaluating the movement towards sustainable development is the biggest challenge in implementing sustainable development. Strategies for moving towards sustainable development must be based on proper awareness and sufficient information. On the other hand the key characteristic in the science of game theory is that each player should make the best decision that yields the highest benefit. Of course, this is contingent on the player analyzing and evaluating the reactions and responses of others regarding their decision and choice before making their own decision and choice (Abduli, 2012).

Given that game theory deals with the study of decision-making in interactive situations, its primary objective is to model and analyze the behavior of players in decision-making contexts. A prerequisite for this is the assumption of rationality, meaning each player chooses an action based on their own preferences and constraints, taking into account the actions of their rivals that align with their interests (Osborne & Rubinstein, 1994). On the other hand the concept of sustainable development is strictly related to sustainability, and it expresses the concern of the methods that countries use in their economic development. In other words, carrying out maximum and rapid economic growth puts a lot of pressure on land capacity. Sustainability is the ultimate goal of sustainable development and describes the state that sustainable development should achieve. Such a situation is achieved when all people (players) can satisfy their basic needs and desires and this is also guaranteed for future generations (Zamani & Javaherian, 2015).

If the number of players (factors) involved in a confrontation is limited, game theory can be very useful because in this case, the behavior of each player has a significant impact on the payoff of other players (Shy, 1995). The most important principle of game theory is that all players in a game have common knowledge. In other words, all players in a game know the structure of the game and also know that their rivals know it, and they are aware that their rivals also know that others are aware of it, and so on (Mas-Colell et al., 1995). Game theory attempts to model situations in which individuals' interests are conflicting. The ultimate goal of this knowledge is to find the optimal strategy for the players (Salimian & Shahbazi, 2017).

Game theory, using models and mathematical equations, analyzes the cooperative or competitive behaviors of logical and intelligent agents and attempts to model the controlling mathematical behaviors of conditions (Osborne & Rubinstein, 1994). On the other hand, game theory has various applications in the development of different sciences including economics, social sciences, and other sciences (Colman, 2021). Active researchers in the field of economics utilize game theory in their models because it allows them to model under conditions where prices are not responsive (Gibbons, 1997). The main objective of game theory is to model conditions in which individuals' interests are in conflict. This theory seeks to find the optimal strategy that players can use (Salimian & Shahbazi, 2017). Additionally, game theory, by employing mathematical relationships, analyzes rational cooperation and competition among individuals or firms, based on the assumption of rationality, to model decisions made by conflicting parties (Myerson, 1991).

The theoretical modeling of game theory has had a remarkable expansion in international economics, labor economics, macroeconomics, and public finance and is advancing towards the economics of development and economic history (Salimian & Sobhanian, 2024). Game theory, using models and mathematical equations, analyzes the cooperative or competitive behaviors of logical and intelligent agents and attempts to model the controlling mathematical behaviors of conditions (Osborne & Rubinstein, 1994). On the other hand, game theory has various applications in the development of different sciences including economics, social sciences, and other sciences (Colman, 2021). Active researchers in the field of economics utilize game theory in their models because it allows them to model under conditions where prices are not responsive (Gibbons, 1997). The main objective of game theory is to model conditions in which individuals' interests are in conflict. This theory seeks to find the optimal strategy that players can use (Salimian & Shahbazi, 2017). Additionally, game theory, by employing mathematical relationships, analyzes rational cooperation and competition among individuals or firms, based on the assumption of rationality, to model decisions made by conflicting parties (Myerson, 1991).

In some games, there is an important feature in which the selection of a strategy by players is preferred because the results of this strategy are more desirable for that player compared to other strategies and have greater consequences for that player. In this situation, a player must choose the preferred strategy despite the strategies of the opponents. The strategy chosen by the player to achieve a superior outcome is called the superior strategy (Kreps, 1990). If each player has a superior strategy in a game, naturally they will choose this superior strategy. For this reason, the combination of players' superior strategies is known as the equilibrium of superior strategies (Osborne, 2004). According to the explanations provided, it seems that game theory is the most important and powerful tool for analyzing the discussed conditions in presenting the concepts of competitive extraction on one hand and sustainable development on the other hand.

3.2. Research Modeling

To explain the extraction of common resources, we utilize the density distribution function of the triangular distribution, which is represented by the function $y = 2(1 - x)$. The area under this function is equal to $2x - x^2$. On the other hand, the amount of resource extraction depends on three factors: the level of sanctions on countries (LS), the share of the parties in the common natural resource (γ), and the amount of remaining resources (x) [$EP = f(LS, \gamma, x)$], which is represented as $EP = LS.\gamma.x$.

The level of countries' extraction capacity from a common source is directly related to each country's share of that source and inversely related to the sanction factor. In other words, as each country's share of the common source increases, the extraction capacity also increases, and vice versa. Additionally, with an increase in the un-sanction factor (reduction of sanctions), the extraction capacity increases, and vice versa. Of course, for simplicity and better visualization, the un-sanction factor is denoted as LS (un-sanctions), and its value is considered within the range of zero to one, where the value of LS equal to one represents un-sanctions and the value of LS equal to zero represents complete sanctions.

By drawing both EP graph and the area under the y graph, the following relationship can be established:

$$LS.\gamma.x = 2x - x^2$$

By solving the above equation, the value of x^* is obtained as follows:

$$x^* = 2 - LS.\gamma$$

By substituting the optimal value of x, denoted as (x^*), into the function EP, we have:

$$EP^* = LS.\gamma(2 - LS.\gamma)$$

In the absence of sanctions ($LS = 1$) and full availability of resources ($\gamma = 1$), the extraction power level is equal to 1. In the case of moderate sanctions ($LS = 0.5$) and severe sanctions ($LS = 0.1$), the extraction power levels are 75% and 19% respectively. When half of the resources are available ($\gamma = 0.5$) and there are un-sanctions ($LS = 1$), the extraction power level is 75%. With half of the resources available and in the case of moderate sanctions ($LS = 0.5$) and severe sanctions ($LS = 0.1$), the extraction power levels are 0.4375 and 0.0975 respectively.

The total extractable capacity of two countries sharing a common resource is determined by the following relationship:

$$EP_T = (LS_i\gamma_i + LS_{-i}\gamma_{-i})(2 - (LS_i\gamma_i + LS_{-i}\gamma_{-i}))$$

As previously mentioned, the shares of Iran and Qatar in the South Pars/North Dome common field are 25% and 75% respectively. When neither party is under sanctions, the total extraction capacity is equal to one unit ($EP_T = 1$).

Iran's extraction power from the following equation is obtained, which indicates Iran's share of total extraction:

$$EP_{Iran} = \frac{LS_i\gamma_i}{LS_i\gamma_i + LS_{-i}\gamma_{-i}} \left(LS_i\gamma_i + LS_{-i}\gamma_{-i} \left(2 - (LS_i\gamma_i + LS_{-i}\gamma_{-i})\right)\right)$$

$$EP_{Iran} = -LS_i\gamma_i \left(LS_i\gamma_i + LS_{-i}\gamma_{-i} - 2\right)$$

The extraction capacity of Qatar can be obtained from the following relationship, which indicates Qatar's share of the total extraction:

$$EP_{Qatar} = \frac{LS_{-i}\gamma_{-i}}{LS_i\gamma_i + LS_{-i}\gamma_{-i}} \left(LS_i\gamma_i + LS_{-i}\gamma_{-i} \left(2 - (LS_i\gamma_i + LS_{-i}\gamma_{-i})\right)\right)$$

$$EP_{Qatar} = -LS_{-i}\gamma_{-i} \left(LS_i\gamma_i + LS_{-i}\gamma_{-i} - 2\right)$$

Under normal conditions (absence of sanctions on both parties and Qatar's share is 3 times that of Iran), Iran's extraction capacity is equal to 25% and Qatar's extraction capacity is equal to 75%. Therefore, the total extraction capacity is equal to one unit. In other words, both parties can extract the entire reserves in the joint source.

Now we will examine the changes in the power function of countries' extraction with respect to a one-unit increase in the un-sanction factor:

$$\frac{\partial EP_i}{\partial LS_i} = -\gamma_i(2LS_i\gamma_i + LS_{-i}\gamma_{-i} - 2) \geq 0$$

$$\frac{\partial EP_{-i}}{\partial LS_{-i}} = -\gamma_{-i}(2LS_{-i}\gamma_{-i} + LS_i\gamma_i - 2) \geq 0$$

The derivative of power with respect to un-sanction factor of a country indicates that if the un-sanction factor increases by one unit, the extraction level of that country increases by a corresponding amount.

$$\frac{\partial EP_i}{\partial LS_{-i}} = -LS_i\gamma_i\gamma_{-i} \leq 0$$

$$\frac{\partial EP_{-i}}{\partial LS_i} = -LS_{-i}\gamma_{-i}\gamma_i \leq 0$$

Also, by deriving the power from the extraction of each country relative to the factor of un-sanction of the opposite country, it can be observed that with an increase of one unit of the un-sanction factor of the opposite country, the amount of extraction power decreases proportionally.

In different circumstances, depending on the country and the extent of the sanctions, the extraction capacity of the parties and therefore the total extraction capacity differ from the initial state. Assuming that Iran is under moderate sanctions ($LS_i = 0.5$), Iran's extraction capacity decreases from 25% to about 14% ($EP_{Iran} = 0.140625$), and Qatar's extraction capacity increases from 75% to about 84% ($EP_{Qatar} = 0.84375$).

In a situation where one of the parties involved in a common resource or both countries are under sanctions, a portion of the reserves will not be extracted by any of the countries, and this is referred to as *the un-Extractable Percentage*. It can be derived from the following relationship:

$$NEP = LS_i^2\gamma_i^2 + 2\,LS_i\gamma_i(LS_{-i}\gamma_{-i} - 1) + LS_{-i}^2\gamma_{-i}^2 - 2\,LS_{-i}\gamma_{-i} + 1$$

The value of NEP when Iran is under moderate sanctions ($LS_i = 0.5$) equals 0.015625.

Based on the assumption that Iran is under severe sanctions ($LS_i = 0.1$), the extraction capacity of Iran decreases from 25% to approximately 3% ($EP_{Iran} = 0.030625$), and the extraction capacity of Qatar increases from 75% to around 91% ($EP_{Qatar} = 0.91875$). The NEP value in the scenario where Iran is under severe sanctions ($LS_i = 0.1$) equals 0.050625.

Based on the assumption that the level of sanctions on Qatar is moderate ($LS_{-i} = 0.5$), Iran's extraction capacity increases from 25% to approximately 34% ($EP_{Iran} = 0.34375$), while Qatar's extraction capacity decreases from 75% to approximately 51% ($EP_{Qatar} = 0.515625$). The value of NEP, under the condition of moderate sanctions on Qatar ($LS_{-i} = 0.5$), amounts to 0.140625.

Assuming that Qatar is under severe sanctions ($LS_{-i} = 0.1$), Iran's extraction capacity increases from 25% to approximately 41% ($EP_{Iran} = 0.41875$), while Qatar's extraction capacity decreases from 75% to approximately 51% ($EP_{Qatar} = 0.125625$). The value of NEP under the condition of severe sanctions on Qatar ($LS_{-i} = 0.1$) is equal to 0.455625.

In a situation where both parties involved in a common resource are under the average sanction ($LS_i = 0.5$ ، $LS_{-i} = 0.5$), the extraction power of the parties diminishes. In this scenario, the extraction power of Iran is approximately 18% ($EP_{Iran} = 0.1875$) and the extraction power of Qatar is approximately 56% ($EP_{Qatar} = 0.5625$). Consequently, these two countries together extract 75% of the resources and theun-extractable percentage (NEP) amounts to 25%.

In a scenario where both parties involved are severely sanctioned over a common resource ($LS_i = 0.1$ ، $LS_{-i} = 0.1$), the extraction power of both parties is greatly reduced. In this case, the extraction power of Iran is approximately 4% ($EP_{Iran} = 0.0475$) and the extraction power of Qatar is about 14% ($EP_{Qatar} = 0.1425$). Consequently, these two countries collectively extract 19% of the resources, leaving theun-extractable percentage (NEP) at 81%.

$$\frac{\partial NEP}{\partial LS_i} = 2LS_i\gamma_i^2 + 2LS_{-i}\gamma_{-i}\gamma_i - 2\gamma_i \leq 0$$

$$\frac{\partial NEP}{\partial LS_{-i}} = 2LS_{-i}\gamma_{-i}^2 + 2LS_i\gamma_i\gamma_{-i} - 2\gamma_{-i} \leq 0$$

The derivation from the percentage ofun-extractable resources of each country relative to the factor of un-sanction indicates that, in the event of a one-unit increase in the factor of un-sanction, the percentage ofun-extractable resources decreases by the above-mentioned amount.

In order to provide a more accurate depiction of each country's extraction capacity, the extraction potential of countries under various sanction conditions is also expressed geometrically. In the first scenario, assuming un-sanctions ($LS_{-i} = 1$), the extraction functions will be as follows.

$$EP_{Iran} = \frac{LS_i(5 - LS_i)}{16}$$
$$EP_{Qatar} = \frac{3(5 - LS_i)}{16}$$
$$NEP = \frac{LS_i^2 - 2LS_i + 1}{16}$$
$$EP_T = \frac{(LS_i + 3)(5 - LS_i)}{16}$$

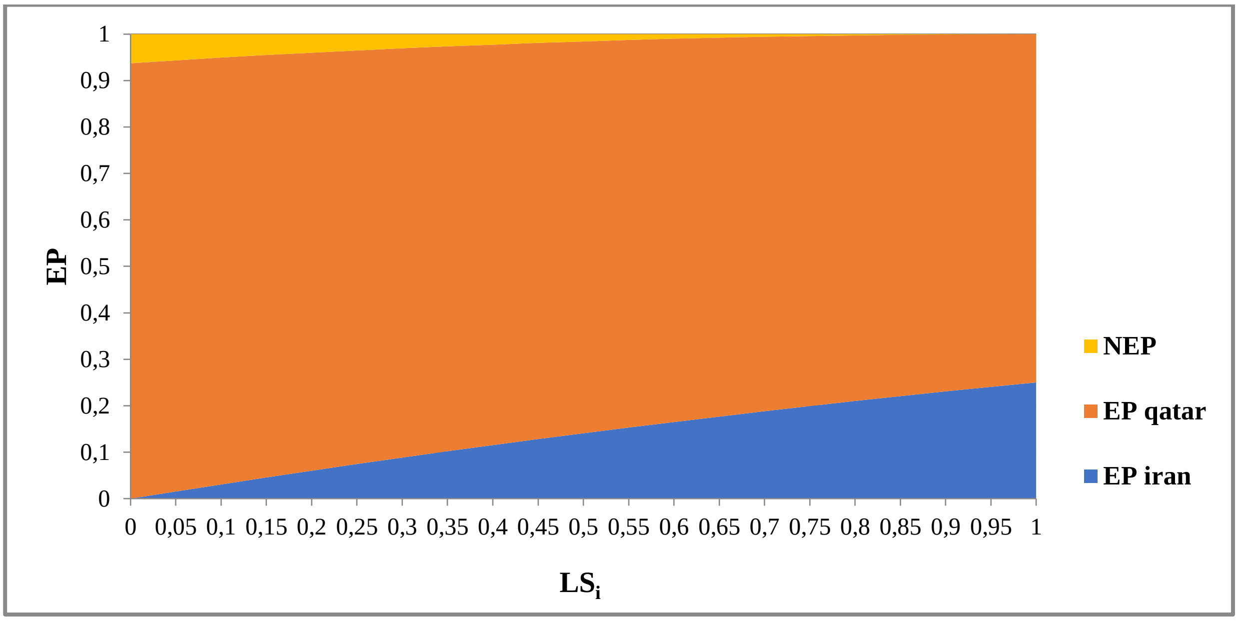

Figure 1. The country extraction functions under the assumption of different sanction conditions for Iran and the absence of sanctions for Qatar ($LS_{-i} = 1$), source: authors own work

The above graph indicates that in the absence of sanctions on Iran ($LS_i = 1$), Iran's extraction potential will be 25 percent and Qatar's extraction potential will be 75 percent. In this scenario, the total extraction potential is equal to one unit, with theun-extractable percentage being zero. By increasing sanctions on Iran (reducing the un-sanction factor), Iran's extraction potential decreases while Qatar's extraction potential increases. As a result of the sanctions, the total extraction potential becomes less than one unit and a portion of the resources remains unextracted. In the most severe scenario ($LS_i = 0$), Iran's extraction potential equals zero and Qatar's extraction potential increases to approximately 93 percent. In this case, the total extraction potential will be about 93 percent, with theun-extractable percentage being approximately 6 percent.

Assuming that Iran is not under sanctions, the extraction functions of countries ($LS_i = 1$) will be as follows:

$$EP_{Iran} = \frac{7 - 3LS_{-i}}{16}$$
$$EP_{Qatar} = \frac{3LS_{-i}(7 - 3LS_{-i})}{16}$$
$$NEP = \frac{9(LS_{-i}^2 - 2LS_{-i} + 1)}{16}$$
$$EP_T = \frac{(3LS_{-i} + 1)(7 - 3LS_{-i})}{16}$$

The figure 2 indicates that in the absence of sanctions on Qatar, Iran's extraction capacity will be 25% and Qatar's extraction capacity will be 75%. In this scenario, the total extraction capacity equals one unit, and theun-extractable percentage is zero. By increasing the sanctions on Qatar (reducing the factor of un-sanction on Qatar), the level of Qatar's extraction capacity decreases, while Iran's extraction capacity increases. As a result of the sanctions, the total extraction capacity becomes less than one unit, and a portion of the extraction resources are not utilized. In the most severe case ($LS_{-i} = 0$), Qatar's extraction capacity equals zero, and Iran's extraction capacity increases by about 44%. In this situation, the total extraction capacity is approximately 44%, and theun-extractable percentage is approximately 56%.

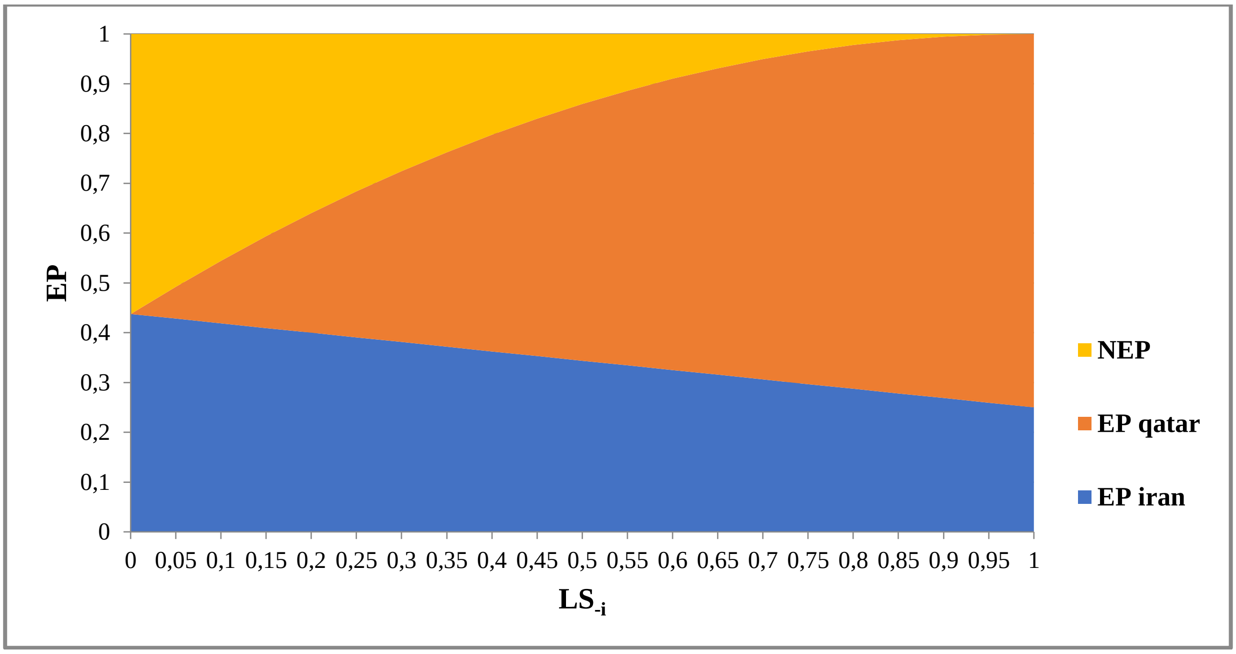

Figure 2. The functions of extracting countries under different assumptions of sanctions against Qatar and un-sanction against Iran ($LS_i = 1$)

The profit function of both parties in a common source is the same as the common profit function that arises from the difference between revenue and cost ($\pi = TR - TC$). The income of each country is obtained from the product of the quantity extracted at the commodity price ($TR = P.EP$). However, the cost function is considered as ($TC = \frac{CE}{LS\,(2-LS)} EP$). As mentioned before, the value of the LS factor (the factor of sanctions) is in the range of zero and one, and with the increase of the sanction factor (reduction of sanctions), the total cost decreases. If un-sanctions are imposed on the country ($LS = 1$), the total cost will be equal to the product of the extraction cost at the extraction quantity ($TC = CE.EP$).

In the case of an average sanction ($LS = 0.5$), the total cost is equal to:

$TC = 1.33\,CE.EP$

In the case of severe sanctions ($LS = 0.1$), the total cost is equal to:

$TC = 5.26\,CE.EP$

The cost of oil and gas extraction varies in different regions of the world. For example, the cost of extracting each barrel of oil in Kuwait and Qatar is around 8$, in Iran it's approximately 12$, and in the UK and Norway, it ranges between 30$ and 40$. Additionally, the cost of gas extraction for Iran will be higher than Qatar, as mentioned above. If sanctions are imposed on a country, the cost of oil and gas extraction will increase. So, the calculation of the profit for both parties will be as follows:

$$\pi = P.EP - \frac{CE}{LS\,(2-LS)}\,EP$$

$$\pi_{Iran} = P.EP_{Iran} - \frac{CEi}{LS_i(2-LS_i)} EP_{Iran}$$

$$\pi_{Qatar} = P.EP_{Qatar} - \frac{CE_{-i}}{LS_{-i}(2-LS_{-i})} EP_{Qatar}$$

By substituting the power function of extraction for two countries into the profit function relevant to each country, their profit function will be as follows:

$$\pi_{Iran} = \frac{CE_i.\gamma_i.(LS_i\gamma_i + LS_{-i}\gamma_{-i} - 2)}{2 - LS_i} - P.LS_i\gamma_i(LS_i\gamma_i + LS_{-i}\gamma_{-i} - 2)$$

$$\pi_{Qatar} = \frac{CE_{-i}.\gamma_{-i}.(LS_i\gamma_i + LS_{-i}\gamma_{-i} - 2)}{2 - LS_{-i}} - P.LS_{-i}.\gamma_{-i}(LS_i\gamma_i + LS_{-i}\gamma_{-i} - 2)$$

Oil and gas extracted by Qatar are exported to other parts of the world at global prices, while oil and gas extracted by Iran are used for domestic consumption. Part of this consumption is for providing household gas, and the rest is for industrial purposes, including the operation of factories. Assuming the selling price of natural gas per Mmbtu is 10$, and the extraction cost per unit of gas for Iran and Qatar is 2$ and 1$ respectively, in the absence of sanctions on both countries, Iran's profit for each unit of extracted gas would be 2$, and Qatar's profit would be 6.75$. It is clear that with an increase in sanctions on Iran (reduction in Iran's absence of sanctions, denoted as

LS_i), Iran's profit is reduced, and Qatar's profit increases. The reason for the increase in Qatar's profit is that the increase in sanctions on Iran increases Qatar's extraction capacity, thereby increasing its profit.
With the increase of sanctions on Iran and assuming the absence of sanctions being equivalent to half a unit (average sanction), Iran's profit for each unit of extracted natural gas decreases by approximately one dollar, while Qatar's profit increases to 7.6 dollars. In a scenario where Iran is under severe sanctions ($LS_i = 0.1$), the country incurs losses and experiences a negative outcome for each unit of extracted natural gas ($\pi_{Iran} = -0.02$), whereas Qatar will achieve an equivalent profit of 8.25 dollars.
In the current political circumstances, where Qatar has favorable relations with advanced countries, Iran occasionally falls under sanctions. To analyze Iran's profit function under such conditions, we consider a scenario in which Qatar is not under sanctions ($LS_{-i} = 1$) and the price of each unit of gas (per unit of Mmbtu) is 10$, as well as the extraction cost of each unit of gas for Iran and Qatar is 2$ and 1$ respectively. This is considered as the base scenario. We then increment the price of each unit of gas by 10% at each stage and compare the profit function graph of Iran under different values of the factor of un-sanction.
The following chart illustrates that in the base scenario (the lowest chart), where the price of each unit of gas is considered to be 10$, Iran's profit at the point where the factor of Iran's un-sanction equals one is 2$ per unit of gas, and at the point where the factor of Iran's un-sanction is half a unit, it is approximately 1.03$. In the second scenario (the chart above the base scenario), where the price of gas has increased by 10% (to 11$), at the point where the factor of Iran's un-sanction equals one, Iran's profit is 2.25$, and at the point where the factor of Iran's un-sanction is half a unit, the profit is approximately 1.17$.

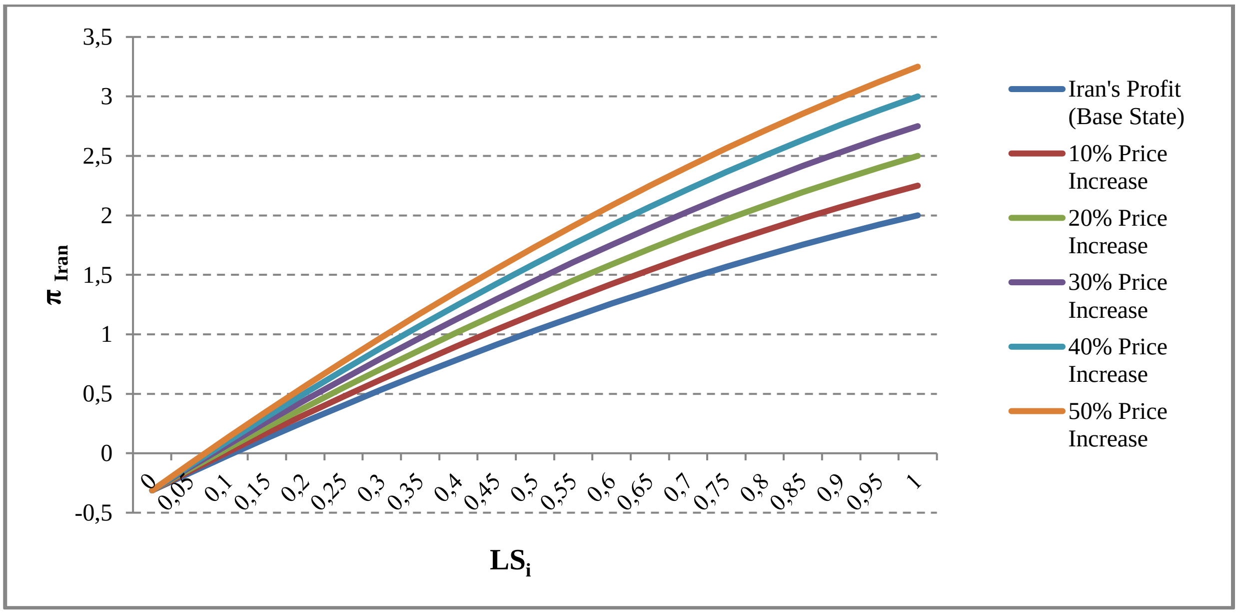

Figure 3. The Iranian Profit Function (Base Price: 10$) and a 10% Increase in Gas Price per Unit

The diagram illustrates that with a 10% increase in the price of gas at each stage, Iran's profit amount increases. To the extent that if the factor amount of un-sanction against Iran is one, at each stage, Iran's profit increases by 0.25$ compared to the previous stage.
The analysis of Iran's profit function is currently being conducted under the same conditions as when Qatar is not under sanctions ($LS_{-i} = 1$). To investigate this issue, the price of each unit of gas (per unit Mmbtu) is taken as 10 dollars and the extraction cost of each unit of gas for Iran and Qatar is assumed to be 2 dollars and 1 dollar, respectively, as the base case. At each stage, the extraction cost for Iran is increased by 10%, and the profit function graph under various levels of Iran's un-sanction factor is examined.
The following chart indicates that in the base case (the top chart) where the extraction cost of each unit of gas for Iran is considered to be 2$, Iran's profit level at the point where the factor of un-sanction against Iran equals one per unit of gas is 2$, and at the point where the level of un-sanction against Iran equals half a unit, it is about 1.03$. In the second scenario (the lower chart compared to the base case chart), where the extraction cost of each unit of gas for Iran has increased by 10% (to 2.2$), Iran's profit level at the point where the level of un-sanction against Iran equals one is 1.95$, and at the point where the level of un-sanction against Iran equals half a unit, the profit level is approximately 0.99$.
The chart indicates that with a 10% increase in the extraction cost of each unit of gas for Iran at each stage, the amount of Iran's profit decreases. To the point that if the factor amount of Iran's un-sanction is one, in each stage, Iran's profit decreases by 0.05 dollars compared to the previous stage.

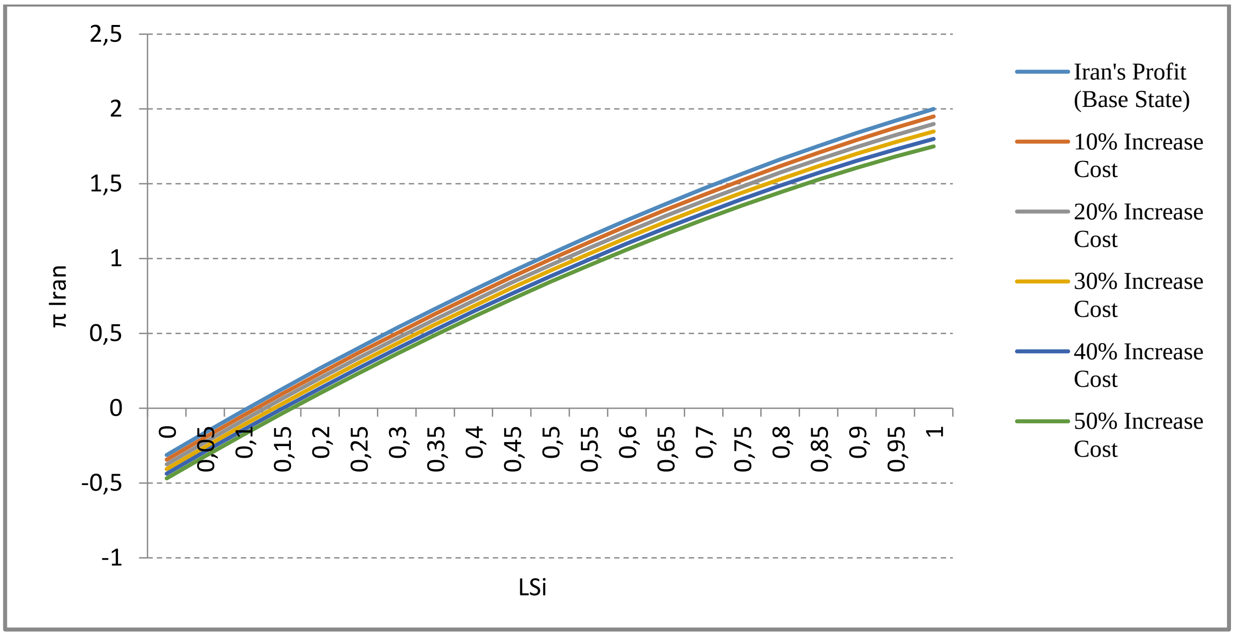

Figure 4. Iran's profit margin (gas extraction cost for Iran: 2$) and a 10% increase in extraction expenses

The diagram below shows the cost of resource extraction for Iran and Qatar, which are 2$ and 1$ respectively. When we compare the Iran profit function in different scenarios based on price, it is observed that in the base case (the upper curve) where the value of the factor *Iran sanction factor* is equal to one, if the price of each unit of extracted gas is 10$, Iran's profit is 2$, and at a price of 11$ per unit, Iran's profit will be 2.25$. In the second diagram (the lower curve from the base case) where the sanction factor has increased by 10% (the un-sanction factor equals 0.9), it is observed that when the price of each unit of gas is 10$, Iran's profit is approximately 1.84$, and at a price of 11$ per unit of gas, the profit is approximately 2.07$.

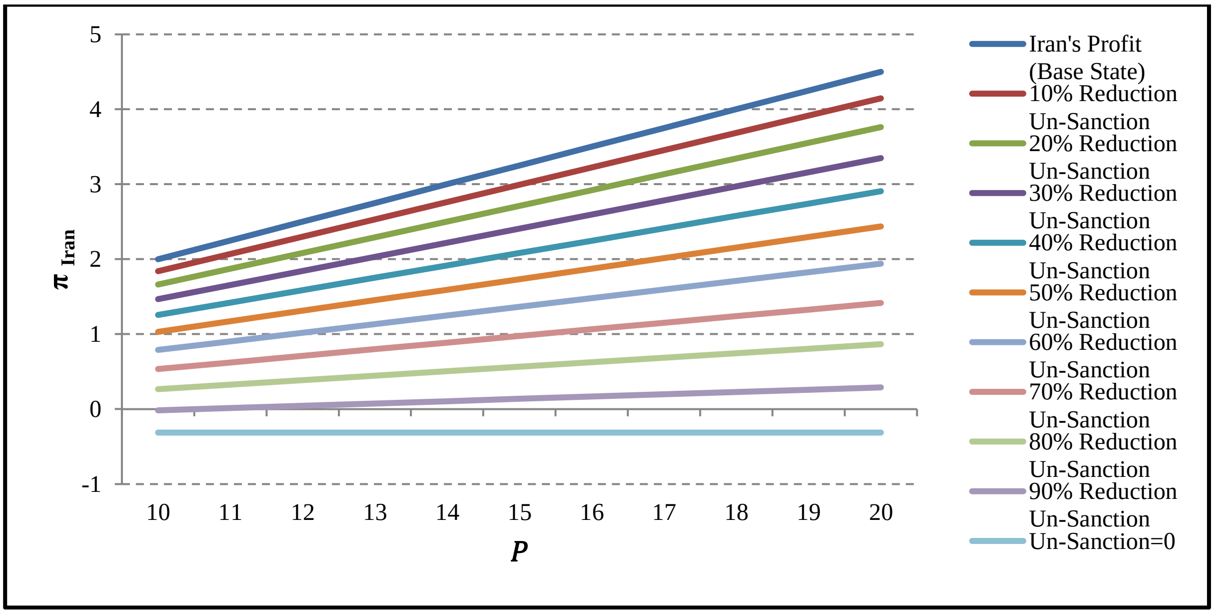

Figure 5. The Iranian surplus function (base price of gas: 10$, cost of gas extraction for Iran in the base state: 2$) and a 10% increase due to the sanction factor (10% decrease due to the un-sanction factor of Iran)

The above diagram indicates that as the price of each unit of extracted gas increases (movement on each diagram towards the right), Iran's profit increases. However, with the increase in sanctions (reduction in the un-sanction factor), Iran's profit diagram moves downwards in terms of price, indicating a decrease in Iran's profit.

Given that the purpose of writing this paper is to examine the dual factors of the parties' share of common resources and the sanction factor, we will further investigate the Nash equilibrium in modeling the exploitation of a common resource.

Currently, we consider the profit function of Iran and Qatar relative to the derivative extraction capacity. Therefore, we have:

$$\frac{\partial \pi_{iran}}{\partial EP_{Iran}} = \frac{CE_i}{LS_i(LS_i - 2)} + P \geq 0$$

$$\frac{\partial \pi_{qatar}}{\partial EP_{Qatar}} = \frac{CE_{-i}}{LS_{-i}(LS_{-i} - 2)} + P \geq 0$$

In order to find a Nash equilibrium and to determine how the impact of sanctions will affect the profits of the parties, the following results lead to the conclusion that, first, the profit function of Iran is examined. Since the denominator of the above relations is negative ($LS(LS - 2) < 0$), the numerator of the fraction must also be negative. Therefore:

$$CE_i + P(LS_i(LS_i - 2)) \leq 0$$

By substituting the values of P and CE_i, which are equal to 10 and 2 respectively, into the above inequality, we have:

$$1 - \frac{2\sqrt{5}}{5} \leq LS_i \leq 1 + \frac{2\sqrt{5}}{5}$$

The variable LS_i lies in the interval from zero to one, making values greater than 1 unacceptable. Therefore, we have:

$$0.1055 \leq LS_i \leq 1$$

The obtained result indicates that Iran's profit in the above-mentioned context is positive, although with an increase in the sanction factor (decrease in the un-sanction factor), Iran's profit will decrease. Additionally, within the range of zero to 0.1055, Iran's outcome (profit) is negative.

Now, we turn our attention to examining the profit function. Therefore, we have:

$$CE_{-i} + P(LS_{-i}(LS_{-i} - 2)) \leq 0$$

By replacing the values of P and CE_{-i} with 10 and 1, respectively, in the above inequality, we have:

$$1 - \frac{3\sqrt{10}}{10} \leq LS_{-i} \leq 1 + \frac{3\sqrt{10}}{10}$$

The variable LS_{-i} takes values in the interval from zero to one, therefore, values greater than 1 are unacceptable. Hence, we have:

$$0.0513 \leq LS_{-i} \leq 1$$

The obtained result indicates that in regard to the above, the amount of profit generated by Qatar is positive, although with an increase in the sanction factor (decrease in the un-sanction factor), the amount of profit generated by Qatar will be reduced. Also, in the range from zero to 0.0513, the consequence (profit) for Qatar is negative.

4. Conclusion

The effective management of economic resources, notably natural resources such as oil and gas, by governments is of paramount importance. Many developing countries utilize these resources to strengthen their economic infrastructure and as a source of developmental momentum. The exploitation of shared natural resources among countries necessitates responsible utilization and sustainable management of these resources. Furthermore, collaboration among countries in exploiting mutual resources contributes to resource optimization, the promotion of long-term resource sustainability, the enhancement of diplomatic relations between parties, and the promotion of peace. This initiative is aimed at achieving the economic and social development principles of countries based on the United Nations rules.

The share of each country in the common natural resource is a factor affecting the amount of extraction and utilization of the resource by each country. On the other hand, sanctions are among important factors influencing the extraction and utilization of common resources. Many factors play a role in the level of extraction of common resources, but one of these factors is the intensity of sanctions imposed on the target country. Therefore, investigating and identifying the intensity of sanctions imposed on a country is of particular importance, and in this study, this factor has been effectively considered. Furthermore, imposing sanctions against a country leads to an increase in the cost of resource extraction from the common resource. The three mentioned factors have an impact on the final utilization of each country from the common natural resource, and thus the modeling of this research has been based on these three factors. Modeling the game between two interested countries in a common natural resource has been done using game theory and utilizing the triangular distribution method.

The results of the research indicate that the level of extraction by each country from a common resource depends on the share of the stakeholders as well as the extent of sanctions imposed on the parties. Additionally, in each period, the unextracted portion of the resource (NEP) is dependent on the share factor and sanctions. The concluding section of the modeling demonstrates that in the profit function of the parties, if the un-sanction factor for Iran (LS_i) is between 0.1055 and 1 ($0.1055 \leq LS_i \leq 1$), the profit from resource extraction by Iran is positive, and if it is between 0 and 0.1055 ($0 \leq LS_i \leq 0.1055$), Iran's profit is negative. Similarly, if the un-sanction factor for

Qatar is between 0.0513 and 1 ($0.0513 \leq LS_{-i} \leq 1$), the profit from resource extraction by Qatar is positive, otherwise, Qatar's profit will be negative.

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