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Research Article

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Examining the Exploitation Strategies of Common Natural Resource (Game Theory Approach)

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Abstract

Exploitation of natural resources such as oil and gas fields, coal and water basins is very important in the economic growth of countries. The importance of this issue for countries, especially the common natural resources, is twofold. Exploitation of common resources between countries is of particular importance due to its special role in economic growth, increasing stability, reducing political tensions and promoting cooperation between countries. This study focuses on modeling the exploitation of common natural resources through the design of a static game between two countries. The modeling performed addresses the effect of each country's share of the common resource and the impact of sanctions on the benefits obtained by both parties, using a mathematical approach. The results showed that the adoption of cooperation policy by each country depends on the share of each country and the level of sanctions imposed on the interested parties. In general, each country only adopts the policy of cooperation in the exploitation of common resources if the level of sanctions imposed against the other party is low and insignificant. In other words, increasing the level of sanctions drives countries towards adopting a non-cooperative policy.

Keywords: Common natural resources, Sanction, Game theory, Nash equilibrium.

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Data Availability

In this paper, the method of game theory is used and does not include data.
1. Introduction

Exploiting common resources between countries holds great importance due to its potential to foster economic growth, enhance sustainability, and promote international cooperation (Asamoah & et al, 2019). Common resources such as oil and gas fields and freshwater basins often transcend national boundaries and require joint management and equitable use (Beyene & Wadley, 2004). This cooperative approach allows for the equitable distribution of benefits and mitigates conflicts that may arise from competing interests (Were, 2016).

The exploitation of common resources plays a significant role in addressing pressing environmental challenges on a global scale. When countries work together to combat shared environmental threats, like transboundary air pollution, the potential for positive ecological outcomes is amplified (Petersen-Perlman & Wolf, 2015). By leveraging shared resources, countries can collectively implement more effective and sustainable policies, contributing to the preservation of delicate ecosystems and the mitigation of environmental degradation. Effective cooperation and coordination between countries are essential for the sustainable exploitation of common resources (Bratland, 2006). Cooperation enhances resource efficiency, prevents overexploitation, and promotes long-term resource sustainability. For instance, the cooperation between countries in the Nile Basin has facilitated the joint management of water resources, leading to improved water allocation and conflict resolution (Kameri-Mbote, 2007).

The utilization of common resources between nations extends beyond economic and environmental considerations, playing a crucial role in fostering diplomatic relations, regional stability and promoting peace (Nguyen & Nghiem, 2021). Sharing resources can act as a catalyst for trust-building, cooperative frameworks, and conflict resolution among countries. By recognizing the interdependence resulting from common resource exploitation, countries are encouraged to develop robust governance structures, strengthen regional partnerships, and foster a sense of shared responsibility. By recognizing the shared benefits and interdependencies, countries can forge partnerships based on the principles of mutual respect, fairness, and collective responsibility.

The fair distribution of common resources involves balancing conflicting interests and ensuring that no country is disproportionately disadvantaged or excluded from accessing and utilizing these resources. A fair distribution mechanism takes into account factors such as historical rights, geographic proximity, socioeconomic conditions, and the principles of intergenerational equity. Additionally, joint exploitation of resources encourages knowledge transfer, technological advancements, and capacity building among participating nations (Ostrom, 2008). Joint management of resources, such as oil and gas fields and transboundary water bodies, enables coordinated conservation efforts and ensures the long-term viability of these essential ecosystems.

Competition for access, utilization rights, and the distribution of benefits can lead to disputes and conflicts. Conflicting interests may arise due to differing priorities, economic disparities, or unequal bargaining power. Divergent national policies, regulatory frameworks, and economic aspirations can amplify conflicts of interest between countries in the exploitation of common resources. Countries may pursue strategies that prioritize short-term gains or national self-interest, which can clash with the principles of sustainable resource management and equitable distribution. Conflicting interests may also arise when countries seek to protect and secure their access to resources, potentially leading to competition, exclusivity, and even resource hoarding. Resolving these conflicts requires comprehensive assessments of shared resources, consideration of social and environmental implications, and striving for mutually beneficial solutions.
Effective conflict resolution mechanisms are vital for addressing conflicts of interest in the exploitation of common resources between countries. International legal frameworks, such as bilateral agreements or multilateral conventions, provide avenues for negotiation, dispute settlement, and the establishment of mutually agreed-upon rules and regulations (Ostrom, 2008). The management of natural resources, especially shared natural resources that exist in border regions of countries, faces numerous challenges. When two countries have shared access to natural resources such as a river, metallic minerals, oil and gas, each has an incentive to maximize their own benefits from the resource. However, since each country strives for greater achievements, the risk of overexploitation of resources results in a tragedy of the commons (Mildenberger, 2019).

The leading challenges in operating natural resources shared between two or more countries include competition, environmental degradation, and political tensions. As a result of the competition, each country seeks to maximize profits from this shared resource, which can lead to irrational exploitation and damage to the environment. In addition to these challenges, countries that share resources may also face political tensions because each is seeking to preserve its own national interests (Lebillon, 2003). This can be observed in disputes such as the one over the use of the Nile River. Egypt, Sudan, and Ethiopia have all claimed ownership of this river, which provides a significant portion of their water resources.

One of the challenges in the field of natural resource utilization shared between countries is the existence of nationalistic sentiments among residents of that region. These sentiments often lead to conflicts over ownership and resource sharing (Poncian & Jose, 2019 and Andreasson, 2015).

If one stakeholder faces limitations such as sanctions, the other may seek to maximize their share of the resource by not cooperating. Sanctions refer to a set of actions taken to restrict or completely cut off communication, trade, or any other activities with a country, company, or individual. Usually, sanctions are a result of non-compliance with laws, legal systems, human rights, or unethical actions (Carisch & Rickard Martin, 2013). Economic sanctions often lead to restricted access to shared resources and decreased investment in affected industries. For instance, the current sanctions on Iran's oil exports have led to further restrictions on the country's petrochemical industries, resulting in a decline in investment and the dissolution of related industries (Shapovalova & et al, 2020).

The best strategy for countries to utilize shared resources depends on the conditions that are available. In some cases, cooperation is one of the best ways to benefit from shared resources. Cooperation can lead to reducing costs, sharing knowledge and experience, and increasing resource efficiency. Severe sanctions can have negative consequences, including hostile reactions and non-cooperation among countries. Sanctions can also cause economic problems and damage relationships, further reducing the likelihood of cooperation. Additionally, sanctions may impose restrictions on shared natural resources, stifle economic development, hinder international trade, and harm diplomatic relations between countries (Dudlak, 2018).

On the one hand, the challenges in the field of natural resources management become more intense due to differences in knowledge level, capacity, and political factors (including sanctions). The differences among countries in their share and extraction rate, and the unilateral approach to the extraction of a shared resource, are among the most important challenges facing countries in the extraction of shared resources. In addition, sanctions against one of the countries involved in the joint field are also a significant challenge discussed in this article. The goal of governments in extracting resources (especially shared resources) is to achieve greater social benefits and maximize revenue (Cerqueti & Ventura, 2020).
One of the characteristics of common resources between countries is that these resources are not uniformly distributed (equally) and the different share of countries can provide a relative advantage for a country that has a greater share of resources. Logical exploitation and joint development can be effective if the issue of restriction is resolved (Irsadanar & Kimura, 2021). Different legal positions in the field of territorial sovereignty in accordance with the common area are the challenges ahead of common resources (Hayashi, 2012).

Since foreign currency income from the sale of natural resources has a significant impact on government budgets (Cerqueti & Ventura, 2020 and Silva & Costa, 2019), countries are trying to exploit and extract natural resources faster. Rapid and rational exploitation of common resources between countries is of double importance. As negligence in the extraction of common resources such as oil and gas causes more extraction of these scarce resources by the rival (partner) country (due to its fluid nature). Most of the studies conducted in the field of common resources between countries have considered a symmetrical and identical situation (in terms of the parties’ share and extraction power) for the parties. While in many common resources between countries, there is not necessarily an equal share or the same extraction power. For example, in South Pars field - Northern Dome (common field between Iran and Qatar), Iran’s share is 25% and Qatar’s share is 75%. Also, the extraction power of Iran (due to the imposition of international sanctions against this country) is far less than the extraction power of Qatar. In this study, it has been tried to examine the situation of the countries in terms of share and power of extraction in different states, and this factor is the innovation aspect of the study.

Since there is a conflict of interests in the mutual relations between countries regarding the extraction and exploitation of shared resources, the main issue of these present researches is to determine how strategic behavior between countries is in the extraction of these shared resources, and which strategy (cooperation or non-cooperation) is optimal for players in exploiting a shared resource. Additionally, how does the factor of sanctions and unequal share of the parties affect the exploitation of shared resources?

After this introduction, the article continues with a detailed examination of the literature in the next section. Section 3 describes the methods used and the data analyzed. In Section 4, we present the empirical results, and Section 5 concludes with an overview, including a discussion of policy implications.

2. Literature Review

The strategies of countries that share resources such as metal mines, oil and gas, and water are important for both resource-rich nations and those that rely on imports. These resources are especially valuable for developing nations, as their government budgets often depend heavily on revenue from their sale.

The studies that have been written in the field of strategies for exploiting a common resource have mainly adopted three approaches:

i. Determining the optimal strategy through political and legal policies

ii. Determining the optimal strategy through the game matrix form

iii. Determining the optimal strategy through modeling

Table 1 lists a number of studies that have investigated common resources between countries through political and legal policies.

Table 1

<table>
<thead>
<tr>
<th>Research Approach</th>
<th>Authors (Year)</th>
<th>Case Study</th>
<th>Key Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Political &amp; Legal Approach</td>
<td>Hayashi (2012)</td>
<td>China &amp; Japan</td>
<td>The participation of the Japanese in the development of a joint field with</td>
</tr>
</tbody>
</table>
Table 2: Studies conducted in the field of shared resources with the approach of game matrix form

<table>
<thead>
<tr>
<th>Research Approach</th>
<th>Authors (Year)</th>
<th>Case Study</th>
<th>Key Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static Game</td>
<td>Sheikhmohammadi &amp; et al (2011)</td>
<td>Iran &amp; United Arab Emirates</td>
<td>Commitment to negotiation and prevention of military actions</td>
</tr>
<tr>
<td></td>
<td>Li &amp; et al (2013)</td>
<td>Russia &amp; China</td>
<td>Adherence to cooperation of the parties and joint development of the oil field</td>
</tr>
<tr>
<td></td>
<td>Schitka (2014)</td>
<td>General State</td>
<td>Presenting suggestions on how to resolve potential deadlocks in negotiations between parties for the purpose of comprehensive agreements on oil and gas field integration</td>
</tr>
<tr>
<td></td>
<td>Esmaeili &amp; et al (2015)</td>
<td>Iran &amp; Iraq &amp; Qatar</td>
<td>How to adopt an optimal strategy for the exploitation of common resources</td>
</tr>
<tr>
<td></td>
<td>Havas (2015)</td>
<td>Norway &amp; Russia</td>
<td>Expectation of higher investment return through faster extraction of resources</td>
</tr>
<tr>
<td></td>
<td>Bayati &amp; et al (2019)</td>
<td>Iran &amp; Qatar</td>
<td>Non-cooperation by the parties in the exploitation of common resources</td>
</tr>
<tr>
<td></td>
<td>Toufighi &amp; et al (2020)</td>
<td>Iran &amp; Saudi Arabia</td>
<td>Commitment to cooperation by Iran &amp; non-commitment to cooperation by Saudi Arabia</td>
</tr>
<tr>
<td></td>
<td>Bahrini &amp; et al (2021)</td>
<td>General State</td>
<td>Using the Graph Model for Conflict Resolution</td>
</tr>
<tr>
<td></td>
<td>Salimian &amp; et al (2023)</td>
<td>General State</td>
<td>Adherence or non-adherence based on the parties share and extraction power</td>
</tr>
</tbody>
</table>

Source: research findings

Table 3: Studies conducted in the field of common resources with a modeling approach

<table>
<thead>
<tr>
<th>Research Approach</th>
<th>Authors (Year)</th>
<th>Case Study</th>
<th>Key Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modling</td>
<td>Caputo &amp; Lueck (2003)</td>
<td>General State</td>
<td>Creating sustainable income through shared ownership</td>
</tr>
<tr>
<td></td>
<td>Salimian &amp; Shahbazi (2017)</td>
<td>General State</td>
<td>Extract more resources with less effort</td>
</tr>
<tr>
<td></td>
<td>Mamada and Perrings (2022)</td>
<td>General State</td>
<td>Ensuring joint action resulting from interdependence</td>
</tr>
</tbody>
</table>

Source: research findings
This study attempts to examine the static game of stakeholders utilizing a common resource using mathematical and game theoretic concepts.

3. Methodology

In the methodology section, first the theory of games is explained and then the modeling of the static game between two countries in the exploitation of a common resource is explained based on the economic profit function and with a mathematical approach. The modeling done is based on the two factors of parties' contribution and extraction power.

3.1. Game theory

Game theory uses models and mathematical relationships to analyze the cooperative or competitive behavior of logical and intelligent entities and attempts to model the mathematical behaviors governing strategic situations and conflict of interest (Osborne & Rubinstein, 2012). Game theory has many applications in the development of various sciences, including economics, social sciences, and more (Colman, 2021). Many modelers use game theory because it allows them to think like an economist when the price theory is not responsive (Gibbons, 1997). Game theory aims to model situations where individuals' interests are in conflict. The ultimate goal of this knowledge is to find the optimal strategy for players (Salimian & Shahbazi, 2017).

In static games with complete information, each player selects their strategy with full knowledge of the rival player's interests, while being unaware of the rival player's strategy choice. In other words, players simultaneously choose their own strategy without knowing their opponent's strategy choice (Pindyck, 2018). Another fundamental assumption is that the consequences of the game are known to all players. The resulting equilibrium in static games is called the Nash equilibrium and is defined as follows:

\[ u_i(\sigma_i, \sigma_{-i}) \geq u_i(\sigma_i', \sigma_{-i}) \]

The best player's strategy is to have the optimal response to the selected performance of other competitors (Mas-Colell, 1995), equilibrium occurs when firstly, each player chooses a strategy based on their belief towards the rival's choice that delivers the maximum outcome for them, and secondly, the player's belief is correct, meaning that the rival actually chooses the strategy that has taken form in the player's belief. The strategies that players choose through this method form their equilibrium strategy (Shy, 1995).

Some games have this important feature where choosing one strategy is preferred for some or all players over choosing any other strategies, because the outcome of this strategy is more desirable and has a greater consequence for that player compared to choosing any other strategies. Naturally, in this situation, regardless of the strategy chosen by other players (opponents), that player must choose the preferred strategy. This strategy is called the dominant strategy, and the other strategies of that player are called dominated strategies (von Neumann and Morgenstern, 1994). If each player in a game has a dominant strategy, it is natural for them to choose that dominant strategy. Therefore, the combination of strategies that are formed from the dominant strategies of players is called the dominant strategy equilibrium (Osborne, 2004).

The game elements are a common resource shared by two countries, and each of these two countries will have two options to start the game: either commit to cooperation (C) or not commit to cooperation (NC).

The set of strategies for the two players is as follows:

\[ S_1 = \{C, NC\} \]
\[ S_2 = \{C, NC\} \]

The combination of the two countries' strategies is as follows:
\[ S = S_1 \ast S_2 = \{(C, C), (C, NC), (NC, C), (NC, NC)\} \]

The consequences of players (from two countries involved in a common resource) are derived from the economic profit function and are based on the defined conditions in the modeling section.

3.2. Modeling

To determine the outcomes of different strategies in a typical game between countries, it is necessary to determine the preference for each player. When it comes to using a common resource, the best outcome for each country is when that country does not cooperate while the other side does.

On the other hand, the worst possible outcome occurs when the target country commits to cooperation while the other country does not. To fill in the cells of the matrix, we use the profit function. This function measures economic profit by calculating the difference between revenue and explicit and opportunity costs. Now we proceed to explain the components and variables of the model:

Table 4

<table>
<thead>
<tr>
<th>Variable</th>
<th>The amount and value of each variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \alpha )</td>
<td>The share of the country 1</td>
</tr>
<tr>
<td>( 1 - \alpha )</td>
<td>The share of the country 2</td>
</tr>
<tr>
<td>( p )</td>
<td>Selling price of resources</td>
</tr>
<tr>
<td>( q )</td>
<td>The number of extracted units of resources</td>
</tr>
<tr>
<td>( S_1 )</td>
<td>The amount of sanctions imposed on the country 1</td>
</tr>
<tr>
<td>( S_2 )</td>
<td>The amount of sanctions imposed on the country 2</td>
</tr>
<tr>
<td>( \beta )</td>
<td>Adjustment factor: in this research, its size has been considered as 0.1</td>
</tr>
<tr>
<td>( c )</td>
<td>The cost of extracting each unit of resources</td>
</tr>
</tbody>
</table>

Source: research findings

The significant aspect of this scenario relates to the calculation of revenue and extraction costs. The scenario assumes that a common resource can produce \( q \) units in each period, which can then be sold at a price of \( p \). The revenue component, which takes into account each country's initial share of the common resource and the level of sanctions, is calculated using the following equation.

For Country 1:
\[
\left( \frac{\alpha(1-S_1)}{1+S_1} \right) qp
\]

For Country 2:
\[
\left( \frac{(1-\alpha)(1-S_2)}{1+S_2} \right) qp
\]

As previously stated, \( \alpha \) and \( 1-\alpha \) represent the share of country 1 and country 2, respectively, from the common resource \((0 \leq \alpha \leq 1)\). In the real world, the value of sanctions is not fixed, so for simplicity, the value of the sanctions is considered in the range of zero to one \((0 \leq S \leq 1)\). No sanctions are represented by \( S=0 \) and severe sanctions are represented by \( S=1 \). In other words, as sanctions against a country increase, the variable \( S \) increases. The above equation is for the case where each country adheres to a policy of cooperation with the other party. For example, if country 1 is willing to cooperate with the other party and is not subject to sanctions \((S_1 = 0)\), the amount of resource extraction by country 1 will be equal to
the initial share (α). However, if the level of sanctions imposed on country 1 is 0.2 or 0.5 units, the amount of resource extraction by country 1 will be reduced to 0.66 and 0.33 of its initial share, respectively. If country 1’s initial share of the common resource is 0.5 units and the level of sanctions imposed on it is 0.2 or 0.5 units, the final amount of resource extraction in each period will be 0.33 and 0.16, respectively. Therefore, as the level of sanctions increases, the amount of resource extraction and consequently income decreases.

If either or both countries fail to cooperate with each other, the revenue share will depend not only on the initial share and the sanctions levied on that country but also on the sanctions imposed on the opposite party.

\[
\text{for Country 1: } \left(\frac{\alpha(1-S_2)}{1+S_1} + \beta S_2\right) q p \quad \& \quad \text{for Country 2: } \left(\frac{(1-\alpha)(1-S_2)}{1+S_2} + \beta S_1\right) q p
\]

The relationship above indicates that if a country is under sanctions, the amount of its initial share will be reduced. However, if the opposing party is also under sanctions, this country can extract more resources to some extent, although this increase in resource extraction resulting from the imposition of sanctions against the opposing party cannot compensate for the decrease in resource extraction due to sanctions against itself. For example, if the stakeholders in a joint resource have an equal share and the level of sanctions imposed on these two countries is 0.5 units, then each country extracts about 0.16 resources without considering the sanctions on the opposing party. The 0.5-unit sanction imposed on the opposing party causes the amount of resource extraction to increase by \(\beta S\), and therefore the total amount of resource extraction increases from 0.16 to about 0.19.

The cost portion, which is a function of each country’s initial share of the common resource and the level of sanctions, is calculated from the following equation:

\[
\text{for Country 1: } \left(\frac{\alpha(1-S_1)}{1+S_1} \right) q c \quad \& \quad \text{for Country 2: } \left(\frac{(1-\alpha)(1-S_2)}{1+S_2}\right) q c
\]

The above relationship pertains to a scenario where each country cooperates with the opposing party. If a country cooperates and is not under sanctions, it can extract resources at the same initial share (α) multiplied by the extraction cost. If a country has an initial share of 0.5 units and faces sanctions of 0.2 or 0.5 units, its final extractions cost will be 0.33c and 0.16c, respectively. Cooperative extraction ensures a constant cost per unit of resources.

When one or both countries fail to cooperate with each other, the cost of extracting each unit of resources increases. This cost is determined by the initial share of resources and the level of sanctions imposed on the non-cooperating country.

\[
\text{for Country 1: } \left(\frac{\alpha(1-S_1)}{1+S_1} + \beta S_2\right) q \left(1 + \frac{\alpha S_1}{\alpha + S_1}\right) c \\
\text{for Country 2: } \left(\frac{(1-\alpha)(1-S_2)}{1+S_2} + \beta S_1\right) q \left(1 + \frac{(1-\alpha)S_2}{(1-\alpha) + S_2}\right) c
\]

The above relationship suggests that if a country is subject to sanctions, its initial cost of resource extraction rises. For example, if Country 1 does not face sanctions, then the cost of extracting each unit of resources is equivalent to the initial cost. However, in cases where this country’s share of common resources is 0.5 units and the extent of sanctions imposed on this country ranges from 0.25 to 0.5 units, the final cost would be 1.125 to 1.25 times the initial cost, respectively.

4. Results
The process of modeling the static game of two players for exploiting a common resource is as follows.

### Table 5

The game matrix between two countries in exploiting a common natural resource

<table>
<thead>
<tr>
<th>Country 1</th>
<th>Country 2</th>
<th>C</th>
<th>NC</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>$\pi_1(C,C)$, $\pi_2(C,C)$</td>
<td>$\pi_1(C,NC)$, $\pi_2(C,NC)$</td>
<td></td>
</tr>
<tr>
<td>NC</td>
<td>$\pi_1(\text{NC, C})$, $\pi_2(\text{NC, C})$</td>
<td>$\pi_1(\text{NC, NC})$, $\pi_2(\text{NC, NC})$</td>
<td></td>
</tr>
</tbody>
</table>

Source: research findings

We are examining the economic profit function of each country based on mathematical relationships in different situations.

\[
\pi_1(C,C) = \left( \frac{\alpha(1 - S_1)}{1 + S_1} \right) q_p - \left( \frac{\alpha(1 - S_1)}{1 + S_1} \right) q_c
\]

\[
\pi_2(C,C) = \left( \frac{(1 - \alpha)(1 - S_2)}{1 + S_2} \right) q_p - \left( \frac{(1 - \alpha)(1 - S_2)}{1 + S_2} \right) q_c
\]

\[
\pi_1(C,NC) = \left( \frac{\alpha(1 - S_1)}{1 + S_1} \right) q_p - \left( \frac{\alpha(1 - S_1)}{1 + S_1} \right) q_c
\]

\[
\pi_2(C,NC) = \left( \frac{(1 - \alpha)(1 - S_2)}{1 + S_2} \right) q_p - \left( \frac{(1 - \alpha)(1 - S_2)}{1 + S_2} \right) q_c
\]

\[
\pi_1(NC,C) = \left( \frac{\alpha(1 - S_1)}{1 + S_1} + \beta S_1 \right) q_p - \left( \frac{\alpha(1 - S_1)}{1 + S_1} + \beta S_1 \right) q \left( 1 + \frac{(1 - \alpha)S_2}{\alpha + S_1} \right) c
\]

\[
\pi_2(NC,C) = \left( \frac{(1 - \alpha)(1 - S_2)}{1 + S_2} + \beta S_2 \right) q_p - \left( \frac{(1 - \alpha)(1 - S_2)}{1 + S_2} + \beta S_2 \right) q \left( 1 + \frac{\alpha S_1}{\alpha + S_1} \right) c
\]

\[
\pi_1(NC,NC) = \left( \frac{\alpha(1 - S_1)}{1 + S_1} + \beta S_1 \right) q_p - \left( \frac{\alpha(1 - S_1)}{1 + S_1} + \beta S_1 \right) q \left( 1 + \frac{(1 - \alpha)S_2}{\alpha + S_1} \right) c
\]

\[
\pi_2(NC,NC) = \left( \frac{(1 - \alpha)(1 - S_2)}{1 + S_2} + \beta S_2 \right) q_p - \left( \frac{(1 - \alpha)(1 - S_2)}{1 + S_2} + \beta S_2 \right) q \left( 1 + \frac{(1 - \alpha)S_2}{(1 - \alpha) + S_2} \right) c
\]

The strategy (C,C) implies that both countries adhere to cooperation in extracting resources. Each of the countries, based on their initial share and considering the sanction factor (which leads to a decrease in each country’s initial share), will extract a portion of the shared resources. In this situation, where both countries are willing to cooperate in resource extraction, the cost of extracting each unit of the shared resources is c.

The strategy (C,NC) suggests that Country 1 is committed to cooperation, whereas Country 2 has no interest in collaborating in resource extraction. As a result of the imposed sanctions, Country 1’s share of extracted resources decreases while Country 2 compensates for some of this decrease due to its lack of commitment to cooperation. This is attributed to the restrictions imposed on Country 1 and the absence of collaboration from Country 2. The
cost of extracting each unit of resource for Country 1 remains constant, while Country 2's cost increases as a consequence of the sanctions.

The strategy (NC,C) implies that Country 1 does not tend to cooperate with the opposing party in extracting common resources, while Country 2 continues to adhere to a policy of cooperation. In this situation, a contrary trend to what was mentioned in the previous situation arises.

The strategy (NC,NC) implies that the parties involved do not have an interest in cooperating in the extraction of a shared resource. In this situation, each country cannot extract its initial share due to the sanctions imposed on it, and therefore the amount extracted by each country decreases. However, part of this decrease is compensated due to the sanctions imposed on the other party, and the extraction cost also increases due to the sanctions imposed on both countries.

For simplicity in expressing the content, let's assume that the natural resource shared between two countries is an oil field from which 1000 barrels of oil are extracted in each period \( q = 1000 \), and each barrel of oil is sold in the market for \$100 \( p = 100 \) , while the cost of extracting each barrel of oil is approximately \$10 \( c = 10 \$ \).

Now we are examining the behavioral strategies of the parties in the game. If Country 2 adopts a policy of cooperation in resource extraction, what policy will Country 1 adopt, taking into account factors such as the initial share, sanctions, etc.? If \( \pi_1(C,C) \geq \pi_1(NC, C) \), or in other words, \( \pi_1(C,C) - \pi_1(NC, C) \geq 0 \), Country 1 remains committed to cooperating with the other side in resource extraction. Therefore, we have:

\[
\left( \frac{\alpha(1 - S_1)}{1 + S_1} \right) q_1 p - \left( \frac{\alpha(1 - S_1)}{1 + S_1} \right) q_1 c - \left( \frac{\alpha(1 - S_1)}{1 + S_1} + \beta S_2 \right) q_1 p - \left( \frac{\alpha(1 - S_1)}{1 + S_1} + \beta S_2 \right) q_1 \left( 1 + \frac{\alpha S_1}{\alpha + S_1} \right) c \geq 0
\]

With solving the above equation, the following relationship is obtained:

\[
S_2^2(\alpha - 9) - 10\alpha S_2 + S_1(10\alpha^2 - S_2(8\alpha + 9)) - 9S_2\alpha \geq 0
\]

Since the denominator of the above expression is positive, the numerator must also be positive in order to establish a relationship. Therefore:

\[
S_2^2(\alpha - 9) - 10\alpha S_2 + S_1(10\alpha^2 - S_2(8\alpha + 9)) - 9S_2\alpha \geq 0
\]

The result of the above relationship is as follows:

\[
\text{if } S_2^2(\alpha - 9) - S_1(8\alpha + 9) - 9\alpha < 0 \Rightarrow S_2 \leq \frac{10S_1\alpha^2(S_1 - 1)}{S_2^2(\alpha - 9) - S_1(8\alpha + 9) - 9\alpha}
\]

\[
\text{if } S_2^2(\alpha - 9) - S_1(8\alpha + 9) - 9\alpha > 0 \Rightarrow S_2 \geq \frac{10S_1\alpha^2(S_1 - 1)}{S_2^2(\alpha - 9) - S_1(8\alpha + 9) - 9\alpha}
\]

Among the two aforementioned relationships, only the first relationship is correct and logical. Therefore, based on this inequality, a range of sanctions can be obtained for country 2, which is a function of the share and sanctions of country 1, and in that range, country 1 has a tendency to adhere to cooperation in resource extraction.

\[
S_2 \leq \frac{10S_1\alpha^2(S_1 - 1)}{S_2^2(\alpha - 9) - S_1(8\alpha + 9) - 9\alpha}
\]

<table>
<thead>
<tr>
<th>Table 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Necessary condition for the adherence of country 1 to cooperation</td>
</tr>
<tr>
<td>( \alpha = 0.25 )</td>
</tr>
</tbody>
</table>
For example, if the share of the first country from the common resource is 0.25 units and the level of sanctions imposed on country 1 is 0.25 units, a range of sanctions against country 2 is mentioned ($S_2 \leq 2.11\%$), within which country 2 pursues a policy of cooperation in the extraction of common resources. In other words, if the above inequality ($S_2 \leq 2.11\%$) is satisfied, the first country will pursue cooperation. Otherwise, it will adopt a non-compliant policy towards cooperation, as demonstrated by the above example.

On the other hand, if country 2 adopts a policy of non-cooperation in resource extraction, what policy will country 1 pursue considering factors such as initial share components, sanctions, etc.? If $\pi_1(C, NC) \geq \pi_1(NC, NC)$ or $\pi_1(C, NC) - \pi_1(NC, NC) \geq 0$, Country 1 remains committed to cooperation with the opposite party in resource extraction. Therefore, we have:

$$\left(\frac{\alpha(1 - S_1)}{1 + S_1}\right) q_p - \left(\frac{\alpha(1 - S_1)}{1 + S_1}\right) q_c - \left(\frac{\alpha(1 - S_1)}{1 + S_1} + \beta S_2\right) q_p - \left(\frac{\alpha(1 - S_1)}{1 + S_1} + \beta S_2\right) q \left(1 + \frac{\alpha S_1}{\alpha + S_1}\right) c \geq 0$$

Similar to the previous situation, and by solving the above equation, the following relation is obtained:

$$S_2^2(\alpha - 9) - 10\alpha^2 + S_1(10\alpha^2 - S_2(8\alpha + 9)) - 9S_2^2 \geq 0$$

Since the denominator of the above expression is positive, in order to establish a relationship, the numerator must also be positive. Therefore:

$$S_2^2(\alpha - 9) - 10\alpha^2 + S_1(10\alpha^2 - S_2(8\alpha + 9)) - 9S_2^2 \alpha \geq 0$$

The result of the above relationship is as follows:

If $S_2^2(\alpha - 9) - 9S_2^2(8\alpha + 9) - 9\alpha < 0 \Rightarrow S_2 \leq \frac{10S_1\alpha^2(S_1 - 1)}{S_2^2(\alpha - 9) - S_1(8\alpha + 9) - 9\alpha}$

If $S_2^2(\alpha - 9) - S_1(8\alpha + 9) - 9\alpha > 0 \Rightarrow S_2 \geq \frac{10S_1\alpha^2(S_1 - 1)}{S_2^2(\alpha - 9) - S_1(8\alpha + 9) - 9\alpha}$

Among these two relationships, only the first relationship is correct and logical. Therefore, to maintain country 1’s commitment to cooperation in resource extraction, a range of sanctions against country 2 is specified based on the share of country 1 and the sanctions, subject to the following inequality, within which country 1 adopts a policy of cooperation in resource extraction.

$$S_2 \leq \frac{10S_1\alpha^2(S_1 - 1)}{S_2^2(\alpha - 9) - S_1(8\alpha + 9) - 9\alpha}$$

Table 7

<table>
<thead>
<tr>
<th>Country 1</th>
<th>$\alpha = 0.25$</th>
<th>$\alpha = 0.5$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S_1 = 0.25$</td>
<td>$S_2 \leq 2.11%$</td>
<td>$S_2 \leq 5.66%$</td>
</tr>
<tr>
<td>$S_1 = 0.5$</td>
<td>$S_2 \leq 1.57%$</td>
<td>$S_2 \leq 4.76%$</td>
</tr>
</tbody>
</table>
The question at hand is whether Country 1 has a dominant strategy. Since the two inequations obtained for $S_2$ overlap, Country 1 will always adopt a cooperative policy if these inequations are valid. On the other hand, if these inequations are not valid simultaneously, Country 1’s dominant strategy would be to not cooperate in the extraction of a common resource with its counterpart.

On the other hand, if country 1 pursues a policy of cooperation in resource extraction, what policy will country 2 adopt considering factors such as initial share, sanctions, etc.? If the relationship of $\pi_2(C, C) \geq \pi_2(C, NC)$ ($\pi_2(C, C) - \pi_2(C, NC) \geq 0$) holds, country 2 will remain committed to cooperating with the counterpart in resource extraction. Therefore, we have:

$$\frac{((1 - a)(1 - S_2) - (1 - a)(1 - S_2))}{1 + S_2} q_p - \frac{((1 - a)(1 - S_2) + \beta S_1)}{1 + S_2} q_c - \frac{((1 - a)(1 - S_2) + \beta S_1) q (1 + (1 - a) S_2)}{(1 - a) + S_2} \geq 0$$

Since the denominator is always positive, the numerator of this fraction must be negative in order for the overall fraction to be negative. Therefore:

$$S_1 (S_2 + 1) (S_2 (a + 8) - 9 (a - 1)) + 10 S_2 (S_2 - 1) (a - 1)^2 \leq 0$$

The result of the above inequality is as follows:

If $(s_2 + 1) (s_2 (a + 8) - 9 (a - 1)) < 0$ ⇒ $S_1 \geq \frac{10 S_2 (1 - S_2) (a - 1)^2}{(S_2 + 1) (S_2 (a + 8) - 9 (a - 1))}$

If $(s_2 + 1) (s_2 (a + 8) - 9 (a - 1)) > 0$ ⇒ $S_1 \leq \frac{10 S_2 (1 - S_2) (a - 1)^2}{(S_2 + 1) (S_2 (a + 8) - 9 (a - 1))}$

Among the two aforementioned relationships, only the second relationship is valid and logical. Therefore, a range of sanctions imposed on country 1 is specified, which is a function of the share and sanctions imposed on country 2, and within that range, country 1 adopts a policy of cooperation in the extraction of common resources.

$$S_1 \leq \frac{10 S_2 (1 - S_2) (a - 1)^2}{(S_2 + 1) (S_2 (a + 8) - 9 (a - 1))}$$

### Table 8

<table>
<thead>
<tr>
<th>Country 2</th>
<th>$\alpha = 0.25$</th>
<th>$\alpha = 0.5$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S_2 = 0.25$</td>
<td>$S_1 \leq 9.57%$</td>
<td>$S_1 \leq 5.66%$</td>
</tr>
<tr>
<td>$S_2 = 0.5$</td>
<td>$S_1 \leq 8.62%$</td>
<td>$S_1 \leq 4.76%$</td>
</tr>
</tbody>
</table>

Source: research findings
For example, if the share of country 2 from the common resource is 0.75 units (\( \alpha = 0.25 \)) and the level of sanctions imposed against this country is 0.25 units, a range of sanctions imposed (\( S_1 \leq 9.57 \% \)) on country 1 is specified within which country 2 pursues a policy of cooperation in the extraction of common resources.

But if Country 1 does not adhere to cooperation with the other party in the extraction of the common resource, what policy will Country 2 pursue based on the share factors and sanctions? If \( \pi_2(\text{NC,} C) \geq \pi_2(\text{NC,} NC) \) and thus \( \pi_2(\text{NC,} C) - \pi_2(\text{NC,} NC) \geq 0 \), Country 2 will remain committed to cooperation with the other party in resource extraction. Therefore, we have:

\[
\left(\frac{1 - \alpha}{1 + S_2}\right) q_p - \left(\frac{1 - \alpha}{1 + S_2}\right) q_c - \left(\frac{(1 - \alpha)(1 - S_2)}{1 + S_2} + \beta S_1\right) q_p - \left(\frac{(1 - \alpha)(1 - S_2)}{1 + S_2} + \beta S_1\right) q \left(\frac{1}{1 + S_2}\right) c \geq 0
\]

The following relationship is obtained by solving the above equation:

\[
\frac{S_1(S_2 + 1)(S_2(\alpha + 8) - 9(\alpha - 1)) + 10(S_2 - 1)(\alpha - 1)(S_2(\alpha + 9008) - 9009(\alpha - 1))}{(S_2 + 1)(S_2 + 1 - \alpha)} \geq \frac{90000(S_2 - 1)(\alpha - 1)}{S_2 + 1}
\]

With solving the above equation, we have:

\[
\text{if} \quad \frac{S_2(\alpha + 8) - 9(\alpha - 1)}{S_2 + (1 - \alpha)} < 0 \Rightarrow S_1 \leq \frac{10(1 - \alpha)(S_2 - 1)}{S_2 + 1}
\]

\[
\text{if} \quad \frac{S_2(\alpha + 8) - 9(\alpha - 1)}{S_2 + (1 - \alpha)} > 0 \Rightarrow S_1 \geq \frac{10(1 - \alpha)(S_2 - 1)}{S_2 + 1}
\]

Out of the two above-mentioned incongruous situations, only the second case is acceptable and correct. Therefore, we have:

\[
S_1 \geq \frac{10(1 - \alpha)(S_2 - 1)}{S_2 + 1}
\]

Table 9

| Necessary condition for the adherence of country 1 to cooperation |
|-------------------|-------------------|
| \( \alpha = 0.25 \) | \( \alpha = 0.5 \) |
| \( S_2 = 0.25 \) | \( S_1 \geq -\frac{9}{2} \) | \( S_1 \geq -3 \) |
| \( S_2 = 0.5 \) | \( S_1 \geq -\frac{5}{2} \) | \( S_1 \geq -\frac{5}{3} \) |

Source: research findings

Because the suitable and defined range of \( S_1 \) is between zero and one, the obtained range in the above table is unacceptable, and country 2 adopts a cooperative policy in this situation. If both of the recent scenarios equivalent to \( S_1 \) occur at the same time, then the dominant strategy for country 2 is to cooperate, and adherence to that strategy will ensue. If, on the other hand, the two scenarios do not occur simultaneously, the dominant strategy for country 2 will be to not adhere to cooperation with the other party during extraction of the common resource.
For example, if the second country's share of the joint natural resource is 0.5 units and the amount of sanctions imposed on this country is 0.5 units, regardless of whether the first country cooperates or not, if the level of sanctions imposed on the first country is less than 5.37% (In other words $0 \leq S_1 \leq 5.37\%$), then adherence to cooperation in extracting shared resources is the dominant strategy of the second country.

The results show that each country adopts a strategy of cooperation in exploiting common resources only if the level of sanctions imposed against the other party is very low (less than 10%). Otherwise, countries will adopt a policy of non-cooperation in extracting common resources.

5. Conclusion

The exploitation of natural resources is of significant importance due to the economic benefits, such as an increase in foreign income and investments in countries that possess these resources, creating sustainable development, and strengthening diplomatic relationships. However, natural resources located on political borders can create tensions between countries, leading to political and competitive disputes over early extraction to maximize benefits. Failure to adhere to cooperation in resource extraction can cause political and military tensions, as well as increased environmental pollution. In contrast, joint cooperation in natural resource exploitation offers opportunities for optimizing natural resource use, promoting environmental sustainability, driving economic development, enhancing solidarity, and fostering regional stability. However, international sanctions against one or both interested parties can restrict the exploitation and extraction of resources.

The results showed that the adoption of cooperation policy by each country depends on the share of each country and the level of sanctions imposed on the interested parties. In general, each country only adopts the policy of cooperation in the exploitation of common resources if the level of sanctions imposed against the other party is low and insignificant.

References


Maddahinasab, M. (2018). Legal and philosophical analysis of ownership and sovereignty over hydrocarbon resources in concern with issues on internationally shared hydrocarbon reservoirs (Doctoral dissertation, University of Zurich).


