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Expanding the Cournot Competition Model Considering Sanctions and Resource Share

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Abstract

One of the most important problems in the exploitation of shared natural resources is the difference in the parties' shares, the energy source, the type of technology used in resource exploitation, ensuring the necessary capital for extraction and field development, and so on. In exploiting shared natural resources, it is not possible to simply rely on the principle of national sovereignty and unilaterally engage in the exploitation of these resources. Rational exploitation and joint development can only be effective if the issue of defining boundaries has been resolved. One of the most existing models in the field of exploiting shared natural resources is the Cournot Competition model, but this model is designed based on simple assumptions. This study applies game theory to modify the classical Cournot competition model. A more comprehensive framework is developed by incorporating critical variables specifically, each country's resource share and the impact of sanctions. The results indicate that each country's extraction capacity is directly related to its share of the shared resource and inversely related to the sanction factor. Additionally, each country's "best response" function is not only a function of the level of extraction and total supply (b) and extraction costs but also a function of the interested parties' share of the shared resource and their extraction capacity.

Highlights

- There is a conflict of interest between countries in extracting and exploiting common resources.
- This paper is an extension of Cornot competition based on the conditions of asymmetric use of resources and unequal mining power (sanction level).
- Cournot competition model considers a state of infinite state in this model, a state in which only the share of the two parties involved in the common source is equal and the sanction factor for both countries is zero or equal.
- The extracting power of each country has a direct relationship with that country's share of the common resource and an inverse relationship with the sanctions factor.
- Power function of the extraction of the parties and the undeveloped extraction capacity function depend on the share of the parties as well as the level of sanctions imposed on those countries.

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1. Introduction

The strategic governance of transboundary natural resources is essential for promoting economic resilience, environmental sustainability, and geopolitical stability (Ruiz Serrano et al, 2024). In many developing countries, national economies are deeply intertwined with revenues from the export of nonrenewable resources, particularly hydrocarbons, which exposes them to significant fiscal risks due to fluctuations in global commodity markets (Daniel et al, 2013). These vulnerabilities complicate macroeconomic management and hinder long-term planning. Effective management of shared resources, such as oil reserves, gas fields, and transboundary water systems, requires cooperative frameworks that ensure equitable access and sustainable utilization (Dinar, 2004).

International collaboration in managing these shared ecosystems not only promotes efficient resource use but also builds mutual trust, fosters diplomatic ties, and reduces the likelihood of conflict stemming from competing national interests (Woods, 2023). Establishing joint institutions and multilateral agreements enables countries to exchange knowledge, harmonize regulations, and invest in technological innovation that supports long-term environmental stewardship (Dombrowsky, 2007). However, disparities in national priorities, regulatory frameworks, and economic capacities can challenge these efforts. The case of the Lake Victoria Basin illustrates how fragmented governance and unilateral decision-making often hinder collective sustainability goals and exacerbate regional tensions (Were, 2016).

The resolution of such conflicts relies heavily on robust legal frameworks, including bilateral and multilateral agreements that facilitate negotiation and institutionalize cooperation (Cusato, 2020). By adhering to international norms, states can navigate complex political and economic differences and work towards equitable resource allocation. A salient example is the Nile River Basin, where competition among Egypt, Sudan, and Ethiopia over water usage has heightened regional tensions. Nationalistic agendas and differing development trajectories frequently lead to unilateral projects, such as Ethiopia's Grand Renaissance Dam, which downstream nations perceive as threats to their water security (Swain, 2011). The absence of universally accepted legal mechanisms for resources sharing continues to impede comprehensive governance in such contexts.

This research deals with analyzing the classic game between countries in exploiting common natural resources, in which some competing factors (such as countries holding common reserves of oil and gas) simultaneously engage in the extraction and exploitation of a common resource and continue this process over a long period. In the Cournot Competition model, each country, in deciding its current extraction level from the common resource, takes into account that the extraction cost and selling price depend on the total amount extracted by the parties involved at a certain time. Consequently, the level of extraction and the selling price of the common good depend on the simultaneous actions of the parties, and ultimately, comparative dynamic results are obtained (Lewis & Schmalensee, 1980). In other words, each country seeks to maximize profit by considering extraction costs, selling prices, historical data, and the amount already extracted from the common resource (Salant & et al, 1983). Competition among firms in the extraction of common resources based on the Cournot-Nash equilibrium will result in a more efficient market compared to a scenario with only one firm present, and each firm will supply a quantity of the good that represents the "best response" to the competitor's production level. The concept of the Cournot equilibrium is often used as a solution in models with multiple monopolies, although the conditions leading to such equilibrium have not been fully understood (Novshek, 1985).

The Cournot Competition model demonstrates how the allocation and extraction of common resources between interested parties work well, but this model is based on simple assumptions, in the following, reference is made to them.

Firstly, in the standard Cournot competition framework, it is typically assumed that firms have symmetric access to a common-pool resource, with each participant holding an equal proportion often modeled as a 50-50 split. However, this assumption does not always reflect real-world scenarios, where resource endowments and extraction rights can be highly asymmetric. In practice, the distribution of ownership or utilization rights over shared natural resources often varies due to geopolitical agreements, historical claims, or technical capabilities. For instance, in the case of the South Pars/North Dome gas field jointly exploited by Iran and Qatar, empirical evidence indicates a substantial imbalance: Iran controls approximately 25% of the resource, whereas Qatar exploits around 75%. This disparity in access rights significantly influences the strategic extraction behavior of the players involved, with Qatar's larger entitlement enabling it to extract at a rate nearly three times that of Iran.

Secondly, it is possible that the parties involved in a common resource do not have equal power and capability for extraction. Imposition of sanctions against a country greatly reduces that country's ability to extract common resources (Shapovalova & et al, 2020 , Dudlak., 2018). For example, due to the sanctions imposed by the United States, Iran currently has less capability to extract and utilize natural resources, including those in the South Pars/North Dome gas field, than it had several years ago.

Thirdly, traditional Cournot competition models often rest on the simplifying assumption of symmetric marginal extraction costs across firms sharing a common-pool resource. However, such homogeneity rarely exists in actual resource extraction contexts. Empirical data indicate significant cost disparities across producers. For instance, Iran's marginal cost of oil production is estimated to be roughly 1.5 times higher than that of its southern Persian Gulf counterparts. Similarly, Norway incurs production costs nearly triple the regional average in the Persian Gulf, reflecting differences in geological conditions, technological maturity, and institutional frameworks. Nevertheless, the cost effects of geopolitical constraints such as sanctions are not uniform. Sanctioned states may respond strategically by adopting adaptive measures ranging from technological substitution and domestic capacity, building to triangulated trade partnerships. For example, following the 2014 sanctions, Russia's Arctic energy initiatives demonstrated how innovation and geopolitical re-alignment could mitigate cost surges (Shapovalova & et al, 2020). Therefore, while sanctions typically elevate operational costs, modeling efforts should account for heterogeneity and potential endogeneity in cost structures rather than relying on uniform cost assumptions.

Despite several studies modeling joint extraction strategies, few works incorporate both asymmetric resource shares and external economic constraints such as sanctions. Our model fills this theoretical gap by introducing endogenous constraints through geopolitical factors- a dimension underexplored in existing Cournot-based models (Novshek, 1985; Dudlak, 2018).

Lastly, imposing sanctions against a country, which reduces that country's extraction capability, increases the extraction costs, a factor not considered in the Cournot Competition model. For a more accurate modeling of the exploitation of common resources, it is necessary to set aside the assumptions of equal share, equal extraction capability, equal extraction cost for the parties involved, and their constancy, and to model based on realistic assumptions.

The structure of this paper is divided into five distinct parts. It opens with a general introduction, setting the stage for the discussion. The second section delves into the theoretical foundations and relevant prior research. In the third section, the analytical methodology employed in the investigation is thoroughly described. The fourth section presents the formulation and analysis of the game-theoretic model. Finally, the fifth section wraps up the paper with a synthesis of the principal findings and a set of practical recommendations.

2. Literature review and Research background

The correct and logical strategy in utilizing common natural resources is very essential and vital for both countries possessing these resources and countries dependent on importing resources such as oil, gas, and water. Since conflicting interests exist in the mutual relations of countries in exploiting common resources, as well as the strategic behavior of these countries towards each other, the decisions of these countries have a significant impact on resource extraction considering the situation (strategy) of other countries (Salimian et al, 2023).

In the field of strategy, various approaches have been employed in the exploitation of shared natural resources among countries. Research conducted in this area has mostly adopted one of the following three approaches:

1) Determining optimal strategy with a political and legal approach (most studies in this area have been conducted).
2) Determining optimal strategy through game theoretic matrix form.
3) Determining optimal strategy through the use of mathematical models and

game theory.

The classical Cournot model has been a foundational tool in industrial organization for analyzing strategic interactions among firms. However, its application to common-pool resource (CPR) scenarios has garnered increasing interest as global resource scarcity and environmental constraints become more pronounced.

For instance, Sandal & Steinshamn (2004) developed a dynamic Cournot-competitive model for harvesting a common resource. Their results demonstrated that firms' harvesting strategies are significantly affected by resource regeneration dynamics and intertemporal decision-making. This approach emphasizes the sustainability challenges that arise under decentralized competition in CPR settings. Fischer & Laxminarayan (2005) extended this discourse by analyzing the sequential development of an exhaustible resource, comparing monopoly and competitive regimes. They found that competition could exacerbate resource depletion, raising concerns over long-term conservation under Cournot-type interactions. More recently, Zhang & et al (2020) proposed a Cournot oligopoly game-based framework for local energy trading that accounts for the uncertainty and cost of renewable resources. Their study highlights the increasing relevance of integrating environmental uncertainty and decentralized decision-making into Cournot-based models, particularly in energy systems.

2.1. Research background

Subsequently, the studies conducted in each of these three areas will be discussed in detail in the following table (Table 1).

Table 1. The background of the research is based on 3 different approaches

Research Strategy	Researchers (Year)	Field Investigation	Main Result
Political & Legal Approach	Hayashi (2012)	China & Japan	Collapse of cooperation mechanisms under geopolitical tension with a focus on sanctions-induced disruptions in resource extraction dynamics
	Salameh & Chedid (2022)	Common natural resources in the Mediterranean Sea	Formulating strategic policy guidance for actors engaged in the governance of shared resources
	Irsadanar & Kimura (2021)	China & Japan	The breakdown of Sino-Japanese collaboration over joint resource extraction in the East China Sea, driven by mutual distrust and diplomatic tension

	Sheikhmohammadi & et al (2011)	Iran & United Arab Emirates	Commitment to negotiations aimed at preventing the impact of sanctions on Iran's resource extraction
	Li & et al (2013)	Russia & China	Ensuring sustained intergovernmental collaboration and coordinated strategies for the integrated exploitation of the petroleum reservoir
	Esmaeili & et al (2015)	Iran & Iraq & Qatar	Formulating a logical strategy for the sustainable utilization of shared resources
Static Game	Havas (2015)	Norway & Russia	Anticipation of increased investment gains by accelerating the pace of resource extraction
	Bayati & et al (2019)	Iran & Qatar	Lack of joint effort among stakeholders in utilizing shared natural assets
	Toufighi & et al (2020)	Iran & Saudi Arabia	Iran's willingness to collaborate contrasted with Saudi Arabia's refusal to engage cooperatively
	Salimian & et al (2023)	General State	Compliance or defiance influenced by each party's stake and extraction capability
	Caputo & Lueck (2003)	General State	Generating long-term revenue via collaborative asset possession
Modeling	Salimian & Shahbazi (2017)	General State	Maximize resource output while minimizing required effort
	Mamipour & et al (2024)	Iran & Qqtar	Lack of economic justification for Iran to extract resources under conditions of severe sanctions

Source: *research findings*

The economic and geopolitical effects of sanctions -particularly on the oil and gas sectors- have been extensively documented in academic research. For example, Shapovalova & et al (2020) demonstrate how Western sanctions have altered Russia's Arctic offshore petroleum development by restricting access to capital and technology. Similarly, Dudlák (2018) examines Iran's post-sanctions oil industry, showing how sanctions severely disrupted investment and export capacity. Esmaeili & et al (2015) analyze Iran's shared oil and gas conflicts with Iraq and Qatar, showing that game theory can model sanctions-induced strategic shifts. These studies underline how sanctions change the competitive equilibrium and affect the relative extraction capacities of resource-sharing countries. Accordingly, this paper integrates these insights into a formalized Cournot-based model to reflect the influence of asymmetric extraction capacity caused by sanctions. By incorporating the sanction variable endogenously, the model bridges the gap between theoretical competition and geopolitical constraints, aligning with insights from recent literature that emphasize the interplay of sanctions, strategic behavior, and resource inequality (Caputo & Lueck, 2003; Bayati et al, 2019). This enhanced engagement with the sanctions literature provides a more nuanced and empirically grounded extension of the Cournot framework.

This study aims to expand the Cournot Competition model by incorporating real assumptions (the share of both parties from the resource and the factor of sanctions) in the extraction from a common resource, and to examine and analyze the interaction between stakeholders in exploiting a common resource using mathematical concepts.

3. Modeling

The approach used in the modeling is based on applying the economic relationships derived from game theory, which will be explained in the following sections.

3.1. Game Theory

In the social sciences, game theory provides a powerful analytical lens for examining cooperation, conflict, and negotiation among individuals and groups. It has been used to model voting behavior, legislative bargaining, social dilemmas such as the tragedy of the commons, and the formation of social norms. For instance, the prisoner's dilemma illustrates how rational individuals might fail to cooperate even when it is in their mutual interest, a concept pivotal to understanding collective action problems (Suneja & Das, 2024). Game-theoretic models offer insights into the emergence of trust, the evolution of altruism, and institutional stability, especially in environments marked by limited information, repeated interactions, and strategic uncertainty (Romano & et al, 2021).

Game theory is a branch of applied mathematics that has developed within the context of economics and focuses on the strategic behavior of rational agents. It has broad interdisciplinary applications, including in political science, economics, sociology, biology, computer science, and even philosophy (Sun & et al, 2025). When game theorists use the term "game," they refer to any social situation involving at least two participants in which the interests of the parties are either conflicting or interdependent. In such scenarios, the gain of one player is often linked to the choices of others. Each game has its own principles and rules, and players attempt to maximize their outcomes by adhering to these rules and selecting optimal strategies (Gautam & Benidris, 2023).

A game, in this context, describes a situation where the outcome (e.g., utility, profit, welfare) for each player depends not only on their own intelligent decisions but also on the decisions of other participants. Therefore, when an individual's benefit is not solely a function of their actions but is also influenced by others' actions, the interaction can be modeled as a game. Conventionally, for a scenario to qualify as a game in game-theoretic terms, three conditions must be met: (1) There must be at least two players or agents involved; (2) These players must have interdependent or conflicting interests; and (3) Each player seeks to maximize their own outcomes, but success is contingent not only on their efforts but also on the strategies chosen by others (Salimian & et al, 2024, Wijewardena & Neely, 2023).

The principles of game theory, particularly non-cooperative games such as the Cournot competition model, serve as the foundational analytical framework for our model (Long & Wang, 2023). In this context, each country is conceptualized as a rational player aiming to maximize its own utility—specifically, its profit from resource extraction—while anticipating the strategic behavior of its counterpart (Boyd & et al, 2023). The transition from the general theoretical basis of game theory to the applied Cournot model enables us to formalize strategic interdependence, especially under asymmetric conditions such as unequal resource shares and the presence of sanctions.

3.2. Comparative Frameworks: Limitations and Future Extensions

While the Cournot competition model provides a foundational framework for analyzing quantity-setting behavior among firms sharing a common-pool resource, it is important to recognize alternative paradigms that may capture strategic interactions under different assumptions. In Stackelberg competition, for instance, a leader-follower structure allows one firm to commit to an output level before the others, potentially modeling real-world asymmetries in resource access or geopolitical influence. Bertrand models, by contrast, assume price competition, which may be less applicable to exhaustible resource contexts but still relevant when market prices are a strategic variable. Nash bargaining frameworks are especially pertinent when cooperative extraction agreements or profit-sharing mechanisms are under consideration. While our model extends the Cournot framework to incorporate sanctions and resource share asymmetries, future work could explore how these dynamics would manifest under Stackelberg or bargaining structures, potentially revealing deeper insights into strategic resource exploitation.

4. Game Modeling

The strategic payoffs for the two participating states exploiting a shared resource are formally characterized through their respective utility (or objective) functions, with equilibrium outcomes contingent upon the structural assumptions and constraints specified within this section. Demand is a function of the total aggregate of products supplied. Furthermore, firms are fully informed of all the conditions of the model. The equilibrium resulting from Cournot competition is such that none of the firms unilaterally have a tendency to change the level of their product production resulting from this competition. Moreover, it can be said that while most research in economic fields, although they have paid little attention to sanctions, the limited number of studies conducted in the field of sanctions have considered and incorporated this important factor in a binary or multilevel manner into modeling, which in this study, this important factor will be included as a primary variable in the modeling.

Assume y represents the amount of remaining reserves, x_T represents the identified reserves of the common source, x represents the amount of extracted reserves, and x_0 represents the amount of unextracted reserves from the natural source ($x_T = x + x_0$). For modeling the exploitation of common resources, we use a triangular distribution. The following equation represents the amount of remaining reserves from the common source and the amount of extracted reserves from the common source:

$$y = 1 - x \tag{1}$$

For simplicity, it is assumed that the total reserves of the common resource are equal to one unit. The above relation indicates that as much as is extracted from the common resource, the remaining reserves are reduced by the same amount. The extraction potential of each country is directly related to its share ($0 \leq \alpha \leq 1$) and inversely related to the level of sanctions imposed against that country ($0 \leq S \leq 1$), where the higher the value of S, the stricter the sanctions, and in the case of $S = 1$, complete sanctions, and $S = 0$ means no sanctions (The sanction factor is considered a static parameter). Also, the extraction potential of each country is directly related to imposing sanctions against a rival country. Furthermore, the amount of extracted reserves (extraction potential) from the common resource depends on the total reserves available in the resource.

$$EP_1 = (\alpha(1 - S_1) + (1 - \alpha)S_2)X_T \tag{2}$$

$$EP_2 = ((1 - \alpha)(1 - S_2) + \alpha S_1)X_T \tag{3}$$

The above relationships indicate that the greater a country's share of a common resource, the greater its extraction potential, whereas increasing the level of sanctions imposed on the country will reduce the extraction potential. Furthermore, imposing sanctions against a competing country will add to the extraction potential of each country.

The following relationship is obtained by plotting the relationship between (1) and (2) in a graph ($y = EP_1$):

$$1 - x = (\alpha(1 - S_1) + (1 - \alpha)S_2)(x + x_0) \tag{4}$$

To obtain the value of x_1^* in the above relationship, it is solved based on x, and its relationship will be in the form of the following equation:

$$x_1^* = -\frac{\alpha S_1 x_0 + (\alpha - 1)S_2 x_0 - \alpha x_0 + 1}{\alpha S_1 + (\alpha - 1)S_2 - \alpha - 1} \tag{5}$$

By plotting equations (1) and (3) on a graph, the following relationship is obtained for $y = EP_2$.

$$1 - x = ((1 - \alpha)(1 - S_2) + \alpha S_1)(x + x_0) \tag{6}$$

To obtain the value of x_2^* according to the above relationship in terms of x, the equation is solved, the relationship of which will be in the form of the following equation:

$$x_2^* = -\frac{\alpha S_1 x_0 + (\alpha - 1)S_2 x_0 + (1 - \alpha)x_0 - 1}{\alpha S_1 + (\alpha - 1)S_2 - \alpha - 2} \tag{7}$$

Substituting the optimal value of x_1 or x_1^* into the production function (Equation 5) yields the extraction level of the first country (EP_1).

$$EP_1^* = \frac{(x_0 + 1)(\alpha S_1 + (\alpha - 1)S_2 - \alpha)}{\alpha S_1 + (\alpha - 1)S_2 - \alpha - 1} \tag{8}$$

By substituting the optimal amount x_2 or x_2^* (equation 7) into the production function of the first country, we have the extracted power (EP_2).

$$EP_2^* = \frac{(x_0 + 1)(\alpha S_1 + (\alpha - 1)(S_2 - 1)}{\alpha S_1 + (\alpha - 1)S_2 - \alpha - 2} \tag{9}$$

Each country extracts a certain amount of common resources depending on the existing conditions and in order to maximize its own interests. According to the Cournot Competition model, for maximizing its own profit, each country extracts a lesser amount of its share from the resource. Thus, a portion of the resource is not extracted by any of the countries, which in the current model is called "unextracted extraction capacity" and is derived from the following relationship:

$$UnC = 1 - (EP_1 + EP_2) \tag{10}$$

By considering the extraction capacities of both countries in the above relationship, the concept of "untapped extraction capacity" will be as follows:

$$UnC = -\frac{3(x_0 + 1)}{(\alpha S_1 + (\alpha - 1)S_2 - \alpha - 1)(\alpha S_1(\alpha - 1)S_2 - \alpha + 2) - 2x_0 - 1} \tag{11}$$

From the point at which both parties benefit from a common source in order to maximize their own profits through their supply function, they continue their activities. Therefore, a portion of the common resources is not extracted in each period and will remain in the source, the amount of which is obtained from equation 11.

The profit of each firm comes from the difference between income and expenses. However, in the present model, the income of each firm is a function of the extraction capacity of each country and an increasing expense (compared to the Cournot model state and considering the share and the sanction factor) is taken into account as [C(1+αS)]. Considering the ascending expenses is due to the possibility of imposing sanctions against that country, which leads to a decrease in extraction capacity and an increase in the cost of extracting each unit of goods from a common source.

In the following equations (relationship 12 and 13), the profit of each institution is expressed based on the percentage of the amount extracted from the common resource and its cost.

$$\pi_1 = \big(b - (EP_1 + EP_2)\big)EP_1 - (1 + \alpha S_1)C_1 EP_1 \tag{12}$$

$$\pi_2 = \big(b - (EP_1 + EP_2)\big)EP_2 - (1 + (1 - \alpha)S_2)C_2 EP_2 \tag{13}$$

Each firm acts to extract from the common resource with the aim of maximizing its profit. Therefore, the profit function of the first firm with respect to its extraction capability is derived from that country.

$$\frac{\partial \pi_1}{\partial EP_1} = -C_1(\alpha S_1 + 1) - 2EP_1 - EP_2 + b \tag{14}$$

Based on the derived profit function of the first firm relative to the extraction capacity of the country, and solving the equation in terms of the extraction capacity of the first firm, we have:

$$EP_1 = -\frac{C_1(\alpha S_1 + 1) + EP_2 - b}{2} \tag{15}$$

We also take the derivative of the second firm's profit function with respect to the country's extraction capacity.

$$\frac{\partial \pi_2}{\partial EP_2} = C_2\big((\alpha - 1)S_2 - 1\big) - EP_1 - 2EP_2 + b \tag{16}$$

By deriving from the profit function of the second firm relative to the extraction capacity of that country and solving the equation in terms of the extraction capacity of the second firm, we have:

$$EP_2 = \frac{C_2\big((\alpha-1)S_2-1\big) - EP_1 + b}{2} \tag{17}$$

Each firm maximizes its profit based on its level of production and its rival, as a function of its own production relative to the production level of its rival, which is the same as the "best response" function. By substituting equation 17 into equation 15, the best response function of the first firm relative to the output level of the second firm is obtained.

$$EP_1^{**} = -\frac{2C_1(\alpha S_1 + 1) + C_2\big((\alpha-1)S_2-1\big) - b}{3} \tag{18}$$

The replacement of relation 15 in relation 17 yields the second firm's best response function with respect to the quantity extracted by the first firm.

$$EP_2^{**} = \frac{C_1(\alpha S_1 + 1) + 2C_2\big((\alpha-1)S_2-1\big) + b}{3} \tag{19}$$

The relationship between 18 and 19 represents the non-zero sum game between countries in exploiting common resources, which also takes into account the asymmetric distribution share and unequal extraction capabilities in the modeling. Table 2 below shows the values of functions EP_1^*, EP_2^*, UnC, EP_1^{**} and EP_2^{**} in several hypothetical cases. The values and functions below are obtained assuming $x_0 = 0$.

Table ۲. The derivatives of countries' extraction according to hypothetical values

	Variable Values	EP_1^*	EP_2^*	UnC	EP_1^{**}	EP_2^{**}
1	$\alpha = 1, S_1 = 0, S_2 = 1$	0.5	0	0.5	$\frac{b-2C_1+C_2}{3}$	$\frac{b+C_1-2C_2}{3}$
2	$\alpha = 0.5, S_1 = 0, S_2 = 0$	0.33,3	0.33,3	0.33,3	$\frac{b-2C_1+C_2}{3}$	$\frac{b+C_1-2C_2}{3}$
3	$\alpha = 0.5, S_1 = 0.5, S_2 = 0.5$	0.33,3	0.33,3	0.33,3	$\frac{4b-10C_1+5C_2}{12}$	$\frac{4b+5C_1-10C_2}{12}$
4	$\alpha = 0.5, S_1 = 0.25, S_2 = 0.25$	0.33,3	0.33,3	0.33,3	$\frac{8b-18C_1+9C_2}{24}$	$\frac{8b+9C_1-18C_2}{24}$
5	$\alpha = 0.5, S_1 = 0.75, S_2 = 0.75$	0.33,3	0.33,3	0.33,3	$\frac{8b-22C_1+11C_2}{24}$	$\frac{8b+11C_1-22C_2}{24}$
6	$\alpha = 0.25, S_1 = 0, S_2 = 0$	0.2	0.42,8	0.37,2	$\frac{b-2C_1+C_2}{3}$	$\frac{b+C_1-2C_2}{3}$
7	$\alpha = 0.25, S_1 = 0.5, S_2 = 0$	0.11,1	0.46,7	0.42,2	$\frac{4b-9C_1+4C_2}{12}$	$\frac{8b+9C_1-16C_2}{24}$

Source: *research findings*

The first state from Table 1 indicates that if the entire resource is solely available to a firm, this firm extracts half of the resources to maximize its profit and does not extract the remaining half. In other words, the firm continues operating at the demand function's midpoint. However, the second state, which represents Cournot competition, shows that each firm extracts one-third of the total resource, leaving the remaining one-third in the resource. This scenario shows that when both countries have equal shares and face no sanctions, the outcomes align with the predictions of the classical Cournot model. In this case, the supply functions of two firms are as follows: $\frac{b-2C_1+C_2}{3}$ and $\frac{b+C_1-2C_2}{3}$ If we apply the assumption of equal costs according to the Cournot model, the results will be the same as the Cournot model in the form of $\frac{b-C}{3}$. In other words, it is established that the Cournot model is a case of the present model's infinite states.

States 3, 4, and 5 also indicate a very important issue. These states also support the results of Cournot. Although Cournot does not consider the sanction factor, these results indicate that if the countries' shares in a common resource are equal, then if the countries with this common resource are equally sanctioned (weak sanction of 25% or severe sanction of 75%), then the Cournot model's results will still hold, and each country will extract the remaining $1/3$ resource. In other words, in a similar situation, the shares and sanctions of the countries will still have the same supply as the Cournot model.

State 6 represents a situation where if one of the countries, for example, has a $1/4$ share of a common resource and none of the countries are under sanction, then the share of the country with a smaller share of the resource (25%) from extraction will be equal to 0.2, and the share of the country with a larger share (75%) will be equal to 42.8%. This finding, where a country with a 75% share extracts only 42.8% of the output, may seem counterintuitive but aligns with the principle of diminishing marginal returns. As extraction expands, marginal profit per unit decreases faster for the dominant player, incentivizing partial restraint. Moreover, this highlights a key insight: market power does not translate directly into extraction dominance under interdependent strategic constraints. Additionally, state 7 shows that if one of the countries, for example, has a $1/4$ share of a common resource and this country is under sanction (not so severe sanction of 0.5), then the share of the country with a smaller share (25%) and under sanction will be much less than the previous state (11.1%), and the other country will increase its extraction more than the previous state (46.7%).

These results are very important and show the impact of sanctions on the extraction of shared resources. If a country experiences more severe sanctions, then another country, as a partner in the shared resource, will take advantage of this situation and its extraction level will be dependent on the level of sanctions imposed on the other country. This situation can send important signals to countries that are partners in a shared resource (share and sanction).

Ultimately, it should be noted that the advantage of this type of modeling lies in its utilization of shared resources, taking into account the asymmetric share and unequal extraction capacity (based on the factor of sanctions) in the modeling. Therefore, considering the obtained equations, an infinite number of possible situations (of which the Cournot model is one) can be taken into account for the share and the factor of sanctions, and the results can be interpreted.

5. Concluding and Recommendations

The allocation strategies and policy objectives governing the exploitation of economic resources particularly exhaustible natural assets such as oil and gas, play a pivotal role in national economic planning. In advanced economies, such resources are frequently leveraged to reinforce macroeconomic foundations and to drive long-term developmental trajectories. When these resources are transboundary in nature, their joint utilization necessitates cooperative governance frameworks, emphasizing efficient extraction, intertemporal sustainability, and equitable benefit distribution across state actors. Deliberate mismanagement of resources often politically driven can be far more destructive than unintentional inefficiencies, accelerating depletion and undermining sustainability. Such management, driven by political motives and, in other words, by exploitative and politically motivated actions, paves the way for quicker and more extensive depletion of resources, as well as the reverse and negative role of these resources in developmental trends.

Collaborative strategies among nations in managing common-pool resources contribute to the efficient allocation of resources, enhance intertemporal sustainability, foster mutual diplomatic engagement, and act as a stabilizing mechanism promoting geopolitical equilibrium and conflict mitigation. The results of this study clearly support the notion that cooperative strategies yield mutually beneficial outcomes. When countries collaborate, they tend to moderate extraction rates, share technology, and prevent overexploitation. This not only improves economic efficiency but also builds diplomatic trust, stabilizes regional politics, and fosters peaceful dispute resolution mechanisms. Such cooperative frameworks are essential for preserving transboundary ecosystems and achieving the Sustainable Development Goals (SDGs), particularly goals 6, 13, and 16.

When cooperative mechanisms for the governance of common-pool resources are lacking, the divergence in national interests tends to escalate, fostering non-cooperative equilibria characterized by strategic competition. This study highlights that responsible and sustainable management of shared resources is not only a theoretical necessity but also a practical imperative. The findings reinforce that intentional, exploitative management - often driven by political or short-term economic gains - can accelerate depletion rates, provoke diplomatic tension, and inflict long-term ecological damage, far beyond the harm caused by unintentional inefficiencies. Thus, deliberate mismanagement poses a disproportionately greater threat to sustainable development and regional stability. From a strategic perspective, sanctions represent a critical exogenous determinant influencing the rate and pattern of extraction in common-pool resource settings. The effectiveness and impact of sanctions are shaped by a multitude of variables, among which the intensity or stringency of the imposed measures on the target nation plays a pivotal role. Accordingly, in the analysis of sanction regimes, quantifying and characterizing the severity of sanctions emerges as a central analytical task. This dimension has been explicitly modeled and systematically integrated into the present study's framework to capture its implications for strategic behavior and resource appropriation dynamics.

Importantly, these findings have significant real-world applications. In countries facing sanctions, such as Iran, the model suggests that shifts in extraction strategy are essential to avoid overburdening limited capabilities. Policymakers can use this model to simulate the effects of international pressure on extraction output and redesign incentive mechanisms to ensure equitable exploitation. Moreover, in transboundary resource regions, this model could be employed to predict strategic behavior of rival states and help shape negotiation strategies.

One of the most important models in the field of common resource extraction is the Cournot competition model. The Cournot competition, which demonstrates how to exploit common resources between countries, is based on simple assumptions such as equal share of the parties from the common resource, equal extraction capacity, equal extraction costs for the interested parties, and their constancy, while in the real world, such constraints do not exist. In this study, modeling is based on more realistic assumptions, in which different shares of the parties, different extraction capacities resulting from sanctions, unequal costs, and the upward trend of these costs during sanctions are also taken into account.

One of the most significant findings of this model is that the Cournot competition framework represents only a specific equilibrium configuration out of a theoretically infinite set of possible states. Specifically, the model captures a scenario in which the resource allocation between the two agents exploiting a common-pool resource is perfectly symmetric, and both parties possess equal extraction capabilities. Moreover, the results indicate that both the extraction power function and the "undeveloped extraction capacity" function are explicitly dependent on the distribution of resource shares whether symmetric or asymmetric, as well as the level and structure of economic sanctions imposed on the respective countries. This interdependence highlights the sensitivity of strategic extraction behavior to institutional asymmetries and external constraints within the competitive environment.

The mathematical results and simulations reinforce the theoretical assumption that asymmetries in share and sanction severity directly affect strategic extraction levels. These findings validate the model's assumptions and support the conclusion that a country's optimal extraction decision is a function of both its relative share and sanction status. Therefore, the model provides both descriptive and prescriptive insights into international natural resource policy under asymmetric conditions.

Additionally, future extensions of this model could incorporate environmental externalities and sustainability constraints, especially since overextraction in sanction-driven strategies could accelerate ecological degradation. Integrating environmental costs into the profit function would enhance policy relevance in line with SDG 12 (Responsible Consumption and Production).

Beyond examining the direct impacts of sanctions on resource extraction behavior, it is critical to explore potential policy countermeasures available to affected countries. In response to extraction suppression caused by sanctions, a resource-sharing nation may adopt a range of strategies to mitigate economic loss. These include enhancing extraction efficiency through technological investment, pursuing regional alliances or barter agreements that bypass conventional financial sanctions, and initiating diplomatic engagement to renegotiate shared resource arrangements. For instance, in contexts like the Iran-Qatar shared South Pars/North Dome gas field, policy options could include increasing domestic refining capacity to reduce reliance on exports, or leveraging alternative markets via regional blocs. These strategies may not only stabilize production but also reduce vulnerability to external shocks. Incorporating such policy dimensions would enrich the strategic implications of our model and inform more adaptive responses to geopolitical constraints.

Author Contributions

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The authors declare no conflict of interest.

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