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Cooperative and Competitive Game Analysis between Iran, Kuwait, and Saudi Arabia in Management of the Arash (Al-Durra) Gas Field

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Highlights

- Game-theoretic analysis identifies the optimal strategic choices available to the parties in the Al-Durra (Arash) gas field dispute.
- Iran's accession to UNCLOS would significantly strengthen its legal position in maritime resource claims.
- Strategic modeling demonstrates that Iran's persistent isolation adversely affects its long-term national interests.
- Legal assessment highlights Iran's non-ratification of UNCLOS as a major impediment to asserting its rights.
- While full cooperation among Iran, Kuwait, and Saudi Arabia represents the most efficient outcome, it remains unstable due to persistent regional rivalries.

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Abstract

The Arash (Al-Durra) gas field, located in the northern Persian Gulf, constitutes a shared hydrocarbon resource claimed by Iran, Kuwait, and Saudi Arabia, where unresolved maritime boundary disputes have transformed its development into a multifaceted geopolitical and legal challenge. Employing game-theoretic modeling, this study examines the strategic behavior of the three states across various cooperative and competitive scenarios. The analysis demonstrates that trilateral cooperation yields the highest aggregate economic and security gains; however, entrenched political frictions and legal constraints—most notably Iran's non-accession to the United Nations Convention on the Law of the Sea (UNCLOS)—significantly limit the feasibility of collaborative outcomes in the near term. Under competitive equilibria, Iran incurs the greatest relative losses, while Saudi Arabia and Kuwait typically achieve more favorable payoffs, particularly through bilateral coordination. The study further assesses how Iran could enhance its legal posture by acceding to UNCLOS and adopting a calibrated strategy that integrates proactive diplomacy with prudent resource development. Such an approach would strengthen Iran's bargaining leverage and mitigate its strategic isolation. Overall, the research provides a systematic evaluation of the legal, geopolitical, and economic dimensions of the Arash field dispute and offers pragmatic policy recommendations aimed at reducing tensions and facilitating equitable, long-term resource governance in the region.

Keywords: Arash gas field, Game theory, Joint exploitation, Persian Gulf.

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1. Introduction

Strategic interactions among states possessing transboundary and shared hydrocarbon reserves constitute a critical yet insufficiently explored aspect of global energy security. The Persian Gulf—home to some of the world's most extensive joint oil and gas fields, such as South Pars/North Dome (Iran–Qatar), Rumaila (Iraq–Kuwait), and Arash (Al-Durra)—exemplifies the geological continuity of reservoirs that extend across political boundaries, creating a complex landscape of mutual dependence and competition. While coordinated management of these assets can enhance extraction efficiency and contribute to market stability, longstanding disputes over sovereignty, divergent production policies, and persistent geopolitical frictions have instead transformed them into sources of instability at regional and global levels. These tensions jeopardize the sustainable exploitation of shared reservoirs and generate volatility in global energy supplies, affecting prices, economic resilience, and geopolitical alignments. With 48 percent of global oil reserves and 39 percent of global natural gas reserves located in the Persian Gulf (Noroozizadeh, 2021, pp. 7–8), the region remains indispensable to energy-importing economies; however, the absence of binding multilateral legal frameworks and the conflicting strategic priorities of littoral states have amplified rivalry rather than cooperation.

The Arash (Al-Durra) gas field—estimated to contain roughly 220 billion cubic meters of gas and disputed by Iran, Kuwait, and Saudi Arabia since the late 1960s (ISNA, 2023)—illustrates how overlapping maritime claims and divergent legal interpretations can escalate into high-stakes geopolitical confrontations, particularly amid rising global energy demand. This study investigates the possible modes of interaction among Iran, Kuwait, and Saudi Arabia in exploiting the Arash gas field from a game-theoretic perspective, identifying three primary scenarios: trilateral cooperation, a Kuwait–Saudi alliance against Iran, and complete non-cooperation. The underlying hypothesis is that trilateral cooperation yields the most stable equilibrium by maximizing collective gains and minimizing conflict, whereas a bilateral alliance between Kuwait and Saudi Arabia significantly constrains Iran's access to the field and imposes considerable economic and political costs. In a non-cooperative environment, Iran may nonetheless improve its position through mixed strategies that balance deterrence with diplomatic engagement. Drawing on game theory as conceptualized by von Neumann and Morgenstern (1944), this research employs mathematical modeling to analyze decision-making under conditions of interdependence and shared resource exploitation. The findings assess how each scenario affects regional stability and global energy security, and the paper concludes by outlining strategic policy recommendations for Iran.

1.1. Theoretical and conceptual framework

International Political Economy (IPE) analyzes the interplay between political authority and economic dynamics in the global system, explaining how states, markets, and international institutions shape patterns of resource distribution and governance (Gilpin, 2011, pp. 12–15). Within the context of shared hydrocarbon fields, IPE provides a powerful analytical framework for understanding how geopolitical rivalry, sovereignty claims, and economic interdependence influence both cooperation and conflict. Hydrocarbon deposits in the Persian Gulf function as strategic commodities, and in the case of the Arash (Al-Durra) gas field, control over exploration and production is essential not only for securing economic rents but also for enhancing geopolitical leverage for Iran, Kuwait, and Saudi Arabia. As Morgenthau argues, geography and natural resources—together with industrial capacity, military capability, and population—form core elements of national power (Morgenthau, 1948, pp. 127–169).

Consequently, competition to control and exploit shared reserves such as Arash reflects broader efforts by regional actors to reinforce their strategic position within the international system (Waltz, 1979, p. 126). At the same time, the joint exploitation of shared resources can serve as a foundation for economic

growth and expanded cooperation (Asamoah et al., 2019). Although coordinated management has the potential to maximize long-term collective benefits, states frequently prioritize rapid extraction to secure immediate revenue streams, driven by concerns that rivals will extract the resource first. This tendency is illustrated by empirical evidence showing that even after joining OPEC, member states continue to compete in production rates despite formal coordination mechanisms (Colgan, 2014, p. 605). Moreover, IPE highlights the dynamics of the "resource curse," whereby dependence on oil revenues generates rent-seeking, weakens governance institutions, undermines democratization, and reduces incentives for long-term cooperative frameworks (Ross, 2012). Overall, IPE demonstrates that shared oil and gas fields tend to become arenas of competition rather than cooperation because states prioritize regime security and short-term power preservation over broader systemic stability.

1.2. Game theory as an analytical framework

Game theory is fundamentally the study of how rational actors make decisions in interactive environments, where each player's optimal choice depends on the actions of others (Abdoli, 2007, p. 4). By relying on cost–benefit calculations and strategic reasoning, it provides analytical tools for understanding situations in which decision-makers influence one another's outcomes. Its applications span diverse fields—including corporate competition, political rivalries, strategic planning, conflict management, and auctions—demonstrating its versatility as a method for examining interdependent decision-making (Osborne, 2000, p. 1). Through its emphasis on strategic behavior in interconnected settings, game theory reveals how competitive incentives can undermine collective welfare and how institutions, credible commitments, or negotiated agreements can facilitate cooperation even among adversarial actors (Abdollahzadeh, 2024).

Within international relations, game theory is widely employed to analyze negotiation dynamics, conflict escalation, coalition formation, and prospects for cooperation under conditions of mutual dependence. Modeling in game theory begins by defining the interaction among decision-makers and then proceeds to formal analysis grounded in the rationality assumptions of rational choice theory (Osborne, 2000, p. 2). Rational choice theory—central to most game-theoretic models—holds that actors select the option that maximizes their expected utility from among the available alternatives. It consists of two key components: the set of feasible actions and the actor's preference ordering over potential outcomes. In each strategic situation, the player must choose one option from a set constrained not by personal whims but by structural and external conditions surrounding the interaction (Osborne, 2000, p. 4).

The subsequent sections will outline the essential elements of game theory and introduce the analytical model used to examine the strategic behavior of Iran, Kuwait, and Saudi Arabia in the management of the Arash (Al-Durra) gas field.

1.3. Formal modeling

Formal modeling is a research method that uses precise and structured simplifications to translate political and social arguments into logical and mathematical frameworks. By articulating the underlying assumptions, clarifying causal mechanisms, and systematizing strategic interactions, it allows researchers to analyze complex issues with analytical rigor. Although such models are intentionally abstract, their purpose is to distill social interactions into their essential components in order to enhance our understanding of real-world phenomena and assess the generalizability of theoretical claims (Morrow, 1994, pp. 6–7).

1.4. Rationality

Rationality is one of the core assumptions of game theory. Within this framework, and while acknowledging both the objectives of the players and the constraints imposed by the game structure, it is assumed that players possess defined goals and the freedom to exercise their decision-making capacity. Here, rationality refers to selecting the strategy that best advances one's objectives; it does not imply that decisions are necessarily logical in a philosophical sense or ethical in a normative sense. Under utility theory, each player pursues specific goals and chooses, from among the available alternatives, the action that yields the highest expected payoff (Morrow, 1994, p. 17).

Game theory further posits that decision-makers hold beliefs about the consequences of their choices, which are expressed as probability distributions derived from the player's understanding of the state of the world. Decisions may be made under conditions of certainty, risk, or uncertainty. Under conditions of certainty, the player knows the state of the world prior to choosing and selects the option that maximizes utility. Under conditions of risk, the probabilities of different possible states are known, typically inferred from experience or repeated interaction (Morrow, 1994, pp. 28–29). Under conditions of uncertainty, however, these probabilities are either unknown or not meaningful. Most political and social decision-making takes place under such uncertainty. In these environments, individuals form subjective probabilistic judgments based on available information, prior experience, and beliefs. Nevertheless, for analytical simplicity, some models treat highly uncertain situations as decision-making under risk. For example, although elections unfold under genuine uncertainty because outcomes cannot be known in advance, they can still be analyzed as decision problems under risk (Morrow, 1994, pp. 28–29).

1.5. Zero-sum game

A zero-sum game, denoted by the expression $\sum^{n} M_i = 0$, refers to a strategic setting in which any gain by one player is matched by an equivalent loss to another. The players are therefore in pure competition and have no incentive to cooperate. Zero-sum games may involve more than two players; in such cases, subsets of players may collude to impose losses on others (Morrow, 1994: 75).

By contrast, non-zero-sum games incorporate both competitive and cooperative incentives, allowing players to benefit through cooperation. These games are classified into two categories based on the enforceability of agreements. In cooperative games, players may negotiate and form binding agreements before or during the game, and communication among them is permitted. In non-cooperative games, communication and binding agreements are not allowed, and players cannot rely on externally enforced commitments. Thus, the fundamental distinction between the two lies in whether players can secure mutually beneficial agreements. In cooperative games, coordination occurs through enforceable contracts, whereas in non-cooperative games, coordination—if it occurs at all—must emerge from the strategic structure of the game itself and is sustained only by the players' aligned interests (Morrow, 1994: 75–76).

1.6. Nash equilibrium

A Nash Equilibrium is defined as a situation in which each player's strategy constitutes the optimal response to the strategies chosen by the other players. When all participants adopt their respective best-response strategies, no player has an incentive to unilaterally alter their strategy (Morrow, 1994, p. 80). In this state, any deviation from the equilibrium would result in a lower payoff for the deviating player, thereby ensuring stability. Importantly, the existence of a Nash Equilibrium relies on each player's accurate anticipation of the others' strategies (Morrow, 1994, pp. 80–81).

In the context of a non-cooperative three-player zero-sum game, the Nash Equilibrium is represented by a set of strategies s_A , s_B , and s_C^* corresponding to players A, B, and C, respectively. Each player's strategy in this equilibrium serves as the optimal response to the combined strategies of the other two participants.

- $u_A\ (s_A^*, s_B^*, s_C^*) \geq u_A\ (s_A\ , s_B^*, s_C^*)$ for all possible s_A,
- $u_B\ (s_A^*, s_B^*, s_C^*) \geq u_B\ (s_A^*, s_B\ , s_C^*)$ for all possible s_B,
- $u_C\ (s_A^*, s_B^*, s_C^*) \geq u_C\ s_A^*, s_B^*, s_C\ )$ for all possible s_C.

Here, $u_i$denotes the payoff function for each player i. Since the game is zero-sum, the relationship

$$u_A + u_B + u_C = 0$$

holds, meaning that one player's gain is exactly equal to the combined losses of the other two players. In two-player games, analyzing a Nash Equilibrium using minimax strategies is relatively straightforward because the competition is directly between the two participants. However, in three-player zero-sum games, the interactions are more complex due to the simultaneous confrontation with two independent players, which prevents the direct application of the minimax theorem.

1.7. Game with three or more players (*n*-player game)

In a game over common resources or public goods with more than two players—essentially a Multiple Prisoner's Dilemma—consider three players: A, B, and C. Each player can choose either to cooperate (C) or to defect (D). The strategic form of the game is defined as follows:

Set of players:

$$N = \{A, B, C\}$$

Set of strategies for each player:

$$S_A = \{D, C\}, S_B = \{D, C\}, S_C = \{D, C\}$$

Combined strategy set:

$$S = S_A \times S_B \times S_C = \{(D,D,D), (D,D,C), (D,C,D), (D,C,C), (C,D,D), (C,D,C), (C,C,D), (C,C,C)\}$$

In each strategy triplet, the first letter corresponds to player A, the second to player B, and the third to player C. This set enumerates all possible combinations of strategies and predicts the players' behavior in all potential scenarios. The matrix representation of the game, showing payoffs for each combination, is provided in Chapter Three.

In the strategy set S, each triplet represents the choices of the three players: the first letter corresponds to player A, the second to player B, and the third to player C (Abdoli, 2007: 43–46). This set enumerates all possible strategies that the players may adopt, effectively predicting their behavior across all potential scenarios. The game can also be represented in a matrix form (see Table 1), which explicitly shows the payoffs corresponding to each combination of strategies for players A, B, and C.

Because the game involves three players, the payoffs are represented using two separate 2×2 matrices, each corresponding to one of player C's strategy choices—cooperation (C) or defection (D). The payoffs for each player are assigned values ranging from 1 to 6, and within each payoff tuple, the order of values corresponds to players A, B, and C, respectively (Abdoli, 1386: p. 45).

Table 1
The matrix form of the game (Abdoli, 2007: p. 45)

Player C's Choice = Cooperation (C)

		Player B: C	Player B: D
Player A	C	5,5,5	3,6,3
	D	6,3,3	4,4,1

Player C's Choice = De-cooperation (D)

		Player B: C	Player B: D
Player A	C	3,3,6	1,4,4
	D	4,1,4	2,2,2

2. Literature review

While previous research has examined aspects of joint oil and gas fields, the Arash (Al-Durra) gas field in particular has received limited comprehensive analysis. Most studies have addressed either legal, geopolitical, or economic dimensions in isolation. A few studies focused on legal challenges and international agreements, others explored geopolitical and diplomatic consequences, and only one utilized game theory to study cooperation and competition strategies among countries. This lack of integrated analysis highlights a key gap that the present study seeks to address.

Noori and Khoshchehreh (2016), in their work *"Barriers and Strategies for Exploiting Iran's Joint Oil and Gas Fields"*, investigated the legal, contractual, financial, and geopolitical obstacles to exploiting Iran's shared oil and gas resources, including the Arash field. They identified issues such as unresolved border delimitation, neighboring countries' energy policies, and the absence of effective cooperation agreements as fundamental challenges. Their study emphasized that diplomatic engagement and contractual reform could enhance resource productivity. However, their analysis focused primarily on general barriers and legal/contractual issues, without a specific game-theoretical modeling approach to evaluate the Arash field dispute or quantify the strategic advantages and disadvantages of different courses of action.

Rezaei et al. (2021), in *"The Approach of the 1982 Law of the Sea Convention to Maritime Disputes with a Focus on the Arash Gas Field"*, analyzed the legal dimensions of the dispute among Iran, Kuwait, and Saudi Arabia under the United Nations Convention on the Law of the Sea (UNCLOS). They highlighted the obligation of states to cooperate in exploiting shared resources and to avoid unilateral actions that could jeopardize potential agreements. The study noted that Kuwait and Saudi Arabia's unilateral development efforts conflict with these principles and suggested that Iran pursue practical exploitation measures while engaging in trilateral negotiations. Nevertheless, the study did not consider economic or geopolitical factors, nor did it employ formal analytical models such as game theory, limiting its applicability in evaluating strategic outcomes and long-term implications of cooperation versus competition.

Toufighi et al. (2022), in *"Modeling of Production Strategies from Common Offshore Gas Field with Game Theory Approach"*, applied game theory to analyze production strategies in joint oil and gas fields, particularly the Arash gas field. Their mathematical modeling examined both cooperation and non-cooperation strategies among the involved players, demonstrating that cooperation, as the Nash equilibrium, produces the highest economic benefits for all parties. The study calculated optimal

production quantities, selling prices, and profits for each player, concluding that multilateral development and collaboration are the most advantageous approaches for exploiting shared resources. However, the research predominantly concentrated on mathematical and economic aspects, paying limited attention to geopolitical, legal, and security dimensions of the dispute.

The report *"The Gulf–Iranian Dispute Over Durra Field"* (Ab'ad Center for Studies and Research, 2023) analyzes the geopolitical, legal, and security aspects of the Arash (Al-Durra) gas field dispute between Iran, Kuwait, and Saudi Arabia. It reviews the historical evolution of the dispute from the 1960s to the present, emphasizing ongoing disagreements over maritime boundary delimitation as a major obstacle to trilateral agreement. Kuwait and Saudi Arabia assert joint ownership and accuse Iran of violating international law principles, while Iran claims its rights over the field and considers the unilateral actions of the other two countries illegal. The report discusses potential conflict-resolution scenarios, including direct negotiations, third-party mediation, and referral to the International Court of Justice. Despite its focus on political and diplomatic dimensions, the report does not include economic analyses or formal modeling approaches such as game theory.

Overall, existing studies on the Arash gas field have largely addressed individual dimensions of the dispute—legal, geopolitical, or economic—but none has provided an integrated analysis combining all three. Legal research has examined international law and contractual issues, geopolitical studies have explored political and regional implications, and the game-theory-based study has concentrated on economic modeling and strategies for cooperation and competition. Therefore, a comprehensive approach that simultaneously considers legal, geopolitical, and economic factors remains necessary to better understand the challenges and opportunities for cooperative exploitation of the Arash gas field.

2.1. Disputes between Iran, Kuwait, and Saudi Arabia over the Arash gas field

The significance of maritime territory has long been recognized for its roles in navigation, fishing, communication, and strategic control, making it a critical concern for states throughout history. In the modern era, the discovery of mineral and energy resources has further elevated the importance of asserting ownership and control over maritime areas (Mousazadeh, 2021: 233). Currently, oil and gas extraction occurs in the maritime waters of approximately 80 countries, encompassing over 800 offshore oil and gas fields (Mousazadeh, 2021: 234). Around 20% of global natural gas production is sourced from offshore fields, and this share is projected to rise to roughly 30% by 2040 (IEA, 2018) (see Figure 1).

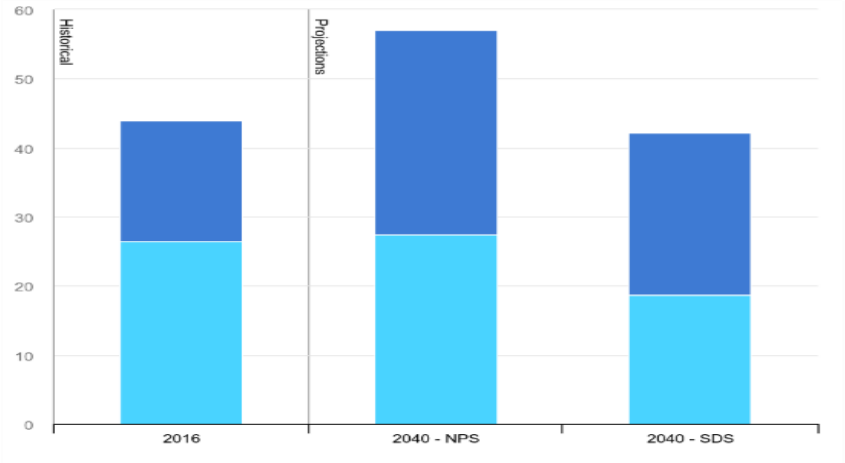

Figure 1
The share of global natural gas production (International Energy Agency, 2018)

The Arash (Al-Durra) gas field is a strategically located offshore reserve in the northern Persian Gulf, claimed by Iran, Kuwait, and Saudi Arabia. Estimated proven gas reserves are approximately 220 billion cubic meters. Discovered in 1967 by the Japanese company AOC, the field became the subject of overlapping concessions: Iran granted rights to the Anglo-Iranian Oil Company (later British Petroleum), while Kuwait awarded rights to Royal Dutch Shell, creating conflicts over the northern section of the field (Hashemi, 2023).

Maritime boundary negotiations have yet to produce a conclusive settlement. Iran's maritime boundary model attributes roughly 40% of the field to Iranian waters, whereas Kuwait contends the field lies within the neutral zone between Kuwait and Saudi Arabia, disputing Iran's exploitation rights (Hashemi, 2023). Iran initiated drilling in the early 2000s but paused operations to avoid escalating tensions with Kuwait.

Currently, development is managed by Khafji Joint Operations, a partnership equally owned by Kuwait Oil Company and Saudi Aramco. As of 2020, natural gas reserves are estimated at about 297,324 million cubic meters, and crude oil reserves at roughly 300 million barrels. Planned production for 2029 includes 9,302 million cubic meters of gas and 30.66 million barrels of oil annually (GEM, 2024).

The field's location at 28.9686° N latitude and 49.1122° E longitude places it at a geopolitically sensitive point between the three countries. Ongoing legal disputes and competing ownership claims continue to pose significant challenges to its development, with negotiations remaining unresolved (GEM, 2024).

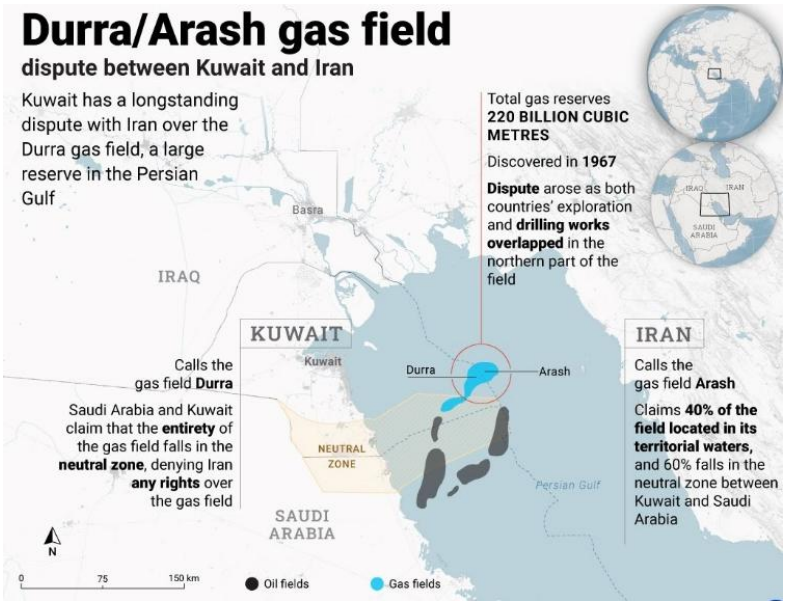

Figure 2
The Durra/Arash gas field (Anadolu Ajansi)

2.2. Challenges of the Arash gas field crisis

The Arash (Al-Durra) gas field dispute is one of the longest-running border conflicts in the Persian Gulf, with origins in the 1960s. Located in the northwestern Persian Gulf at the intersection of Iran, Kuwait, and Saudi Arabia, the conflict persists due to the absence of clearly defined maritime boundaries (Rasanah, 2023: 3). The dispute initially arose from overlapping exploitation rights granted to Royal Dutch Shell by Kuwait and to British Petroleum by Iran, resulting in contested areas of development. Tensions escalated in 2001 when Iran announced its intention to explore the field,

prompting Kuwait and Saudi Arabia to formalize an agreement on maritime boundaries for its development (Abaad Studies, 2023; Rasanah, 2023: 3).

Diplomatic relations among the three countries have remained strained due to conflicting ownership claims. Members of the Gulf Cooperation Council have consistently pressured Iran to provide legal documentation to support its claims (Aljebori, 2024: 8). In 2022, despite requests from Kuwait and Saudi Arabia to initiate negotiations on maritime boundaries, Iran rejected the principle of maritime delimitation and the final determination of ownership rights (Rasanah, 2023: 3-4).

After more than six decades, Iran has yet to agree to official maritime delimitation and continues to advocate for trilateral participation in the field's development. In March 2023, Saudi Arabia and Kuwait signed an agreement for joint development, which Iran declared illegal, warning that continued unilateral actions could prompt independent drilling in the claimed area (Rasanah, 2023: 3-4).

Saudi and Kuwaiti officials, in response to Iran's ownership claims, have maintained a firm, coordinated stance, asserting that the field lies entirely within their shared territorial waters and that Iran has no right to exploit it. They have emphasized that any unilateral actions by Iran would trigger serious retaliation (Rasanah, 2023: 7-8). Their main strategy involves insisting on official maritime boundary delimitation, which would legally invalidate Iran's claims. Meanwhile, Iran continues to resist delimitation, relying on diplomatic channels to delay resolution (Rasanah, 2023: 8).

2.3. The law of the sea and its implications for the Arash gas field dispute (UNCLOS, 1982)

The Law of the Sea constitutes a central branch of international law, regulating the exploitation of marine resources, the delimitation of maritime boundaries, and the resolution of disputes between states over oceanic territories. With the growth of economic activities at sea—particularly in energy extraction, fisheries, and marine environmental protection—the need for a coherent legal framework became critical. This led to the adoption of the United Nations Convention on the Law of the Sea (UNCLOS) in 1982, widely regarded as the cornerstone of modern maritime law (IMO).

UNCLOS provides a comprehensive foundation for defining the rights and responsibilities of states regarding the use and management of oceans and their natural resources. In addition to codifying traditional principles of maritime law, the Convention introduced new legal regimes, including the Exclusive Economic Zone (EEZ), rights over the continental shelf, and mechanisms for resolving maritime disputes (IMO).

Although Iran actively participated in the Third United Nations Conference on the Law of the Sea and signed the Convention, it has never ratified UNCLOS. Consequently, Iran is not legally bound to implement all provisions of the Convention. Moreover, in its interpretative statement upon signing, Iran challenged certain principles, such as transit passage through straits, the definition of the EEZ, and the legal regime of islands, and asserted that the rights of non-member states should not be affected by the Convention.

Iran's non-membership in UNCLOS has direct implications for maritime disputes, including the Arash (Al-Durra) gas field conflict. While Saudi Arabia and Kuwait, as UNCLOS members, reference the Convention to support their claims and delineate maritime boundaries, Iran relies on customary international law and bilateral negotiations. This divergence in legal frameworks has further complicated efforts to resolve the dispute, contributing to ongoing uncertainty and limiting the prospects for a trilateral agreement on the field's exploitation.

This section analyzes the Arash/Al-Durra gas field dispute from an international law perspective, focusing on the legal regime governing the sea, principles of delimiting the continental shelf and

Exclusive Economic Zone (EEZ), and mechanisms for resolving maritime disputes. It also considers the challenges arising from Iran's non-membership in UNCLOS.

Under Article 56 of UNCLOS, coastal states enjoy sovereign rights to explore, exploit, conserve, and manage natural resources—both living (e.g., fisheries) and non-living (e.g., oil and gas)—within 200 nautical miles from their baseline. When disputes arise regarding rights and jurisdiction within the EEZ, Article 59 stipulates that these conflicts should be settled on the principle of equality, balancing the interests of the parties and the international community.

In the case of the Arash/Al-Durra gas field:

- Kuwait and Saudi Arabia assert that the field lies entirely within their EEZ. They formalized a bilateral EEZ boundary agreement in 2022, excluding Iran from the decision-making process due to its non-membership in UNCLOS.
- Iran disputes this unilateral delimitation, claiming that 40% of the field falls within its EEZ, but it has avoided entering into formal EEZ boundary negotiations with Kuwait and Saudi Arabia.

The dispute is complicated by the lack of official EEZ delimitation between the three countries. Iran's non-membership in UNCLOS prevents it from utilizing the Convention's dispute resolution mechanisms, such as arbitration or recourse to the International Tribunal for the Law of the Sea. As a result, Iran's legal claim remains informal and unsupported by binding international procedures, while Kuwait and Saudi Arabia rely on UNCLOS principles to justify their bilateral agreement and assert control over the field.

In summary, the legal challenges of the Arash/Al-Durra dispute revolve around EEZ delimitation, access to dispute resolution mechanisms, and the consequences of Iran's non-ratification of UNCLOS, leaving the field's status uncertain and contributing to ongoing regional tensions.

2.4. Continental shelf: legal concepts and the Arash gas field dispute

The continental shelf is a fundamental concept in international maritime law, defining the sovereign rights of coastal states over natural resources in the seabed and subsoil. Article 77 of UNCLOS (1982) provides that coastal states automatically hold the right to explore and exploit resources of their continental shelf, including minerals, oil, gas, and living organisms on or under the seabed. No other state may exploit these resources without the coastal state's consent.

In the Arash/Al-Durra dispute:

- Iran asserts that part of the field lies within its continental shelf but has not formally recognized the delimitation with Kuwait and Saudi Arabia. Iran considers any bilateral agreements between these two states as invalid and maintains that, under customary international law, unilateral development by Kuwait and Saudi Arabia is illegal without trilateral consent.
- Kuwait and Saudi Arabia, however, have established a bilateral agreement in 2022, designating the Arash field as part of their shared continental shelf and EEZ, claiming that development is consistent with international law.

Article 83 of UNCLOS stipulates that delimitation of the continental shelf between adjacent or opposite states should be achieved via a bilateral agreement. If no agreement is reached, the matter may be referred to the International Court of Justice (ICJ) or other international dispute resolution mechanisms. Due to Iran's non-membership in UNCLOS, it lacks access to these formal mechanisms, weakening its legal position. Moreover, Iran's refusal to recognize maritime boundary delimitations further complicates its claim.

This dispute has broader implications:

- Legal: Divergent interpretations of UNCLOS and Iran's non-membership create a legal impasse. Kuwait and Saudi Arabia prioritize joint exploitation, while Iran insists on trilateral agreements, fostering competition and diplomatic tension.
- Economic: The field is strategically important for the energy-dependent economies of Iran, Kuwait, and Saudi Arabia. Prolonged disputes over resource exploitation can affect regional energy security, disrupt supply, and increase geopolitical instability.

Analyzing this dispute using game theory offers a structured approach to understand strategic decision-making by the three countries. By constructing a game theory matrix, the potential outcomes of cooperation and competition can be explored, identifying the strategies that maximize or minimize gains for each player while clarifying the interplay between legal, economic, and geopolitical factors.

This sets the foundation for the next section, which models Iran, Kuwait, and Saudi Arabia as rational players and examines possible scenarios using cooperative and non-cooperative game frameworks.

2.5. Analysis of collaborative and competitive games in the exploitation and control of the Arash gas field

In the previous section, the historical, legal, and political challenges surrounding the dispute over the Arash gas field involving Iran, Kuwait, and Saudi Arabia were examined. To better understand the actors' strategies and predict potential outcomes, this study now employs game theory as an analytical framework. Using this approach, each country is considered a rational actor that makes decisions based on economic, security, and geopolitical interests.

The interactions among Iran, Kuwait, and Saudi Arabia can be modeled as a three-player game, where each actor has a set of possible strategies—such as cooperation, competition, or diplomatic engagement—and receives corresponding payoffs.

In this context, decision matrices will be constructed for three key scenarios:

1. Iran competing against Kuwait and Saudi Arabia's cooperation,
2. Tripartite cooperation, and
3. Full-scale competition.

Finally, by applying the concept of Nash equilibrium, the analysis will identify the most likely outcomes and evaluate their implications for the future development and management of the Arash gas field.

2.6. Main elements of the game

The main elements of the game include the players, their strategies, possible scenarios, and associated payoff values, which can be described as follows. In this section, game theory is employed to examine the strategic interactions among Iran, Kuwait, and Saudi Arabia regarding the control and exploitation of the Arash gas field. Each country faces two primary strategies:

1. **Cooperation (C):** This strategy entails negotiating with the other parties and reaching an agreement for joint exploitation of the field.
2. **Competition (D):** This strategy involves actions such as independent drilling and obstructing the other parties from exploiting the field.

Considering that each country chooses between these two strategies, a total of eight possible scenarios can be identified ($2 \times 2 \times 2 = 8$). This matrix of eight states illustrates how the decision of each country

influences the gains or losses of the others and highlights the consequences of each scenario for all players. The following table presents all possible combinations of cooperation and competition and outlines the corresponding payoffs for each strategy adopted by the players.

Table 2
Players' strategies, strategies' payoffs, and description

Row	Strategy (IR, KU, SA)	Payoff	Description
1	(C, C, C)	(6,6,6)	Tripartite cooperation and joint exploitation: Leads to reduced tensions and maximized economic benefits for all parties.
2	(C, C, D)	(5,5,2)	Cooperation between Iran and Kuwait, with unilateral action by Saudi Arabia: Results in benefits for Iran and Kuwait, while Saudi Arabia experiences relative isolation.
3	(C, D, C)	(5,2,5)	Cooperation between Iran and Saudi Arabia, with unilateral action by Kuwait: Generates increased tension and regional instability.
4	(C, D, D)	(4,2,2)	Iran's willingness to cooperate, with unilateral action by Saudi Arabia and Kuwait: Creates the possibility of an agreement that excludes Iran.
5	(D, C, C)	(7,3,3)	Unilateral action by Iran, with cooperation between Kuwait and Saudi Arabia aimed at limiting Iran: May expose Iran to potential international pressure.
6	(D, C, D)	(4,2,7)	Competition between Iran and Saudi Arabia, with Kuwait's willingness to cooperate: Increases the possibility of conflict between the two regional powers.
7	(D, D, C)	(3,7,3)	Saudi Arabia's willingness to cooperate, with independent actions by Iran and Kuwait: Provides maximum benefits to Kuwait, while Iran and Saudi Arabia incur relative losses.
8	(D, D, D)	(1,1,1)	Independent actions by all three countries without agreement: Heightens the likelihood of conflict, leads to market instability, and results in losses for all parties.

This analysis indicates that the most favorable scenario for all three countries is full cooperation (C, C, C), wherein Iran, Kuwait, and Saudi Arabia jointly exploit the Arash gas field through a stable trilateral agreement. Such a scenario, characterized by the lowest likelihood of conflict, yields the highest economic and security returns for all parties. However, achieving full cooperation may be challenging due to the existing regional rivalry, particularly between Iran and Saudi Arabia.

Conversely, the most probable interaction among these countries corresponds to the (D, C, C)strategy, in which Iran pursues unilateral action and begins independent drilling, while Kuwait and Saudi Arabia cooperate to limit Iran's influence. Although Iran may obtain short-term gains through unilateral action, it is likely to encounter long-term diplomatic and international pressures, including sanctions or potential litigation initiated by Kuwait and Saudi Arabia in international courts.

The least desirable scenario is complete competition (D, D, D), where all three countries act unilaterally. This outcome could trigger market instability, exacerbate legal disputes, and heighten regional security tensions, ultimately resulting in negative consequences for all players.

The corresponding payoff matrix for these scenarios can be represented as follows:

Table 3

The players' payoff matrix: Each cell of the table represents an outcome for each player, and higher numbers indicate greater benefits.

IR, Ku, SA	C, C, C	C, C, D	C, D, C	C, D, D	D, C, C	D, C, D	D, D, C	D, D, D
Payoff IR	6	5	5	4	7	4	3	1
Payoff KU	6	5	2	2	3	2	7	1
Payoff SA	6	2	5	2	3	7	3	1

2.7. The complete cooperation (C, C, C) game matrix considering Iran's potential membership in UNCLOS

The matrix presented below analyzes the scenario of full cooperation among Iran, Kuwait, and Saudi Arabia, considering the potential impact of Iran's membership or non-membership in the United Nations Convention on the Law of the Sea (UNCLOS). It evaluates the effects and implications of Iran's acceptance or non-acceptance of the Convention within the context of this cooperative scenario.

Table 4

The complete cooperation (C, C, C) game matrix considering Iran's potential membership in UNCLOS

IR, KU, SA	C1, C1	C1, C2	C2, C1	C2, C2
C1: IR accepts UNCLOS	8,8,8	7,6,6	6,7,7	5,5,5
C2: IR rejects UNCLOS	7,7,7	6,6,6	5,7,7	4,4,4

In the above matrix, the columns C1 and C1 represent the conditions of full cooperation, considering Iran's membership in UNCLOS and the willingness of Kuwait and Saudi Arabia to cooperate with Iran (outcome 8,8,8). Under these circumstances, stable trilateral cooperation is achieved, allowing the joint exploitation and management of the Arash gas field. Conversely, if Iran does not become a member of UNCLOS but still demonstrates a willingness to cooperate and negotiate, a trilateral agreement and joint management can occur outside the framework of the Convention (outcome 7,7,7).

In the C1 and C2 scenarios, cooperation among the three countries is more limited. While Iran's accession to UNCLOS secures a stronger legal position to benefit from the field, Kuwait and Saudi Arabia retain the capacity to impose certain restrictions on Iran's utilization (outcomes 7,6,6). If Iran does not join the Convention, negotiations may continue, but a stable agreement resolving the dispute is unlikely.

In the third scenario, C2, C1, Iran's acceptance of UNCLOS enables it to exploit the Arash gas field despite existing limitations. However, if Iran refrains from joining, it must make concessions to Kuwait and Saudi Arabia to maintain an agreement.

In the final scenario, C2, C2, even if Iran becomes a member of the Convention, the probability of reaching an agreement diminishes due to prolonged negotiations. In the worst-case scenario, where Iran does not accept UNCLOS (outcome 4,4,4), negotiations among the three countries reach a deadlock, leaving the future exploitation and management of the Arash gas field uncertain. Overall, this matrix illustrates the significant influence of Iran's legal and diplomatic decisions on the degree of trilateral cooperation in the management of the field.

2.8. Game matrix in the scenario of Iran competition and Kuwait and Saudi Arabia cooperation (D, C, C)

The final modeled matrix in this study examines the current state of the Arash/Al-Durra gas field dispute. It analyzes the consequences of strategic decisions by the involved actors, including Iran's potential threat of unilateral action and independent drilling, alongside Kuwait and Saudi Arabia's coordinated efforts to manage and exploit the field while limiting Iran's influence. The matrix further evaluates the potential outcomes of the continuation of this situation, providing insights into the likely economic, legal, and geopolitical implications for all parties involved.

Table 5
The final modeled matrix of the current state of the Arash/Al-Durra gas field dispute

IR, KU, SA	C1, C1	C1, C2	C2, C1	C2, C2
D1 IR Independent Action	7,3,3	5,4,4	3,5,5	1,6,6
D2 IR Using Legal Pressure	6,3,3	4,4,4	2,5,5	0,6,6

This section examines various scenarios in which Iran adopts a competitive strategy (D) while Kuwait and Saudi Arabia continue to cooperate (C, C). Each scenario produces distinct impacts on the strategic interactions among the three countries, with the distribution of benefits and losses dependent on the reciprocal responses of the parties involved.

In the first scenario (D1, C1, C1), Iran, by pursuing unilateral actions, achieves significant short-term economic gains and attains the highest profit relative to the other players (7,3,3 outcome). However, this approach may trigger adverse reactions from Kuwait and Saudi Arabia due to their bilateral cooperation under the 2022 agreement, potentially resulting in trade restrictions, diplomatic pressure, and reduced access to international energy markets for Iran.

In the second scenario (D1, C1, C2), as Iran continues its independent drilling, Saudi Arabia and Kuwait may employ diplomatic measures or refer the dispute to international arbitration. In this context, Iran faces legal challenges that could delay or obstruct its exploitation activities. Nevertheless, it retains partial access to the field (5,4,4 outcome), although at a substantial diplomatic cost.

In the third scenario (D1, C2, C1), Kuwait and Saudi Arabia may adopt a more assertive strategy by initiating legal actions against Iran in international forums. This could result in restrictive rulings from international courts, directly limiting Iran's ability to exploit the Arash gas field (3,5,5 outcome), thereby enhancing the control of Kuwait and Saudi Arabia over the field.

In the fourth scenario (D1, C2, C2), the intensity of reciprocal actions increases, with Kuwait and Saudi Arabia pursuing legal measures and requesting the imposition of international sanctions against Iran. Consequently, Iran's access to financial resources and global markets would be severely constrained (1,6,6 outcome). This scenario represents the most advantageous outcome for Kuwait and Saudi Arabia, as they would effectively manage and exploit the field without Iranian involvement.

In the fifth scenario (D2, C1, C1), if Iran favors diplomatic negotiation and legal engagement rather than full confrontation, it may secure concessions through limited cooperation. Unlike unilateral drilling, this strategy allows Iran to derive some economic benefits from the Arash gas field while avoiding legal and diplomatic repercussions or international isolation (6,3,3 outcome).

While adopting a purely competitive approach can yield immediate economic gains, it also incurs significant long-term diplomatic and legal costs. The D1, C1, C1 scenario, despite its short-term profitability, heightens tensions and provokes countermeasures from Kuwait and Saudi Arabia. In

contrast, the D2, C1, C1 scenario emphasizes diplomatic engagement and negotiation, minimizing political risks while maintaining access to economic benefits.

Overall, to achieve sustainable long-term advantages, Iran must balance competition with diplomatic and legal engagement. Leveraging negotiation strategies and international legal mechanisms can help mitigate the costs associated with unilateral competitive actions while preserving opportunities for resource exploitation.

2.9. Nash equilibrium in the Arash gas field dispute

To analyze the strategies of Iran, Kuwait, and Saudi Arabia in the Arash gas field dispute, it is necessary to revisit the conditions for establishing a Nash equilibrium in a three-player game and then apply these conditions to the current strategic interactions among the three countries.

As previously discussed, a Nash equilibrium is a situation in which no player can unilaterally change their strategy to achieve a higher payoff, given the strategies of the other players. In other words, each player selects a strategy that constitutes the best response to the strategies chosen by the other participants. The following section examines the possible equilibrium states in the Arash gas field dispute, considering the behaviors and strategic incentives of Iran, Kuwait, and Saudi Arabia.

The present scenario is characterized by Iran adopting a competitive strategy while Kuwait and Saudi Arabia cooperate, represented as (D, C, C). In this configuration, Iran engages in independent drilling or unilateral actions to exploit the field, whereas Kuwait and Saudi Arabia coordinate their management and exploitation efforts through bilateral cooperation. The corresponding payoff values are (7, 3, 3), reflecting high short-term gains for Iran. To determine whether this scenario constitutes a stable equilibrium, it is necessary to examine the incentives of each player to change their strategy (Table 4).

First, if Iran were to change its strategy from competition (D) to cooperation (C), the game would shift to (C, C, C), reducing Iran's payoff from 7 to 6 (Table 2). Since this change results in a lower payoff, Iran has no incentive to deviate and would maintain its competitive strategy. Next, assessing Kuwait's incentive to switch from cooperation (C) to competition (D) in the (D, C, C) scenario reveals that Kuwait's payoff under cooperation is 3. By changing its strategy, the game would transition to (D, D, C), increasing Kuwait's payoff from 3 to 7. Because this change yields a higher benefit, Kuwait is motivated to abandon cooperation in favor of competition.

Therefore, the (D, C, C) scenario cannot be considered a Nash equilibrium, as at least one player (Kuwait) has a strong incentive to alter their strategy.

2.10. Stable Nash equilibrium

Given that (D, C, C) is not a Nash equilibrium, it is necessary to identify a state in which none of the countries has an incentive to unilaterally alter their strategy. An examination of the outcomes of alternative scenarios indicates that the (D, D, C) configuration represents a stable Nash equilibrium (Table 2).

In this scenario, Iran maintains its competitive strategy because switching to cooperation (C) would reduce its payoff from 3 to 1. Kuwait, which previously had an incentive to shift from cooperation to competition in the (D, C, C) scenario, now attains its maximum possible payoff of 7 and therefore has no motivation to revert to cooperation. Likewise, Saudi Arabia continues its cooperative strategy (C), as changing to competition (D) would decrease its payoff from 3 to 1.

Consequently, the (D, D, C) state constitutes a stable equilibrium, as no player can achieve a higher payoff through unilateral strategy changes. From a policy perspective, this scenario suggests that

escalating competition between Iran and Kuwait could ultimately benefit Saudi Arabia. By maintaining its cooperative stance while the other two countries compete, Saudi Arabia is able to leverage their conflict to its advantage without directly engaging in competition, thereby shifting the strategic balance in its favor.

3. Conclusions

This study analyzed the dispute over the Arash gas field among Iran, Kuwait, and Saudi Arabia from a game theory perspective. Initially, the significance of shared hydrocarbon resources in the Persian Gulf and the associated geopolitical challenges were outlined. Using the game theory framework, various scenarios of cooperation and competition among the three countries were examined, with the primary objective of identifying stable equilibria and assessing their strategic implications for all players.

The results indicate that the optimal scenario for all three countries is full cooperation (C, C, C), in which Iran, Kuwait, and Saudi Arabia jointly exploit the Arash gas field through a trilateral agreement. This approach provides long-term economic, security, and political benefits, reduces regional tensions, enhances energy market stability, and minimizes potential costs arising from geopolitical conflicts. However, the stability of this scenario is fragile, as any party may be tempted to switch from cooperation to competition in pursuit of greater individual gains.

Conversely, the (D, C, C) scenario—where Iran independently exploits the field—may yield short-term economic benefits for Iran. Nevertheless, the responses of Kuwait and Saudi Arabia through legal and diplomatic measures could increase international pressure and limit Iran's long-term advantages.

The Nash equilibrium analysis identified the (D, D, C) scenario—where Iran and Kuwait compete while Saudi Arabia remains cooperative—as the most likely stable outcome. In this configuration, Iran and Kuwait engage in competition to maximize their respective shares of the field's resources, while Saudi Arabia, by maintaining a cooperative stance, can leverage the conflict between the other two countries to strengthen its strategic position.

From an international law perspective, Iran faces significant challenges in asserting its claims over the Arash gas field due to its non-membership in the United Nations Convention on the Law of the Sea (UNCLOS). While Kuwait and Saudi Arabia assert sovereignty based on UNCLOS principles, Iran maintains that 40% of the field lies within its continental shelf and that any bilateral agreements between Kuwait and Saudi Arabia are invalid. Accession to UNCLOS would strengthen Iran's legal position and create broader opportunities for negotiation and a comprehensive agreement. Furthermore, pursuing cooperation with one of the disputing parties or adopting a flexible strategy that balances competition and cooperation—rather than confronting both countries simultaneously—could enhance Iran's long-term interests in the Arash gas field.

Nomenclature

EEZ	Exclusive Economic Zone
ICJ	International Court of Justice
IPE	International Political Economy
OPEC	Organization of the Petroleum Exporting Countries
UNCLOS	United Nations Convention on the Law of the Sea

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Appendix: Python code for game theory modeling of the Arash gas field

This appendix presents the Python code used for game theory modeling of the Arash gas field dispute. In this model, the possible strategy combinations of the three countries—Iran, Kuwait, and Saudi Arabia—are defined under two options: "Cooperate" and "Compete." Various scenarios are formulated based on these combinations, and payoff values are assigned to each scenario. These values represent the relative benefits or losses for each country under different strategic interactions. The implemented code simulates this payoff matrix, allowing for systematic analysis of the strategic decisions of the players. All code was generated using artificial intelligence and executed in Google Colab to ensure efficient computation and convenient access to the results.

https://colab.research.google.com/drive/1-cWOsELYWvwmcacKD1ZSHB8krp0FVkAC?usp=sharing

https://colab.research.google.com/drive/1QnRkEFBVLpuB6c9LDU-mictYvOPEAbm3?usp=sharing