ТЕХНИЧЕСКИЕ НАУКИ | TECHNICAL SCIENCES

ИНФОРМАТИКА, ВЫЧИСЛИТЕЛЬНАЯ ТЕХНИКА И УПРАВЛЕНИЕ INFORMATICS, COMPUTER ENGINEERING AND MANAGEMENT

Современная наука и инновации.
2024. № 1 (45). С. 8-24.
Modern Science and Innovations.
2024;1(45):8-24.

ТЕХНИЧЕСКИЕ НАУКИ / TECHNICAL SCIENCE

ИНФОРМАТИКА, ВЫЧИСЛИТЕЛЬНАЯ ТЕХНИКА И УПРАВЛЕНИЕ / INFORMATICS, COMPUTER ENGINEERING AND MANAGEMENT

Научная статья / Original article

УДК 519.833, 519.834
https://doi.org/10.37493/2307-910X.2024.1.1

Дмитрий Анатольевич Первухин [Dmitry A. Pervukhin][1*],
Давардуст Хади [Davardoost Hadi][2],
Дмитрий Дмитриевич Котов [Dmitry D. Kotov][3]

Моделирование и анализ использования общих газовых ресурсов Ирана и Катара в различных сценариях распределения ресурсов и мощности добычи: подход на основе теории игр

Modeling and analysis of the utilization of common gas resources between Iran and Qatar, considering various scenarios of resource distribution and extraction power: a game theory approach

[1, 2, 3]Санкт-Петербургский горный университет императрицы Екатерины II, г. Санкт-Петербург, Россия / St. Petersburg Mining University of Empress Catherine II, St. Petersburg, Russia

****Автор, ответственный за переписку: Дмитрий Анатольевич Первухин, pervuchin@rambler.ru / Corresponding author: Dmitry A. Pervukhin, pervuchin@rambler.ru***

Аннотация. *Нефть и газ являются движущими силами многих видов экономической и производственной деятельности, поэтому они занимают важнейшее место в экономическом росте и развитии. Газовое месторождение Южный Парс/Северный купол - крупнейшее в мире газовое месторождение между Ираном и Катаром, которое нуждается в правильной разработке и использовании. Иран и Катар совместно владеют этим месторождением, и на них лежит ответственность за разработку соответствующих стратегий по эксплуатации нефти и газа. В данном исследовании анализируются четыре статические игровые модели равновесия Нэша и оптимальные стратегии между Ираном и Катаром по эксплуатации их общего ресурса. Предполагается, что добывающая способность Ирана зависит от международных санкций, что приводит к неравенству добывающих способностей. Различные условия модели включают "равное распределение ресурсов и равную добывающую способность", "неравное распределение с равной добывающей способностью", "равное распределение с неравной добывающей способностью" и "неравное распределение с неравной добывающей способностью". Результаты исследования показывают, что в первых двух сценариях, в которых ни одна из стран не подвергается санкциям, обе страны должны принять решение о непринятии обязательств по сотрудничеству. Однако в двух* *последних сценариях, когда Иран находится под санкциями и обладает более слабой добывающей силой, он должен придерживаться политики сотрудничества, в то время как Катар должен придерживаться подхода, не предполагающего сотрудничества. Таким образом, решение страны об участии в эксплуатации общих ресурсов зависит от ее добывающей способности, а не от распределения ресурсов. Следовательно, можно утверждать, что на общее газовое месторождение Ирана и Катара, которое поделено неравномерно, существенно влияют санкции. Из-за санкций Ирана его добывающая способность снизилась, и он принял стратегию сотрудничества с Катаром. В то же время доминирующей стратегией Катара является отказ от сотрудничества. В результате Иран страдает от эксплуатации общих ресурсов в условиях санкций.*

Ключевые слова: газовое месторождение Южный Парс, теория игр, равновесие Нэша, добывающая способность, распределение ресурсов, Иран, Катар

Для цитирования: *Первухин Д. А., Давардуст Хади, Котов Д. Д. Моделирование и анализ использования общих газовых ресурсов Ирана и Катара в различных сценариях распределения ресурсов и мощности добычи: подход на основе теории игр // Современная наука и инновации. 2024. № 1 (45). С. 8-24.* https://doi.org/10.37493/2307-910X.2024.1.1

Abstract. *Oil and gas are the drivers of many economic and production activities, so they have a crucial place in economic growth and development. South Pars/North Dome gas field is the world's largest gas field between Iran and Qatar, which needs to be properly developed and utilized. Iran and Qatar jointly own this field and they have the responsibility to develop appropriate strategies for oil and gas exploitation. This study analyzes four static Nash equilibrium game models and the optimal strategies between Iran and Qatar to exploit their common resource. Iran's extraction capacity is assumed to be affected by international sanctions, which leads to inequality of extraction capacity. The different conditions of the model include "equal resource allocation and equal extractive capacity", "unequal allocation with equal extractive capacity", "equal allocation with unequal extractive capacity" and "unequal allocation with unequal extractive capacity". The results of the study show that in the first two scenarios, in which neither country is sanctioned, both countries must decide not to commit to cooperation. However, in the latter two scenarios, when Iran is under sanctions and has weaker extractive power, it should adopt a cooperative policy, while Qatar should adopt a non-cooperative approach. Thus, a country's decision to participate in the exploitation of shared resources depends on its extractive power rather than resource allocation. Consequently, it can be argued that Iran and Qatar's shared gas field, which is unequally divided, is significantly affected by sanctions. Iran's sanctions caused its production capacity to decrease, and it adopted a strategy of cooperation with Qatar. At the same time, Qatar's dominant strategy is non-cooperation. As a result, Iran suffers from exploitation of common resources under sanctions.*

Keywords: South Pars gas field, game theory, Nash equilibrium, production capacity, resource allocation, Iran, Qatar

For citation: *Pervukhin DA, Davardoost Hadi, Kotov DD. Modeling and analysis of the utilization of common gas resources between Iran and Qatar, considering various scenarios of resource distribution and extraction power: a game theory approach. Modern Science and Innovations. 2024;1(45):8-24.* https://doi.org/10.37493/2307-910X.2024.1.1

Introduction. The oil and gas sector is one of the largest and most strategically important industries in the world. Research shows that hydrocarbon resources will remain the main source of energy until at least 2050. Following the oil shock of the 1970s, awareness of the importance of efficient management and consumption of energy resources increased throughout the world. In most developing oil-exporting countries, oil revenues account for a significant share of foreign exchange and government revenues, being the most important factor determining economic performance. The oil and gas industry has a significant impact on economic activity, living standards, social security systems, and the supply of goods and services that rely heavily on oil and gas revenues [1-3].

According to international statistics provided by BP, in 2021 and 2022 the world's total proven oil reserves will be about 1,732.4 billion barrels. Iran accounts for 157.8 billion barrels, which is 9.1% of total reserves. In addition, Qatar has oil reserves of 25.2 billion barrels, which is 1.5% of the total. Also, if we consider the world's total proven natural gas reserves of about 188.1 trillion cubic meters, Iran's share is 32.1 trillion cubic meters, or 17.1% of the total. On the other hand, Qatar's proven natural gas reserves are 24.7 trillion cubic meters, or 13.1%. Thus, these two countries have an impressive amount of world oil and gas reserves: Iran - 10.6% of world oil reserves, and Qatar - 30.2% of all gas reserves [4, 5].

Natural resources, including oil and gas, often cross the territorial and political boundaries of two or more countries, requiring international cooperation in their management. Since the oil shocks of the 1970s, managing the consumption and exploitation of these cross-border resources has become a priority for energy policy at the international, regional and national levels. Development of general deposits is a complex process involving technical, economic, legal and political problems. These problems can hinder the attraction of foreign investment, the introduction of modern technologies and the involvement of countries with different legal and political frameworks. Several factors must be considered when developing energy policy, including fuel availability, associated costs and prices, stakeholder interests, fuel source and required infrastructure [6-13]. According to Bailey [6], taking these aspects into account is critical to developing effective energy policies. For the effective use and joint development of shared resources, it is essential to resolve any issues of demarcation between the relevant parties [14-16].

One of the key problems in the use of these resources is the different legal positions regarding territorial sovereignty over a common territory [17]. Conflict occurs when two or more players disagree on an issue. One of the mathematical approaches to analyzing the behavior of players in a conflict is game theory, first presented by Morgenstern [18]. Game theory is especially useful when the number of players (agents) in conflict with each other is limited, since in this case the behavior of each player has a significant impact on the returns of the other players [19]. This is a powerful tool for predicting and analyzing possible actions of players and the outcome of a conflict over shared resources [20]. The purpose of this study is to improve our understanding of conflicts of interest between countries in the process of extracting and exploiting shared resources, using a game theory approach. In particular, the focus is on studying the strategic behavior of Iran and Qatar regarding the South Pars/North Dome field. Iran's ownership of 25% of the field's resources is complicated by international sanctions, while Qatar owns 75% and uses advanced technologies in resource extraction (this study). The South Pars/North Dome field is the largest gas reservoir in the world, shared by Iran and Qatar, and is expected to play a key role in meeting the growing demand for natural gas in the future in both countries. However, since there are no fixed boundaries for joint gas fields, the failure of one party to extract the resource could result in the other party taking a larger share. If Iran fails to increase gas production from the South Pars/North Dome field, Qatar could lay claim to a larger share of this valuable resource. The geographical location of the (South Pars) / (North Dome) gas fields and the productivity growth trend of the entire South Pars field compared to Qatar are shown in Figure 1.

The main contribution of this work is the introduction of two influencing factors, namely the “share effect” and the “sanction effect” regarding the exploitation of common resources. These factors shed light on how common resources are used and managed, providing critical information for policymakers and resource managers. The share effect is associated with the distribution of resources that are commonly owned by countries, which can be characterized by either symmetric or asymmetric distribution. When studying the equity effect, which is often demarcated by geographic boundaries between countries, it is important to consider the nature of shared resources. To do this, it is necessary to determine whether these resources are in a liquid or solid state, since this can significantly affect their distribution among participating countries. Unlike solid minerals, which can be easily divided based on established borders between countries, common oil and gas resources migrate due to their fluidity. As a result, any interested government within its territorial domain can exploit it, which may include a significant portion of the reservoir located in a neighboring country, without its consent.

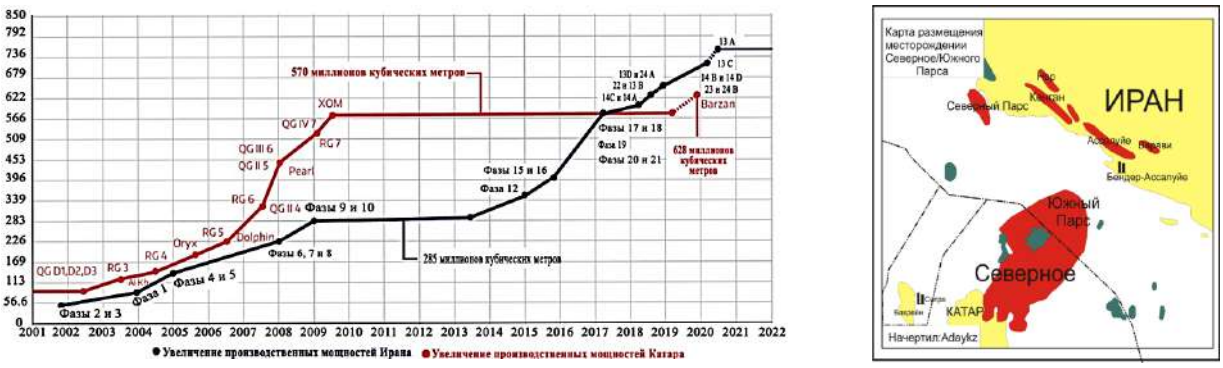

Figure 1 – Geographical location of (South Pars gas field) / (North Dome field) and the trend of increasing productivity of the total South Pars field compared to Qatar

The effect of sanctions highlights the critical role of international relations between countries, especially in allowing access to modern technologies for resource extraction. For example, countries such as Iran, which have significant oil and gas reserves but are currently subject to sanctions by developed countries, face restrictions on access to advanced technologies, which reduces their ability to extract natural resources. However, many empirical studies overlook this factor, which influences the strategic choices of both countries involved in the exploitation of shared natural resources. This study addresses two critical questions: first, how does the distribution of common resources among countries, whether equal or unequal, affect their strategic decision-making? Second, how does the Nash equilibrium change if international sanctions impede one country's ability to extract resources? Following the introduction, the study is presented in the following format. The following section discusses the literature review in detail. In Section 3 we describe the methodology used as well as the data used in the analysis. Next, Section 4 details the empirical results, and Section 5 provides an overview, including a discussion of policy implications [21, 22].

Literature review. The exploitation of commonly owned natural resources by countries is an important issue that has been addressed in several empirical studies from legal and economic perspectives. Game theory has been applied in the literature to study various issues related to shared oil and gas resources, including modeling, management, and conflict resolution. Game theory is a valuable tool for identifying potential conflicts or opportunities for cooperation among stakeholders involved in managing shared resources. This is especially true in situations where resources are shared across multiple jurisdictions or where there is a risk of overexploitation. Using game theory, decision makers can analyze the behavior and incentives of various participants, predict possible outcomes, and develop strategies that promote efficient and sustainable use of resources. Ultimately, this approach can facilitate effective collaboration and mitigate the negative environmental and social impacts of joint resource management. Given that this study is devoted to the study of conflicts of interest in the exploitation of oil and gas resources using game theory, this section will only review empirical studies in which game theory has been used to study the problem of oil and gas resource exploitation [23-27]. First, a summary of relevant studies in other countries will be given, followed by studies of Iran's oil and gas resources (Table 1).

Table 1 – Summary of relevant studies for other countries and Iran

Reg.	Authors	Topical research	Game type	results	Ref.
Other countries	Hayashi (2012)	China and Japan	Non-game (political and legal approach)	Participation of the Japanese in the development of a joint field with China.	[17, 28]
	Aplak and Sogut (2013)	Energy management between industry and the environment	Fuzzy set theory (MCDM) and game theory	When using renewable energy sources in industry, the environment develops protective reflexes to preserve nature.	[29]

Reg.	Authors	Topical research	Game type	results	Ref.
	Lee et al. (2013)	Russia and China	Static game	The optimal strategy for both parties: commitment to cooperation and joint development of the oil field.	[30, 31]
	Yang and Kong (2014)	General state	Dynamic game (Stackelberg model)	The need for cooperation between countries in securing strategic oil reserves.	[32]
	Shitka (2014)	General state	Static game	Presentation of proposals to overcome possible deadlocks in negotiations between the parties with the aim of concluding comprehensive agreements on the integration of oil and gas fields.	[33, 34]
	Khawas (2015)	Norway-Russia	Static game	The sooner a country starts producing oil, the higher the expected return on investment.	[35, 36]
	Serketi and Ventura (2020)	General state	Dynamic game	The need to regulate appropriate terms in contracts is due to the lack of trust between the parties and the provision of incomplete information	[37]
	Irsadanar and Kimura (2021)	China and Japan	Non-game (political and legal approach)	The end of cooperation between China and Japan in the field of extraction of shared resources in the East China Sea due to a lack of trust between the parties.	[14]
	Mamada and Perrings (2022)	Shared fishing source for two companies	Static game	Guarantees collaboration using an entanglement mechanism.	[38, 39]
	Harismavan and Visanjaya (2022)	Indonesia and Malaysia	Non-game (political-legal approach)	Joint developments based on international experience.	[40]
Iran	Sheikh Mohammadi et al. (2011)	Iran and United Arab Emirates	Non-game (graphical conflict resolution model (GCRM))	Negotiations are necessary to resolve the dispute and both sides must avoid hostilities	[41]
	Esmaili et al. (2015)	Iran, Iraq and Qatar	Non-game (simulated strategies for using common fields)	Countries that rely heavily on oil and gas revenues use optimal strategies to exploit them. Shared Resources	[42, 43]
	Salimian and Shahbazi (2017)	Iran	Game theory (cooperative and non-cooperative scenarios)	Partner countries should exploit shared resources with less activity.	[1]
	Maddahinasab (2018)	Iran	Legal and philosophical aspects of property rights and sovereignty	Relying on common agreements is a practical way to solve problems associated with oil production	[44]
	Bayati et al. (2019)	Iran and Qatar	Game theory (cooperative and non-cooperative scenarios)	The non-cooperation strategy was optimal for both countries. Both countries adopted a policy of non-cooperation in the exploitation of shared resources, which resulted in an increase in the current net worth of both countries	[45]
	Tufigi et al. (2020)	Iran and Saudi Arabia	Theory of games on the general Foruzan field.	The joint behavior of both countries can lead to more effective use of the common field	[46]
	Rassaf et al. (2021)	Iran	Game theory (Nash equilibrium)	The United States was unable to eliminate Iranian oil exports due to several factors, such as the lack of	[47]

Reg.	Authors	Topical research	Game type	results	Ref.
				full understanding between the United States and Europe and Iran's attempts to circumvent sanctions.	
	Bahrini et al. (2021)	Iran	Non-game (Graph model of conflict resolution)	These proposed concepts can help decision makers and policy makers gain a clearer understanding of conflict, ensuring more optimal outcomes	[48]
	Tufigi et al. (2022)	Iran, Saudi Arabia and Kuwait	Optimization mathematical modeling for the Arash gas field	A strategy of cooperation through multilateral and joint development of a common field. In addition, all three countries must cooperate in managing and developing a common gas field in a manner that benefits everyone equally.	[49]

It can be concluded that most reviews have determined that the optimal approach for parties under comparable and balanced conditions remains the same, regardless of differences in conditions in countries sharing reservoirs. In this study, the Nash equilibrium was studied by analyzing two important factors. The first determining factor is "resource distribution," which refers to the fact that some countries have a larger share of an economic resource and, accordingly, greater power to extract it. A second determining factor is the extent to which sanctions or comparable circumstances reduce production opportunities, depending on their level of severity. In the modeling section, these effects were identified and discussed to further understand their potential impact on reserve production. A distinctive feature of this study is the examination of these effects in four different scenarios to determine their impact on resource production in the South Pars/North Dome gas field in Iran and Qatar.

Materials and research methods. Maximizing the interests of all stakeholders involved in the use of a shared natural resource can be a challenging task. However, it needs to be done. To address this problem, this study proposes a game theory-based mechanism to optimize the use of shared natural resources. This mechanism is applicable to various scenarios related to inequality in the distribution of resources and the ability to extract them. Economic profit functions are used to model the results of this mechanism for all participants in the game.

Game theory. Game theory is designed to model situations in which people's interests come into conflict and determine the best strategy for each player [1]. In static games with complete information, each player chooses his strategy based on his own interests, without knowing the interests of his opponent. Players choose strategies simultaneously [50]. Additionally, it is assumed that all players understand the consequences of the game. A Nash equilibrium is a situation where no player has any reason to change strategy.

$$u_i(\sigma_i, \sigma_{-i}) \geq u_i(\sigma_i', \sigma_{-i}) \quad (1)$$

To achieve a Nash equilibrium, each player must choose a strategy that maximizes the outcome based on his belief in his opponent's choice. The player must also understand the opponent's strategy and coordinate their actions to achieve a Nash equilibrium. This decision process gives players Nash equilibrium strategies [19] . Many games have a decisive element where players choose a certain strategy over others because it leads to a better outcome. If other strategies fail, the player will naturally choose the dominant strategy, regardless of the opponent's move. The most preferred strategy in the game is the dominant strategy, and the rest are dominated strategies. Each player is likely to choose their dominant strategy over others. A dominant strategy equilibrium is the dominant strategy for all players [51]. In this exploration game, two partner countries share one resource. The game starts with a couple of options available for each country. They can either commit to cooperation (C) or not (D). The following defines the available strategies for two players:

$$S_i = \{C, D\}, \ i = 1, 2. \quad (2)$$

Below is a brief description of the strategies that have been combined between Iran and Qatar:

$$S = S_1 \times S_2 = \{(CI, CQ), (CI, DQ), (DI, CQ), (DI, DQ)\} . \qquad (3)$$

The economic profit function is used to determine the outcomes for Iran and Qatar in the allocation of common resources. The results depend on the scenarios specified in the simulation section.

Modeling of hood power modes. To model play across different modes, it is important to consider two assumed resource statuses between countries: equal and unequal distribution. In addition, international sanctions are believed to be affecting Iran's production capacity. When a country falls under sanctions, it loses access to the necessary mining capacity, which leads to an unequal distribution of mining capacity. This study assumes that Iran is under international sanctions and sanctions are expected to have a greater impact than the distribution of general resources. In other words, production levels will be significantly lower when sanctions are in place. To better understand the scenarios, in the first case it is assumed that the common resource is equally distributed between both countries and no sanctions are imposed. In the second case, the resource is distributed unevenly, one of the countries has an advantage, but sanctions are not imposed. The third scenario assumes a symmetrical distribution between countries, but one of them is under sanctions, which leads to a decrease in production capacity. Finally, the fourth scenario assumes an uneven distribution, and one of the countries is under sanctions. It is important to note that cooperation between countries is necessary to ensure that each of them respects its share in the extraction process in each of the four scenarios. In all cases, each country has the opportunity to accept or not accept an obligation to cooperate with another country (Table 2).

Table 1– Modeling of fume hood power modes

Extraction power	**Resource Allocation**	
	Equal (no sanctions)	Unequal (sanctions)
Equal (no sanctions)	Case 1 (EE)	Case 2 (EU)
Unequal (sanctions)	Case 3 (UE)	Case 4 (UU)

To determine the results of different strategies in a game between countries in normal form, it is necessary to set priorities for each player. When it comes to using a common resource, the best outcome for each country is achieved when one party does not cooperate and the other cooperates. On the other hand, the worst result is achieved when one country commits to cooperation and the other does not. To populate the cells of the matrix, we use the profit function, which measures economic profit by calculating the difference between revenue and explicit and opportunity costs. In this context, it is assumed that a common source of oil and gas can produce (q) units during each period, which can then be sold at a price (p). An important aspect related to extraction costs is that if countries cooperate, the costs are (C) units. However, when there is no cooperation, there are two types of cost structures. The first type of cost structure occurs in cases where the distribution of the common source is uneven; the costs incurred by a country are directly proportional to its share of the total resource. The second type of cost structure occurs in the case of sanctions, where the costs incurred are inversely proportional to the sanction rate.

When resources are shared equally between two parties without obligations to cooperate, the cost of extracting them will be inversely proportional to their share. This phenomenon is known as the “share effect” and results in a production cost of two units [52–56]. However, if the resources are distributed asymmetrically, and 75% belongs to Qatar, and the extraction conditions are ideal, for example, the availability of land, then in the absence of cooperation the cost of extraction for each country will be different. In particular, Qatar's production costs will be lower, while Iran's will be higher. Therefore, if cooperation is not achieved, the cost of production for both countries will be 4 units and 1.33 units for Iran and Qatar respectively.

In addition to the share effect, the extractive capacity of countries, also known as the “sanctions effect,” plays a decisive role in determining the cost of resource extraction. In fact, it has a more significant impact than the share factor. To take into account the impact of sanctions, it is assumed that the cost of production has an inverse relationship with the sanctions factor, as does the cost of the share. Thus, the impact of sanctions is defined as ($\frac{1}{s}$). For example, if the following scenario is considered: 0<S≤ 1, then the sanctions factor implies that a movement towards zero will lead to more severe sanctions, and a movement towards a value of one will lead to less severe sanctions. This means that when (S) equals 1, no penalty is imposed. It is assumed that the severity of sanctions is inversely proportional to this value. Thus, as (S) approaches zero, the impact of sanctions (or the cost of production) will increase, while moving towards one will result in a decrease in the impact of sanctions (or the cost of production).

Research results and their discussion. Case 1: Equal resource distribution and equal mining capacity. In the first scenario, we assume that the resources between the two countries are equally distributed and that their ability to extract resources is also the same. This results in a specific game matrix as shown in Table 3. The state (CI, CQ) assumes that both countries cooperate with each other. This means that resources are distributed equally, half of its resources are missing, and the country pays exactly for the number of resources that it has extracted. The cost of extracting these resources is the same for both countries, which is the unit cost. In the state (CI, DQ) Iran is ready to cooperate with Qatar, but Qatar does not want to. Qatar plans to extract more than half (α> 0.5) of the resources. The production cost for Qatar will be inversely proportional to the amount of resources halved and will be equal to 2 units. On the other hand, Iran will produce less than half (1-α) of the resources. Thanks to the cooperation agreement, their production costs will remain at the level of one unit. Alternatively, in the (DI, CQ) state, Qatar is committed to cooperation but Iran is not. Iran plans to extract more than half (α> 0.5) of the resources, and the cost of their extraction will be equal to 2 units. The condition (DI, DQ), also known as non-cooperation, occurs when both countries decide not to coordinate their policies. As a result, each country extracts half the resources, and since they both choose not to cooperate, their extraction costs are equal to 2 units (the reciprocal of the resource share). Although both countries are not subject to sanctions and resources are distributed evenly, they produce and sell the same number of resources. However, the output is reduced by A1 units compared to what they would have received if they had cooperated due to the additional costs each country bears. This is because they fear that another country will extract resources faster than them. If they cooperated, they could extract the same amount of resources at a lower cost. Table 3 presents the players' optimal strategies and the Nash equilibrium. In this game, the strategy of both countries is not to cooperate because it is more profitable than to cooperate. This means that no matter what the other player chooses, each country will choose not to commit because it will lead to a better outcome. According to the results, a Nash equilibrium is achieved when both countries decide not to commit. As already stated, neither player has any motivation to deviate from this result.

Table 3 – Nash equilibrium under equal resource allocation and equal extraction capacity

Case 1		**Qatar (Q)**	
		C	**D**
Iran (I)	C	$\frac{q}{2}p-\frac{q}{2}$, $\frac{q}{2}p-\frac{q}{2}$	$(1-\alpha)qp-(1-\alpha)q$, $\alpha qp-2\alpha q$
	D	$\alpha qp-2\alpha q$, $(1-\alpha)qp-(1-\alpha)q$	$\frac{q}{2}p-2\frac{q}{2}-A_1$, $\frac{q}{2}p-2\frac{q}{2}-A_1$

Case 2: Unequal distribution and equal extraction power. If we assume that resources are not equally distributed between the two countries and that they have equal opportunities to extract them without any sanctions, then the resulting game matrix is presented in Table 4. In state (CI, CQ), both countries agreed to cooperate with each other. This means that despite the uneven distribution of resources, neither country is currently under sanctions, they can both extract the resources they need based on their fair share. Since they cooperate, the cost of production is equal for both countries and is 1 unit. Thus, Iran can extract 25% of its resources, and Qatar - up to 75% of its resources. Condition (CI, DQ) is a situation where Iran intends to cooperate and Qatar refuses to participate. In this situation, Qatar seeks to extract the majority of the resource (more than 75% or γ > 0.75) but incurs a production cost of 1.33 units, which decreases as the amount of resource extracted increases. On

the other hand, Iran receives less than 25% (1- γ) of the resource, but its production costs remain constant at one unit due to the cooperative policy. According to the state (DI, CQ), Qatar agrees to cooperate, but Iran does not. As a result, Iran intends to take the majority of the resource, more than 25%, which is reflected in a β value greater than 0.25. In addition, it is noted that the cost of extracting the resource for Iran is 4 units. On the other hand, Qatar will receive less than 75% share of the resource (calculated as 1-β), but since they have a cooperative policy, their extraction costs will remain at a low level of 1 unit. In the (DI, DQ) state, countries simultaneously extract resources and do not cooperate with each other. As a result, Iran incurs higher production costs than Qatar. Both countries incur additional costs because each fear that the other will extract resources at a faster pace. If countries cooperated, they could extract the same resources at a lower cost, but each would incur additional costs by not cooperating. For Iran, these costs are lower because it has slightly fewer resources than Qatar (A2<A1). The Nash equilibrium of the game is presented in Table 4. The most efficient approach for both countries is not to cooperate with each other. This means that regardless of the actions taken by the other country, the best course of action for both parties are to not cooperate. The results show that the Nash equilibrium and the outcome of the game are achieved when both players choose this tactic, and therefore both countries end up choosing strategy D.

Table 2– Nash equilibrium for unequal distribution and equal extraction power

Case 2		**Qatar (Q)**	
		C	**D**
Iran (I)	C	$\frac{1}{4}qp - \frac{1}{4}q, \frac{3}{4}qp - \frac{3}{4}q$	$(1-\gamma)qp - (1-\gamma)q, \gamma qp - 1.33\gamma q$
	D	$\beta qp - 4\beta q, (1-\beta)qp - (1-\beta)q$	$\frac{1}{4}qp - \frac{1}{4}(4)q - A_2, \frac{3}{4}qp - \frac{3}{4}(1.33)q - A_1$

Case 3: Equal distribution of resources and unequal mining opportunities. The third scenario assumes an equal distribution of resources between the two countries, but their ability to extract these resources differs due to sanctions imposed on Iran. As already mentioned, the cost of resource extraction depends on two key factors: the share of resources and the ability to extract them (in this case, under the influence of sanctions). The ability to extract resources has a greater impact than the share of resources. Therefore, Table 5 presents the game matrix for this scenario.

Table 5 – Nash equilibrium under equal resource allocation and unequal extraction capacity

Case 3		**Qatar (Q)**	
		C	**D**
Iran (I)	C	$S\frac{q}{2}p - \frac{1}{S}\frac{q}{2}, \quad \frac{q}{2}p - \frac{q}{2}$	$\frac{S}{2}qp - \frac{S}{2}q, \left(1-\frac{S}{2}\right)qp - 2\left(1-\frac{S}{2}\right)q$
	D	$\alpha Sqp - 2\alpha\frac{1}{S}q, \quad \frac{q}{2}p - \frac{q}{2}$	$\frac{S}{2}qp - 2\frac{1}{\frac{S}{2}}q - A_3, \left(1-\frac{S}{2}\right)qp - 2\left(1-\frac{S}{2}\right)q - A_1$

The condition (CI, CQ) indicates that both countries have committed to cooperate with each other. The distribution of resources is equal, but one of the countries is under sanctions. Each country strives to extract 50% of the resources and pays the cost of the extracted resources. Since there is cooperation, the extraction costs are the same for both countries. However, due to sanctions, Iran cannot extract its fair share of resources. Therefore, it is expected that if sanctions are imposed, Iran may receive even less than its fair share of resources. In this scenario, Qatar will continue to extract its 50 percent share of resources while remaining committed to cooperation. If sanctions are not imposed (S = 1), both countries will have equal production opportunities. However, if (S = 0), Iran will still be able to produce fewer resources at a higher price. In state (CI, CQ), only Iran undertakes cooperation obligations. In such a situation, Qatar will most likely be able to extract more than half of the resources, given the severity of sanctions imposed on Iran. The severity of the sanctions directly affects how much Qatar will produce. If sanctions against Iran are strict (S→0), then Qatar will produce more resources ($(1-\frac{S}{2}) \to 1$). If sanctions are not imposed (S = 1), then both countries will produce the same amount of resources. Since Iran has committed to cooperation, it spends as much as its share of the production. Qatar, on the other hand, is spending twice as much because it has not committed to cooperation. The coefficient "2" represents the equity effect when resources are shared equally between two countries, resulting in each country's production share being half of the total resources. In a scenario in which Qatar adopts a cooperative approach (strategy C), and Iran does not (strategy D), Iran seeks to obtain more than 50% of the available resources (represented by $\alpha > 0.5$). However, due to sanctions, its actual share will be (αS). In addition, due to non-compliance with the terms of cooperation and influence sanctions, the cost of production for Iran will be equal to $2\alpha\frac{1}{S}$. This is because Iran is not committed to cooperation and therefore incurs a penalty. Conversely, Qatar, being committed to cooperation, is entitled to 50% of the resources and will only incur 1 unit of production cost for each resource token. note that Qatar's commitment to cooperation limits resource extraction to 50%, while Iran cannot even reach its 50% share. State (D_I, D_Q) involves both countries refusing to cooperate, resulting in each trying to take more than half of the resources for yourself. However, in this scenario, Qatar expects Iran to be punished. Therefore, Qatar aims to extract more than 75% of the resource to compensate for the penalty, which becomes increasingly severe as (S) approaches zero. Qatar's share of resources can be represented as follows $(1-\frac{S}{2})$. However, due to the distribution of resources, the cost of production for Qatar will also double. In contrast, Iran's share and production cost will be equal $\frac{S}{2}$to and $2\frac{1}{\frac{S}{2}}$, respectively. The strategy envisions a scenario in which Iran is currently under sanctions and has a symmetrical resource allocation with Qatar. In a particular situation, if A_3 units of Iran's results and A_1 units of Qatar's results are obtained, this may result in additional costs. This is because Iran fears that Qatar will extract resources faster. However, if both countries come to a mutual cooperation agreement, they will be able to extract the same amount of resources without additional costs. Due to sanctions, Iran produces fewer resources than Qatar, resulting in lower output (where $A_3 < A_2 < A_1$). Table 5 illustrates the Nash equilibrium of the game. Unlike Examples 1 and 2, in this case Iran's dominant strategy is cooperation, while Qatar's is non-cooperation. Therefore, regardless of Qatar's choice, Iran will always choose cooperation, while Qatar will choose non-cooperation because it has a higher payoff. The reason for Qatar's dominant strategy is obvious: its decision is influenced by the sanctions imposed on Iran. On the other hand, Iran's dominant strategy is cooperation, since sanctions will lead to a significant increase in production costs. Therefore, it is in Iran's interests to remain cooperative. It is worth noting that these results are consistent with the results of the study by Tufighi et al. [46] , in which the Nash equilibrium is of the form (CI, DQ).

Case 4: Unequal distribution of resources and unequal opportunities to extract them. In the latter case, we assume that resources are unevenly distributed, with a larger share going to Qatar. Additionally, both countries have different levels of extractive capacity, with Iran under sanctions. It is important to note that the cost of production depends on two important factors: the share of resources, or the "share effect," and the capacity of production, or the "sanction effect." The last factor is much stronger than the first. Therefore, we can use Table 6 to depict the game matrix given these circumstances. The status (CI, CQ) indicates that both countries have agreed to cooperate with each other. However, in this scenario there is an uneven distribution of resources, a large share of which goes to Qatar. In addition, Iran is under sanctions, which prevents it from extracting its entire share. Therefore, the two countries intend to cooperate in the extraction of resources by paying the cost of extraction (which is 1 unit). Iran's share of the resource is 25%, but due to sanctions it can only extract a fraction of that share. It is important to note that the effect of sanctions is more significant than the distribution of shares. As a result, Iran's resource extraction capabilities are expected to be further constrained, leading to a decline in the recovery rate ($\frac{1}{4}$S). Despite restrictions from Iran, Qatar remains committed to cooperation and continues to extract its share of resources (75%). State (CI, DQ) implies Iran's commitment to cooperation, while Qatar abstains from it. As a result, Qatar is trying to extract more than 75% of the resources, since it has a large share and is aware of the sanctions against Iran. The extent of recovery depends on the severity of sanctions imposed on Iran. The dependence ($1-\frac{S}{2}\gamma$) shows that the stricter the sanctions, the greater the amount of resources (more than 75%) Qatar will extract; the inverse relationship is also true. Thus, if sanctions against Iran intensify, its share of resource production will be inferior to the indicator in example 3.

In particular, Iran's share in this situation will be $\frac{S}{2}\gamma$while in example 3 it will be $\frac{S}{2}$. Since γ is numerically less than 1, Iran's share will be significantly smaller. Additionally, Iran spends an amount equal to its share of production due to a commitment to cooperate, while Qatar spends 1.33 times its share of production because it is not committed to cooperation.

Condition (DI, CQ) describes a scenario in which Qatar agrees to cooperate but Iran does not. As a result, Iran usually receives a large share of the resources, more than 25%. However, due to the imposition of sanctions, the share of production is reduced to (βS), and the cost of production increases to ($4\beta\frac{1}{S}$) due to non-cooperation and the effect of sanctions. On the other hand, Qatar commits to cooperation, resulting in a share of 75% of the resources, while the extraction costs remain at 1 unit each. Despite Qatar's commitments, it does not extract more than 75% of its resources. Conversely, Iran produces less than its 25% share.

When both countries choose the non-cooperative mode (DI, DQ), their goal is to extract more resources than their fair share. However, Qatar intends to extract more than 75% of all available resources. This means that an increase in sanctions, indicated by a lower value of S, will lead to an increase in the share of resources withdrawn by Qatar, which can be calculated as ($1-\frac{S}{2}\gamma$). As a result of this uneven distribution, Qatar faces higher resource extraction costs - 1.33 times higher than Iran. The share of production and production costs for Iran due to sanctions are $\frac{S}{2}\gamma$and $4\frac{1}{\frac{S}{2}\gamma}$respectively, which are equal. Due to economic sanctions and uneven distribution of resources, additional costs may arise for Iran per unit of production A_4 and Qatar per unit of production A_1. Qatar is at greater risk of rapidly running out of resources, while Iran is limited by lower production rates due to the factors mentioned earlier. This entails a decrease in the level of production in the sequence A_4, A_3, A_2, A_1. Table 6 shows the Nash equilibrium of the game. In the fourth case, it is in Iran's interest to cooperate, while Qatar still chooses not to cooperate. This means that regardless of Qatar's choice, Iran will cooperate and Qatar will not. The imposition of harsh sanctions and the allocation of limited resources will effectively reduce production rates while increasing production costs. This desire for cooperation is beneficial to the country. It is worth noting that these findings are consistent with those of Tufighi et al. [46].

Table 6 – Nash equilibrium under unequal resource allocation and unequal extraction capacity

Case 4		Qatar (Q)	
		C	D
Iran (I)	C	$\frac{1}{4}Sqp-\frac{1}{4}\frac{1}{S}q$, $\frac{3}{4}qp-\frac{3}{4}q$	$\frac{S}{2}\gamma qp-\frac{S}{2}\gamma q$, $\left(1-\frac{S}{2}\gamma\right)qp-1.33\left(1-\frac{S}{2}\gamma\right)q$
	D	$\beta Sqp-4\beta\frac{1}{S}q$, $\frac{3}{4}qp-\frac{3}{4}q$	$\frac{S}{2}\gamma qp-4\frac{1}{S}q-A_4$, $\left(1-\frac{S}{2}\gamma\right)qp-1.33\left(1-\frac{S}{2}\gamma\right)q-A_1$

Application of the obtained results to the common gas fields of Iran and Qatar. This study analyzes the application of the Nash equilibrium to natural gas fields jointly owned by Iran and Qatar, namely the South Pars/North Dome field, in which Iran owns 25% and Qatar owns 75%. The unstable political situation in Iran means that it is periodically subject to sanctions. As a result, two scenarios are analyzed based on the behavior of Iran and Qatar. In the second case, when Iran is not under sanctions, the dominant strategy of both Iran and Qatar is non-cooperation. Therefore, the Nash equilibrium has the form (DI, DQ). Conversely, in the fourth case, when Iran is under sanctions, its dominant strategy changes to a commitment to cooperation; however, due to Iran's limited resources, Qatar's strategy becomes one of non-cooperation. In this case, the Nash equilibrium has the form (CI, DQ).

Conclusion. The Persian Gulf region is considered the world's premier energy hub due to its geo-economic importance and the presence of approximately 48% and 40% of the world's oil and gas reserves, respectively. Following the oil shocks of the 1970s, experts began to focus on more efficient ways to use oil and gas resources. Although Iran has a significant share of total oil and gas reserves - approximately 9% and 17% respectively - its ability to extract these resources has been significantly weakened by international sanctions. Because of these sanctions, Iran cannot continuously extract its 25% from the South Pars/North Dome field. This study aims to help policymakers and managers understand the situation and identify policy options. Conflicts of interest often arise when countries share resources and each uses different strategies to achieve its goals. This question was explored in four separate cases using a static game design with complete information: In the first case, resources were assumed to be distributed evenly between countries and no country was under sanctions. The second case assumes an unequal distribution of resources between countries, while no country is subject to sanctions. The third case assumes an equal distribution of resources, with one country benefiting from sanctions, and the last case assumes an unequal distribution of resources, with one country being sanctioned**.**

The results indicate that in the first two cases, both countries are unlikely to cooperate, regardless of the choice of the other side. Similarly, in the third and fourth cases, the sanctioned country benefits from committing to cooperation while the other country chooses not to cooperate. Whether or not to cooperate in extracting shared resources depends on each country's extraction capabilities, and the allocation of resources does not affect the Nash equilibrium. As a result, the unequal distribution of the gas field between Iran and Qatar, coupled with Iranian sanctions, has led to significant consequences. Iran's decline in gas production has forced it to cooperate with Qatar, while Qatar chooses not to cooperate. This puts Iran at a disadvantage in managing shared resources under sanctions. When Iran is not under sanctions, the dominant strategy for both Iran and Qatar is non-cooperation (DI, DQ). However, choosing the cooperation state (CI, CQ) may lead to better results for both countries. Therefore, it is recommended that Iran and Qatar pursue a cooperative strategy to achieve a more favorable outcome. In the fourth case, when Iran faces sanctions and has a smaller share of resources, non-cooperation may lead to higher production costs. It is therefore critical to encourage Iran to commit to cooperation to achieve better results. To achieve this goal, policymakers should prioritize finding diplomatic solutions to ease or lift sanctions. This may include negotiations with relevant international bodies or countries responsible for imposing sanctions. Additionally, policymakers should explore alternative ways for countries to cooperate so that both sides benefit from the extraction of shared resources. For example, this may entail joint ventures or resource-sharing agreements subject to sanctions restrictions. In addition, policymakers should explore options to mitigate the impact of sanctions on the extractive potential of a sanctioned country. This could include investing in advanced technology or providing financial incentives to develop more efficient mining methods.

ЛИТЕРАТУРА

1. Salimian S., Shahbazi K. Iran's Strategy in Utilizing Common Resources of Oil and Gas: Game Theory Approach // Iranian Journal of Economic Studies. 2017. Т. 6. № 2. С. 185–202.
2. Pervukhin D. et al. A sustainable development goals-based mathematical model for selecting oil and gas investment projects under uncertainty and limited resources // Advanced Mathematical Models & Applications. 2023. Vol. 8. No. 3.
3. Первухин Д. А., Давардуст Х., Котов Д. Д. Методы разрешения конфликта организационнотехнических систем в нефтегазовой отрасли // Современная наука и инновации. 2023. № 2. С. 71–82.
4. Afanaseva O. et al. Risk assessment of investment projects using the simulation decomposition method //International Scientific Conference Fundamental and Applied Scientific Research in the Development of Agriculture in the Far East. Cham: Springer Nature Switzerland, 2023. P. 776–785.
5. Путило С. Ю. и др. Многомерный корреляционно-регрессионный анализ работы структурного подразделения предприятия по транспортировке природного газа // Анализ и прогнозирование систем управления в промышленности, на транспорте и в логистике. 2022. С. 208–214.
6. Bailey R. Headings for an EEC common energy policy // Energy Policy. 1976. Vol. 4. No. 4. P. 308–321.

7. Fetisov V. et al. Regulation and impact of VOC and CO2 emissions on low-carbon energy systems resilient to climate change: A case study on an environmental issue in the oil and gas industry // Energy Science & Engineering. 2023. Vol. 11. No. 4. P. 1516–1535.
8. Fetisov V. et al. On the Integration of CO2 capture technologies for an oil refinery // Energies. 2023. Vol. 16. No. 2. P. 865.
9. Fetisov V., Davardoost H., Mogylevets V. Technological aspects of methane–hydrogen mixture transportation through operating gas pipelines considering industrial and fire safety // Fire. 2023. Vol. 6. No. 10. P. 409.
10. Afanasyev M. et al. System modeling in solving mineral complex logistic problems with the anylogic software environment // Transportation Research Procedia. 2023. Vol. 68. P. 483–491.
11. Akhoondi A. et al. Recent advances in the synthesis of ZnO-based electrochemical sensors // Synthesis and Sintering. 2023. Vol. 3. No. 4. P. 259–274.
12. Ilyushin Y. V., Pervukhin D. A., Afanaseva O. V. Application of the theory of systems with distributed parameters for mineral complex facilities management // ARPN Journal of Engineering and Applied Sciences. 2019. Vol. 14. No. 22. P. 3852–3864.
13. Матрохина К. В. и др. Развитие методологии сценарного анализа инвестиционных проектов предприятий минерально-сырьевого комплекса // Записки Горного института. 2023. № 259. С. 112–124.
14. Irsadanar R. J. P., Kimura K. Japan-China 2008 Agreement: Common-Pool Resource Governance Problem // Jurnal Studi Pemerintahan. 2021. P. 193-211.
15. Агагена А., Михайлов А. В., Елисеев А. С. Влияние погодно-климатических, горно-геологических и организационно-технических факторов на ресурс карьерного экскаватора // Транспортное, горное и строительное машиностроение: наука и производство. 2022. № 17-2. С. 294–298.
16. Нуцкова М. В., Алхаззаа Мохаммад. Обзор проблем крепления скважин и применяемых тампонажных материалов // Деловой журнал Neftegaz.RU. 2023. № 11(143). С. 90–95.
17. Hayashi M. The 2008 Japan-China Agreement on Cooperation for the Development of East China Sea Resources // Maritime Border Diplomacy. Brill Nijhoff, 2012. С. 35–46.
18. Morgenstern O. The collaboration between Oskar Morgenstern and John von Neumann on the theory of games. Princeton University Press, 2004.
19. Shy O. Industrial organization: theory and applications. MIT press, 1996.
20. Madani K., Hipel K. W. Non-cooperative stability definitions for strategic analysis of generic water resources conflicts // Water resources management. 2011. Vol. 25. P. 1949–1977.
21. Фетисов В. Г., Буслаев Г. В., Шалыгин А. В. Оценка потенциала Росии по хранению водорода в месторождениях каменной соли. Научный журнал российского газового общества. 2023. № 2. С. 22–29.
22. Шалыгин А. В., Фетисов В. Г., Карякина И. В. Исследование работы аппарата воздушного охлаждения в системе магистрального газопровода // Транспорт и хранение нефтепродуктов и углеводородного сырья. 2023. № 2. С. 29–32.
23. Асадулаги М. М., Васильков О. С. Применение регуляторов распределенного и сосредоточенного типа для системы управления гидролитосферным процессом Кисловодского месторождения // Всероссийская научная конференция по проблемам управления в технических системах. – Федеральное государственное автономное образовательное учреждение высшего образования Санкт-Петербургский государственный электротехнический университет ЛЭТИ им. ВИ Ульянова (Ленина), 2019. Т. 1. С. 8–11.
24. Асадулаги М., Амаль М. Проектирование сосредоточенного и распределенного регулятора для управления гидролитосферным процессом // Системный синтез и прикладная синергетика. 2019. С. 461–469.
25. Новожилов И. М. и др. Разработка пространственно распределенной математической модели пласта сложной формы // Известия СПбГЭТУ ЛЭТИ. 2021. № 10. С. 63–69.
26. Martirosyan K. V., Chenyshev A. B., Martirosyan A. V. Application of Bayes Networks in the Design of the Information System "Mineral Water Deposit" // 2023 XXVI International Conference on Soft Computing and Measurements (SCM). IEEE, 2023. P. 236–239.
27. Martirosyan A. V., Martirosyan K. V., Chernyshev A. B. Investigation of Popov's Lines' Limiting Position to Ensure the Process Control Systems' Absolute Stability // 2023 XXVI International Conference on Soft Computing and Measurements (SCM). IEEE, 2023. P. 69–72.
28. Лицзюань Ч., Пономаренко Т. В., Ханьюэ С. Трансформация китайских угольных компаний в соответствии с концепцией ESG-требований устойчивого развития // Journal of Central Asia Economy. 2022. Т. 6. № 3.
29. Aplak H. S., Sogut M. Z. Game theory approach in decisional process of energy management for industrial sector // Energy Conversion and Management. 2013. Т. 74. С. 70–80.
30. Li F. S., Li T. A., Ding X. The game analysis and measures of Sino-Russia oil project cooperation // Applied Mechanics and Materials. 2013. Т. 291. С. 1255–1258.
31. Канимбуе Л. и др. Платинометалльное оруденение Норильского района: история и перспективы изучения // Известия Уральского государственного горного университета. 2022. № 4 (68). С. 56–63.
32. Yang J., Cong R. G. Is there an optimal strategic oil reserve for each country? A study based on the game theory // The Open Fuels & Energy Science Journal. 2014. Т. 7. № 1.
33. Schitka B. B. Applying game theory to oil and gas unitization agreements: how to resolve mutually beneficial, yet competitive situations // The Journal of World Energy Law & Business. 2014. Vol. 7. No. 6. P. 572–581.

34. Yungmeister D., Gasimov E. Drill rig with a down-the-hole hammer for regulating the drilling rate by changing the air flow // E3S Web of Conferences. EDP Sciences, 2021. Vol. 326. P. 00018.
35. Havas V. War of attrition in the Arctic offshore: Technology spillovers and risky investments in oil and gas extraction : дис. 2015.
36. Теплякова А. В., Алиева Л., Жуков И. А. Компьютерное моделирование динамических процессов в элементах бурильных машин ударного действия // Транспортное, горное и строительное машиностроение: наука и производство. 2023. № 19. С. 161–171.
37. Cerqueti R., Ventura M. Optimal concession contracts for oil exploitation // Energy Policy. 2020. Т. 147. С. 111900.
38. Mamada R., Perrings C. "Entanglement" and the Exploitation of Common Pool Resources: A Quantum Solution to the Prisoner's Dilemma // International Game Theory Review. 2022. Vol. 24. No. 01. P. 2150009.
39. Юнгмейстер Д. А., Тимофеев М. И., Исаев А. И., Гасымов Э. Э. Совершенствование исполнительного органа тоннелепроходческого механизированного комплекса S-782 // Горный информационно-аналитический бюллетень. 2023. № 1. С. 107–118.
40. Kharismawan G. K., Wisanjaya I. G. P. E. Peaceful Utilization of Transboundary Reservoir in Continental Shelf of Ambalat // Journal of International Law. 2010. Vol. 32. No. 2. С. 338.
41. Sheikhmohammady M. et al. Modeling and analysis of the conflict over the Triple Islands in the Persian Gulf // 2011 IEEE International Conference on Systems, Man, and Cybernetics. IEEE, 2011. P. 3046–3050.
42. Esmaeili M., Bahrini A., Shayanrad S. Using game theory approach to interpret stable policies for Iran's oil and gas common resources conflicts with Iraq and Qatar // Journal of Industrial Engineering International. 2015. Vol. 11. P. 543–554.
43. Устинов Д. А., Аисар А. Р. Исследование алгоритмов работы дистанционной защиты в системах распределенной генерации // Академия наук высшей школы Российской Федерации. 2023. С. 41.
44. Maddahinasab M. Legal and philosophical analysis of ownership and sovereignty over hydrocarbon resources in concern with issues on internationally shared hydrocarbon reservoirs : дис. University of Zurich, 2018.
45. Bayati E., Safavi B., Jafarzadeh A. Iran and Qatar cooperation in gas production from South Pars (North Dome) gas-condensate field: a game theory framework. 2019.
46. Toufighi S. P., Mehregan M., Jafarnejad A. Optimization of Iran's Production in Forouzan Common Oil Filed based on Game Theory // Mathematics Interdisciplinary Research. 2020. Vol. 5. No. 3. С. 173–192.
47. Rassaf M. et al. Global Effects of Iran Oil Sanctions: an Application of Games Theory // Journal of Economic Modeling Research. 2021. Vol. 12. No. 43. P. 133–175.
47. Bahrini A., Riggs R. J., Esmaeili M. Social choice rules, fallback bargaining, and related games in common resource conflicts // Journal of Hydrology. 2021. Vol. 602. P. 126663.
49. Toufighi S. P., Mehregan M., Jafarnejad A. Modeling of Production Strategies from Common Offshore Gas Field with Game Theory Approach // Mathematics Interdisciplinary Research. 2022. Vol. 7. No. 1. P. 21–44.
50. Kyslytsia S. et al. The Current State of Energy Efficiency and Light Quality of Led Products //International Conference BUILDING INNOVATIONS. Cham: Springer International Publishing, 2022. С. 235–242.
51. Юнгмейстер Д. А., Гасымов Э. Э., Борисов С. В., Тимофеев М. И. Исследование эффективности бурения горных пород при использовании поршня-ударника с бойком и регулируемой задвижки в погружном пневмоударнике // Транспортное, горное и строительное машиностроение: наука и производство. 2024. № 24. С. 96–105.
52. Большунов А. В. и др. Результаты комплексных экспериментальных исследований на станции Восток в Антарктиде // Записки Горного института. 2023. № 263. С. 724–741.
53. Куликова Е. Ю., Полянкин А. Г., Потокина А. М. Специфика управления геотехническими рисками при проектировании подземных сооружений // Записки Горного института. 2023. №. 264. С. 895–905.
54. Череповицын А. Е., Цветков П. С., Евсеева О. О. Критический анализ методических подходов к оценке устойчивости арктических нефтегазовых проектов // Записки Горного института. 2021. Т. 249. С. 463–478.
55. Кривощеков С. Н., Кочнев А. А., Равелев К. А. Разработка алгоритма определения технологических параметров нагнетания кислотного состава при обработке призабойной зоны пласта с учетом экономической эффективности // Записки Горного института. 2021. Т. 250. С. 587–595.
56. Глебова Е. В., Волохина А. Т., Вихров А. Е. Оценка эффективности управления культурой производственной безопасности в компаниях ТЭК // Записки Горного института. 2023. № 259. С. 68–78.

REFERENCES

1. Salimian S, Shahbazi K. Iran's Strategy in Utilizing Common Resources of Oil and Gas: Game Theory Approach. Iranian Journal of Economic Studies. 2017;6(2):185-202.
2. Pervukhin D. et al. A sustainable development goals-based mathematical model for selecting oil and gas investment projects under uncertainty and limited resources. Advanced Mathematical Models & Applications. 2023;8(3).
3. Pervukhin DA, Davardoost H, Kotov DD. Methods of conflict resolution of organizational and technical systems in the oil and gas industry. Modern Science and Innovations. 2023;(2):71-82. (In Russ.).
4. Afanaseva O et al. Risk assessment of investment projects using the simulation decomposition method // International Scientific Conference Fundamental and Applied Scientific Research in the Development of Agriculture in the Far East. Cham: Springer Nature Switzerland; 2023. P. 776-785.

5. Putilo SYu et al. Multidimensional correlation and regression analysis of the work of a structural unit of an enterprise for the transportation of natural gas. Analysis and forecasting of control systems in industry, transport and logistics. 2022;208-214. (In Russ.).
6. Bailey R. Headings for an EEC common energy policy. Energy Policy. 1976;4(4):308-321.
7. Fetisov V et al. Regulation and impact of VOC and CO2 emissions on low-carbon energy systems resilient to climate change: A case study on an environmental issue in the oil and gas industry. Energy Science & Engineering. 2023;11(4):1516-1535.
8. Fetisov V et al. On the Integration of CO2 capture technologies for an oil refinery. Energies. 2023;16:2:865.
9. Fetisov V, Davardoost H, Mogylevets V. Technological aspects of methane–hydrogen mixture transportation through operating gas pipelines considering industrial and fire safety. Fire. 2023;6(10):409.
10. Afanasyev M et al. System modeling in solving mineral complex logistic problems with the anylogic software environment. Transportation Research Procedia. 2023;68:483-491.
11. Akhoondi A et al. Recent advances in the synthesis of ZnO-based electrochemical sensors. Synthesis and Sintering. 2023;3(4):259-274.
12. Ilyushin YV, Pervukhin DA, Afanaseva OV. Application of the theory of systems with distributed parameters for mineral complex facilities management. ARPN Journal of Engineering and Applied Sciences. 2019;14(22):3852-3864.
13. Matrokhina KV et al. Development of methodology for scenario analysis of investment projects of enterprises of the mineral resource complex. Journal of Mining Institute. 2023;259:112-124. (In Russ.).
14. Irsadanar RJP, Kimura K. Japan-China 2008 Agreement: Common-Pool Resource Governance Problem. Jurnal Studi Pemerintahan. 2021;193-211.
15. Agagurna Abdelwahab, Mikhailov A.V., Eliseev A.S. The impact of weather, climatic, mining, geological, organizational, and technical factors on the resource of a mining. Transport, mining and construction engineering: science and production. 2022;17-2:294-298. (In Russ.).
16. Nutskova MV, Alkhazzaa Mohammad. Review of well casing problems and cementing materials used. Neftegaz.RU. 2023;11(143):90-95. (In Russ.).
17. Hayashi M. The 2008 Japan-China Agreement on Cooperation for the Development of East China Sea Resources. Maritime Border Diplomacy. Brill Nijhoff; 2012. C. 35-46.
18. Morgenstern O. The collaboration between Oskar Morgenstern and John von Neumann on the theory of games. Princeton University Press; 2004.
19. Shy O. Industrial organization: theory and applications. MIT press; 1996.
20. Madani K, Hipel KW. Non-cooperative stability definitions for strategic analysis of generic water resources conflicts. Water resources management. 2011;25:1949-1977. (In Russ.).
21. Fetisov VG, Buslaev GV, Shalygin AV. Assessment of Russia's potential for hydrogen storage in rock salt deposits. Scientific journal of the russian gas society. 2023;2:22-29. (In Russ.).
22. Shalygin AV, Fetisov VG, Karyakina IV. Research of air cooler working in a main gas pipeline system. Transport and storage of Oil Products and hydrocarbons. 2023;2:29-32. (In Russ.).
23. Asadulagi MM, Vasilkov OS. Application of distributed and concentrated type regulators for the control system of the hydrolithosphere process of the Kislovodsk field. The All-Russian Scientific Conference on Control in Technical Systems CTS'2019. Federal State Autonomous Educational Institution of Higher Education St. Petersburg State Electrotechnical University LETI named after VI Ulyanova (Lenina), 2019;1:8-11. (In Russ.).
24. Asadulagi M, Amal M. Design of a concentrated and distributed regulator for controlling the hydrolithosphere process. System synthesis and applied synergetics. 2019;461-469.
25. Novozhilov IM et al. Development of a spatially distributed mathematical model of a formation of complex shape. Proceedings of Saint Petersburg Electrotechnical University. 2021;10:63-69. (In Russ.).
26. Martirosyan KV, Chenyshev AB, Martirosyan AV. Application of Bayes Networks in the Design of the Information System "Mineral Water Deposit". 2023 XXVI International Conference on Soft Computing and Measurements (SCM). IEEE; 2023;236-239.
27. Martirosyan AV, Martirosyan KV, Chernyshev AB. Investigation of Popov's Lines' Limiting Position to Ensure the Process Control Systems' Absolute Stability. 2023 XXVI International Conference on Soft Computing and Measurements (SCM). IEEE; 2023;69-72.
28. Zhang L, Ponomarenko TV, Xu H. Transformation of Chinese coal companies according to the ESG concept of sustainability requirements. Ekonomika Tsentralnoy Azii = Journal of Central Asia Economy. 2022;6(3):243–254. (In Russ.).
29. Aplak HS, Sogut MZ. Game theory approach in decisional process of energy management for industrial sector. Energy Conversion and Management. 2013;74:70-80.
30. Li FS, Li TA, Ding X. The game analysis and measures of Sino-Russia oil project cooperation. Applied Mechanics and Materials. 2013;291:1255-1258.
31. Kanimbue L et al. Platinum-metal mineralization of the Norilsk district: history and prospects of research. News of the Ural State Mining University. 2022;4(68):56-63. (In Russ.).
32. Yang J, Cong RG. Is there an optimal strategic oil reserve for each country? A study based on the game theory. The Open Fuels & Energy Science Journal. 2014;7(1).

33. Schitka B. B. Applying game theory to oil and gas unitization agreements: how to resolve mutually beneficial, yet competitive situations. The Journal of World Energy Law & Business. 2014;7(6):572-581.
34. Yungmeister D, Gasimov E. Drill rig with a down-the-hole hammer for regulating the drilling rate by changing the air flow. E3S Web of Conferences. EDP Sciences; 2021;326:00018.
35. Havas V. War of attrition in the Arctic offshore: Technology spillovers and risky investments in oil and gas extraction: dis. 2015.
36. Teplyakova AV, Alieva L, Zhukov IA. Computer simulation of dynamic processes in elements of impact drilling machines. Transport, mining and construction engineering: science and production. 2023;19:161-171. (In Russ.).
37. Cerqueti R, Ventura M. Optimal concession contracts for oil exploitation. Energy Policy. 2020;147:111900.
38. Mamada R., Perrings C. “Entanglement” and the Exploitation of Common Pool Resources: A Quantum Solution to the Prisoner’s Dilemma. International Game Theory Review. 2022;24(01):2150009.
39. Yungmeister DA, Timofeev MI, Isaev AI, Gasymov EE. Improvement of tunnel boring machine S-782 cutter head. Mining informational and analytical bulletin (scientific and technical journal). 2023;1:107-118. (In Russ.).
40. Kharismawan GK, Wisanjaya IGPE. Peaceful Utilization of Transboundary Reservoir in Continental Shelf of Ambalat. Journal of International Law. 2010;32(2):338.
41. Sheikhmohammady M et al. Modeling and analysis of the conflict over the Triple Islands in the Persian Gulf. 2011 IEEE International Conference on Systems, Man, and Cybernetics. IEEE; 2011;3046-3050.
42. Esmaeili M, Bahrini A, Shayanrad S. Using game theory approach to interpret stable policies for Iran’s oil and gas common resources conflicts with Iraq and Qatar. Journal of Industrial Engineering International. 2015;11:543-554.
43. Ustinov DA, Aysar AR. Study of the protection algorithms in distributed generation systems. Doklady Akademii nauk vysshei shkoly Rossiiskoi Federatsii = Proceedings of the Russian higher school Academy of sciences. 2023;41. (In Russ.).
44. Maddahinasab M. Legal and philosophical analysis of ownership and sovereignty over hydrocarbon resources in concern with issues on internationally shared hydrocarbon reservoirs: dis. University of Zurich; 2018.
45. Bayati E, Safavi B, Jafarzadeh A. Iran and Qatar cooperation in gas production from South Pars (North Dome) gas-condensate field: a game theory framework; 2019.
46. Toufighi SP, Mehregan M, Jafarnejad A. Optimization of Iran’s Production in Forouzan Common Oil Filed based on Game Theory. Mathematics Interdisciplinary Research. 2020;5(3):173-192.
47. Rassaf M et al. Global Effects of Iran Oil Sanctions: an Application of Games Theory. Journal of Economic Modeling Research. 2021;12(43):133-175.
47. Bahrini A, Riggs RJ, Esmaeili M. Social choice rules, fallback bargaining, and related games in common resource conflicts. Journal of Hydrology. 2021;602:126663.
49. Toufighi SP, Mehregan M, Jafarnejad A. Modeling of Production Strategies from Common Offshore Gas Field with Game Theory Approach. Mathematics Interdisciplinary Research. 2022;7(1):21-44.
50. Kyslytsia S. et al. The Current State of Energy Efficiency and Light Quality of Led Products. International Conference BUILDING INNOVATIONS. Cham: Springer International Publishing, 2022. P. 235-242.
51. Yungmeister DA, Gasimov EE, Borisov SV, Timofeev MI. Study of the efficiency of rock drilling using a striker and an adjustable valve in a down-the-hole hammer. Transport, mining and construction engineering: science and production. 2024;24:96-105. (In Russ.).
52. Bolshunov AV, Vasilev DA, Dmitriev AN, Ignatev SA, Kadochnikov VG, Krikun NS, Serbin DV, Shadrin VS. Results of complex experimental studies at Vostok station in Antarctica. Journal of Mining Institute. 2023;263:724-741. (In Russ.).
53. Kulikova EY, Polyankin AG, Potokina AM. Specifics of geotechnical risk control in the design of underground structures. Journal of Mining Institute. 2023;264:895-905. (In Russ.).
54. Cherepovitsyn AE, Tcvetkov PS, Evseeva OO. Critical analysis of methodological approaches to assessing sustainability of arctic oil and gas projects. Journal of Mining Institute. 2021;249:463-478. (In Russ.).
55. Krivoshchekov SN, Kochnev AA, Ravelev KA. Development of an algorithm for determining the technological parameters of acid composition injection during treatment of the near-bottomhole zone, taking into account economic efficiency. Journal of Mining Institute. 2021;250:587-595. (In Russ.).
56. Glebova EV, Volokhina AT, Vikhrov AE. Assessment of the efficiency of occupational safety culture management in fuel and energy companies. Journal of Mining Institute. 2023;259:68-78. (In Russ.).

ИНФОРМАЦИЯ ОБ АВТОРАХ

Дмитрий Анатольевич Первухин – доктор технических наук, профессор, Санкт-Петербургский горный университет императрицы Екатерины II, +78123288566, pervuchin@rambler.ru

Давардуст Хади – аспирант, Санкт-Петербургский горный университет императрицы Екатерины II, +79657604209, s215133@stud.spmi.ru

Дмитрий Дмитриевич Котов – аспирант, Санкт-Петербургский горный университет императрицы Екатерины II, +79992125540, s215027@stud.spmi.ru

INFORMATION ABOUT THE AUTHORS

Dmitry A. Pervukhin – Dr. Sci. (Techn.), Professor, Saint Petersburg Mining University Empress Catherine II, +78123288566, pervuchin@rambler.ru

Davardoost Hadi – PhD student, Saint Petersburg Mining University Empress Catherine II, +79657604209, s215133@stud.spmi.ru

Dmitry D. Kotov – PhD student, Saint Petersburg Mining University Empress Catherine II, +79992125540, s215027@stud.spmi.ru

Вклад авторов: все авторы внесли равный вклад в подготовку публикации.
Конфликт интересов: авторы заявляют об отсутствии конфликта интересов.

Contribution of the authors: the authors contributed equally to this article.
Conflict of interest: the authors declare no conflicts of interests.

Статья поступила в редакцию: 12.01.2024;
одобрена после рецензирования: 07.02.2024;
принята к публикации: 07.03.2024.

The article was submitted: 12.01.2024;
approved after reviewing: 07.02.2024;
accepted for publication: 07.03.2024.