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Optimization of Iran's Production in Forouzan Common Oil Filed based on Game Theory

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Abstract

One of Iran's problems in the production of common oil and gas fields is unequal extraction. Therefore, the production of common oil and gas fields in onshore and offshore is essential for Iran, so this must carefully monitor, which can be considered as a game-liked approach, that each player tries to increase its payoff. Therefore, the purpose of this study is to apply game theory in examining Iran's approaches to extracting from common oil fields. For this purpose, the present study seeks to design a mathematical model to optimize the production of Iran against a competitor using a game. Since the proposed model is in the field of mathematical modeling, the research strategy is a case study. Meanwhile, the data-gathering tool is descriptive. The results showed that Iran's equilibrium in Forouzan oil field is cooperation, and the equilibrium of Saudi Arabia is non-cooperation. Finally, the executive policies based on research results presented.

Keywords: Game Theory, Common Fields, Oil & gas, Cooperative Game, Forouzan oil Filed.

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1. Introduction

In the age of globalization, Small and large countries around the world are looking to join coalitions, multilateral agreements, and economic cooperation. These

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activities are all degrees of convergence. The greater the homogeneity of countries and the higher the understanding of convergence in them, the easier it will be to achieve convergence and the higher its level [13]. According to available information, Iran has 28 common oil and gas fields. Of these, 18 are oil fields, four are gas fields, and six are oil and gas reserves. The National Iranian Oil Company has so far started production from more than ten joint oil and gas fields, but production from 18 common reservoirs has not yet begun. Iran's common oil and gas fields located onshore and offshore. 15 of 28 common fields are in the warm waters of the Persian Gulf, and 13 are onshore. According to Iran's western and southern borders with Arab countries, most of Iran's common fields with these countries are concentrated. Iraq, with 12 common fields, is at the top of Iran's common hydrocarbon neighbors. The UAE followed with seven reservoirs, Saudi Arabia, with four reservoirs, Qatar with two reservoirs, and Oman, Kuwait, and Turkmenistan with one reservoir each [18].

Considering the importance of energy resources, especially oil and gas, and the global need for oil and gas resources and the potential that the Persian Gulf has in this regard can be an opportunity for Iran to use these resources and also cooperate with other countries in the Persian. Despite the opportunities that exist for Iran in this field, Iran also faces a series of obstacles. The first obstacle is the unequal production of these countries compared to Iran, the next hurdle is the sanctions that have imposed on Iran, and the last, Iran's technological weakness in the industries used to extract these resources. One of the fields in which Iran has not performed well is the Forouzan oil field in the Persian Gulf, which shared with Saudi Arabia in the Kharg Island region. This field was discovered in 1966 by the capacity of oil in place of two billion and 309 million barrels. This field shared with Marjan filed in Saudi Arabia. The latest state of Iran's extraction from the Forouzan common oil field is about 40,000 barrels per day. Meanwhile, the Saudi company Aramco extracts over 405,000 barrels of crude oil per day from the Saudi part of the field. There is a common capital between Iran and its neighbors, which

Figure 1: Forouzan Oil Filed.

must consider with a fair, correct, and just view, based on the national interests of both countries and nations. Based on the above, the present study also seeks to optimize the consequences of exploiting Iran's common oil fields offshore with a game theory approach.

Despite the research in theoretical viewpoints in common field struggle, the solution ideas are not yet all around applied to real common field confliction. Subsequently, in this study, it is endeavored to delineate the useful utility of the game theory approach in managing Iran's common oil field. By the other words, by presenting a mathematical model of oil field production between Iran and its neighboring countries that share a common field, they would be able to settle on better decisions and, therefore, manage their common field more effectively. The remainder of the paper is structured as follows: Section 2 reviews the literature. Section 3 presents the research methodology and illustrate the mathematical model. In section 4, presented and discussed the results. Finally, section 5 concludes the research with contributions and recommendations for future studies.

2. Approaches in Common Fields

Convergence is a process in which political units voluntarily relinquish their full authority to achieve common goals and pursue a supranational power [8]. Among regional convergence theories, neo-conservatism has distinguished with its complexity and ambition and has attracted much criticism. This theory was first formulated in the late 1950s and early 1960s, primarily through the work of Ernst Haas and Leon Lindberg, in response to the establishment of the European Coal and Steel Union and the European Economic Relations. This theory was in its infancy until the mid-1960s. During which time, the European Union seemed to be evolving to defend its assumptions [16]. In other words, Haas's method was limited to explaining convergence in pluralistic democracies. In his collaboration with Philip Schmidt, Haas sought to bring the theory of forced convergence closer to the European Convergence Project and to present a general application of modernism [4]. Functionalism and modernism have an economic foundation. In simpler terms, they believe that economic cooperation is the most effective way to increase regional integration. Making peace, the need to overcome war, to prevent the continuation of war, are the main concerns of theories of convergence [12]. Some of Iran's problems in common fields are reducing the amount of revenue from withdrawals from common reservoirs compared to neighboring countries, imbalances in economic and political issues related to common areas with neighboring countries, maximal and non-safe production of common reservoirs from neighboring countries and as well as the non-exploitation of a significant amount of oil remaining in the reservoirs due to improper production. Also, some subjects have caused problems such sanctions against Iran, lack of access to modern technology in various fields of exploration, drilling, and production of oil from reservoirs in the Persian Gulf region, and especially in the case of common reservoir [17].

3. Game Theory and Common Oil Fields

In 2008, Kashani examined the legal status of oil and gas resources located on the border between countries. The existence of common oil and gas reservoirs will lead to complex legal problems such as the right of sovereignty and ownership of reservoirs, the amount of hydrocarbon production, and migration from underground reservoirs [11]. In 2009, Mohammadi and Motamedi conducted a dynamic optimization of oil production in Iran (Case study: Haftgel oil field with emphasis on conservation production). This study uses a model of maximizing benefits with restrictions and technical considerations of production to achieve the optimal path of oil production [15]. In 2012, Argha has examined the sanctions on Iran's oil and gas sector using game theory. In the Nash equilibrium obtained from the static game, Iran adopts a strategy of handing over to domestic companies. The United States a strategy of putting more pressure, and international companies were choosing a strategy of greater participation, which will lead to a lower level of output than Iran's oil fields [1]. In 2015, Mirzaalian et al. examined the technical and legal approaches in the development of joint oil and gas fields. In addition to emphasizing the need to pay special attention to the development of common fields, various methods of development and production of these fields explained with the aim of further exploitation and productivity [14]. In 2015, Shalbaf and Maleki conducted a study on the policy-making of the common Oil and Gas Repositories Office: A case study of the common fields of Iran and Iraq. In this article, it shows that under the conditions of cooperation in managing the common field with Iraq, the national interests will be provided more [19]. In 2015, Esmaili et al. conducted an article entitled "Using Game Theory Approach to Select Sustainable Strategies for Iran's Common Oil and Gas Resources vs. Iraq and Qatar". In this study, a game with incomplete information $2 * 2$ used. Prisoners' dilemma games, chicken games, and hunters game were used to examine the consequences of the players, which were predicted due to the unavailability of information and strategy of the players and the incompleteness of the game [6]. In 2015, Havas Wilma examines the oil and gas extraction strategies of Norway and Russia, which want to enter the North Pole. The results of the game show that the sooner the extraction begins, the higher the expected return on investment [10]. In 2017, Hajiani examined the legal and contractual solutions for the operation of common oil and gas fields (a case study of the South Pars region of Iran and the North Qatar oil field). This study examines the legal and contractual solutions for the operation of joint oil and gas fields in the South Pars region of Iran, which is one of the largest oil and gas fields in the country, and the North Qatar oil field[9]. In 2017, Salimian and Shahbazi examined Iran's strategies for using common oil and gas fields with a game theory approach. Using two approaches, cooperative and non-cooperative games and static games with complete information and simplified assumptions in the number of reserves and the same costs and strategies identified the best strategy for Iran and other countries in using common oil fields [18]. In 2018, Emami Meybodi and Fotouhi examined the integration and strategy for exploiting the common oil and gas fields. Despite the advantages of the integration method, there are problems with the implementation of this method, and this makes it not easy for countries to agree on the integration of the field [5]. In 2019, Bayati et al. examined the cooperation between Iran and Qatar in extracting common South Pars gas reserves with emphasis on game theory. The results based on the design of the non-cooperative game showed that the choice of non-cooperation strategy is optimal only for Iran, but also for the rival country, and the lack of cooperation has more economic benefits for Iran [2].

For all four previous types of research, simple classic models with incomplete information solved without considering revenue and cost functions. The parameters such as production period, managers' decision-making, political conditions, and the possibility of cooperation or non-cooperation of players make the relevant model more realistic. Therefore, in addition to considering the uncertainty in oil and gas reservoirs and the phase behavior of fluids overtime during the production, this research will study how managers and some political conditions in the region make decisions about cooperation or non-cooperation and also production period. Also, a model has presented, including the revenue, cost, and payoff functions of each player based on the start date of production, each player's conditions using the data of master development plans.

4. Research Methodology

The research method of this research is survey type. Based on the type of data collected, this research is quantitative. From the macro perspective, the present study is legitimate, and the researcher is not fully involved. It is fundamental in terms of purpose and result and specialized texts and research backgrounds used for modeling. After modeling different modes, a sensitivity analysis performed on the model, the model was studied, and in this regard, it led to the development of knowledge related to coordination in the field of common oil and gas fields. This research is based on descriptive data based on how data is collected and according to the type of information. The present study aims to develop a mathematical model with a game theory approach. Therefore, the present study is developmental. Due to the development of this research and the fact that it is examined at the level of common oil and gas fields, and seeks to model the conditions of the research and its assumptions. Therefore, it can apply to all countries that have common oil and gas fields with Iran in the offshore and onshore. The research steps presented in Figure 2. In this section, the functions and development of the mathematical model are explained. The most widely used function of estimating oil demand is the Cooper study [3]. In this study, it examined crude oil demand for 23 countries in the period 1979 to 2000 and used the variables of crude oil price, income, and per capita demand of the previous year as an independent variable,

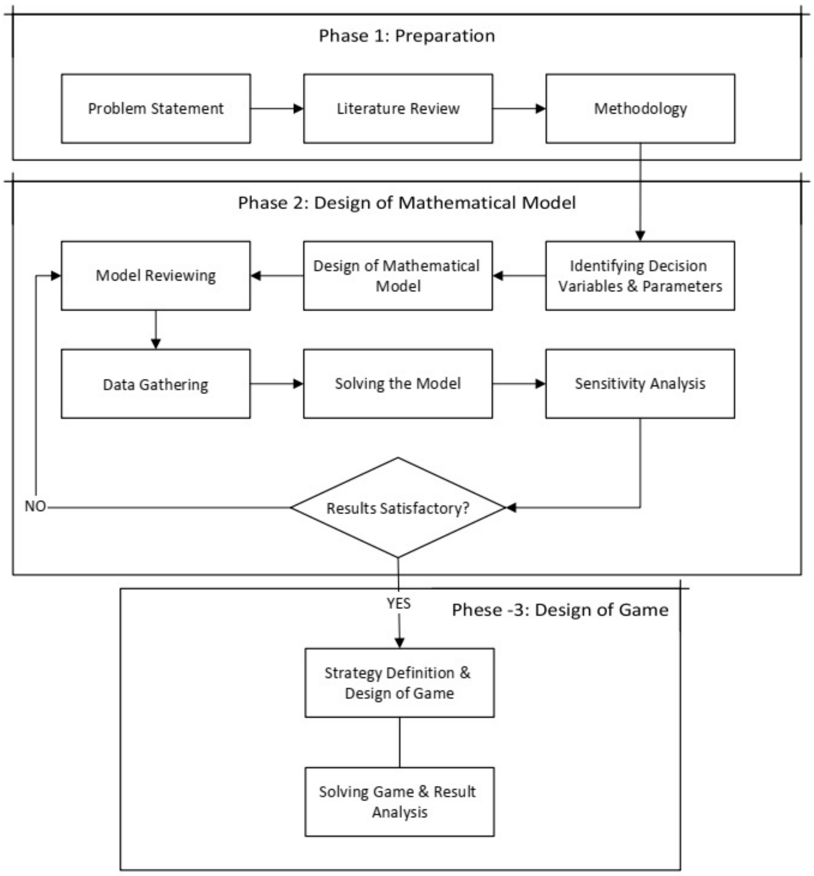

Figure 2: Research steps.

the model of which is as follows:

$$D = e^{\alpha_0 + \alpha_1 \ln GDP + \alpha_2 \ln P_t + \epsilon_t}. \tag{1}$$

To determine the subordinate oil revenues of Iran and Saudi Arabia from the common production of oil and gas fields, the pattern of forecasting the prices of crude oil of Iran and Saudi Arabia based on the EIA price model used. However, to specify the cost function, first, the cost function of each of the operational stages of exploration, development, and production is defined. Then the extended form of the cost function is introduced. For this purpose, the components of the model (variables and parameters) first described in Table 1. Revenues from oil sales based on a demand function and oil prices are shown in Gao's studies as

Table 1: Variables and parameters of the Mathematical Model.

Description	Notation	Dimension	Reference
Crude Oil Demand	D	Barrel Per Day	OPEC Database
Crude Oil Price	P_t	US Dollar per Barrel	Research results
Crude Oil Production	X_t	Barrel Per Day	Research results
Regression Coefficient	δ_0	-	Research results
Regression Coefficient	δ_1	-	Research results
Share of OPEC	y_t	-	OPEC Database
Regression Coefficient	δ_2	-	Research results
Time Trend	T	Year	Gao, 2009
Exploration Cost Percent	ω	Percent	Gao, 2009
Surface Development Cost	β_1	US Dollar per Barrel	EIA
Oil Well Development Cost	β_2	US Dollar per Barrel	EIA
Well Quantity	N_t	No.	MDP
Production Cost Index	$d(t)$	-	Research results
Depreciation Cost Index	$d'(t)$	-	Research results
Gas Injection Rate	gi_t	Billion Cubic Feet	EIA
Water Injection Rate	wi_t	Million Barrel	EIA
Holding Cost	chs	US Dollar per Barrel	EIA
Exploration Cost Function	TC_E	USD per day	Research results
Development Cost Function	TC_D	USD per day	Research results
Production Cost Function	TC_P	USD per day	Research results
Holding Cost Function	TC_H	USD per day	Research results
Water Injection Cost Function	TC_{WI}	USD per day	Research results
Gas Injection Cost Function	TC_{GI}	USD per day	Research results
Total Cost Function	TC	USD per day	Research results
Total Revenue Function	TR	USD per day	Research results
Payoff Function	πi	USD per day	Research results
Production Variable Cost Function	TC_{VP}	USD per day	Research results
Production Maintenance Cost Function	TC_{PFM}	USD per day	Research results

follows:

$$R(X_t) = X_t \times P_t(X_t), \tag{2}$$

$$\log P_t = \delta_0 + \delta_1 y_t + \delta_2 T + \epsilon. \tag{3}$$

As a result, the price function of demand for OPEC oil is as follows:

$$P_t = e^{\delta_0 + \delta_1 y_t + \delta_2 T}. \tag{4}$$

Therefore, the revenue function summarized as the following equation:

$$TR = R(X_t) = (X_t) \times e^{\delta_0 + \delta_1 y_t + \delta_2 T}. \tag{5}$$

The next function is the cost of exploration. These costs include all costs associated with search operations, mapping, geology, geophysics, seismic, drilling of exploratory and descriptive wells, and so on. This cost is relative to the total cost of upstream operations[7]. According to Massron's research, these costs are 10 to 20 percent of the total production cost [20]

$$TC_E = \omega \times TC. \tag{6}$$

Development costs are another cost associated with production from common fields. These costs divided into two parts: 1- The cost of infrastructure and maintenance of surface facilities and 2- The cost of oil wells. These costs have been measured and reported by the EIA in 1996 for different fields of different sizes and different geological roles:

$$TC_D = \beta_1 X_t + \beta_2 N_t. \tag{7}$$

Other important costs include the operation of the field. Considering the details of the necessary costs at this stage and based on previous studies, all the costs of the field operation can be divided into two components: the variable cost of operation and the cost of repairs of production and wellhead facilities. The variable cost of operation refers to the costs associated with human resources and other current operating costs. Numerous studies have conducted to calculate this cost, but one of the most common and fundamental studies conducted to determine the function of the cost of oil production from the hydrocarbon fields of the Persian Gulf region by the EIA in 1996. After examining the production costs of various marine and terrestrial fields in the Persian Gulf region, this research, concludes that the general figure is a function of the variable cost of production the hydrocarbon fields in this region as follows:

$$TC_{VP} = 0.7714 \times (X_t)^{-0.2423}. \tag{8}$$

Now, since this function is estimated based on the values of 1986, to use this function in the present study, its coefficients must be updated according to the time domain of the research; In this regard, the following index can be used to update this cost function:

$$d(t) = 0.28 \frac{P_t - P_{1986}}{P_{1986}}. \tag{9}$$

In this case, the final form of the production variable cost function is rewritten as follows:

$$TC_{VP} = (1 + d(t))(0.7714 \times (X_t)^{-0.2423}). \tag{10}$$

The cost of the production facilities maintenance and extracted from the study of the World Energy Studies Center (CGES) on the oil production capacity of the Persian Gulf in 1993 and studies conducted by Gao [7].

$$TC_{PFM} = 0.44 \times (X_t). \tag{11}$$

Of course, to estimate the depreciation costs of the field production facilities, such as the variable cost production function, the function must be updated concerning the period of the field production. Thus, the mathematical form of the cost function of the production facilities maintenance and the source based on the production period suggested as follows:

$$TC_{PFM} = (1 + d'(t))(0.44 \times (X_t)), \tag{12}$$

$$d'(t) = 0.28 \frac{P_t - P_{1996}}{P_{1996}}. \tag{13}$$

Finally, it is possible to estimate the cost of production of these fields during their lifetime as follows from the set of two functions of the variable cost of production and maintenance cost of production and wellhead facilities:

$$TC_P = (1 + d(t))(0.7714 \times (X_t)^{-0.2423}) + (1 + d'(t))(0.44 \times (X_t)). \tag{14}$$

The cost of injecting water and gas into oil fields is another cost:

$$G_{It} = 0.176 gi_t, \tag{15}$$

$$W_{It} = 0.78 wi_t. \tag{16}$$

Now, according to the above relations and functions, the general payoff function was calculated, and the results are given below. Eq. 17, indicates the total cost function and Eq. 18, indicates the total payoff function:

$$\begin{aligned} TC &= TC_E + TC_D + TC_P + TC_H + TC_{WI} + TC_{GI}, \\ TC &= (1 + \omega) \times \Big\{ (\beta_1 X_t + \beta_2 N_t) \\ &\quad + (1 + d(t))(0.7714 \times (X_t)^{-0.2423}) + (1 + d'(t))(0.44 \times (X_t)) \\ &\quad + (0.5 \times chs \times e^{\delta_0 + \delta_1 y_t + \delta_2 T}) + \frac{0.176}{365} Gi_t + \frac{0.78}{365} Wi_t \Big\}, \end{aligned} \tag{17}$$

$$\begin{aligned} \pi i &= TR - TC, \\ \pi i &= [(X_t) \times e^{\delta_0 + \delta_1 y_t + \delta_2 T}] \\ &\quad - \Big[(1 + \omega) \times \Big\{ (\beta_1 X_t + \beta_2 N_t) \\ &\quad + (1 + d(t))(0.7714 \times (X_t)^{-0.2423}) + (1 + d'(t))(0.44 \times (X_t)) \\ &\quad + (0.5 \times chs \times e^{\delta_0 + \delta_1 y_t + \delta_2 T}) + \frac{0.176}{365} Gi_t + \frac{0.78}{365} Wi_t \Big\} \Big]. \end{aligned} \tag{18}$$

Table 2: Estimation of Parameters of Oil field Players.

δ_2	δ_1	δ_0	Parameter	Country
3.9239	-0.0417	3.56895	Estimated Value	Iran
0.1478	0.0014	0.0417	Standard Error	
-	-	0.7476	R^2	
6.0142	0.1274	5.3268	Estimated Value	Saudi Arabia
0.09748	0.0001	0.02147	Standard Error	
-	-	0.80125	R^2	

5. Findings and Analysis of Results

The mathematical model of the research, along with the parameters and variables in the previous section, fully explained. In this section, using the collected data and Eviews software, the model parameters analyzed and estimated. Table 2 describes the estimation values of the demand function parameters for oil field players: In this section, the results of Iran and Saudi Arabia optimized in Forouzan field, which is an oil field located offshore, and the researcher was trying to find the optimal amount of production and payoff of each player. After solving the mathematical model by MATLAB software and finding the optimal daily production value of each player, the optimal benefits of each player extracted as described in Table 3. Figure 3 shows the current and optimal state of production in Iran and Saudi Arabia in Forouzan field:

Table 3: Optimal Benefits of Players.

Saudi Arabia	**Iran**	**Description**
423762	115232	X_t^*, Optimal Production, BPD
402000	40000	Present Production, BPD
33829170	13083379	$\pi^* i$, USD
79.83	88.86	Optimal Oil Price, USD

As can be seen, with the increase in the exploration cost parameter from 10 percent to 20 percent, not only is there no significant change in the increase in the optimal production rate, but the optimal payoff is also reduced by 1.03 percent due to the rise in costs. The current number of wells in Iran in Forouzan filed for Iran is equal to 24. In this section, by increasing the number of wells, the researcher seeks to investigate the extent of changes in production volume and optimal payoff: As can be seen, with the number of wells increases, the production rate increases by only 0.8 percent, and the payoff decreases by 0.9 percent.

In the following, based on the results of the previous section and determining the strategies of each player, the game will be designed. An equilibrium will find in each game. In this case, for each player, two strategies of cooperation and non-cooperation are defined, which are followed by the equilibrium of each

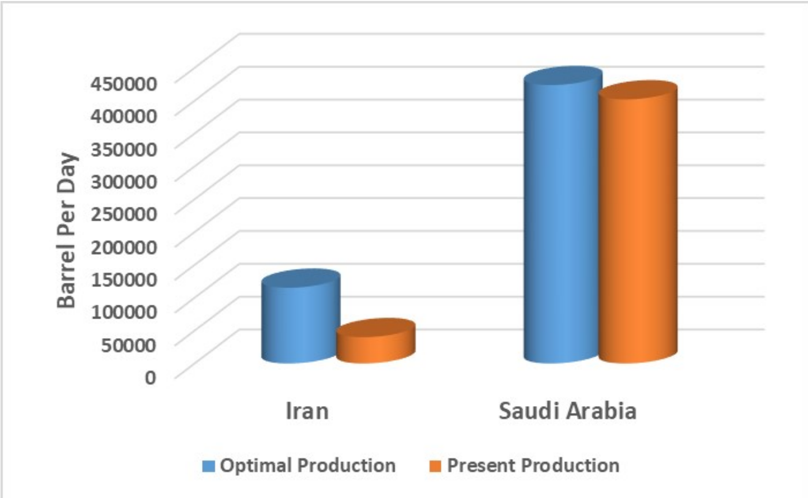

Figure 3: Present & Optimal Production Rate Forouzan.

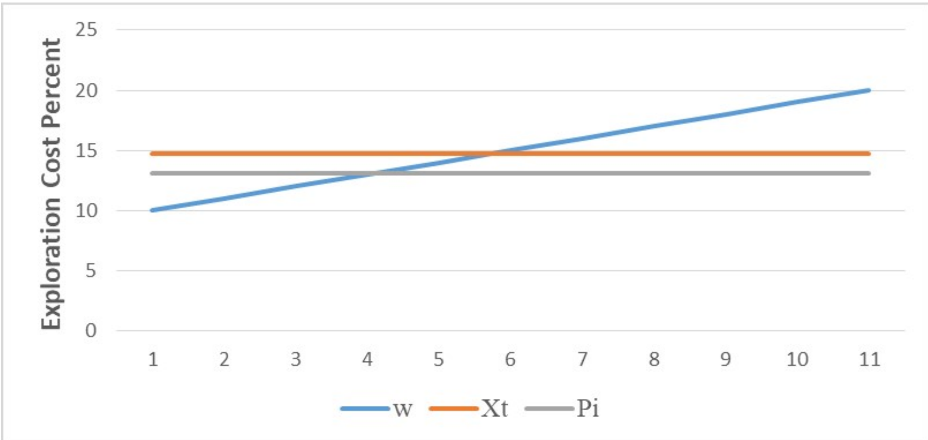

Figure 4: Sensitivity Analysis - Exploration Cost Percent.

field from the defined games. To calculate the payoff of each player in this field according to the strategies, their accumulation payoff calculated, which used the information of the master development plan of the field and the results of the optimal values of the previous step. Figure 6 shows the amount of production in Iran based on the master development plan of Forouzan filed from 2020 to 2045. Iran's recovery factor in Forouzan field was assumed 11 percent, considering the methods of enhancing the primary and secondary production, while the recovery

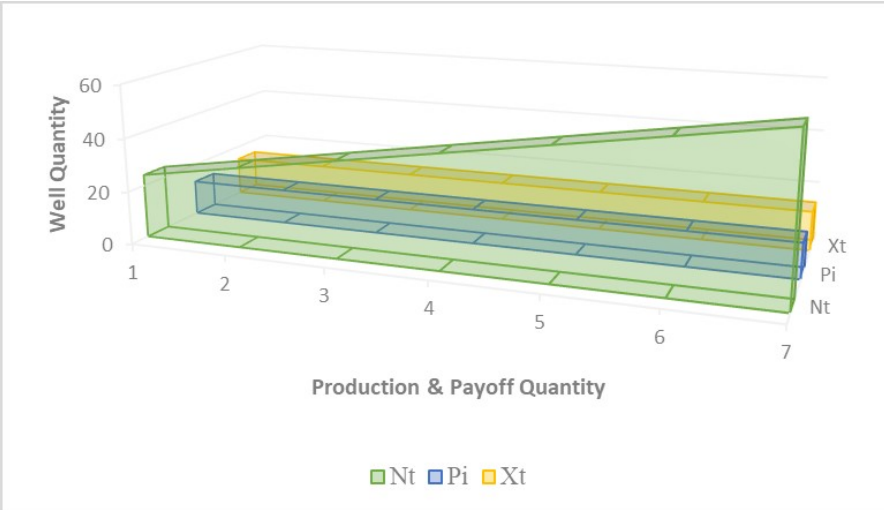

Figure 5: Sensitivity Analysis - Well Quantity.

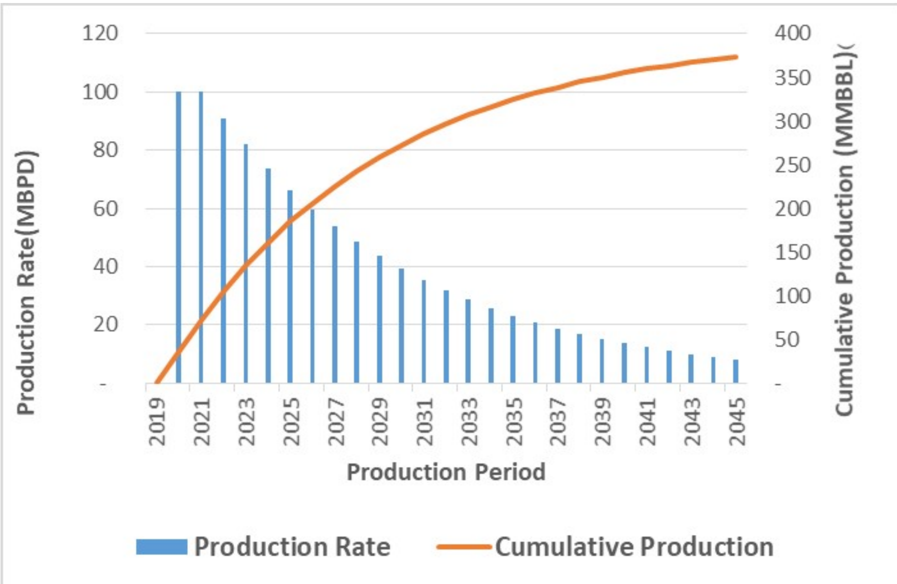

Figure 6: Iran Production Forecast - MDP.

factor for Saudi Arabia is 60 percent. The field's recoverable oil is estimated at 2.013 billion barrels over 25 years. Given that, the life of 25-year-old oil fields is considered, and considering the rate of pressure drop in reservoirs, the following assumptions for game design between the two countries are defined:

Assumptions of non-cooperation: Considering the political conditions and international sanctions, the information of common fields for each player is the basis for the non-cooperation of MDP information. Considering that the results of the proposed model of this research are consistent with the information contained in MDP, so to find the values and, consequently, the payoff of each player, the answers obtained from the mathematical model of the Forouzan field based on reservoir and processing engineering logic. If the two countries do not cooperate, the production of each player, in this case, are as described in Figures 7 and 8.

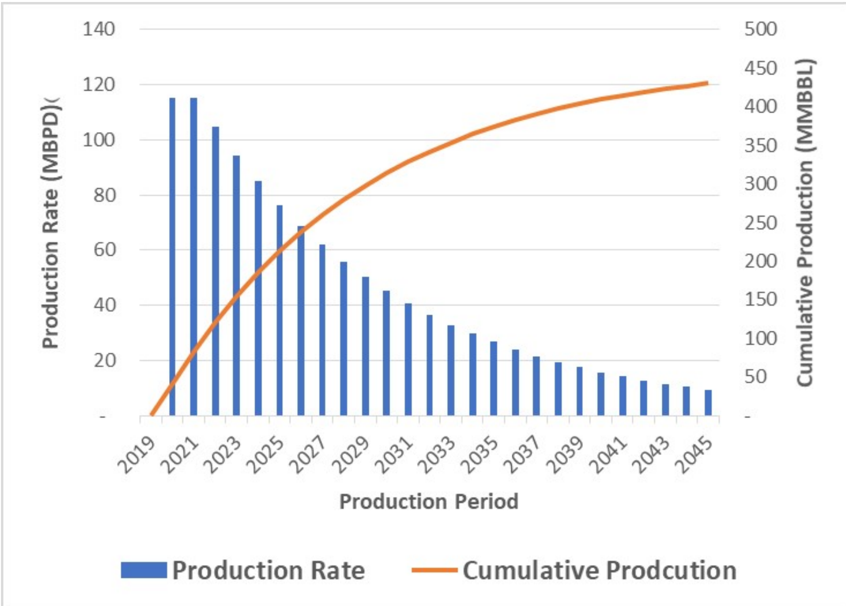

Figure 7: Production Profile - Proposed Model - Iran - NC.

Assumptions of cooperation: If an agreement is reached and the countries work together, it is assumed that according to the field development plan, each of the actors will produce, and the calculations for the reservoir pressure drop are included in the development plan. It should be noted that if one of the parties cooperates, the non-cooperating party produces in the same way as before. If the two countries signed a cooperation agreement for a 50% production of the field and assuming that the parties observe the production rate, the following chart will display the production profile for each player. At the same time, in the strategy of cooperation, this opportunity will be provided for Iran to use the technologies available to the other side. In this section, the results of the payoff calculations of

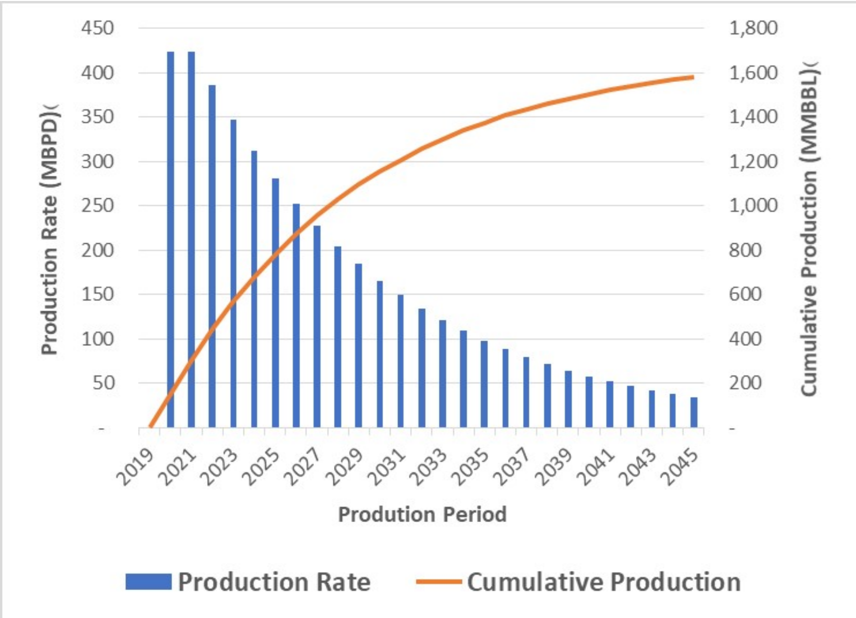

Figure 8: Production Profile - Proposed Model -Saudi Arabia - NC.

each country in terms of billions of dollars over 25 years are presented in terms of strategic form: The above functions indicate the amount of profit in different cases

Payoff Function	Payoff, BUSD	Collection of strategies
$U_{SA}(C,C)$	80.349	$C \in S_{Iran}, C \in S_{SA}$
$U_{Iran}(C,NC)$	69.491	$C \in S_{Iran}, NC \in S_{SA}$
$U_{SA}(C,NC)$	98.268	$C \in S_{Iran}, NC \in S_{SA}$
$U_{Iran}(NC,C)$	50.186	$NC \in S_{Iran}, C \in S_{SA}$
$U_{SA}(NC,C)$	115.611	$NC \in S_{Iran}, C \in S_{SA}$
$U_{Iran}(NC,NC)$	38.241	$NC \in S_{Iran}, NC \in S_{SA}$
$U_{SA}(NC,NC)$	126.343	$NC \in S_{Iran}, NC \in S_{SA}$

for both countries. The first two functions show the payoff margin in a situation where both countries are cooperating in extracting common reserves, which is \$ 89.436 billion for Iran and \$ 80.349 billion for Saudi Arabia. The cooperation between Iran and Saudi Arabia in production from Forouzan field is such that the countries must increase production in a completely equal manner following the profile of the master development plan for the field. The third function shows Iran's cumulative profit in a condition that is based on agreement. According to the transaction between Iran and Saudi Arabia, Iran chooses the strategy of non-

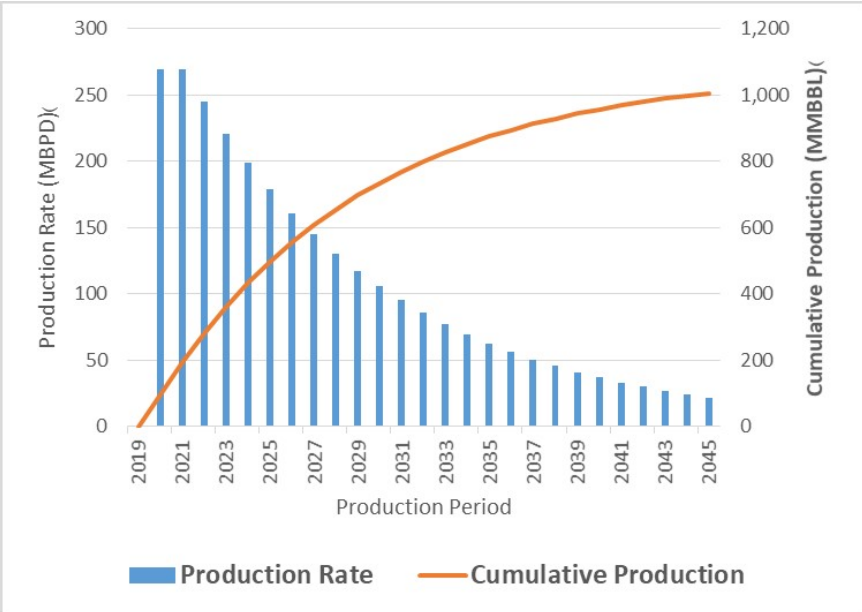

Figure 9: Production Profile - Proposed Model - Iran & Saudi Arabia- C.

cooperation, in which case Iran's profit is equal to \$ 69.491 billion. The fourth function is for Saudi Arabia, which, like the third function of Iran, cooperates, and Saudi Arabia chooses non-cooperation, which will amount to \$ 98.268 billion. The fifth function is the opposite of the third function and is equal to \$50.86 billion, and the sixth function is the opposite of the fourth function and is equivalent to \$ 115.611 billion. The seventh and eighth functions show the cumulative profit of each player in a situation where both countries are not cooperating in oil extraction and continue their production process in the same way as before, which is \$ 38.241 billion for Iran and \$ 126.343 billion for Saudi Arabia. The matrix form of the two countries' payoffs in this field is as follows: Now it can solve the above game

		Saudi Arabia	
	Strategy	C	NC
Iran	C	89.436 ,80.349	69.491,98.268
	NC	50.186,115.611	38.241,126.343

using conventional solving methods, the results of which are as follows.

Solution using Iterative Elimination of Strictly Dominated Strategy (IESDS): In this game, the strategy of non-cooperation is dominated by Iran.

Because if Saudi Arabia chooses the strategy of cooperation, the payoff of Iran by selecting the strategy of cooperation is \$ 89.4366, and by choosing the strategy of non-cooperation, it is equal to \$ 506.86 billion, and in this situation, cooperation is better than non-cooperation. Also, if Saudi Arabia chooses a non-cooperation strategy, Iran's payoff will be equal to \$ 69.491 billion by choosing a cooperation strategy and \$ 384.241 billion by choosing a non-cooperation strategy, and in this case, the cooperation strategy is better than non-cooperation. Thus, in any case, the strategy of cooperation is better than the strategy of non-cooperation, and therefore, we consider cooperation as a strictly dominant strategy or non-cooperation as a strictly dominated strategy for Iran. The same argument can be used for Saudi Arabia, saying that if Iran chooses a strategy of cooperation, Saudi Arabia's payoff will be \$ 80.349 billion by choosing cooperation and \$ 98.268 million by choosing non-cooperation. This situation of non-cooperation will be better than cooperation for Saudi Arabia. Also, if Iran chooses the strategy of non-cooperation, Saudi Arabia's payoff by choosing cooperation is equal to 115. 611 billion dollars and by choosing the strategy of non-cooperation of 126.343 billion dollars, and in this situation, non-cooperation will be better than cooperation for Saudi Arabia, it shows that the strategy of cooperation for Saudi Arabia is strictly dominated and it does not choose it. The relationships of this method are as follows:

$$U_I = (s'_I = C, s_{-I} = C) = 89.343 > U_I(s_I = C, s_{-I} = NC) = 50.186,$$
$$U_I = (s'_I = NC, s_{-I} = C) = 69.491 > U_I(s_I = NC, s_{-I} = NC) = 38.241,$$

$$U_I = (s'_I, s_{-I}) > U_I(s_I, s_{-I}) \qquad \forall s'_I = NC \in S_I, \forall s_{-I} \in \{NC, C\} = S_{SA},$$

$$U_I = (s_{-I} = NC, s'_I = C) = 98.268, U_I = (s_{-I} = C, s_I = C) = 80.349,$$
$$U_I = (s_{-I} = NC, s'_I = NC) = 126.343, U_I = (s_{-I} = C, s_I = NC) = 115.611.$$

Therefore, non- cooperation is the strictly dominant strategy for Saudi Arabia. So, the completely dominant strategy of this game can be written as follows

$$D^s = (s_{Iran}, s_{SA}) = (C, NC).$$

Solution using Nash Equilibrium Method: Calculations related to finding Nash equilibrium in this game are given.

$$B_1(C) = C,$$
$$B_1(NC) = C,$$
$$B_2(C) = NC,$$
$$B_2(NC) = NC.$$

Nash equilibrium occurs when both players react to each other at the same time.

		Saudi Arabia	
	Strategy	C	NC
Iran	C	89.436 ,80.349	69.491,98.268
	NC	50.186,115.611	38.241,126.343

Here the Nash equilibrium is where both elements are marked simultaneously. Based on the best answers above, the equilibrium of the game is as follows.

$$\begin{cases} B_1(NC) = C \\ B_2(NC) = NC \end{cases} \rightarrow N(G) = C, NC$$

In other words, the equilibrium of the game includes Iran's cooperation and Saudi Arabia's non- cooperation in production from this field. Figure 10 shows the equilibrium of the game and Iran's payoff in different situations.

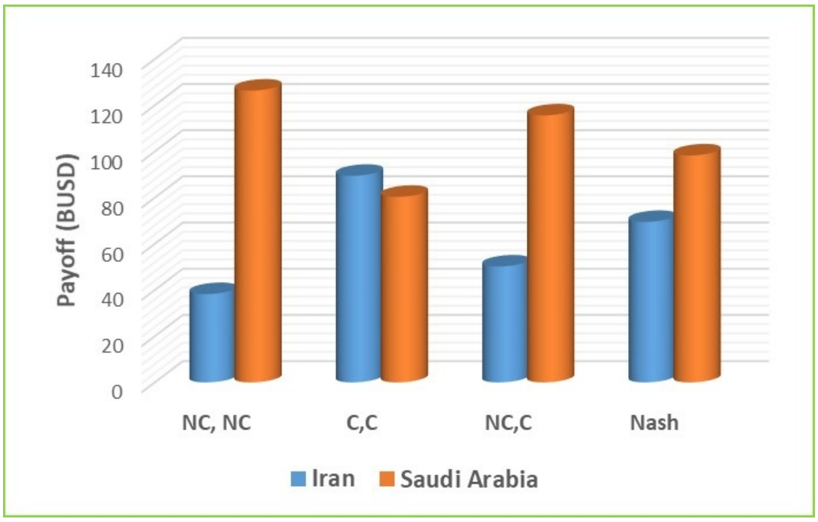

Figure 10: Players Payoff in Game.

6. Conclusions and Suggestions

According to the theory of convergence in today's world, convergence and regionalism are one of the ways of economic development, security, resolving regional crises, and advancing political goals. Convergence theory can be applied to all parts of the world, including the Persian Gulf. The results of the games designed in this study showed that Iran's optimal strategy in the common field of Forouzan is cooperation, which is in line with the theory of convergence. Still, due to many challenges in the convergence process between Iran and Saudi Arabia, this convergence will not be possible in the early future. In the case of conservation production of common fields, the application of this theory will be helpful because conservation production increases the values of the common fields and protects the benefits of present and future generations. So conservation production is a dynamic concept because future production of oil reservoirs is a function of the quantity and quality of production today. If we consider conservation production, it will be possible to choose a strategy based on convergence theory. Given the current situation, Iran's equilibrium in Forouzan field is a strategy of cooperation, and the equilibrium of Saudi Arabia is a strategy of non-cooperation.

In general, given that the issue of production from common fields is extremely important, a company with an independent legal entity or a subsidiary with the same title, which is affiliated with the Ministry of Petroleum, should be established while establishing more accessible regulations for attracting capital and development activities. To especially review the delimitation agreements, to focus on the development activities of the common reservoirs following the principle of cooperation based on the theory of convergence. It is suggested that in future research, different scenarios be examined in the form of non-cooperation for the production and development of common fields using simulation tools and compare the results with this research. The mathematical model of research can be developed in future research to show more realistic conditions, as well as the uncertainty of information and the vague future perspective. From this perspective, the model can be expanded by adding random components to the demand and time to replace competing technology.

Conflicts of Interest. The authors declare that there are no conflicts of interest regarding the publication of this article.

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