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Optimization of The Private Sector Cooperative Approach in Investment Projects of the National Iranian Oil Company Using Game Theory Approach

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Abstract

The aim of this research is to design scenarios based on cooperative game theory scenarios to examine the rewards and penalties observed from sharing or not sharing knowledge among companies. The statistical population of the study includes managers and experts from 10 subsidiary companies of the National Iranian Oil Company, among whom 10 senior managers were selected for pairwise comparisons using the snowball sampling method. The research method is classified as descriptive, applied, interpretive, exploratory, with a quantitative and qualitative nature. This study emphasizes the importance of efficient knowledge sharing as a means to foster cooperative in the investment portfolios of the National Iranian Oil Company to compete with foreign competitors during sanctions. By reviewing the results of the four scenarios derived from the game, it was observed that the rewards companies receive from sharing knowledge are dependent on the behavior resulting from knowledge sharing by other companies. The more capable an organization is in influential factors related to knowledge transfer and innovation; the more benefits companies will gain if they cooperate. Sensitivity analysis regarding the costs of project cooperative, which arises due to the difficulty of implementing joint projects, showed that as the costs increase, companies tend to shift from a cooperative strategy towards a retaliation strategy and then towards anon-cooperative strategy. The impact of companies' intellectual capital status on the selection of cooperative strategies was observed. Companies that decide to collaborate, if equipped with higher intellectual capital due to experience and empowerment, tend to prefer an optimal strategy towards cooperative.

Keywords:
Knowledge Management
Knowledge Sharing
Game Theory
National Iranian Oil Company
Sanctions

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INTRODUCTION

Game theory is the study of interactions and cooperatives among individuals and organizations. Game theory concepts are employed when multiple actors influence each other's actions. The language of game theory provides a formal way to formulate strategic scenarios, determine their structure, analyze them, and understand their outcomes (Jafarzadeh et al., 2021). The objective of studying game theory is to analyze the game itself, which serves as a formal model of an interactive situation between players. The internal stability and mathematical foundation of game theory make it a powerful tool for modeling and designing automated decision-making processes in environments requiring the interaction of forces (Safari & Soufi, 2014). Game theory is a branch of economics that examines profit-oriented interactions between players. The central question in game theory is: What is the best and most logical action that a player should take to win? (Yang, 2022). One of the most important and common applications of game theory in the field of player interactions is negotiation. Negotiation and bargaining are involved in many activities related to organizations and businesses. Various negotiations are classified based on complexity in reaching agreements in dynamic environments involving multiple players and uncertain situations (Mohammadi, 2022). Managers and economists often seek calculation methods and mathematical models, and game theory is one such model capable of representing the conflicts and cooperatives among negotiators (Mahmoudi et al., 2021). According to game theory, two types of games can be defined: cooperative games and non-cooperative games. Non-cooperative games are those in which each player independently chooses their strategy, while cooperative games involve the possibility of joint activities, and this type of cooperative is preferred over individual actions by players (Hoshangi et al., 2020). In cooperative games, the final income is the result of a combination of players' strategies. Therefore, the goal of each player in a cooperative game is not only to increase their own income but also to increase the opponent's income (Bayati et al., 2019). Analysis of cooperative games is based on two main axes: coalition formation and division of the values obtained from cooperation (Shahriari et al., 2020). In the context of a group of players (coalition) sharing values and achievements, the availability of a linearly transferable commodity (such as money) is of great importance. Considering the presence of a transferable commodity (value) among players and its transfer for continuing the game and achieving the game's objectives, there are various models for analyzing the game. The most significant of these are utility-based models (Shafiei & Farahgol, 2019). The reason for utilizing cooperative games is the transferable utility, and modeling this situation. Under these circumstances, if a company gains higher profits compared to other companies in a coalition, it will make the best decision to continue the coalition. In such circumstances, a plan that can distribute profits fairly and satisfactorily among coalition members is highly important (Safari et al., 2022). In this study, utility is defined as the extent of players' preferences for receiving goods (value) and their satisfaction from it. Players can transfer a portion of their goods (value) to other players without losing anything, and this occurs when the price of the goods is the same for all players. Accordingly, in this study, the utility of the knowledge transfer model is utilized for analyzing cooperative gameplay. Knowledge plays a fundamental role in competition. If investment companies possess rare and important knowledge, they will gain significant profits. In other words, if they share their scarce knowledge, its value diminishes, and their profits are affected. Under these circumstances, the question arises as to why companies share their specialized knowledge with others?

THEORETICAL FOUNDATIONS AND RESEARCH BACKGROUND

The Technology Development Headquarters of the Oil, Gas, and Coal Industry, under the supervision of the Scientific and Technological Deputy of the Presidency, aims to identify gaps in the technology development chain to complete the value chain of the oil and gas industry. Looking at the statistics and performance of developed countries, it can be understood that one of the indicators and criteria of economic development is the role of research and technology in advancing the economic goals of countries. Since the oil and gas industries play a major role in the country's economy, promoting research and technology in these industries can lead to significant changes in the country's economic structure (Mortazavi Nezhad and Nazari, 2021). The examination of Iran's oil industry indicates that the implementation process of projects in the country has been slow, and there is a lack of adequate use of state-of-the-art technologies. In the literature review of game theory in the oil industry, Madadiamiri et al. (2022) examined the methods of acquiring technology in the oil and gas industry using game theory. As a result, it was found that acquiring technology through long-term cooperation, with certain conditions, improves its effects on the industry, while a purely independent approach has short-term beneficial effects and sometimes conflicts with the principle of resource conservation. Houshmandi et al. (2021) conducted a study on the conflict and interaction between OPEC and gas-exporting countries using game theory. The results showed that in the cumulative response function, OPEC and the consortium of gas-exporting countries will exhibit retaliatory strategies towards each other. Moreover, based on the instantaneous response function, the oil demand is assessed to be more attractive than the demand for gas, possibly due to the diverse applications of oil compared to gas. Safiloo and Sadeghi-Shahdani (2019) in their article stated that: "Oil and gas industry projects, in general, and the upper part of it, in particular, are very complex and uncertain, and therefore, investing in these projects is associated with high risk." Ahmadi et al. (2018) evaluated the integration of the sales of Iranian petrochemical products using quantum game theory. The results showed that unified sales of petrochemical products can be beneficial for both the country's industries and the petrochemical sector. Tataei and Rahnamarodposhti (2017) studied market failure using the recommended basket based on coalition game theory. In this study, the optimal investment portfolio formation pattern, which is optimized by securities with systematic risks, is presented using cooperative game theory. The resulting investment portfolio has had a positive performance and, given the negative performance of the market during the study period, has managed to outperform the market. Nasrabadi et al. (2022) studied the development of technology in the oil and gas industry using an evolutionary game theory approach. The results showed that the government must have legal oversight with minimal incentives and the key parameters indicate that it is an important factor in the execution Project attention is focused on the private sector's revenues and costs, with government revenues and costs not significantly affecting outputs and behavior changes. Safari et al. (2022) conducted a study on pricing strategies for the re-production of worn-out balls in Iran's oil and gas industry using game theory. The study revealed different results for Nash equilibrium and Stackelberg equilibrium. In the Nash game, the scenario of collecting worn-out products from consumers and their re-production by the producer was selected as the best scenario. In the Stackelberg game, the third-party scenario of collecting worn-out products and reproducing them along with the producer was chosen. Yang (2022) studied the reduction of greenhouse gases in oil and energy companies using game theory. His study created a game model to analyze strategic decisions for the development of oil companies and renewable energy industries. Furthermore, the results indicated that oil and energy companies should choose cooperative development strategies influenced by carbon neutrality. Keshavarz et al. (2021) presented a model for Iran's oil contract financial regime for negotiators using bargaining game theory. The results provided a bargaining model for preserving the best possible interests of Iran's National Oil Company. Babaei et al. (2020) examined oil pricing and determining production volume for investment using the Stackelberg game theory in Iran's oil industry. The study demonstrated that setting subsidies and intermediate government productions can assure investors of profitability.

Table 1 contains a summary of domestic and foreign studies, showing the year, topic, method, and industry under study. These studies did not observe collaborative games related to knowledge and technology transfer for investment in the oil and gas industry.

Table 1: Related Studies on Game Theory in Terms of Topic, Approach and Industry

Author(s)	Year	Topic	Approach	Industry
Safari et al.	2022	Pricing Strategy for Reproduction of Worn-out Balls and Valves in the Oil & Gas Industry: Using Game Theory in Four Scenarios of Closed-loop Supply Chain	Nash Equilibrium and Stackelberg	Oil & Gas
Yang	2022	How Should Oil Companies and New Energy Companies Collaborate and Compete in Carbon Neutrality? Approach Based on Cooperative Game Theory	Cooperative	Oil
Nasrabadi et al.	2022	Evolutionary Game Theory Approach to the Development of Oil & Gas Equipment Technology: Case Study of Ten Major Product Groups in the Oil Industry	Evolutionary	Oil & Gas
Mohammadi Timur	2022	Examination of Technology Acquisition Method in Iran's Upstream Oil & Gas Industry Using Game Theory in Cooperative (Transfer) and Non-cooperative (Independence) Modes	Cooperative and Non-cooperative	Oil & Gas
Keshavarz et al.	2021	Modeling the Financial Regime of Iran's Oil Contract Using Bargaining Game Theory for Negotiators' Guidance	Bargaining Game	Oil
Jafarzadeh et al.	2021	Potential Coalitions for Gas Exports from the Southern Corridor to Europe: Cooperative Game Theory Framework	Participatory	Gas
Houshangi et al.	2021	Confrontation or Interaction of OPEC and Gas Exporting Countries Forum? Combination Approach from the Perspective of Game Theory and Dynamic Variable Models	Participatory	Oil & Gas
Babaei et al.	2020	Game Theory Approach for Oil Pricing and Production Volume Determination for Investors Considering Government and Intermediate Producers	Stackelberg	Oil
Rai et al.	2020	Competitive Gas Trading Mechanism Based on Cooperative Game Models in the Chinese Gas Market	Cooperative	Gas
Bayati et al.	2020	Cooperation of Iran and Qatar in Extracting Gas from Joint South Pars (North Dome) Reservoirs with Emphasis on Game Theory	Nash Equilibrium and Non-cooperative	Oil & Gas
Wang et al.	2019	Purchasing Strategies for Retailers' Power Based on Non-cooperative Game	Non-cooperative	Oil
Shahriari et al.	2019	Examination of Iran's Oil Policies in OPEC Based on Game Theory	Nash Equilibrium	Oil
Araujo and Léontie	2018	Strategic Game Theory for Modeling Decision-making Issues in the Oil & Gas Industry	Stackelberg	Oil & Gas
Ahmadi	2018	Assessment of Integration of Country's Petrochemical Industry Product Sales within a Quantum Game Framework	Quantum	Petrochemical
Chena et al.	2017	Examination of Oil Import/Export Allocation Mechanism in China Using Dynamic Game Theory	Dynamic	Oil
Lotfi and Navidi	2017	A New Model for Determining OPEC's Oil Production Level Based on Price Predictions and Game Theory	Nash Equilibrium	Oil
Wood et al.	2016	OPEC, Seven Sisters, and Oil Market Dominance: Evolutionary Game Theory and Agent-based Modeling Approach	Evolutionary	Oil
Esmaili et al.	2015	Using Game Theory Approach to Interpret Sustainable Policies for Iran's Oil & Gas Resources with Iraq and Qatar	Nash Equilibrium	Oil & Gas

Nazari Adli and Khakestari	2015	Analysis of Iran's Approach in the Oil Market Using Cooperative Games and Impact of Sanctions on Oil Revenues	Cooperative	Oil
Ebrahimi et al.	2013	Analysis of Iran's Oil & Gas Sanctions: Application of Game Theory	Nash Equilibrium	Oil & Gas

METHODOLOGY

In general, the research methodology framework consists of distinct and sequential stages and activities. In the pre-process stage, the main objectives of the research are defined. The problem or issues addressed by this study involve identifying the optimal analytical tools for decision-making processes within the National Iranian Oil Company. Accordingly, given that the research issue is the primary determinant of the research method, this study employs Kumar's (2005) classification, utilizing applied, interpretive, exploratory, and mixed quantitative and qualitative research methods. Generally, the problem-solving process in collaborative games, similar to other modeling approaches, comprises two stages: modeling and analysis. The modeling stages include the five-step process illustrated in Fig. 1.

By reviewing and summarizing the content related to the field of knowledge management, particularly knowledge transfer, and also investigating the influential factors on knowledge transfer, a conceptual model for this study has been proposed. The factors influencing knowledge transfer are categorized into four distinct groups (Fig. 2).

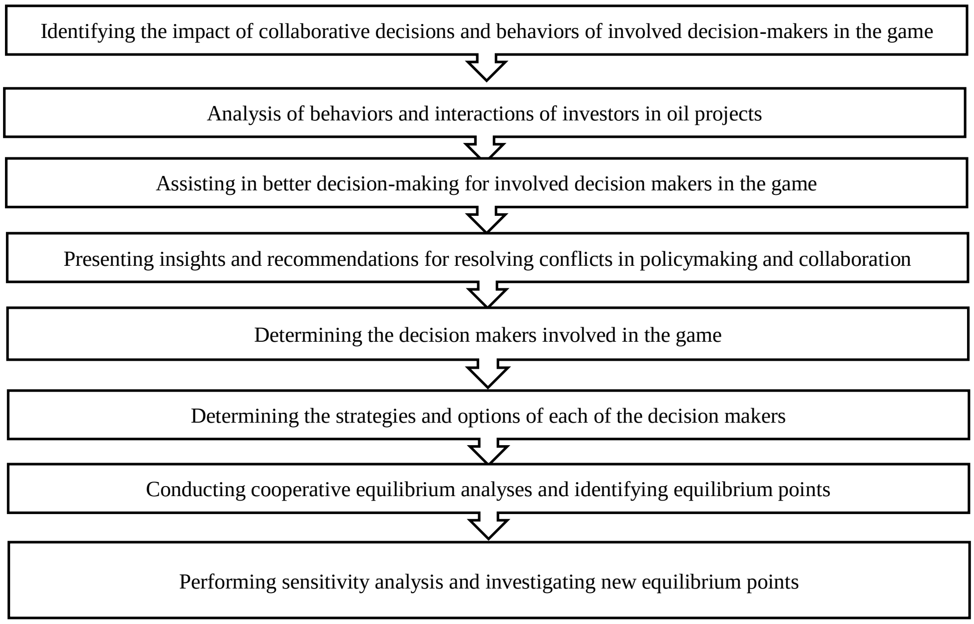

Fig. 1. Collaborative Game Problem-Solving Structural Diagram

Initially, through exploratory and confirmatory factor analysis, the structures were examined to confirm the appropriateness and fit of the factors. Then, in two stages, the relationships between the model variables were examined through correlation testing and path analysis for validation. Following this, using the concept of game theory and the factors influencing knowledge transfer, a model was developed to select an optimal strategy for a company's knowledge transfer cooperative with other firms.

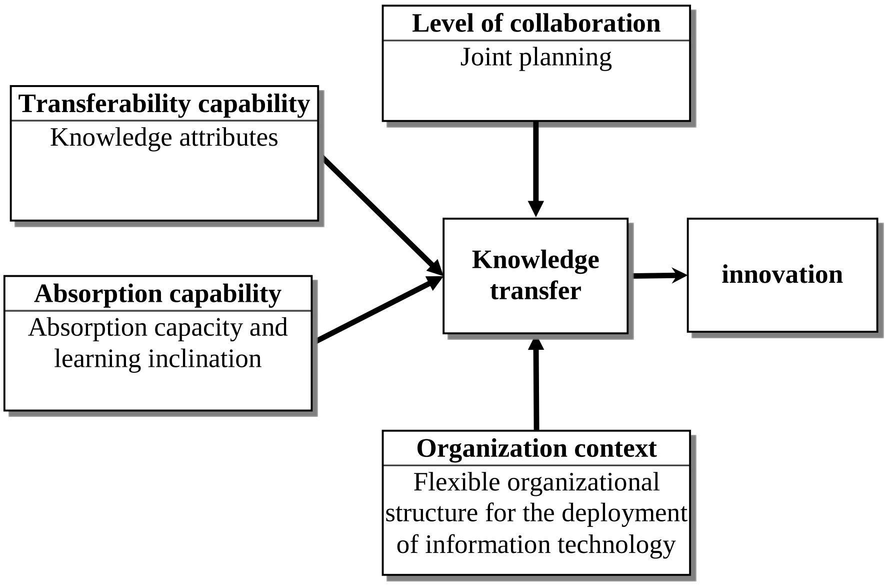

Fig. 2. Conceptual Model of the Research

DATA ANALYSIS

Considering the nature of cooperatives aimed at enhancing innovation through knowledge transfer, multiple game models are developed. The first game model assumes a constant innovative power in collaborating companies for knowledge transfer, and the second model incorporates penalties for non-cooperative when a company chooses not to cooperate in knowledge transfer. Ultimately, the third game model interprets innovation creation based on the components of the conceptual research model. Additionally, various scenarios of cooperatives between investment companies were analyzed using real data. To apply game theory in cooperatives between investment companies in petroleum projects of the National Iranian Oil Company, we assume investment companies as players in this game. In the cooperative process, they seek innovation based on knowledge transfer and aim to maximize the income (utility) they receive through increased innovation in this process by interacting and cooperating with others.

First game model

In this type of game, it's assumed that companies have equal innovative capacities. In this game, companies in the cooperative process make decisions about cooperative or non-cooperative. The structure of this game is symmetric and presented in Table 2.

Table 2: Payoff Matrix in First Game Model

Player B

		Collaborative	Non-Collaborative
Player A	Collaborative	$E_{IN} - \frac{C}{2}, E_{IN} - \frac{C}{2}$	$\boldsymbol{E_{IN} - C, E_{IN}}$
	Non-Collaborative	$E_{IN}, E_{IN} - C$	$\mathbf{0, 0}$

E_{IN}: Revenue generated from innovation.
C: Cost incurred by the company. This cost includes cooperative and communication expenses with other companies.
If both companies choose cooperative, their costs will decrease to C/2, and if both companies choose non-cooperative, their payoff will be zero. For companies, the pure strategy can be either cooperative or non-cooperative. A mixed strategy is a probabilistic combination of two strategies, where one strategy is chosen with probability P or q and the other strategy with probability 1-P or 1-q. In the research literature, more emphasis is usually placed on mixed strategies in secondary importance, except when an absolute strategy is not apparent. It's often observed that participants in a game are willing to distribute some of their resources (such as energy, time, money, etc.) and make a decision to cooperate in a cooperative game. Therefore, the effort to choose a mixed strategy can be considered as shown in Table 3. If a participant decides to cooperate, it implies that they are fully committed to using all their resources, such as energy, time, and other resources. If they decide not to cooperate, their effort is zero.

Table 3: Effort Matrix for Cooperation
Player B

		Collaborative	Non-Collaborative
Player A			
	Collaborative	p, q	$\boldsymbol{p, 1-q}$
	Non-Collaborative	$1-p, q$	$\boldsymbol{1-p, 1-q}$

Second game model: cooperative game with Non-Cooperation penalty

As shown in Table 4, is developed with an adjusting factor. In the case of knowledge transfer-based cooperative between companies, some situations can result in short-term and long-term losses or gains for the companies. Some of these include the fact that a company loses credibility and reputation in the market by avoiding cooperative or that trust from other companies for future cooperatives decreases. Additionally, the National Iranian Oil Company might offer incentives to investors who actively engage in knowledge transfer or impose penalties on those who avoid cooperative. Therefore, a combination of these factors termed the non-cooperation penalty factor (δ), is incorporated into the model.

Table 4: Payoff Matrix in Game Model 2
Player B

		Collaborative	Non-Collaborative
Player A			
	Collaborative	$E_{IN} - \frac{C}{2}, E_{IN} - \frac{C}{2}$	$\boldsymbol{E_{IN} - C, E_{IN} -}$ □
	Non-Collaborative	$E_{IN} - \delta, E_{IN} - C$	$\boldsymbol{0, 0}$

Therefore, the expected payoff for Player (1) is as follows:

$$\pi_1(p) = pq\left(E_{IN} - \frac{C}{2}\right) + p(1-q)(E_{IN} - C) + (1-p)q(E_{IN} - \delta)$$

$$\pi_2(q) = pq\left(E_{IN} - \frac{C}{2}\right) + q(1-p)(E_{IN} - C) + p(1-q)(E_{IN} - \delta)$$

With taking the first derivative of π_1 (p) with respect to p, we have:

$$\frac{\partial \pi_1(p)}{\partial p} = q\left(E_{IN} - \frac{C}{2}\right) + (1-q)(E_{IN} - C) - q(E_{IN} - \delta) = E_{IN} - C - q\left(E_{IN} - \frac{C}{2} - \delta\right)$$

In order to maximize the payoff of the specific company, it is necessary to calculate the point of extremum for the payoff function. For this purpose, the derivative of this function is estimated and set equal to zero.

$$\frac{\partial \pi_1(p)}{\partial p} = 0 \rightarrow q^* = \frac{E_{IN} - C}{E_{IN} - \frac{C}{2} - \delta}$$

And similarly, we have: $p^* = \frac{E_{IN}-C}{E_{IN}-\frac{C}{2}-\delta}$

Considering that $E_{IN} - \frac{C}{2} - \delta \neq 0$ from the above equations, the following results are obtained:

Theorem A: Based on the cooperative game grounded on bilateral knowledge transfer, Table 4 is as follows:

The pair $\{p^*, q^*\}$ constitutes a symmetric non-cooperative equilibrium provided that $0 \leq \frac{E_{IN}-C}{E_{IN}-\frac{C}{2}-\delta} \leq 1$ and $E_{IN} \leq C \leq 2\delta$, or $E_{IN} \geq C \geq 2\delta$, where p* and q* are obtained from the relevant equations. If $E_{IN} > C > 2\delta$, an unfair cooperative scenario exists. As one company becomes more inclined towards cooperative, the other party becomes more insistent on non-cooperation. When both companies deviate from the values of p* and q*, the payoff for the cooperative entity worsens, while the payoff for the non-cooperative entity improves.

1. If $E_{IN} < C < 2\delta$, the optimal strategy with stability for both parties is retaliatory action.
2. If $E_{IN} > C$ and $C < 2\delta$, optimal cooperative is the strategy that ensures stability for both parties.
3. If $E_{IN} < C$ and $C > 2\delta$, optimal non-cooperation is the strategy that ensures stability for both parties.
4. If $E_{IN} = C$, non-cooperation is the best strategy for both companies, provided that $E_{IN} - \frac{C}{2} - \delta > 0$
5. If $\frac{E_{IN}-C}{E_{IN}-\frac{C}{2}-\delta} = 1$, cooperative is the best stable strategy for both parties, provided that $E_{IN} - \frac{C}{2} - \delta > 0$

Clause 1 of Theorem A demonstrates an equilibrium in mixed strategies that is distinct from the absolute equilibrium strategy. By comparing Table 1 with Table 4, these equations are obtained as follows: $T = E_{IN} - \delta$, $R = E_{IN} - \frac{C}{2}$, $S = E_{IN} - C$, $P = 0$

In Proposition A, note 2, it is suggested that when $E_{IN} > C > 2\delta$, the ordering $T > R > S > P$ is proposed, representing the game structure of HD. It is stated that when $E_{IN} > C > 2\delta$ holds, the cooperation game is based on the transfer of knowledge, resembling a game of HD. Naturally, the equilibrium (non-cooperation, cooperation) is stable. Here, the emphasis is on dynamic deviation from a symmetric mixed strategy to an equilibrium (Non-cooperation, Cooperation). Since $\{p^*, q^*\}$ represent a Nash equilibrium, no company can unilaterally deviate from $\{p^*, q^*\}$ and find a better situation. Nonetheless, when one company deviates from $\{p^*, q^*\}$, it's better for the other company to switch to the opposite state. (Non-cooperation, Cooperation) and (Cooperation, Non-cooperation) are two stable absolute strategy equilibria. To address this challenging situation, an approach is to enforce a higher penalty cost for non-cooperation, greater than the cost of cooperation in the future, reputation loss, non-inclusion in other projects, etc., to adjust the payoff matrix.

As indicated by paragraphs 3 and 4 of Proposition A, the behavior of companies changes when the value of δ reaches a certain level of certainty. In paragraph 3 of Proposition A, it's not just that high non-cooperation is penalized, but the cost of cooperation is also high, such that $E_{IN} < C < 2\delta$, and consequently, we have R > T > P > S, where none of the PD and HD games represent this situation. Therefore, the properties of these games cannot be directly applied in this scenario. Nevertheless, a Tit for Tat strategy is chosen. In contrast to paragraph 3 of Proposition A, in paragraph 4, $E_{IN} > C$, meaning that the cost of cooperation is less than its benefits, which is neither like the PD game nor like the HD game. However, the cost of non-cooperation penalty is at least half of the cooperation cost. In this case, if both companies simultaneously deviate from $\{p^*, q^*\}$, the best strategy for both is cooperation. Thus, (Cooperate, Cooperate) is the only stable equilibrium. Unlike paragraph 4 of Proposition A, in paragraph 5, the strategy (non-cooperate, non-cooperate) is a stable equilibrium. In this case, the cost of cooperation is very high, while the penalty for non-cooperation doesn't sufficiently persuade the companies to cooperate.

Fig.3 illustrates various situations. Generally, with a lower penalty for non-cooperation, the likelihood of a company opting for non-cooperation is higher. On the other hand, with an increase in the penalty for non-cooperation, the chances of companies moving towards cooperation are higher (the δ = C/2 line is the reference line).

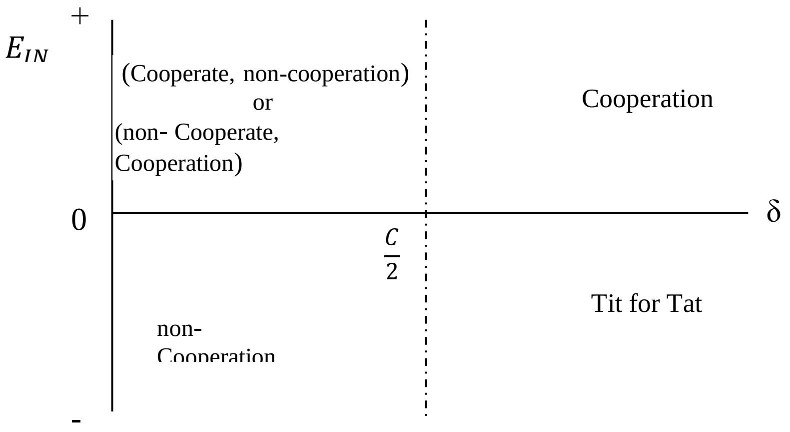

Fig. 3. Different Situations and Optimal Strategies

Third game model: cooperative game based on conceptual model

Elements The innovation component in the research conceptual model is encompassing and influenced by other variables that have also been statistically correlated. In order to enhance the model's capability to interact with influential variables, the innovation variable is re-examined using the standardized coefficients of the path model, reconstruction, and the interactions between the two companies. Considering the companies' categorization into the roles of knowledge sender and receiver, the innovation payoff function for these two companies, which have cooperative and non-cooperative strategies for knowledge transfer cooperation, is generally formulated as Table 5. The calculation functions for the returns of each company are also indicated in Table 6.

Table 5: Cooperative Game Matrix Based on Conceptual Model Elements

Company B

		cooperative	Non-cooperative
Company A	cooperative	A	B
	Non-cooperative	C	D

Table 6: Payoff of Cooperative Game Based on Conceptual Model Elements

R-A		$R_A(\beta_1 TC_A+\alpha_1 AC_B)+R_B(\beta_1 TC_B+\alpha_1 AC_A)+(R_A+R_B)[\gamma_3(LC_A+LC_B)+(\gamma_4 OC_A)]-\frac{C}{2}$
R-B		$R_A(\beta_1 TC_A+\alpha_1 AC_B)+R_B(\beta_1 TC_B+\alpha_1 AC_A)+(R_A+R_B)[\gamma_3(LC_A+LC_B)+(\gamma_4 OC_B)]-\frac{C}{2}$
R-A		$R_A[(\beta_1 TC_A+\alpha_1 AC_B)+(\beta_2 LC_A)+(\beta_3 OC_A)]-C$
R-B		$R_A[(\beta_1 TC_A+\alpha_1 AC_B)+(\beta_2 LC_A)+(\alpha_3 OC_B)]-\sigma$
R-A		$R_B[(\beta_1 TC_B+\alpha_1 AC_A)+(\beta_2 LC_B)+(\alpha_3 OC_A)]-\sigma$
R-B		$R_B[(\beta_1 TC_B+\alpha_1 AC_A)+(\beta_2 LC_B)+(\beta_3 OC_B)]-C$
R-A	0	
R-B	0	

The capability of knowledge transfer of company i (TC_i), The capability of knowledge absorption of company i (AC_i), The organizational context of company i (OC_i), The level of cooperative of company i (LC_i), The baseline value of knowledge for company i(R_i), where R≥0, (β) is the sum of direct and indirect coefficients in the standard path model for sender companies, (α) is the sum of direct and indirect coefficients in the standard path model for receiver companies, (γ) is the sum of direct and indirect coefficients in the standard path model for companies that are both senders and receivers. Therefore, the expected payoff for player A is as follows:

$$\pi_A = pq\left[R_A(\beta_1 TC_A+\alpha_1 AC_B)+R_B(\beta_1 TC_B+\alpha_1 AC_A)+(R_A+R_B)[\gamma_3(LC_A+LC_B)+(\gamma_4 OC_A)]-\frac{C}{2}\right]+p(1-q)[R_A[(\beta_1 TC_A+\alpha_1 AC_B)+(\beta_2 LC_A)+(\beta_3 OC_A)]-C]+(1-p)q[R_B[(\beta_1 TC_B+\alpha_1 AC_A)+(\beta_2 LC_B)+(\alpha_3 OC_A)]-\sigma]$$

$$\pi_B = pq\left[R_A(\beta_1 TC_A+\alpha_1 AC_B)+R_B(\beta_1 TC_B+\alpha_1 AC_A)+(R_A+R_B)[\gamma_3(LC_A+LC_B)+(\gamma_4 OC_B)]-\frac{C}{2}\right]+p(1-q)[R_A[(\beta_1 TC_A+\alpha_1 AC_B)+(\beta_2 LC_A)+(\alpha_3 OC_B)]-\sigma]+(1-p)q[R_B[(\beta_1 TC_B+\alpha_1 AC_A)+(\beta_2 LC_B)+(\beta_3 OC_B)]-C]$$

With the aim of achieving the optimal payoff, we differentiate the function with respect to p and the function with respect to q. We have:

$$\frac{\partial \pi_A}{\partial p_A} = \theta R(\beta_1 TC_A)+\theta R(\alpha_1 AC_B)+\theta R(\beta_2 LC_A)+\theta R(\beta_3 OC_A)-q\theta R(\beta_1 TC_A)-q\theta R(\alpha_1 AC_B)-q\theta R(\beta_3 OC_A)+q\frac{C}{2}-C+q\sigma$$

By setting the above expression equal to zero, the optimal value of q is obtained as follows:

$$\frac{\partial \pi_A}{\partial p_A}=0 \Rightarrow q^* = \frac{\theta R(\beta_1 TC_A+\alpha_1 AC_B+\beta_2 LC_A+\beta_3 OC_A)-C}{\theta R(\beta_1 TC_A+\alpha_1 AC_B+\beta_3 OC_A)-\frac{C}{2}-\sigma}$$

Similarly, if we differentiate the function with respect to q and set it equal to zero, we have:

$$\frac{\partial \pi_B}{\partial q_B}=0 \Rightarrow p^* = \frac{\theta R(\beta_1 TC_A+\alpha_1 AC_B+\alpha_2 LC_B+\alpha_3 OC_B)-C}{\theta R(\beta_1 TC_A+\alpha_1 AC_B+\alpha_3 OC_B)-\frac{C}{2}-\sigma}$$

Theorem B: If the asymmetric game of cooperative based on the components of the conceptual research model is represented in the form of Table 5, then the following results are obtained:

In consideration of the collaborative game model based on the components of the conceptual model

$\{p^*, q^*\}$, a Nash equilibrium will exist for this game, provided that:

$$0 \leq \frac{\theta R(\beta_1 TC_A + \alpha_1 AC_B + \alpha_2 LC_B + \alpha_3 OC_B) - C}{\theta R(\beta_1 TC_A + \alpha_1 AC_B + \alpha_3 OC_B) - \frac{C}{2} - \sigma} \leq 1$$

$$0 \leq \frac{\theta R(\beta_1 TC_A + \alpha_1 AC_B + \beta_2 LC_A + \beta_3 OC_A) - C}{\theta R(\beta_1 TC_A + \alpha_1 AC_B + \beta_3 OC_A) - \frac{C}{2} - \sigma} \leq 1$$

The optimal strategy for player A will be cooperation provided that:

$$\theta R[(\beta_1 TC_A + \alpha_1 AC_B) + (\beta_2 LC_A) + (\beta_3 OC_A)] > C \text{ و } \frac{C}{2} - \theta R \beta_2 LC_A < \sigma$$

The above relationships signify that for player A to choose the cooperation strategy, the innovative payoff for player A when he cooperates and the opposing side chooses non-cooperation, should be greater than the cost of cooperation (C), and at maximum equal to the penalty for non-cooperation. This means that the threshold for the penalty of non-cooperation to encourage player A to cooperate is equal to Player B's optimal strategy for cooperation will be when:

$$\theta R[(\beta_1 TC_A + \alpha_1 AC_B) + (\alpha_2 LC_B) + (\alpha_3 OC_B)] > C \text{ و } \frac{C}{2} - \theta R \alpha_2 LC_B < \sigma$$

Similarly, the above relationships imply that for player B to select a cooperative strategy, it is necessary for the innovation payoff of player B when they cooperate and the opposing party chooses non-cooperation, to be greater than the cost of cooperative, denoted as C. Additionally, $\frac{C}{2} - \theta R \beta_2 LC_A$ must be at most equal to the maximum penalty for non-cooperation, signifying that the threshold penalty for non-cooperation to incentivize player B's cooperative is equal to $\frac{C}{2} - \theta R \alpha_2 LC_B$

Cooperative scenarios of two companies in oil projects

To thoroughly examine and analyze various types of cooperatives using the game-theoretic model developed in this study, several different scenarios for cooperatives were designed to facilitate knowledge transfer between companies to enhance innovation. For this purpose, considering that companies, in each game, choose between cooperative and non-cooperative strategies for knowledge transfer, the scenarios were developed based on the companies' capabilities in components influencing knowledge transfer. Thus, based on the collected data, companies were divided into two categories: those with strong and weak capabilities influencing knowledge transfer. Therefore, if two companies decide to collaborate for knowledge exchange, they can engage in the following 4 scenarios together:

Scenario A: Both companies A and B possess weak knowledge transfer capabilities.

Scenario B: Both companies A and B have strong knowledge transfer capabilities.

Scenario C: Company A has strong knowledge transfer capabilities, while company B is weak in this aspect.

Scenario D: Company A has weak knowledge transfer capabilities, while company B is strong.

Before delving into the examination and analysis of each scenario, the following steps were taken to provide a realistic estimation of the parameters of the proposed model:

1- To calculate the coefficients of the knowledge transfer components (γ_i, α_i, β_i) considering that the knowledge sender is also the knowledge receiver, or simultaneously acts as both a sender and receiver of knowledge, the path coefficients from the investigated models were utilized. As such, these values, based on the data from the studied companies, are as follows:

For knowledge sender companies:

- The coefficient of the impact of knowledge transfer capability $\beta_1 = 0.195$
- The coefficient of the impact of cooperative level in the supply chain $\beta_2 = 0.584$
- The coefficient of the impact of organizational context $\beta_3 = 0.567$

For knowledge receiver companies:

- The coefficient of the impact of knowledge absorption $\alpha_1 = 0.167$
- The coefficient of the impact of cooperative level in the supply chain $\alpha_2 = 0.728$
- The coefficient of the impact of organizational context $\alpha_3 = 0.547$

For companies that are both knowledge sender and receiver:

- The coefficient of the impact of knowledge transfer capability $\gamma_1 = 0.224$
- The coefficient of the impact of knowledge absorption $\gamma_2 = 0$
- The coefficient of the impact of cooperative level in the supply chain $\gamma_3 = 0.59$
- The coefficient of the impact of organizational context $\gamma_4 = 0.422$

2- To calculate the R knowledge source for each company, the concept of intellectual capital was utilized based on the input from knowledge management experts. Various methods exist to calculate the value of intellectual capital. In this research, one of the common methods proposed by Stewart and Leuven, known as the method based on the difference between book value and market value, was employed. Based on this approach, the values of intellectual capital were estimated to be between a minimum of 7,000 billion rials and a maximum of 10,000 billion rials.

3- To calculate the cooperative cost (C), accurate, categorized, and detailed information about cooperative experiences between companies is necessary. Unfortunately, such information is not present in the reports of the studied companies. This cost includes items such as human resource hours involved in the cooperative and knowledge transfer process, equipment used, and system time. As detailed information was lacking in the reports, to provide a desirable estimate of these costs, input was gathered from experts familiar with the industry. After introducing the research topic, the concepts used, and the components that constitute the cost, these experts were asked to provide estimates of cooperative costs in projects they had experience with. Consequently, the cooperative cost was estimated to fall within the range of 1,500 billion rials to 5,000 billion rials

4- For estimating the penalty cost of non-cooperation, a percentage of the average intellectual capital of the companies was considered based on expert opinions. If the average intellectual capital, based on the data from the 10 studied companies, is 10,000 billion rials, the penalty for non-cooperation was taken to be approximately the minimum of ten percent of this amount, which is 1,000 billion rials in calculations. Based on this, with the real data collected from the 10 studied companies, suitable numerical examples can be provided to determine the best strategy for each company in various scenarios.

Scenario A: Both companies A and B have weak capabilities in knowledge transfer components.

In this scenario, Company A, which possesses weak knowledge transfer capabilities, has an intellectual capital of 10,000 billion Rials. On the other hand, Company B, also with weak knowledge transfer capabilities, has an intellectual capital of 7,000 billion Rials. Utilizing an average cooperative cost of 3,000 billion Rials and a non-cooperative penalty of 1,000 billion Rials, and considering the obtained innovation payoffs, the optimal strategy payoff matrix for Company A and Company B has been calculated. The results Table 7 demonstrates various cases of this scenario when the model parameters change.

Table 7: Sensitivity Analysis of Optimal Strategies for Companies in the First Scenario

Both Company A and Company B have weak knowledge transfer components.						
Company A: TC= 0.2, AC= 0.2, LC= 0.2, OC= 0.2 Company B: TC= 0.2, AC= 0.2, LC= 0.2, OC= 0.2						
Sensitivity analysis based on information from two sample companies in the supply chain.						
Different Cases	R_A	R_B	C	σ	Optimal Strategy A	Optimal Strategy B
Main case	10,000	7,000	3,000	1,000	Cooperation	Tit for Tat
Equal Intellectual Capital	7,000	7,000	3,000	1,000	Tit for Tat	Tit for Tat
Equal Higher Intellectual Capital	10,000	10,000	3,000	1,000	Cooperation	Cooperation

Increased Social Penalty	10,000	7,000	3,000	7,000	Cooperation	Tit for Tat
Doubled Intellectual Capital	20,000	14,000	3,000	1,000	Cooperation	Cooperation
Doubled Cooperative Cost	10,000	7,000	6,000	1,000	Tit for Tat	Tit for Tat
Significantly Increased Cooperative Cost	10,000	7,000	11,000	1,000	Non-cooperation	Non-cooperation

Scenario B: Both companies A and B have strong capabilities in knowledge transfer components.

Table 8 presents the calculation results and various outcomes of this scenario when the model parameters are changed.

Table 8: Sensitivity Analysis of Optimal Strategies for Companies in the Second Scenario

Both Company A and Company B are strong in the components of knowledge transfer.						
Company A: TC= 0.8, AC= 0.8, LC= 0.8, OC= 0.8 Company B: TC= 0.8, AC= 0.8, LC= 0.8, OC= 0.8						
Sensitivity analysis based on information from two sample companies in the supply chain.						
Different Cases	R_A	R_B	C	σ	Optimal Strategy A	Optimal Strategy B
Main case	10,000	7,000	3,000	1,000	Cooperation	Cooperation
Equal Intellectual Capital	7,000	7,000	3,000	1,000	Cooperation	Cooperation
Equal Higher Intellectual Capital	10,000	10,000	3,000	1,000	Cooperation	Cooperation
Increased Social Penalty	10,000	7,000	3,000	7,000	Cooperation	Cooperation
Doubled Intellectual Capital	20,000	14,000	3,000	1,000	Cooperation	Cooperation
Doubled Cooperative Cost	10,000	7,000	6,000	1,000	Cooperation	Cooperation
Significantly Increased Cooperative Cost	10,000	7,000	over 12,000	1,000	First Tit for Tat then Non-cooperation.	First Tit for Tat then Non-cooperation.

Scenario C: Company A has strong capabilities in knowledge transfer components, while Company B is weak.

Table (9) presents the calculation results and various outcomes of Scenario C when the model parameters are changed.

Table 9: Sensitivity Analysis of Optimal Strategies for Companies in Scenario C

Company A is strong in terms of knowledge transfer components while company B is weak.						
Company A:TC= 0.8, AC= 0.8, LC= 0.8, OC= 0.8 Company B:TC= 0.2, AC= 0.2, LC= 0.2, OC= 0.2						
Sensitivity analysis based on information from two sample companies in the supply chain.						
Different Cases	R_A	R_B	C	σ	Optimal Strategy A	Optimal Strategy B
Main case	10,000	7,000	3,000	1,000	Cooperation	Tit for Tat
Equal Intellectual Capital	7,000	7,000	3,000	1,000	Cooperation	Tit for Tat
Equal Higher Intellectual Capital	10,000	10,000	3,000	1,000	Cooperation	Cooperation
Increased Social Penalty	10,000	7,000	3,000	7,000	Cooperation	Tit for Tat
Doubled Intellectual Capital	20,000	14,000	3,000	1,000	Cooperation	Cooperation
Doubled Cooperative Cost	10,000	7,000	6,000	1,000	Cooperation	Tit for Tat
Significantly Increased Cooperative Cost	10,000	7,000	over 12,000	1,000	First Tit for Tat then Non-cooperation.	Non-cooperation

Scenario D: Company A has weak capabilities in knowledge transfer components, while Company B is strong.

Table (10) presents the calculation results and various outcomes of Scenario D when the model parameters are changed.

Table 10: Sensitivity Analysis of Optimal Strategies for Companies in Scenario D

Company A is weak in terms of knowledge transfer components, while Company B is strong.
Company A: TC= 0.2, AC= 0.2, LC= 0.2, OC= 0.2 Company B: TC= 0.8, AC= 0.8, LC= 0.8, OC= 0.8
Sensitivity analysis based on information from two sample companies in the supply chain.

Various situations	R_A	R_B	C	σ	Optimal Strategy A	Optimal Strategy B
Main condition	10,000	7,000	3,000	1,000	Cooperation	Cooperation
Intellectual capital equality	7,000	7,000	3,000	1,000	Tit for Tat	Cooperation
Equality of intellectual capital with a higher amount	10,000	10,000	3,000	1,000	Cooperation	Cooperation
Increase in social penalty	10,000	7,000	3,000	7,000	Cooperation	Cooperation
Twofold increase in intellectual capital	20,000	14,000	3,000	1,000	Cooperation	Cooperation
Twofold increase in cooperative costs	10,000	7,000	6,000	1,000	Tit for Tat	Cooperation
Several fold increase in cooperative costs	10,000	7,000	over 8,000	1,000	Non-cooperation	First Tit for Tat then Non-cooperation.

CONCLUSION

Based on the opinions of investment company experts and through specialized interviews with managers of the National Iranian Oil Company, innovation in equipment and project implementation methods within the oil sector is identified as a significant weakness for domestic companies compared to their foreign counterparts. To address this concern, a conceptual model has been developed to facilitate knowledge transfer for innovation among investment firms.

In examining the relationship among research components, companies participating in the knowledge transfer process within the supply chain are categorized into three groups: knowledge sender, knowledge receiver, and mutual sender-receiver. The relationships between these components were analyzed separately for these three groups using the Spearman correlation coefficient. To investigate companies' strategies in knowledge transfer and profit acquisition through increased innovation, three game models were designed and analyzed. In the first model, the amount of profit obtained from knowledge-based innovation transfer was assumed constant for all companies. Different possible scenarios for this game were analyzed in a way that allows them to achieve the maximum profit by selecting an appropriate strategy. In the second model, the penalty component for non-cooperation was introduced as a deterrent for companies that do not collaborate in knowledge transfer. Consequently, efforts were made to identify various collaborative scenarios to enhance companies' profitability, and measures were provided to encourage their increased cooperation.

The results were obtained as follows by solving various numerical examples and utilizing the data collected from 10 subsidiaries of the National Iranian Oil Company:

1- Upon reviewing the results, four scenarios emerge where the higher the organizational capabilities are in terms of factors influencing knowledge transfer and innovation, the more companies will benefit from cooperation. In other words, in various cooperative models, companies with weaker capabilities in terms of these factors can achieve greater profits by enhancing these components through cooperative.

2- Sensitivity analysis regarding the costs of collaborative projects, stemming from the difficulty of implementing joint projects, revealed that as the costs increase, companies shift from a cooperative strategy towards a retaliation strategy, and then towards a non-cooperative strategy. Furthermore, it was observed that companies with weaker capabilities tend to move more quickly towards a non-cooperative strategy.

3- In examining the impact of non-cooperative penalties, it was observed that in projects with high cooperative costs and companies, especially those with low capabilities, inclined towards non-cooperative, setting higher non-cooperative penalties can steer them towards a retaliation strategy.

4- Regarding the influence of companies' intellectual capital status on the choice of cooperative strategy, it was observed that if companies intending to collaborate possess higher intellectual capital due to experience and empowerment, the optimal strategy tends towards cooperative. This cooperative, once again, enhances the level of intellectual capital and knowledge within the companies, leading to improved cooperative. This repetitive cycle over time will result in a leap toward higher profitability and innovation enhancement within the companies.

RECOMMENDATIONS ARISING FROM THE RESEARCH FINDINGS:

1- The most influential factor affecting the transfer of knowledge and innovation for investment companies in this study was identified as the level of cooperative between companies, in both the sender and receiver of knowledge groups. This factor is elucidated by the components of trust between companies and their joint planning. Accordingly, it is suggested that the use of collaborative programs such as joint investments, collaborative research projects, strategic partnerships, and the establishment of communication networks based on new technologies be employed to enhance cooperative levels in the supply chain. Since another determinant variable of cooperative level is trust between companies, it is advisable to implement programs to enhance trust between companies.

2- The second influential factor for innovation in both the sender and receiver knowledge groups is the conducive organizational context factor. The components of the organizational context in this study include flexible organizational structure and the utilization of information technology. Achieving a flexible organizational structure in companies requires strategic planning and the commitment of top management. Furthermore, a greater embrace of new technologies in various business domains leads to the creation of more innovative environments, facilitated by the ease of information flow and exchange in different areas, resulting in the generation of new knowledge. Therefore, it is recommended that companies incorporate investment plans to leverage new information technologies and provide training for their usage across all employee levels in their planning efforts.

3- The next priority among influential factors in knowledge transfer and resulting innovation for sender knowledge companies is the capability of knowledge transfer. Therefore, it is recommended that companies increase transferability by motivating knowledge transfer within the organization, potentially by considering motivational incentives. On the other hand, based on the research findings, investment companies and even the National Iranian Oil Company can impose financial and non-financial penalties on companies that do not participate in knowledge transfer. They can also consider sanctions to incentivize knowledge transfer compared to abstaining from it.

4- Another priority for receiver knowledge companies is the capability to absorb knowledge, which includes components of absorptive capacity and willingness to learn. Given that absorptive capacity doesn't just involve the ability to acquire external knowledge, but also the ability to utilize that knowledge for business purposes and create opportunities for profitability, organizations can move towards establishing a learning organization that fosters a culture of learning.

In summary, to enhance innovation, companies can increase their capabilities in influential factors of knowledge transfer and innovation. They can also elevate cooperative penalties within the supply chain, reduce cooperative costs, and enhance their knowledge resource, which is measured by intellectual capital.

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