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JCPOA revival: A game theoretical approach

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Abstract

This article employs game theory to analyze the potential revitalization of the Joint Comprehensive Plan of Action (JCPOA) and the factors that influence the decision-making processes of Iran and the United States. The JCPOA, an agreement signed in 2015, placed significant restrictions on Iran's nuclear program in return for the lifting of economic sanctions. However, the situation shifted dramatically when the United States withdrew from the agreement in 2018. Despite recent negotiations and renewed hopes for a revival of the JCPOA, events such as the inauguration of Iran's conservative president and ongoing conflict in Ukraine have resulted in a stalemate. This article explores the policy options available to each party and assesses their associated risks and benefits. By applying game theory, it offers a more precise understanding of the strategies employed by both actors and the potential future of the JCPOA. The analysis ultimately concludes that it is highly improbable that the JCPOA will be revived in the near future. Sanctions are likely to remain in place while Iran continues to maintain ambiguity regarding its nuclear program. A major transformation would be required to fundamentally alter the current situation.

Keywords: JCPOA; Iran; United States; Game Theory; Nuclear deal

1. Introduction

The Joint Comprehensive Plan of Action (JCPOA) is an agreement that was signed on July 14, 2015, in Vienna by Iran and other P5+1 members. The agreement imposed significant restrictions on Iran's nuclear program, and in return, many economic sanctions previously imposed due to Iran's nuclear program were lifted. The implementation of the JCPOA initially appeared to resolve one of the most critical security issues in the Middle East that had attracted a lot of attention in the region for years. However, the situation changed rapidly with the victory of Donald Trump in the 2016 presidential election. On May 8, 2018, the United States officially withdrew from the JCPOA, leading to unprecedentedly increased tension between Iran and the United States.

With the recent victory of Joe Biden in the presidential election, hopes for the revival of the Iran nuclear agreement have increased. In April 2021, a new round of negotiations between Iran and the countries participating in the JCPOA and the United States began indirectly. However, despite eight rounds of negotiations in Vienna, However, the developments that took place during the 8 rounds of the Vienna talks, including the inauguration of the conservative president of Iran, Ebrahim Raisi, and the war in Ukraine ultimately led to the deadlock in the negotiations to revive the JCPOA.

This article aims to analyze the revitalization of the Joint Comprehensive Plan of Action (JCPOA) and the factors influencing the decision-making of Iran and the United States by applying game theory. Specifically, it seeks to examine the policy options available to each actor, as well as the risks and benefits associated with each policy. By utilizing game theory, this article strives to provide a more accurate understanding of the approaches taken by both actors and the potential future of the JCPOA

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2. Methodology

This study aims to explore the potential for the revival of the Joint Comprehensive Plan of Action (JCPOA) using a game-theoretical approach. The game-theoretic method, which is a branch of rational selection, can be utilized to analyze and resolve conflicts that arise during the revival of the Joint Comprehensive Plan of Action (JCPOA) at a theoretical level. By applying game theory principles, it is possible to model the interactions between the involved parties and predict their behavior.

Governments continuously interact with each other regarding a wide range of political, economic, security and military issues. Sometimes these interactions are cooperative and sometimes they show themselves in the form of competitive relations, and in all these cases, the decision and behavior of one government directly affects the decision and behavior of another government. It is reciprocally affected by it. Situations like this are defined as "strategic conditions" and each actor should pay attention to the policy of the opposite actor in order to decide what policy to pursue in order to maximize their interests.

In the 1950s, after international relations theory was undergoing the behaviorist revolution, the whole process not only introduced game theory into the study and application of international relations theory, but also caused a fierce debate on the applicability of the game theory in the field of international relations (Zhang, 2021).

Game theory is a theoretical framework for conceiving social situations among competing players. In some respects, game theory is the science of strategy, or at least the optimal decision-making of independent and competing actors in a strategic setting. Game theory has a wide range of applications, including psychology, evolutionary biology, war, politics, economics, and business (Hayes, 2023).

Game theory discusses the interaction among rational, mutually aware players, where the decisions of some players impacts the payoffs of others. A game is described by its players, each player's strategies, and the resulting payoffs from each outcome. Additionally, in sequential games, the game stipulates the timing (or order) of moves (Shor, 2005).

In game theory, each player chooses a policy that optimizes his own objective. Therefore, this method is believed to be able to simulate the conflicts more realistically. Because in practice, the principal concern of players is to maximize their own benefits by making a decision which might not be beneficial to the whole system. These self-optimizing attitudes might provide non-cooperative behaviors from players, even when cooperative behavior is the best solution for all, and that is where game theory can be more powerful than other methods (Madani, 2010).

Game theory can be utilized to predict how individuals behave in conflicts while pursuing their own interests. In a typical game, decision-makers (players) with their own objectives attempt to outmaneuver one another by anticipating each other's decisions. The outcome of the game is determined by the players' decisions. Game theory analyzes the strategies employed by players to maximize their payoffs. A solution to a game prescribes the decisions that decision-makers may make and describes the outcome of the game.

2.1. Applying Game Theory in International Relations

The object of the study of international relations is the analysis of interactions among nation-states. These interactions involve interdependent goal-directed activities. Interdependency means that the achievement of the goals of any nation-state does not depend only upon its own actions, but also upon those of the other nation-states. game theory, whose objective is the formalized analysis of relationships among two or more actors, can assist international relations theoreticians in explaining the interactions among the actors it considers, and practitioners in the field (Correa, 2001).

The use of Game Theory in International Relations generally refers to the Thomas Schelling and his book *The Strategy of Conflict* written in 1960. *Chicken Game* and *Prisoners Dilemma*, which are still being used in today, starts with Schelling. *Conflict and Defense* of Kenneth Boulding and *Fights, Games and Debates* of Anatol Rapoport enabled formal analysis to be used in conflict issues through economic models. Another importance of Game Theory is that Game Theory put decision-making groups in International Relations analysis. Classical International Relations theories such as Realism accept actors as black box and acts as a billiards ball. However, Game Theory emphasizes the importance of bureaucracies and decision-making mechanisms in decision-making process. (Tasci, 2020).

To apply game theory to JCPOA revival we first identify the key actors and their strategic interaction regarding this issue. We then develop a game theoretic model that captures these strategic interactions and simulate potential outcomes of the JCPOA revival.

Our model considers two main actors: Islamic republic of Iran and United states of America. We assume that each player has a set of strategies and preferences over the possible outcomes of the negotiations over the revival of the JCPOA, these preferences are based on the level of sanctions relief, nuclear restrictions and the possible duration of the agreement.

Finally, we validate our results by comparing it with empirical evidence from previews negotiations and agreements between Iran and US.

2.2. Background on JCPOA

Since the mid-2000s Iran's nuclear program has become one of the major political and security problems in the Middle East. At first, the three European countries took the initiative and started a series of negotiations with Iran to prevent further tensions and finally in 2003 both sides signed the Tehran Declaration. Following these negotiations, Iran agreed to accept limitations in its nuclear program and implement the Additional Protocol voluntarily, and three European countries agreed to recognize Iran's right to obtain peaceful nuclear technology and the case Remove Iran from the agenda of the International Atomic Energy Agency's Board of Governors and expand their political and economic relations with Tehran.

The EU had the opportunity to take the lead in these important negotiations only because the Americans were not ready at that time to break the isolation that they have pursued since 1979. Iran even proposed a secret deal to the US but it was turned down. (Sauer, 2007).

Negotiations between the two parties persisted until 2005, during which numerous advancements were made. Despite the strong inclination of the E3 countries to persist in discussions and reach a permanent agreement, the talks ultimately failed to achieve their primary objectives due to obstructions from the United States and the antagonistic policy of the Bush administration towards Iran.

In 2005, when Mahmoud Ahmadinejad came to power in Iran, the Iranian government's approach to the issue of the nuclear program took a hostile form. For the international community the new president meant a less reliable Iran which would prove to further escalate the crisis (Kutchesfahani, 2006).

Iran ended the voluntary implementation of the additional protocol, and this provided the basis for the referral of Iran's case from the International Atomic Energy Agency to the United Nations Security Council. The referral of Iran's nuclear issue to the UN Security Council eventually led to the approval of four UNSC resolutions (1737, 1747, 1803, 1929) and the imposition of severe economic sanctions against Iran. Resolution 1929 of the United Nations Security Council left a significant impact on Iran's economy, because following this resolution, international financial and economic institutions and companies stopped their activities in Iran. But the most severe part of the sanctions was implemented in 2012. When the United States and the European Union imposed sanctions on oil, the central bank and access to SWIFT. As a result of these sanctions, Iran's oil exports decreased drastically, so that in March 2012, Iran's oil exports reached below 2 million barrels per day (Economic Database Center, 2023).

With the inauguration of Hassan Rouhani, the moderate president of Iran in 2013, Iran's diplomatic efforts to end the nuclear crisis were pursued with more intensity, By 2013, Iran had reached an interim agreement with the five members of the UN Security Council (US, Russia, China, France, and the UK) and Germany (P5+1) outlining initial steps that Iran would take regarding its nuclear program in exchange for reduced sanctions. A final, more extensive agreement was reached in 2015, called the Joint Comprehensive Plan of Action. This agreement saw Iran accept limits on a number of the more proliferation-sensitive aspects of their nuclear program and accept more stringent verification and reporting procedures to demonstrate their adherence to the agreement (Davenport, Kimball, & Thielmann, 2015).

Under the terms of the agreement, Iran was limited to operating 5,060 centrifuges, half of the number it previously was operating. All uranium enrichment was ceased at the Fordow site and decommissioned centrifuges were stored under IAEA seal at Natanz. The development of advanced centrifuges was limited to experiments on single centrifuges of four different designs for the first 8 years of the deal, with restrictions loosening thereafter. Uranium enrichment was capped at 3.67% and Iran was allowed to possess a stockpile of no more than 300 kg of enriched material. The core of the heavy water reactor was destroyed by filling it with cement, and in its place was to be built a redesigned reactor that would be unsuitable for producing plutonium (Davenport, Kimball, & Thielmann, 2015). Also, restrictions were placed on the amount of heavy water that Iran could have, and Iran committed to remove its spent fuel from the country in order to create an obstacle on the way to obtaining plutonium through fuel. In short, the reduction of the number of active centrifuges in Iran and the limitation of enriched uranium reserves were implemented for this purpose, so that the time

required to produce a sufficient amount of enriched uranium for use in an atomic bomb would increase from 2-3 months to 12 months. In addition, Iran agreed to comply with the Additional Protocol and submitted to the IAEA's strict monitoring. The increased IAEA presence, with an indefinite duration, continues to make it more difficult for Iran to cease compliance with any of its obligations without detection (Kerr & Katzman, 2018).

To sum it up, The Joint Comprehensive Plan of Action (JCPOA) is a landmark agreement that was signed in July 2015 between Iran and six world powers, including Germany, France, the United Kingdom, Russia, China, and the United States. The deal aimed to resolve the nuclear impasse concerning Iran and provided verifiable assurances that fissile material in Iran could not be diverted toward military purposes. The highest standards on nuclear transparency and inspections ever negotiated were also included in the deal. The lifting of US and United Nations nuclear-related sanctions was also a part of the agreement (seyed N. Mousavian, 2018).

2.3. Current status of the JCPOA

On 8 May 2018, US President Donald J. Trump announced that the United States would pull out of the Joint Comprehensive Plan of Action (JCPOA), which sets limits on Iran's nuclear program to ensure that it cannot produce nuclear weapons. Despite the US withdrawal, the JCPOA remains in force; it is a multilateral agreement to which seven of the original eight parties still adhere (Smith, 2019). In addition to withdrawing from its commitments under the JCPOA, the Trump Administration reinstated severe economic sanctions on Iran.

The sanctions imposed against Iran were not supported by other countries that signed the JCPOA. In reaction to sanctions imposed by the United States, member states of the European Union endeavored to facilitate financial and commercial relations with Iran by establishing specialized instruments to circumvent these sanctions. Ultimately, this mechanism, known as INSTEX, achieved limited success in fostering relations between Iran and the European Union and was only utilized for the export of medical supplies during the Covid-19 pandemic.

On May 8, 2019, Iran's SNSC announced Iran stops some of its measures under JCPOA. The Supreme National Security Council issued a statement addressing the JCPOA member states, stating that the Islamic Republic of Iran has shown considerable restraint in the past one year after the illegal withdrawal of the United States from the JCPOA and violations of United Nations Security Council resolutions. In the statement it was stressed, "In order to protect the security and national interests of the people of Iran, and in implementation of its rights set forth in Paragraph 26 and 36 of the JCPOA, the Islamic Republic of Iran stops some of its measures under the JCPOA from today, 08 May 2019" (SNSC, 2019).

While Iran is still subject to the additional protocol which allows expanded access to civilian facilities, the limits on uranium stockpile size and number of operating centrifuges are no longer in place. Maintaining a stockpile of LEU and having a capability to enrich uranium are not activities inherently in breach of the NPT as, when subject to safeguards, they could be used purely in support of a peaceful civilian nuclear program. However, regaining this capability would place Iran in a position where, upon making a political decision to build a weapon, could "break out" and utilize this civilian stockpile and capability to manufacture a nuclear weapon (Davenport, Kimball, & Thielmann, 2015).

Tensions between Iran and the United States escalated to an unprecedented degree throughout the duration of Trump's presidency. Iran increased its uranium enrichment to 60%, while the United States persisted in its campaign of maximum pressure against Iran, resulting in significant economic strain on the country. However, with the inauguration of Joe Biden as President of the United States in 2021, expectations arose for a change in conditions and a swift revival of the JCPOA.

Negotiations did not start immediately after the assignment of the Biden administration in January 2021. To revive the nuclear deal with Iran was on the political agenda of new US President Biden. However, he likely feared that risky foreign policy moves could undermine its domestic agenda (Guyer, 2022). Ultimately, despite many struggles, the Vienna talks for the return of the United States to the JCPOA began in April 2021.

The Vienna talks, involve all countries that have signed the nuclear deal with Iran. The talks aimed to revive the JCPOA and address the concerns of all parties involved. The negotiations have been challenging, with the United States and Iran Having serious differences in their approaches. However the talks continued, and there have been some progress. (Bobkin, 2022).

Initially, conditions appeared favorable for the revival of the JCPOA and it was anticipated that obstacles to the agreement would be swiftly resolved. However, subsequent developments complicated efforts to revive the JCPOA. The victory of conservative candidate Ebrahim Raisi in the Iranian presidential elections temporarily halted the Vienna talks.

The approach of the new negotiating team differed significantly from that of the previous Iranian government and adopted a more stringent stance in negotiations. Further complicating matters was Russia's military invasion of Ukraine, which again suspended the Vienna talks. Ultimately, after eight rounds of talks in Vienna, the parties were unable to break the impasse and no clear resolution has been reached to date.

2.4. Policy options for each player

2.4.1. United States of America

Nuclear non-proliferation has consistently been a strategic objective of the United States, and the JCPOA can be viewed within this context. As such, the primary aim of the United States in its dealings with Iran is to prevent the country from acquiring nuclear weapons. To achieve this objective, three policy options are available to the United States, which will be discussed in further detail below.

Maintaining economic sanctions:

The current policy, known as 'maximum pressure,' relies on the use of economic sanctions to achieve its objectives. These objectives include limiting Iran's destabilizing non-nuclear activities and incentivizing Iran to maintain compliance with JCPOA limits without reciprocal U.S. compliance with the agreement.

- Pros
 - The continuation of sanctions may increase pressure on Iran to alter its behavior with respect to its foreign policy and nuclear program. By precipitating an economic crisis in Iran, sanctions may fuel social unrest and ultimately compel Iran to make difficult decisions regarding its nuclear program and other issues such as its ballistic missile program and regional policies
 - Economic sanctions could also serve as the impetus for a larger negotiated agreement that addressed Iran's ballistic missile program and regional support for militants in addition to its nuclear program (MacDonald, Roemer, & Klein, 2020).
 - Economic sanctions can be an efficient tool to put pressure on the target country
- Cons
 - Despite the clear effects on the Iranian economy, the effectiveness of these sanctions in the short-term on reducing Iran's desire to pursue nuclear weapons has not been demonstrated (MacDonald, Roemer, & Klein, 2020).
 - Economic sanctions have influenced countries behaviors and induced regime change in the past, but they have been most effective when coordinated internationally, for a highly specific purpose, with unambiguous conditions on their removal as soon as that purpose is met. Unilateral sanctions have not been as effective. Economic sanctions have the added cost of extracting a significant humanitarian toll from civilians (Marinov, 2005).
 - Economic sanctions can have profoundly negative humanitarian consequences. By undermining the economic foundation of the middle class, sanctions may diminish a society's capacity for political change in the target country, which is one of the fundamental objectives of this policy option.

Military Action

Military action can destroy Iran's capability to build nuclear weapons if other options fail, despite the uncertainty and high risk.

- Pros
 - Military action can be an effective policy to prevent Iran from acquiring nuclear weapons and can quickly set back Iran's nuclear program for an indefinite period of time.
 - Military action against Iran could send a strong message to Iran and other governments, demonstrating the willingness of the United States to take any necessary measures to defend its interests
- Cons
 - Military action against Iran could rapidly escalate the situation and heighten regional tensions to an unprecedented degree, potentially laying the groundwork for a large-scale conflict. In response, Iran could take measures such as blocking the Strait of Hormuz, engaging in military action through proxy forces, and threatening the interests of the United States and Israel in the region.

Return to JCPOA

American (and EU) credibility was severely weakened following the backing away from the deal. Reverting to the original deal would be difficult. The U.S. would need to remove sanctions while Iran would need to walk back its nuclear program to comply with the JCPOA limits but neither side would want appear to be making concessions. Thus, while it was generally regarded as an effective non-proliferation tool, returning to the JCPOA status quo is a difficult task, due to the changed nature of the situation.

- Pros
 - Returning to the JCPOA or a similar agreement could be highly effective in preventing Iran from acquiring nuclear weapons. Such an agreement would impose numerous restrictions on Iran's nuclear program and subject it to special inspections by the International Atomic Energy Agency, thereby limiting its scope.

Cons:

- Many contend that a return to the JCPOA would bolster Iran's economy and incentivize the country to persist in its destabilizing behavior. Despite the nuclear agreement, Iran's destabilizing policies in the region could continue, presenting a challenge for the United States and its regional allies.
- Iran's advancements in the years following the withdrawal of the United States from the JCPOA have reduced the country's nuclear breakout time. The revival of the JCPOA may not adequately address this issue.
- The JCPOA does not cover many sensitive issues related to Iran, including the ballistic missile program and regional policies, and all issues must be covered in order to deal with Iran.

2.4.2. Islamic Republic of Iran

Iran's efforts to acquire nuclear technology can be explained in the context of two ultimate foreign policy objectives: first preserving the Islamic Republic's control over Iran and second reaching a regional hegemon status (Pollack, 2013). In the same manner, Fitzpatrick (2006: 531) summarizes Iran's motivations for nuclearization as achieving prestige, asserting national pride and sovereignty as well as ensuring that Iran is accorded equality and respect (Fitzpatrick, 2006).

Compliance with JCPOA

A return to the JCPOA could provide a foundation for the lifting of nuclear sanctions against Iran and improve diplomatic relations between Iran and other parties to the agreement, potentially reducing regional tensions. However, returning to the JCPOA without securing additional concessions compared to the past could diminish Iran's standing among its conservative supporters and proxy groups in the region.

- Pros
 - By capitalizing on the lifting of nuclear sanctions, the sale of oil, and the release of its frozen funds in foreign banks, the Islamic Republic of Iran could improve its economic conditions and reduce the risk of foreign military attack.
 - From the perspective of Iranian public opinion, a return to the JCPOA could be viewed as a positive development for social conditions, as it may alter the country's economic outlook to some degree.
- Cons
 - The primary social body supporting the government in Iran, as well as many influential radical groups, may not view a return to the JCPOA favorably. Such a return could be interpreted as a form of retreat.
 - It cannot be guaranteed that the United States will not withdraw from the Joint Comprehensive Plan of Action (JCPOA) again. If Iran returns to the JCPOA and rolls back its nuclear program, it is possible that the United States will withdraw from the JCPOA once more. This would increase the risk associated with economic activity in Iran. Consequently, the benefits that Iran derives from the new agreement may not be as significant as those from the previous agreement in 2015
 - With the return of all parties to the Joint Comprehensive Plan of Action (JCPOA), sanctions related to Iran's nuclear activities will be lifted. However, sanctions related to terrorism and human rights will largely remain in place. In other words, the situation will not revert to its state in 2015.

Exit NPT and actively Pursuing nuclear bomb:

- Pros
 - The development of nuclear weapons would significantly enhance Iran's military capabilities and would greatly deter foreign intervention in the country.

- It can be used as a bargaining tool
- Cons:
 - The development of nuclear weapons would result in more stringent sanctions and increased isolation of Iran within the international community.
 - Despite creating deterrence against foreign aggression and due to the special conditions in the Middle East, the desired security will not be achieved with nuclear weapons.
 - Iran’s reputation in the international community will be severely damaged.

Ambiguity policy and maintaining the status quo

- Pros
 - Ambiguity in the nuclear program can provide a degree of deterrence and eventually be used as a bargaining tool in negotiations.
 - A policy of ambiguity may prevent the activation of the trigger mechanism in the short term. By preserving Iran’s nuclear capabilities, it may provide an opportunity to avoid more severe sanctions.
- Cons
 - Ambiguity policy can lead to increasing hostility and tension between Iran and other actors.
 - A policy of ambiguity may negatively impact Iran’s reputation within the international community and affect its relations with other countries.

2.5. Assessing JCPOA Revival using Game Theory

2.5.1. Presenting the game in Strategic form

In this section, we will summarize the material presented so far and examine the revival of the Joint Comprehensive Plan of Action (JCPOA) using a game theory approach. Figure 1 presents the policy options of two actors in the form of a strategic game. By analyzing these options, we can gain insight into the potential outcomes and strategies of each actor.

		USA					
		compliance		sanctions		military action	
Iran	compliance	6	8	-4	9	-5	-4
	ext. NEP I	4	2	6	3	8	4
	status quo	10	5	4	7	-7	-2

Figure 1 Iran-US payoff matrix

The numeric values assigned to each player is determined through a comprehensive analysis of the political, economic, and societal ramifications associated with each policy alternative. The pure Nash equilibrium of this game is (ambiguity, sanctions). This means that, in the absence of any significant changes to the current situation, neither side is likely to deviate from this point. In other words, both sides are content with maintaining the status quo and are not motivated to take any actions that would disrupt the current balance.

2.5.2. Presenting the game in extensive form

In Figure 2, which is shown above, we have presented the game in its extensive form. This allows us to examine the best strategy for each player in greater detail. By analyzing the decision tree and considering the potential outcomes of each move, we can determine the optimal course of action for each player and predict their likely behavior.

Based on our analysis, it appears that the current situation regarding the JCPOA is likely to continue. Sanctions will remain in place and Iran will continue to pursue a policy of ambiguity with regards to its nuclear program. This means that there will be no significant changes in the near future and the status quo will be maintained. Both sides will continue to act in their own interests and the situation will remain at a stalemate.

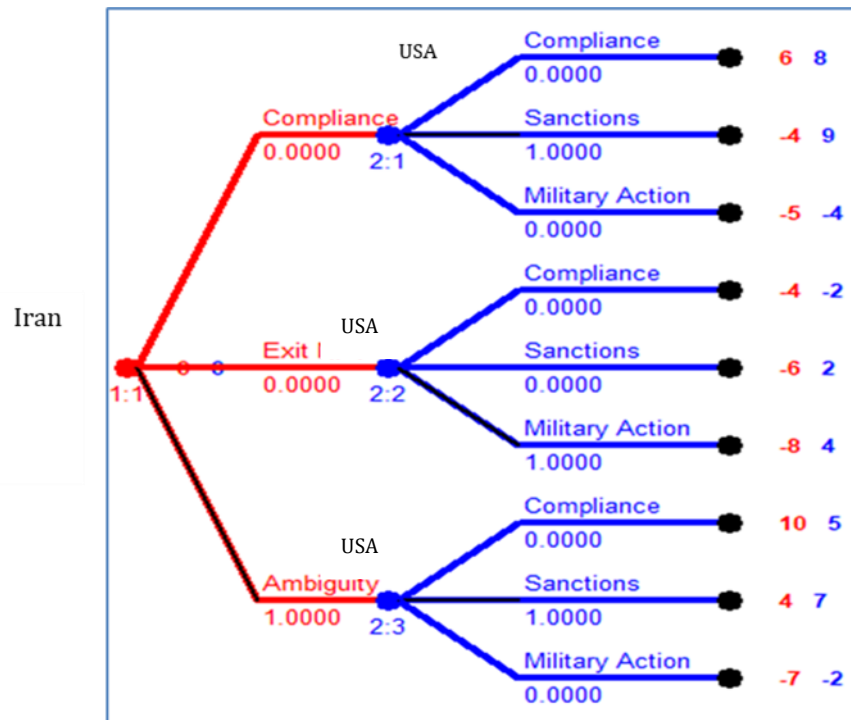


Figure 2 Game presented in Extensive form

3. Conclusion

In conclusion, it should be noted that despite the limitations of the analytical framework of game theory, it can serve as an effective tool for analyzing and predicting international issues. As previously discussed, game theory examines the behavior of actors in strategic situations, including political disputes between governments. Over the past decade, Iran's nuclear program has emerged as a significant political and security issue that has affected the entire region. The signing of the JCPOA in 2015 was widely regarded as a resolution to one of the region's most pressing concerns. However, the United States' withdrawal from the JCPOA in 2018 resulted in increased tension and conflict between the two nations.

With the conclusion of Donald Trump's presidency and the inauguration of Joe Biden, there were hopes that tensions between the governments of Iran and the United States would decrease, leading to a swift revival of the JCPOA. However, political and international developments ultimately resulted in a stalemate, and negotiations to revive the JCPOA were protracted. In this article, we employed a game theory approach to analyze the issue of JCPOA revitalization and ultimately concluded that it is highly unlikely that the JCPOA will be revived in the near future. Sanctions will persist and Iran will maintain its policy of ambiguity regarding its nuclear program. Unless significant changes occur, both countries have little incentive to alter their strategies. Any agreement reached to limit Iran's nuclear program is unlikely to be sustainable. A major transformation would be required to fundamentally alter the current situation.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest.

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