A Game Theoretic Analysis of the Conflict over Iran's Nuclear Program

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***Abstract*— Investigation of the contradictory aspects of modern diplomacy is essential to a valid understanding of the working of the political system. Among these aspects, uncertainty infuses the norms of response to the conflicts. Iran's nuclear program is an example, which has intensified a lot of clashes in the region. Here, we develop a stylized strategic model to address the process of conflict resolution in the current negotiation. Reaching an agreement has been challenging due to the conflict of interests of the players in this game. While the Western countries are worried about Iran's nuclear program, and the potential problems that can be incremented in the region, Iran claims that it is a peaceful program that pursues no threats to its neighbors. The proposed game theory model tries to verify and rationalize the announced framework agreement in negotiation to identify the potential agreement options between Iran and P5+1 countries.**

Keywords: Game theory, Conflict resolution, Iran, Nuclear program, Internatinal politics

I. INTRODUCTION

Iran's nuclear program has been the subject of one of the most serious international conflicts in the 21st century. The Islamic Republic of Iran insists that its ambitious nuclear program is exclusively focused on achieving nuclear power to address the increasing its energy needs. But, the major political powers of the West perceive Iran's nuclear developments as a threat to international security, claiming that Iran is seeking a nuclear weapon.

The continuation of this conflict has major economic, political, and even military implications that threaten the strategic balance in the region, affecting the international relations between the conflict parties [1]. The evolution of Iran's conflict has remained mysterious and hard to predict due to the multiplicity of the involved parties, heterogeneity of their objectives/preferences, and the degree of socio-economic and political changes and instabilities affecting the involved parties, such as the emergence of ISIS, Ukraine-Russia conflict, and Yemen's Houthies; the decreasing energy prices and OPEC's internal conflicts; as well as the internal political changes of the players such as Iran and U.S.A.

Conflict resolution can be facilitated by developing a better understanding of the parties' options, incentives, values, information access level, and preferences. Game theory provides an appropriate framework for studying conflicts and understanding the complex linkages of domestic-international politics. Game theory provides a rigorous flexibility in modeling conflicts. Its central concepts (e.g., utility, choice, strategy, structure, information, and signals) and mathematical logic provide the rigor, but substantial flexibility remains in applying the method to model particular problems [2]. Simple-structured games such as Chicken and Prisoner's dilemma are widely used to investigate the structure of international politics [3-4]. However, as Snidal [5] suggests, international politics is intrinsically dynamic and affects the interactions between players continuously. Thus, simple game structures cannot fully capture complexities of the multi-party international conflicts [4] such as the one over Iran's nuclear program.

Following Powell [6], this study develops a strategic game theoretic model to analyze the current negotiations between Iran and P5+1 (US, UK, France, China, and Russia plus Germany) over the nuclear developments. Analytical techniques are used to analyze the conflict over Iran's nuclear program, in addition to exploring and proposing different approaches to increase the likelihood of reaching a strong agreement with respect to the existing framework agreement.

II. IRAN'S NUCLEAR PROGRAM

Iran's nuclear program was initiated more than half a century ago. In 1967, Iran signed the non-proliferation treaty that was endorsed a few years later. Major developments through time about Iran's nuclear program are summarized in Fig. 1. Iran's nuclear activities had been halted after the 1979 Revolution for more than twenty years. Iran resumed its nuclear research activities and the construction of the Bushehr nuclear facility, jointly with Russia, in 1990s. The UN Security Council asked Iran to suspend its enrichment programs, and then imposed sanctions after Iran refused to do so.

III. METHODOLOGY

Players and their incentives

Iran: In the last decades, Iran has been always under the pressure caused by the international sanctions following the 1979 Revolution and the 8-year war with Iraq [7], which have affected its socio-economic conditions. Access to free market

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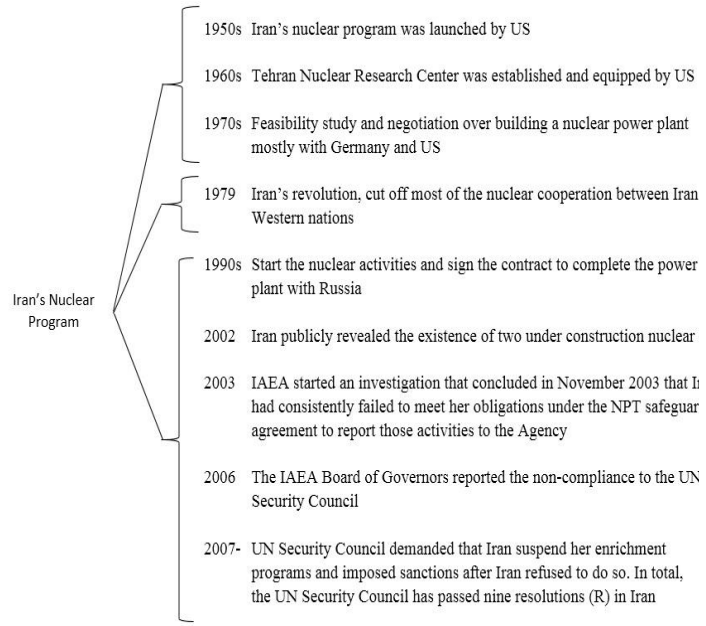

Fig. 1: Iran's nuclear program background [1, 8-9].

and trade can improve Iran's economy and help it address the growing needs of its young population.

Iran wants the international sanctions to be removed. Lifting sanctions would allow Iran to have access to the free market. And even more importantly, Iran can take benefits from new technological achievements that are vital for its long-run economic growth [10]. Iran also likes strengthening its ties with the West to change the Western view of itself as a big threat to the West's interests in the region while it continues its peaceful nuclear program and keeping the research and development sections active along with centrifugal separation independently to produce fuel for the nuclear power plants.

US and EU: Better relations with Iran helps the Western powers address their energy security concerns and increase their regional influence. The latter is strategically important as it helps decreasing Russia's relative power in the region. Without sanctions, the West can directly benefit from Iran's market and resources. On other hand, Western states like to maintain their good relationship with the Arab nations in the region and ensure the safety of Israel.

Russia and China: These countries have politically and economically benefitted from Iran's sanctions. Over the years, they have been able to increase their trades with Iran, increase their regional power and confront US in the region. Lifting the sanctions would not be in their best interest.

Israel: Israel has shown strong signs of concern regarding the possible agreement with Iran over its nuclear program. Israel wants to maintain its safety and security in Middle East. In the meantime, Israel can benefit from regional conflicts such as Iran's nuclear conflict and the current conflicts in Iraq, Syria, Yemen, and Egypt. These conflicts would divert the international attention from the Israel's conflicts with Palestine and its neighbors to other conflicts in Middle East, reducing the international pressure on Israel.

Iran's Neighbors: Iran's neighbors such as the United Arab Emirates and Turkey have been taking advantage of the sanctions on Iran by acting as third party to facilitate economic trades and import of commodities to Iran. In addition to Saudi Arabia, these countries like to maintain their current regional influence in the region and prevent the increased dominance of Shia groups, which are believed to be strongly backed by Iran.

Table I helps compare the level of foreign direct investment (FDI) in Iran with that of other countries in the region. This table suggests that Iran has not been able to take advantage of FDI for its economic growth under the sanctions. Thus, lifting sanctions can potentially increase the FDI in Iran and improve its economic development, which will also be valuable to the investing countries.

Model

We develop an infinite bargaining sequential game with imperfect information to represent the current negotiations between Iran and P5+1. It is assumed that in each negotiation round, the P5+1 countries lead the game by offering their sets of proposals which specify the number of centrifugal separations, n, level of uranium enrichment, r, and duration of the sanctions, y. A crucial assumption, here, is that Iran does not know whether P5+1 countries fully cooperate among themselves or not as Russia and China might have different interests with the US, UK, France and German, i.e. the cooperation information is only available to the P5+1 countries.

Iran can either accept or reject the P5+1's offer in each negotiation round. If it accepts, there is a probability with which each side may defect over time due to the changes in the political conditions within the countries, e.g. change of the dominant political parties in the US and/or Iran. That would lead the game to a new start with different payoffs. The game ends if no one defects. If Iran rejects the offer, it can offer its own sets of proposals to the P5+1 countries. P5+1 can either accept (or bargain and take) or reject Iran's offer.

Table (I): FDI comparison between Iran and its neighbors [11]

Country	FDI ($ million)		Growth Rate (%)
	2002	*2012*	
Iran	3,519	4,662	0.3
Arab Nations	5,758	49,699	7.6
United Arab Emirates	95	9,602	99.8
Turkey	1,082	13,224	11.2
Low Income Countries	3,149	23,992	6.6
Middle East & North Africa	9,649	59,202	5.1
World	**63,2025**	**1,550,475**	**1.5**

One of the key features of the provided model in each stage of the game is that there exists a depreciation of the agreement for Iran that can develop by maintaining the sanctions and even imposing new ones. Similarly, US and EU can experience benefit depreciation from the lack of access to Iran's market and potentials as well as insecurity and conflicts in the Middle East. On the other hand, the other players such as Russia, China, Iran's neighbors and Israel can benefit from benefit appreciation as long as the agreement has not been reached, and sanctions are in place.

The payoffs of the game are shown in Fig. 2 in which a π function is defined on each side that differs in various condition of the game – cooperative or non-cooperative – where the cooperative state occurs with the probability of ρ_i. Following the definition of Milner [12], cooperation happens when players calibrate their behavior to the anticipated inclinations of others via coordination. It should be considered that the payoff of the P5+1 countries is the aggregate demand of Western nations on one side (US, UK, France and Germany) and Eastern (Russia and China) on the other side. Further, it must be taken into account that the payoff of the Western countries is also a function of Israel and Iran's neighbor's requisitions that make the game more complex. The properties of the payoff functions are as follows after normalization:

$\pi = \{(\pi^{IR}, \pi^{5+1}): \pi^{IR} \geq 0, \pi^{5+1} \geq 0, and\ \pi^{IR} + \pi^{5+1} = 1\}$, where

$\pi_n^{IR}, \pi_r^{IR} > 0\ and\ \pi_y^{IR} < 0$, (marginal effects on the payoff) which indicate that Iran's payoff increases as the number of the separation machines and level of uranium enrichment increase.

To indicate the current state of the conflict of interests, for P5+1 countries, the marginal effects on the payoffs considered are as follows: $\pi_n^{5+1}, \pi_r^{5+1} < 0\ and\ \pi_y^{5+1} \lesseqgtr 0$; removing the sanctions is in favor of all the other players but not necessarily for Russia, China and Iran's neighbors. This, indeed, could be a potential source of conflict in negotiation. As stated above, at each stage, if the actors come to an agreement, there might be a perturbation from the agreement on each side with the probability of ε_i. This deviation can occur due to different reasons such as change in political structure or societal ideas and interest – which may shape the strategic behavior of the government [13] – that leads the game to the starting point even with a higher rate of depreciation. As Powell [14] argues cheating is possible because of the large relative gains of players. If the cost of disagreement is low enough, then cooperation may collapse in the model. But, it can become feasible if using force is no longer an issue.

Analyzing the model

Aggregate payoffs under different scenarios are calculated and shown in the Appendix. As suggested by the payoff values reaching an agreement requires a fallback. Let's assume that in the first round, P5+1 starts with their best outcome, and if Iran rejects, it is going to propose its package (nj,rj,yj). Considering the equilibrium at node two (N2), the

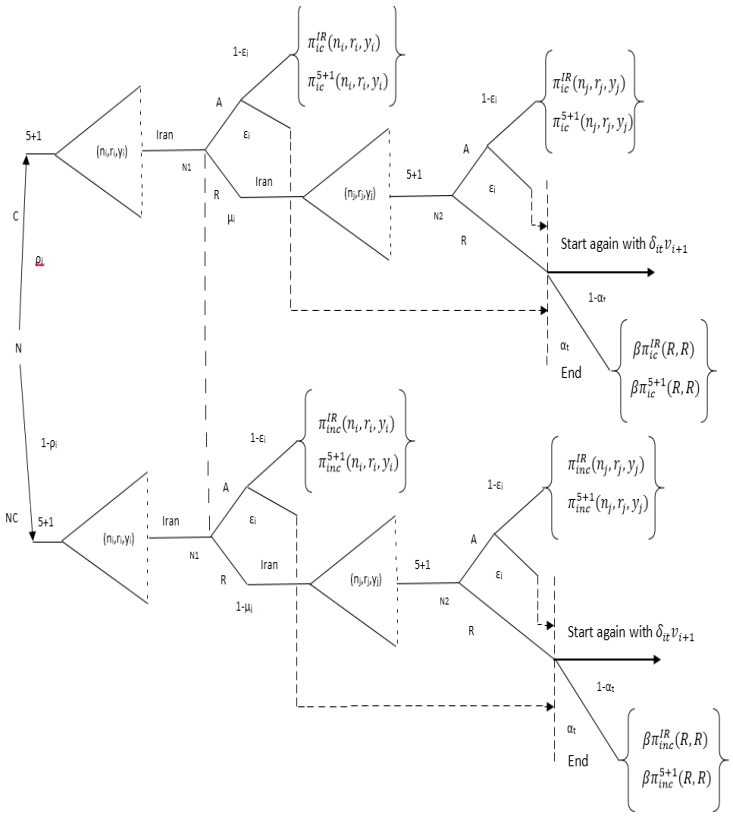

Fig. 2: Iran's nuclear negotiations with P5+1

model needs to be solved in two different states, cooperative and non-cooperative. Because P5+1 knows the state, but the corresponding information is not revealed to Iran (at this stage of the game), we have:

$(1-\varepsilon_i)\pi_{ic,inc}^{5+1}(n_j,r_j,y_j) + \varepsilon_i[(1-\alpha_t)\delta_{it}v_{i+1} + \alpha_t\beta\pi_{ic,inc}^{5+1}(R,R)] = (1-\alpha_t)\delta_{it}v_{i+1} + \alpha_t\beta\pi_{ic,inc}^{5+1}(R,R)$ (1)

which equals to:

$\pi_{ic,inc}^{5+1}(n_j,r_j,y_j) = (1-\alpha_t)\delta_{it}v_{i+1} + \alpha_t\beta\pi_{ic,inc}^{5+1}(R,R)$ (2)

Solving back for P5+1, we will have the notion of equilibrium at node one (N1) as:

$\mu_i\{(1-\varepsilon_i)\pi_{ic}^{IR}(n_i,r_i,y_i) + \varepsilon_i[(1-\alpha_t)\delta_{it}v_{i+1} + \alpha_t\beta\pi_{ic}^{IR}(R,R)]\} + (1-\mu_i)\{(1-\varepsilon_i)\pi_{inc}^{IR}(n_i,r_i,y_i) + \varepsilon_i[(1-\alpha_t)\delta_{it}v_{i+1} + \alpha_t\beta\pi_{inc}^{IR}(R,R)]\} = \mu_i\{(1-\varepsilon_i)\pi_{ic}^{IR}(n_j,r_j,y_j) + \varepsilon_i[(1-\alpha_t)\delta_{it}v_{i+1} + \alpha_t\beta\pi_{ic}^{IR}(R,R)]\} + (1-\mu_i)\{(1-\varepsilon_i)\pi_{inc}^{IR}(n_j,r_j,y_j) + \varepsilon_i[(1-\alpha_t)\delta_{it}v_{i+1} + \alpha_t\beta\pi_{inc}^{IR}(R,R)]\} = v_i$ (3)

Here, μ_i is Iran's posterior belief about the state of the game. If Iran can recognize the state of the game (cooperative or non-cooperative), then μ_i is either equal to one or zero. Therefore, we can solve the model using the Rubinstein-Stahl bargaining approach [15] to derive the value of the game in each known state. If not, it will be the same as the prior belief, ρ_i.

Because the payoffs of the game have been normalized (Table III), at each stage at each stage Iran and P5+1 payoffs add up to one:

$$\pi^{IR} + \pi^{5+1} = 1 \qquad (4)$$

Having known the parameters and by setting $v_i = v_{i+1}$, we can solve the above game. It must be noted that all parameter values can vary over time. For instance, the amount of ε may change when the composition of government or Congress/Parliament changes due in one of the countries (e.g., Iran and U.S.) Therefore, the given values of parameters can change before or after the elections. This issue raises another problem. The payoff values can even change over time (resulting in an evolving game structure [16-17]) because different parties have different interpretations of the existing and predicted political and economic situations. The problems above may lead the game to a stage with no Nash equilibrium. We can define alternative values and payoffs in case of structural governmental changes to capture their effects on the game.

To understand the current framework agreement, we are going to solve the designed game for the assigned parameters while P5+1 are at the non-cooperative state:

$\pi_{inc}^{IR}(R,R) = 0.18, \pi_{ic}^{IR}(R,R) = 0.15$

$\rho_i = \mu_i = 0.5, \varepsilon_i = 0.1, \alpha_t = 0.5,$

$\beta = 0.65, \delta_{IR} = \delta_{5+1} = 0.95$

There is a high probability that (R, R) will be an equilibrium; however, calibrating the parameters as above, with respect to assigned payoffs according to Table III, we can find a subgame perfect equilibrium at scenario 5 in which the offered package from 5+1 would be (5, 000, 5, 10).

IV. DISCUSSION

There are several issues that need to be considered here. We can show that if the probability of continuing the game after each round decreases (1-α_t) – which implies the failure of negotiation – reaching an equilibrium or final agreement will be harder (and in some cases impossible). In that case, Iran needs to satisfy the strictest requests of P5+1 that can cause internal conflicts in Iran. Another practical problem is developing a compromise among the internal parties in Iran and US. Let's say, achieving scenario fifteen might be ideal from Iran's point of view, but impractical because of the imposed limitations by P5+1. As Putnam [18] argues, international relations and domestic politics are entangled and both influence each other to some extent. Therefore, the pressure of the conservative parties in Iran on its current government will increase the probability of deviation from the obligations of any agreement, preventing any compromise in the first place. Because of all of these uncertainties in the game, Iran needed to change the structure of the game by calibrating its plans in the Middle East with P5+1, persuading them that any delay in reaching an agreement would be a significant threat to the security in the region. If the rate of depreciation drops enough for P5+1 while at the same time the payoffs decrease, in case of the failure of negotiation, SPEs might emerge that imply reaching an agreement.

There exist four resolutions in this game that may help to solve the problem, in its final step, by changing the defined parameters:

1) The possible confrontation of Western nations and Russia: This can be the product of Russia's impacts on the Ukraine and Syria crises. Iran has to take advantage of this situation to increase its negotiation power. Iran is expected to communicate to the parties that reaching an agreement is beneficial to all parties and will help resolve the current conflicts in the region.

2) Iran might be requested to guarantee that its nuclear program is not a threat to its Arab neighbors and Israel, and to cut the support to the nations and groups that have conflicts with these nations. In addition, Iran might be asked to implement the Additional Protocol of the IAEA, providing the Agency more access to its nuclear facilities.

3) Russia and China need Iran to seal (even increase) its economic deals with them while Western countries have to be added to this profit-maximization game and increase their share in Iran's growing domestic market in the case of lifting the international sanctions.

4) Iran can improve its foreign diplomacy with Saudi to reduce the conflict between Shia and Sunni, which seems more political than religious, to lessen the Saudi's negative influence on the current negotiation.

V. CONCLUSION

We developed a stylized strategic model – within the game theory framework – to better understand the process of resolving the conflict between Iran and P5+1 over Iran's nuclear program. Arbitrary values were assigned to the unknown parameters to verify the feasibility of the solution of the game and the Lausanne framework agreement.

The proposed game theory model was used to capture the negotiation complexities, and identifying the feasible paths of the agreement. Developing a compromise is feasible when Iran satisfies the economic (monetary) and political (authority) requests of the P5+1 while dealing with the pressure of conservatives in Iran. A final agreement is reachable if both sides can discard (or weaken) the impact of the historical suspicions in their political relations, and make their final decisions considering the current domestic, regional and international demands and requirements.

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APPENDIX

Calculating the payoffs

First, as we can see in Table III, we divided each player's value to the monetary and authority categories, with different weights for each of them. While the monetary values are more important in this negotiation for China, authority values have higher weights for the US and Israel. Then, we assigned the arbitrary payoffs between zero to one to each player based on what our understanding of their priorities. The next step was to calculate the aggregate payoffs for P5+1 countries. In order to do so, we incorporated the values for Israel and neighbors in the model as a portion of the US and EU's values. Then, we took the average of payoffs of Russia and China. After that, in a cooperative mode, we calculated the weighted average for US-EU and Russia-China augmented payoffs, and assigned the lowest value to the non-cooperative mode. In the last step, we normalized the payoffs of Iran and P5+1 countries in such a way that the values sum up to one. The initial values are shown in Table III, and the final payoffs are depicted in Table II.

Table (II): Finalized payoffs under selected scenarios

Scenarios	Non-Cooperative		Cooperative	
	Iran	*5+1*	*Iran*	*5+1*
SC 1 (0,0,20)	0.494	0.506	0.489	0.511
SC 2 (0,0,10)	0.501	0.499	0.493	0.507
SC 3 (0,0,0)	0.505	0.495	0.496	0.504
SC 4 (5,000,5,20)	0.500	0.500	0.497	0.503
SC 5 (5,000,5,10)	0.507	0.493	0.502	0.498
SC 6 (5,000,5,0)	0.511	0.489	0.504	0.496
SC 7 (10000,5,20)	0.504	0.496	0.504	0.496
SC 8 (10000,5,10)	0.513	0.487	0.510	0.490
SC 9 (10000,5,0)	0.517	0.483	0.513	0.487
SC 10 (5,000,20,20)	0.513	0.487	0.512	0.488
SC 11 (5,000,20,10)	0.516	0.484	0.515	0.485
SC 12 (5,000,20,0)	0.520	0.480	0.517	0.483
SC 13 (10000,20,20)	0.516	0.484	0.514	0.486
SC 14 (10000,20,10)	0.518	0.482	0.518	0.482
SC 15 (10000,20,0)	0.523	0.477	0.52	0.48

Table (III): Players' payoffs under selected scenarios

		PLAYER						
SCENARIOS	**Payoff Type**	**Iran**	**US**	**EU**	**Russia**	**China**	**Neighbors**	**Israel**
SC 1 (0,0,20)	Monetary	0.3	0.3	0.3	0.5	0.5	0.5	0.2
	Authority	0	1	1	0.2	0.2	0.1	0.5
SC 2 (0,0,10)	Monetary	0.35	0.3	0.5	0.2	0.2	0.2	0.2
	Authority value	0.1	0.9	0.9	0.2	0.2	0.1	0.5
SC 3 (0,0,0)	Monetary value	0.5	1	1	0.1	0.1	0	0.2
	Authority value	0.2	0.8	0.8	0.2	0.2	0.1	0.5
SC 4 (5,000,5,20)	Monetary value	0.5	0.3	0.3	0.4	0.5	0.5	0.2
	Authority value	0.3	0.8	0.8	0.2	0.2	0.1	0.3
SC 5 (5,000,5,10)	Monetary value	0.6	0.3	0.5	0.12	0.2	0.2	0.2
	Authority value	0.35	0.7	0.7	0.16	0.2	0.1	0.2
SC 6 (5,000,5,0)	Monetary value	0.7	1	1	0.06	0.1	0	0.2
	Authority value	0.4	0.5	0.5	0.1	0.2	0.1	0.3
SC 7 (10000,5,20)	Monetary value	0.6	0.3	0.3	0.35	0.5	0.5	0.2
	Authority value	0.5	0.5	0.5	0.2	0.2	0.04	0.16
SC 8 (10000,5,10)	Monetary value	0.7	0.3	0.5	0.1	0.2	0.2	0.2
	Authority value	0.7	0.35	0.35	0.16	0.2	0.04	0.16
SC 9 (10000,5,0)	Monetary value	0.8	1	1	0.04	0.1	0	0.2
	Authority value	0.8	0.25	0.25	0.1	0.2	0.04	0.16
SC 10 (5,000,20,20)	Monetary value	0.7	0.3	0.3	0.3	0.5	0.5	0.2
	Authority value	0.8	0.16	0.16	0.2	0.2	0.02	0.1
SC 11 (5,000,20,10)	Monetary value	0.8	0.3	0.5	0.08	0.2	0.2	0.2
	Authority value	0.8	0.14	0.14	0.1	0.2	0.02	0.1
SC 12 (5,000,20,0)	Monetary value	0.9	1	1	0.02	0.1	0	0.2
	Authority value	0.9	0.1	0.1	0	0.2	0.02	0.1
SC 13 (10000,20,20)	Monetary value	0.8	0.3	0.3	0.25	0.5	0.5	0.2
	Authority value	0.8	0.1	0.1	0.2	0.2	0	0
SC 14 (10000,20,10)	Monetary value	0.9	0.3	0.5	0.06	0.2	0.2	0.2
	Authority value	0.9	0.06	0.06	0.1	0.2	0	0
SC 15 (10000,20,0)	Monetary value	1	1	1	0	0.1	0	0.2
	Authority value	1	0	0	0	0.2	0	0