Game Theory as a Tool
for Analyzing Terrorism

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Abstract

Terrorist attacks may have a deep impact on our society; for this reason it is necessary that all the disciplines give their contribution for limiting its negative effects. In this note we want to show that Game Theory may be helpful for studying some aspects of terrorism.

1   Introduction

Terrorism represents a relevant challenge for our society as it can modify the behavior of large part of the population and may also attract the attention of policy-makers and move large monetary amounts, with consequences on the economic activities of a nation. Usually, the scenario involves two main actors, the government on one side and the terrorist organizations on the other one.

As it is pointed out in [3] "studies of terrorism risk resemble risk analyses of complex engineering systems" but "unlike natural disasters, it features human intelligence, and unlike industrial disasters it features human intent". This leads to the possibility of modeling and analyzing the situation with the instruments of Game Theory, a discipline that studies, with methods classical for mathematics, the human behavior in those situations in which the final outcome depends on the actions taken by various decision-makers involved in it. We can remark that several game theorists tackled the topic of terrorism in last recent years.

In the following section we introduce some basic elements of Game Theory and in the third section we present in a very informal way three examples of game theoretical approaches to situations related to terrorism.

2   Preliminaries on Game Theory

We start this section recalling the main ingredients of a game, i.e. of an interactive situation:

- *the players*, i.e. the agents, or more precisely, the decision-makers of the situation;

- *the set strategies of each player*, i.e. the possible alternatives among which each agent may choice;

- *the utility function of each player*, i.e. the gain or the loss (in a very wide sense) that each agent gets as consequence of each possible outcome.

A player is supposed to be *rational*, in the sense that his choice is driven by the possibility of reaching a final situation from which he obtain a higher utility and is supposed to be *intelligent*, in the sense that he knows all the possible outcomes of the situation and which subset of outcomes can be obtained after his strategic choice. Of course the outcome can be determined only after the choices of all the agents; the resulting set of strategies, one for each player, is called a *strategy profile*.

In the simplest interactive situation each agent makes his selection in his strategy set independently from the others; the different choices produce a final situation that is evaluated by each agent according to his utility function. These situations are denoted as *non cooperative games*.

In general the players may improve their utilities if they may coordinate their choices; more precisely we said that *binding agreements* are allowed. Of course this new scenario requires the possibility of discussions among the players for negotiating a satisfactory strategy profile and the existence of a *superpartes* authority that may impose the respect of the agreement to the agents. These situations are denoted as *cooperative games*. The agents, maybe all, that subscribe the agreement form a *coalition*.

Cooperative games are usually divided into two groups, the *non transferable utility games (NTU-games)* or *games without side payments* and the

transferable utility games (TU-games) or *games with side payments*. The main difference between these two groups refers to the possibility for the players of a coalition to redistribute among them the total utility they get at the end of the game or not; so, in a NTU-game the players of a coalition get the payoff that the rules of the game assign to them according to the strategy profile, while in a TU-game the players collect their utilities an assign to each player a quota according to the agreement they reached. Of course it is necessary that the utilities of the players of a coalition may be added.

In a non cooperative game and in a NTU-game the solution is a strategy profile that takes into account the needs of all the players; in TU-game the solution is a division rule for deciding which quota of the total utility is assigned to each player.

Now we present a very simple example, known in literature as *prisoner's dilemma*, in order to make clearer the previous concepts.

Example 1 *We consider two players, I and II, each of them has two strategies; the strategies of player I are denoted as T and B, and the strategies of player II are denoted as L and R. We represent the game using a table with two rows and two columns in which each row is associated with a strategy of player I and each column is associated with a strategy of player II. In each cell of the table we write two numbers that represent the monetary utilities obtained from player I and player II, respectively, when the two players choose the strategies associated to the row and the column the cell belongs to. The situation we have in mind is represented by the following table:*

I \ II	L	R
T	2 2	9 1
B	1 9	4 4

First, let us suppose that the players do not (or cannot) cooperate; player I realizes that the strategy T is preferable, because his payoff is anyhow larger ($2 > 1$ and $9 > 4$) and in a similar way player II prefers strategy L; so, the resulting strategy profile is $\{T, L\}$ and the utility is 2 for each of the two players.
Now, let us suppose that the two players may subscribe a binding agreement,

it is straightforward that the two players select the strategy profile $\{B, R\}$ getting the utility 4 for each of them; finally, if they may also exchange their total utility they may agree on one of the two strategy profiles $\{T, R\}$ or $\{B, L\}$ that give them a global utility of 10 instead of 8, that they may share in several ways, for example 5 each.
It is worthwhile to note that all the four strategy profiles can be chosen if we consider that the players may cooperate or not and may transfer the utility or not.

Game theory literature contains several solutions concepts for all the three classes of games; here we just mention the Nash Equilibrium for non cooperative games, the Nash cooperative solutions for the NTU-games and the core and the Shapley value for the TU-games. We refer to [6] and [4] for further details on game theory.
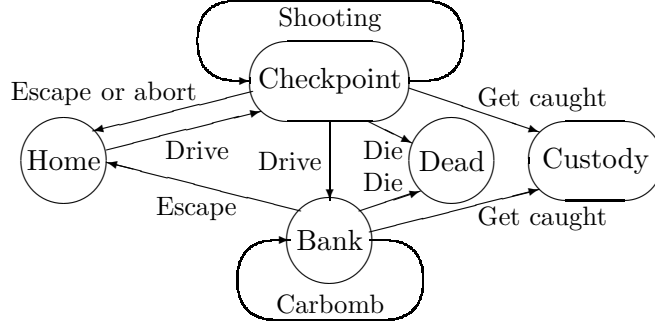
3   Three Examples

In this section we present three examples, one for each class of games, taken from the existing literature, in order to show how game theoretic tools may be used for studying terrorist situation.

3.1   Non Cooperative Example

The first example is a simplified version taken from [8]. Consider a terrorist organization located in a home base and a bank as potential target; suppose that the terrorist uses a car for reaching the bank and must get through a checkpoint to carry out the bombing operation; the possible outcomes are that the terrorist reaches the bank succeeding and escaping to return home, or getting caught at the checkpoint or bank, leading to being placed in custody or getting killed in a shootout.

The situation may be represented by the following graph:

Shooting

Escape or abort → **Checkpoint** → Get caught

Home   Drive   Drive   Die **Dead**   **Custody**
              Die
Escape   →   **Bank**   →   Get caught

Carbomb

The authors examine the checkpoint situation with the instruments of game theory.

Terrorist	*Drive through unnoticed*		*Shoot guard and escape unnoticed*		*Shoot guard and die*		*Get caught*	
Guard								
Unready	−1		−2		−2		2	
		4		3		1		−1
Ready	−2		−3		0		3	
		3		1		1		2

The previous table shows "that at the checkpoint, the terrorist could find the guard welltrained and in ready mode or in an untrained, easily surprised mode. In the latter case, the terrorist might feel there is some degree of positive utility in driving through unnoticed, shooting the guard and continuing (or dying). The only embarrassing outcome would be to get caught by an unready guard. In the second row, the terrorist has less utility for engaging in a shootout with a trained guard, as getting caught can lead to eventual release. The utilities of the guard in each row may be similarly interpreted".

The authors remark that "this example is illustrative, and no real utility values have been specified. It will be a step of the research to conduct the datamining and to interact with experts to elicit the proper structure of the graph and the table elements and utilities".

3.2 NTU-Game Example

A special NTU-Game situation is the so-called Two-Person Bargaining Problem, introduced by Nash in 1950 (see [5]). In [7] Owen generalizes this prob-

lem to the case in which the two players act as representatives; in particular they represent a state and a terrorist organization. The main difference is that in each organization there are persons that accept only strong conditions for the counterpart, the so-called *hawks*, and persons that are available also for weak conditions, the so-called *doves*. The author modifies the classical model, introducing a n-person situation in which for each organization several members have similar but not coincident interests, i.e. the organization are *heterogeneous*. The members of each "organization have similar utilities for the agreements reached, but different utilities for conflict".

The hawks of a party may take actions in order that the counterparty rethinks the value of the agreement; consequently the number of members of the counterparty favorable to the agreement decreases; if also these last members act against the agreement it is possible that the it falls. In a sense the hawkish members seem more in cooperation (against the agreement) than opponents.

An interesting remark is about the role of a third party that may "subsidize the agreement ... by making some sort of side payment to the members of the organization".

3.3   TU-Game Example

In this case we refer to a situation taken from [9]; this example shows that making common the information of each player may improve the global utility of all the players, where we may think to the possibility of sharing information against terrorism even if not all the agents have the same target.

The authors consider a small hotel with 8 rooms, 4 on the bottom floor and 4 on the top floor. On each floor, two rooms are on the north side and two rooms on the south side; on the other hand, on each floor two rooms are on the east side and two rooms on the west side. So, using the floor and the directions north-south and east-west each room may be uniquely described. In one of the rooms of the hotel there is a monster; three persons that sleep in the hotel have partial information about the hiding place of the monster and different preferences. Player 1 knows whether the monster is on the north or south side, player 2 whether it is on the west or east side and player 3 whether it is on the bottom or top floor. Player 1 wants to be as far away from the monster as possible. Player 2 is interested only in being on a different floor than the monster, while player 3 would like to catch the monster and, hence, wants to be in the same room as the monster. It seems

obvious that all players profit from sharing information.

In this case the result of cooperation is that the players in a coalition share their own information. Clearly player 3 needs the cooperation of all the players in order to know the room of the monster; on the other hand if player 2 forms a coalition with player 3 gets all the information required, but has no incentive to cooperate with player 1; finally, the situation of player 1 is a little bit different. In order to maximize his distance from the monster he needs the full information, i.e. he has to form a coalition with all the players, but also using his sole information he can avoid the room of the monster and a coalition with one of the other two players may give him an intermediate result. Note that in the last two cases, using a random choice, player 1 may get the maximal utility (if he is lucky).

The paper by Slikker *et al.* proposes also possible rewards for the players when they share their information, depending on their different interest in cooperation.

4   Concluding Remarks

In this note we presented some simple game theoretic models that can be useful to define strategies against terrorism. The list of authors that used game theory for studying particular aspects of terrorist situations is very long; among them there are Bueno de Mesquita, who in [1] analyzes how decisions of one of the two sides influence the behavior of the other one, taking into account also government investment in counter-terror, negotiated settlements, duration of terrorist conflicts, incentives for moderate terrorists to radicalize their followers, and incentives for governments to encourage extremist challenges to moderate terrorist leaders; Keet in [2] investigates theories of terrorism and its changes over time and applications of game theory, in particular mutations of the prisoner's dilemma, extensive form games for disclosing interactions between actors in a structured format and cooperative games for studying coalition-formation process and strengths and weaknesses in negotiation processes. The aforementioned models were applied to various situations: Israel, Iraq and Peru.

We conclude just mentioning other authors as McCormick who cooperates from long time with Owen, Dietrich who gives a general model for prevention, Woo that analyses the insurance side of the problem, Arce and Sandler that suggest the prevalence of deterrence over preemption.

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