Intelligence Service for a Better Information: Application to a Terrorist Threat

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ABSTRACT

Choosing the best strategy is not always easy when an agent is confronted to a private information on the type of another player. However, spying could be the solution. Indeed, in order to fill this lack of information, an agent could invest in an intelligence service. This private information is present in Bayesian games. The use to the spying is a good alternative in the application to the terrorist problem in the case of an attacker/ defender game. It enables the government to know the nature of the terrorist group or the strategy of them. We focus on two types of terrorists: the fanatics and the moderates. Their objectives and their strategies are not the same, so the government has to adapt to the terrorist threat. The type of the government is common knowledge: strong, average or weak. We compare the different Nash equilibria when spying let us to turn a Bayesian game into a static or dynamic game of complete information.

Keywords: Noncooperative Game, Conflict, Bayesian Game, Security, Terrorism.

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1. INTRODUCTION

Nowadays the majority of the countries are confronted to some conflicts and more particularly to some terrorist threats represented by the terrorist groups. There are many terrorist organizations and sometimes a country has to face to some of them. Their objectives are not the same so an uncertainty can be present concerning the nature of the terrorists. A government can be impugned, so a group can decide to overthrow this government in power and to take its place. An other objective is to inflict the maximum of damages. Some groups can be comparable to criminal organizations. For example, the narco-terrorism is a source of income (colombian drug cartels). The motivations to commit terrorist acts are numerous: ideological, religious, criminal...

A government has not always the same strategy. Indeed, he acts differently according to the nature of the terrorist organization. In this model, we focus on two types: the fanatics and the moderates. The goal of the fanatics is to inflict the maximum of damage. He has the choice between attacking or not. To the contrary, the moderates prefers acting without using the violence. Based on an attacker/defender game, the government will choose his level of protection even if he doesn't know the motivation of them.

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To remedy to this lack of information, a government can invest in an intelligence service. All the governments use the spying in order to improve their security and to get more informations: what is the target of the terrorist? Is the terrorist strong enough to inflict damage? Which information has the terrorist group about this country? All these questions influence the decision of the government. Having the responses is an advantage and enables the government to fight against the terrorist threat and to counter it. Indeed, it enables the government to know the terrorist type and the strategy.

Risks of terrorist attacks are well present nowadays and some economics have analyzed this problem, notably thanks to game theory for the major part. T. Sandler and al.(1983) presented a rational-actor model which analyzed a negotiation process between terrorists and government policymakers. In this article two models are described: the first concerns the terrorists which have the choice between engaging in legal or illegal activities (hostage-taking).
In the second model, the government has to decide to grant terrorist demands or not. They use probability constraints to introduce uncertainty. Sandler, Lapan and Siqueira point out strategies of a terrorist group in the case of an attack considering logistical success or failure du to level of deterrence applied by nations (Sandler and Lapan, 1988 ; Sandler and Siqueira, 2006 ; Lapan and Sandler, 1988). Sandler and Enders (2004) have shown an analysis on transnational terrorism with the use of game theory : they study the problem of hostage taking and the governmental responses to solve this problem. The choice of different targets and the possibility for them to deflect the attack have been analyzed by Sandler and Arce (2003). They distinguish two categories of terrorist: the hard-liners and the moderates. This article focuses on governmental policies and responses in those cases. Moreover, the attacker/defender game has already been applied in areas such as wireless ad hac networks, where a bayesian game specifies the type of the attacker, either malicious or regular. We take back the game of the article from Liu et al.(2006) to apply it in the framework of terrorist conflict. A better information could lead to different equilibria in these papers.

In a first section, we present the attacker/defender model through a bayesian game approach and determinate the equilibrium. Then, we include the intelligence service which lead to a better knowledge on the terrorist type. Finally, we analyze the case where the spying enables the government to know the strategy of the terrorists.

2. THE MODEL IN A BAYESIAN GAME

2.1. Hypotheses

We consider a government threatened by a terrorist group. However, the government doesn't know if the terrorists are aggressive or not. Owing to the uncertainty about the type of the terrorist group, we can represent this game through a two-player Bayesian game. The two players are the government *G* and the terrorist group *T*. The type of the government is common knowledge to the two players. Nevertheless, the type of the terrorists is unknown to the government. Indeed, they have a private information on their type. We assume that there are two kinds of terrorists: the moderates and the fanatics. We denote $\Theta_T = \{0,1\}$ the set of possible

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types for the terrorists. It is obvious that they don't have the same objectives and the same strategies.

Concerning the fanatics, denoted $\Theta_T = 1$, their goals are to wreak havoc if possible, i.e. they believe that the attack is successful. Their two pure strategies are the followings: **Attack** (A) and **Not Attack** ($\bar{A}$). The moderates ($\Theta_T = 0$) prefer to reach their goal without using violence. In order to simplify the model, we assume that these terrorists have only one pure strategy: **Not Attack** ($\bar{A}$).

In order to face to this threat, the government allocates an amount to the protection. His two pure strategies are: **Maximum Protection** ($\overline{P}$) and **Minimum Protection** ($\underline{P}$). The government will not invest in maximum protection if the threat is not credible. However the damage of an attack could be huge if the protection is not sufficient. Indeed, there is a risk to choose a minimum protection. How choosing a strategy without knowing the terrorists' intentions ? Thanks to the Bayesian game, the government has beliefs on the type of terrorists but it remains an uncertainty, regardless. The game is played simultaneously.

Each player has an utility function. The aim of the government is to protect the country. According to the protection level, the security **S** of this country is not the same. The security function depends only on the protection costs: the security is increasing with the protection costs. For a maximum protection $\overline{P}$, the protection cost is maximum ($\overline{C}$) and the security is given by S($\overline{C}$) (A minimum protection $\underline{C}$ gives a minimum security S($\underline{C}$). It is assumed that S(C) > C and $\overline{C} > \underline{C}$. The security enables to attenuate or to counter this attack. The attacking cost is designated by **M** (M > 0). The damage due to the attack are denoted by **dY**, where **Y** is the GDP of the targeted country and **d** is the expected percentage of damage on the GDP. So the difference between the damage and the security (dY-S(C)) represents the real damage if it is positive. To the contrary, if this value is negative, the attack fails. This real damage are a gain for terrorist and a loss for the government.

The game with the payoffs resulting from the strategies is represented by the Table 1 and the Figure 1.

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If Fanatics	Government: Protection $\overline{P}$	Government: Protection $\underline{P}$
Attack	$dY - S(\overline{C}) - M$, $S(\overline{C}) - dY - \overline{C}$	$dY - S(\underline{C}) - M$, $S(\underline{C}) - dY - \underline{C}$
Not Attack	0, $-\overline{C}$	0, $-\underline{C}$

If Moderates	Government: Protection $\overline{P}$	Government: Protection $\underline{P}$
Not Attack	0, $-\overline{C}$	0, $-\underline{C}$

Table 1: Strategic Form Bayesian Game

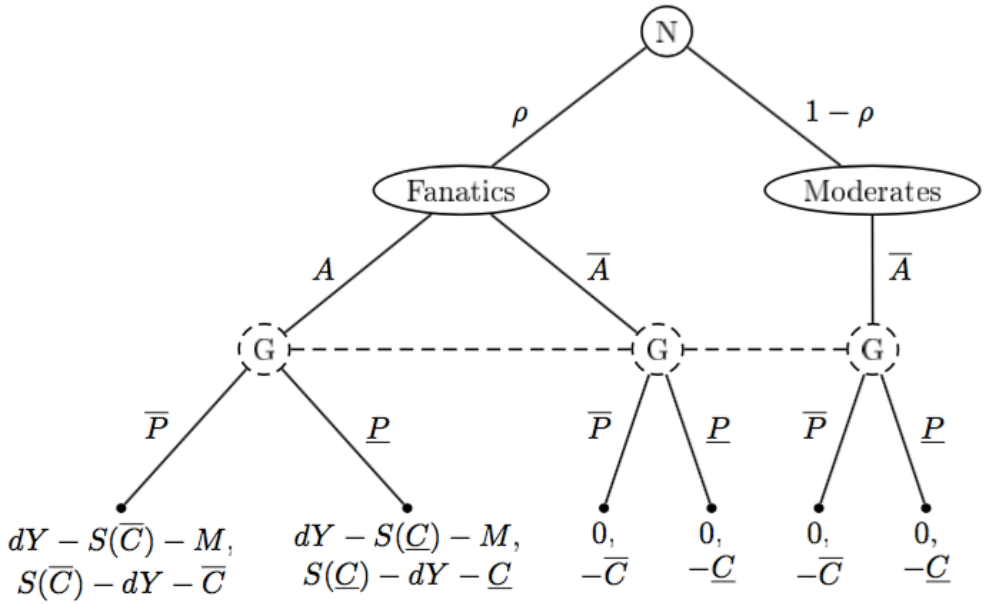

Figure 1: Extensive-Form Bayesian Game

Remark 1:

Even if the government decides to implement a maximum protection, his payoff is -$\overline{C}$ if the terrorists don't attack. The security is present but it is activated only when an attack occurs.

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2.2. Nash Equilibrium

2.2.1. Bayesian Nash Equilibrium

First, we analyze this static Bayesian game. The beliefs on the type of the terrorists are common knowledge. The players are rational and their objectives are to maximize their utilities, i.e. their payoffs. The beliefs for a fanatic and a moderate group is designated by ρ and (1-ρ) respectively.

Definition 1. *In the static Bayesian game* $G = \{A_1, \dots, A_n; T_1, \dots, T_n; \rho_1, \dots, \rho_n; u_1, \dots, u_n\}$, *the strategies* $s^* = (s_1^*, \dots, s_n^*)$ *are a pure strategy Bayesian Nash equilibrium if for each player i and for each of i's types* θ_i *in* T_i, $s_i^*(\theta_i)$ *solves*

$$\max_{a_i \in A_i} \sum_{\theta_{-i} \in T_{-i}} u_i(s_1^*(\theta_1), \dots, s_{i-1}^*(\theta_{i-1}), a_i, s_{i+1}^*(\theta_{i+1}), \dots, s_n^*(\theta_n); \theta)\rho_i(\theta_{-i}|\theta_i)$$

According to some parameters, several cases can be distinguished:

- If dY - S($\underline{C}$) – M > dY – S($\overline{C}$) – M > 0, so the fanatics have a dominant strategy: Attack (A). It corresponds to a strong terrorist group or to a weak country
- If dY - S($\underline{C}$) – M > 0 > dY- S($\overline{C}$) - M, the fanatics attack only if the government does not protect himself efficiently. This is the case of an average terrorist group or an average country
- If 0 > dY- S($\underline{C}$) – M > dY- S($\overline{C}$) - M, the fanatics are too weak to attack (Not Attack) because the country is too strong. ($\overline{A}$) is the best strategy.

Remark 2:
The difference between the maximal damage and the security can be interpreted either by the strength of terrorists or by the strength of the country. In this model, we assume that this difference represents the power of the country. The type of the country is common knowledge. Indeed, it is easier to know the nature of the country than the type of a terrorist group.

In order to determinate the Bayesian Nash Equilibrium, we specify the expected utility based on the beliefs. In the case where the terrorists play the strategy $(A|\theta_T = 1, \overline{A}|\theta_T = 0)$, the expected payoffs of the government is given by:

$$Eu_G(\overline{P}) = \rho(S(\overline{C}) - dY - \overline{C}) + (1 - \rho)(-\overline{C}) \quad (1)$$

$$Eu_G(\underline{P}) = \rho(S(\underline{C}) - dY - \underline{C}) + (1 - \rho)(-\underline{C}) \quad (2)$$

Remark 3:
Here we determine only the Bayesian Nash Equilibrium in pure strategy. The government anticipates the type thanks to beliefs which are probabilities. So it is irrelevant to study the

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Bayesian Nash Equilibrium in mixed-strategies because of probabilities on the strategies in addition to beliefs.

The government chooses the maximum protection level ($\overline{P}$) if his expected utility to play this strategy is greater than his expected utility from a minimum protection ($\underline{P}$):

$$Eu_G(\overline{P}) > Eu_G(\underline{P})$$

$$\rho > \frac{\overline{C} - \underline{C}}{S(\overline{C}) - S(\underline{C})} \equiv \tilde{\rho} \qquad (3)$$

For this level of belief, the best response of the government is to play $\overline{P}$ in this case. The terrorists know the best response of the government. If the country is weak, $((A|\theta_T = 1, \overline{A}|\theta_T = 0), \overline{P}, \rho)$ is a Bayesian Nash Equilibrium. Even if the protection is maximal, the terrorists' payoff is greater than their payoff if they don't attack: dY - S($\overline{C}$) – M > 0.
For an average and a strong country, this strategy is not a BNE. The fanatics will decide to change their strategy and to play Not Attack ($\overline{A}$), because of d Y- S($\overline{C}$) – M < 0.

For $\rho < \frac{\overline{C}-\underline{C}}{S(\overline{C})-S(\underline{C})}$, the best response of the government is to invest in a minimum protection $\underline{P}$.$((A|\theta_T = 1, \overline{A}|\theta_T = 0, \underline{P}, \rho)$ is a pure strategy Bayesian Nash Equilibrium.

When the terrorists decide not to attack corresponding to the strategy $(\overline{A}|\theta_T = 1, \overline{A}|\theta_T = 0)$, the dominant strategy for the government is to play $\underline{P}$ without considering the belief. Indeed, the corresponding expected payoffs do not depend on the beliefs:

$$Eu_G(\overline{P}) = \rho(-\overline{C}) + (1-\rho)(-\overline{C}) = -\overline{C} \qquad (4)$$

$$Eu_G(\underline{P}) = \rho(-\underline{C}) + (1-\rho)(-\underline{C}) = -\underline{C} \qquad (5)$$

For a weak and an average government, the best response for fanatics is to play A because the attack gives them a better payoff. So $((\overline{A}|\theta_T = 1, \overline{A}|\theta_T = 0), \underline{P})$ is not a BNE. However, this strategy is a BNE for a strong country.

The different situations are summarized by the figures 2 and 3.

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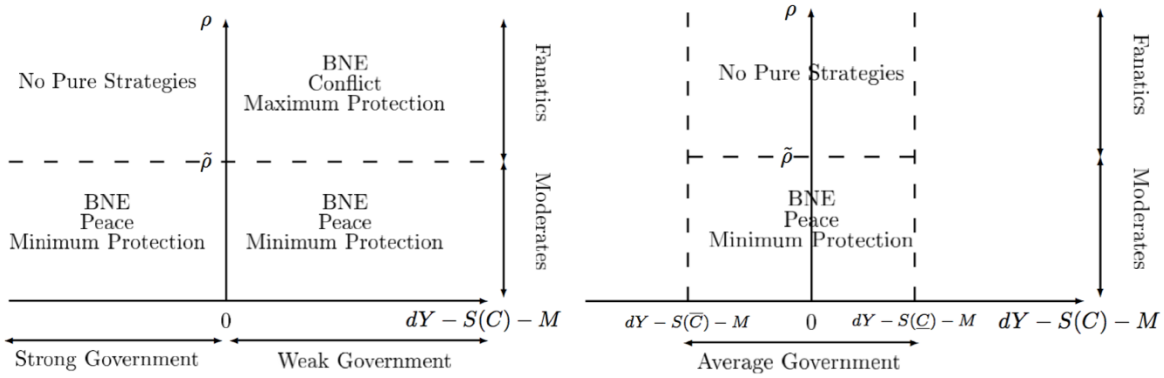

Figure 2: BNE when Fanatics *Attack* and Moderates do *Not Attack* according to the government's beliefs

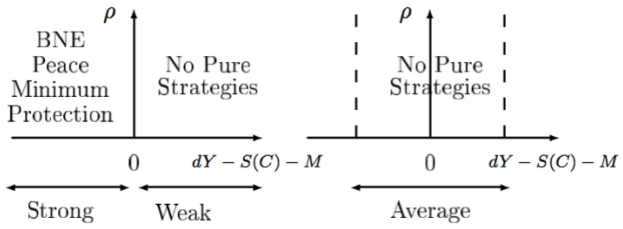

Figure 3: BNE when Fanatics and Moderates do *Not Attack* according to the government's beliefs

2.2.2. Perfect Bayesian Equilibrium

Bayesian Nash equilibria can be irrelevant because they can rely on incredible threats. The interest of dynamic Bayesian game is to repeat the game in order to update the beliefs of an agent on the type of other players. We suppose that there is no discount factor. So the payoffs are the same than in the static Bayesian game. The beliefs are updated thanks to the Bayes' rules:

$$\rho(\theta_T = i|a_T) = \frac{P(a_T|\theta_T = i)\rho(\theta_T = i)}{P(a_T|\theta_T = i)\rho(\theta_T = i) + P(a_T|\theta_T = -i)\rho(\theta_T = -i)} \quad (6)$$

The type of the terrorists can not be perfectly determined. Indeed, if the terrorists play Not Attack, the government will not know the type. However, he knows it only if the terrorist group decides to Attack. In this case, the terrorists are fanatic. We have to determine a semi-separating equilibrium. In mixed strategy equilibrium, the Perfect Bayesian Equilibrium (PBE) is given by (x*, y*, ρ), where x* and y* respectively define the probability to play Attack for terrorists and the probability to play Maximum Protection for the government. From these probabilities, we specify the expected payoffs for each player:

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$$Eu_G(\overline{P}) = \rho[x(S(\overline{C}) - dY - \overline{C}) + (1-x)(-\overline{C})] + (1-\rho)[-\overline{C}]$$

$$\Leftrightarrow Eu_G(\overline{P}) = x(S(\overline{C}) - dY)\rho(\theta_T = 1) - \overline{C} \quad (7)$$

$$Eu_G(\underline{P}) = \rho[x(S(\underline{C}) - dY - \underline{C}) + (1-x)(-\underline{C})] + (1-\rho)[-\underline{C}]$$

$$\Leftrightarrow Eu_G(\underline{P}) = x(S(\underline{C}) - dY)\rho(\theta_T = 1) - \underline{C} \quad (8)$$

By comparing his expected payoffs, we obtain the probability x*:

$$Eu_G(\overline{P}) > Eu_G(\underline{P})$$

$$\Rightarrow x > \frac{\overline{C} - \underline{C}}{(S(\overline{C}) - S(\underline{C}))\rho(\theta_T = 1)} \equiv x^* \quad (9)$$

The terrorists compare too the expected payoffs depending on the chosen strategy:

$$Eu_T(A) = y(dY - S(\overline{C}) - M) + (1-y)(dY - S(\underline{C}) - M)$$

$$\Leftrightarrow Eu_T(A) = y(S(\overline{C}) - S(\underline{C})) + dY - S(\underline{C}) - M \quad (10)$$

$$Eu_T(\overline{A}) = 0 \quad (11)$$

So the terrorists attack only if this expected payoff is positive:

$$Eu_T(A) > 0$$

$$\Rightarrow y < \frac{dY - S(\underline{C}) - M}{S(\overline{C}) - S(\underline{C})} \equiv y^* \quad (12)$$

The Perfect Bayesian Equilibrium in mixed strategy (x*, y*, ρ) is given by the equations (6), (9) and (12). However there is not always a pure strategy according to the strength of the country. The best response of the government is to play Maximum Protection if $x > \frac{\overline{C}-\underline{C}}{(S(\overline{C})-S(\underline{C}))\rho(\theta_T=1)}$, so y=1. But the terrorists attacks only if $y < \frac{dY-S(\underline{C})-M}{S(\overline{C})-S(\underline{C})}$. As y=1, there is No Attack, therefore x=0. In this case, the equation (9) does not hold and the government plays Minimum Protection. But the best response to this strategy is to play Attack for terrorist... There is no pure strategy unless:

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$$\frac{dY - S(\underline{C}) - M}{S(\overline{C}) - S(\underline{C})} > 1 \tag{13}$$
$$\Rightarrow dY - S(\overline{C}) - M > 0$$

The pure strategy PBE exists only for a weak country.

3. INTELLIGENCE SERVICE: KNOWLEDGE ON THE TYPE

In this section we assume that a government can invest in an intelligence service to have a better information. The cost of the intelligence service is designated by the parameter I. It results in a change of an imperfect information into a perfect one. We suppose that this intelligence service enables only to know the type of the terrorist.

3.1 Nash Equilibria

The intelligence service enables to know the nature of the terrorist group. The type of terrorists is now common knowledge. We are confronted to two different games represented by the figure 4 and the tables 2 and 3.

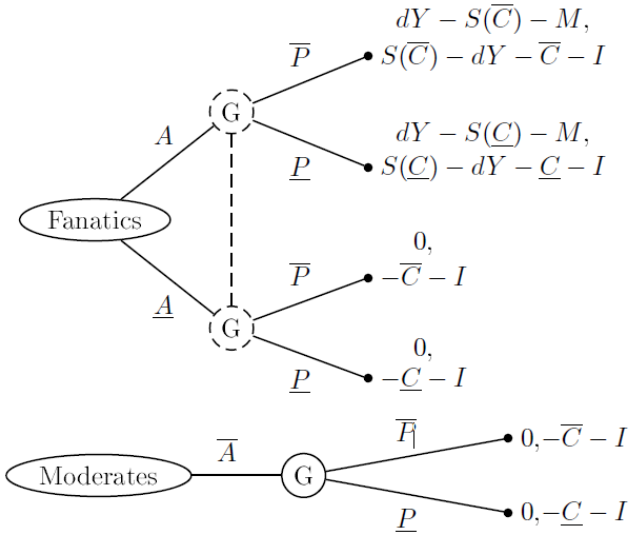

Figure 4: Knowledge only on the terrorist type

Fanatics \ Government	Protection $\overline{P}$	Protection $\underline{P}$
Attack	$dY - S(\overline{C}) - M,$ $S(\overline{C}) - dY - \overline{C} - I$	$dY - S(\underline{C}) - M,$ $S(\underline{C}) - dY - \underline{C} - I$
Not Attack	$0,$ $-\overline{C} - I$	$0,$ $-\underline{C} - I$

Table 2: Strategic Form Game for a fanatic terrorist group

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If Moderates	Government: Protection $\overline{P}$	Government: Protection $\underline{P}$
Not Attack	0, $-\overline{C} - I$	0, $-\underline{C} - I$

Table 3: Strategic Form Game for a moderate terrorist group

If the government faces to moderates, so his best strategy is to invest in a minimum protection because of the non-violence of this group. The moderates have only one strategy. So the Nash Equilibrium is (Not Attack $\bar{A}$, Minimum Protection $\underline{P}$).

Concerning the fanatics, each player has two pure strategies as in the first game and play simultaneously (Table 2). As in the previous part, the conditions on dY-S(C)-M determine the strength of government. However we have to focus on the security function. Indeed, the government has to compare his payoffs depending on the protection level, and more particularly the difference between the security and his cost. The security function can be either concave or convex [Figures 5 and 6]. According to the elasticity of this function, the marginal protection cost has not the same effect. So two cases have to be analyzed in order to determine the Nash Equilibrium:

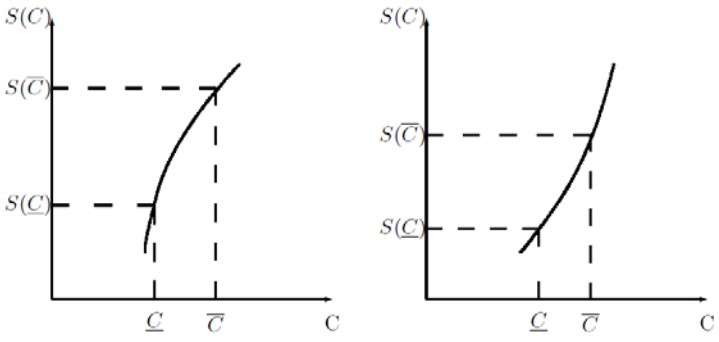

Figure 5: a)$S(\overline{C}) - \overline{C} > S(\underline{C}) - \underline{C}$

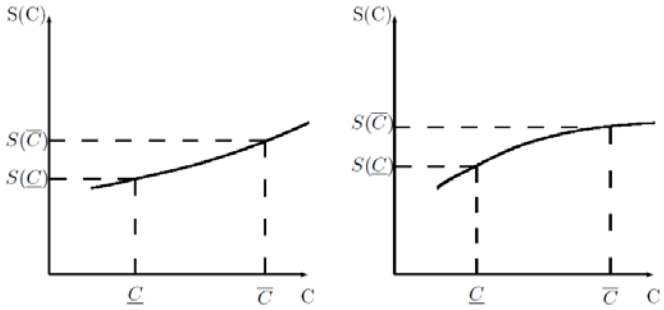

Figure 6: b)$S(\overline{C}) - \overline{C} < S(\underline{C}) - \underline{C}$

a) Either $S(\overline{C}) - \overline{C} > S(\underline{C}) - \underline{C} \Leftrightarrow S(\overline{C}) - S(\underline{C}) > \overline{C} - \underline{C}$:
   - For a weak country, the Nash equilibrium is (Attack A, Maximum Protection $\bar{P}$)

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- For an average country, there is no pure strategy Nash equilibrium.
- If the government is strong, the best strategies are (Not Attack $\bar{A}$, Minimum Protection $\underline{P}$)

b) Or $S(\overline{C}) - \overline{C} < S(\underline{C}) - \underline{C} \Leftrightarrow S(\overline{C}) - S(\underline{C}) < \overline{C} - \underline{C}$:

- If the country is weak or average, the Equilibrium is (Attack A, Minimum Protection $\underline{P}$)
- For a strong government, they play (Not Attack $\bar{A}$, Minimum Protection $\underline{P}$)

All Nash equilibria are summarized in the figure 7 taking the previous conditions into account.

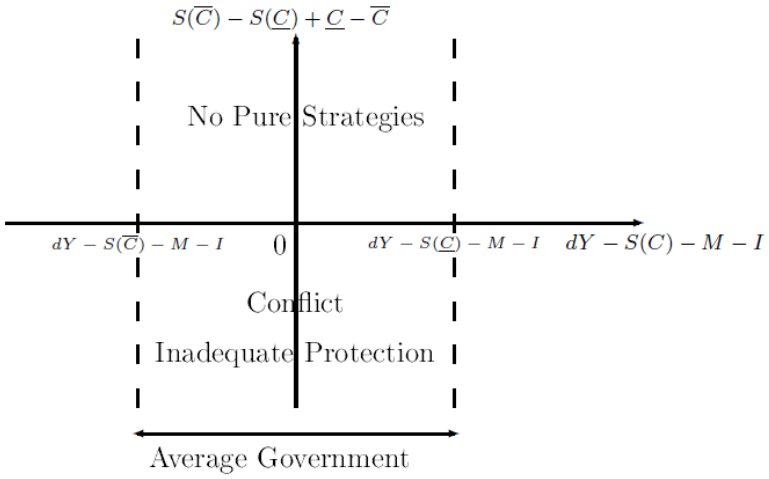

Figure 7: Nash Equilibrium / Knowledge on the terrorist type

3.2 Analysis

In the Bayesian game the government is confronted to some uncertainty about the best decision to take because he doesn't know the type of the terrorists. Through his beliefs, he tries to guess the type. His strategy is taken from his anticipations. There are four cases where there is no pure strategy. However, in the situation of BNE, the chosen strategy of the government is adapted to the terrorist action. In the case of conflict, the government decides to allocate the maximum amount to the protection. When terrorists don't attack, the country establishes a minimum level of protection. The problem of uncertainty to choose an action is present for each type of government. Indeed, the goal of fanatics is to wreak havoc on the country. However, the terrorists don't attack if they are confronted to a strong or an average country, otherwise their payoff is negative.

In the simultaneous static game, there is less uncertainty. Concerning the moderates, it leads to the best strategy for the government (Minimum Protection) because the only one for terrorists

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is No Attack. For the fanatics, there is only one situation where the government has no pure strategy: it corresponds to the case where the terrorists face to an average government. It is obvious to show the dilemma of the terrorists. If they attack, the government protects himself efficiently and the terrorists' payoff is negative. On the contrary, if they decide not to attack, the best response of the government is to apply a minimum protection: the payoff of the terrorist group could be better. Nevertheless, the chosen strategy could not be the best in some cases. For example, if the terrorists decide to attack a weak or an average country, he plays Minimum Protection whereas playing Maximum Protection seems to be more appropriate. However, it corresponds to the best strategy for the government. His payoff is greater because of the security function:

- If the government protects himself at a maximum level, there will be few damages but a huge spending in protection.
- Whereas the country chooses a minimum level of protection, the costs are low but he suffers lots of damage.

By comparing the two cases, it reveals that the security costs more and more expensive so the government thinks that the amount of damage are lower than the security costs.

In this situation, the payoff is greater but will not it be preferable to have less damage and more spending? In the government's utility, we could include the public opinion which has a preference for the security, even if it is very costly.

4. INTELLIGENCE SERVICE: KNOWLEDGE ON THE TYPE AND ON THE STRATEGY

In this section, it is assumed that the government has the knowledge on the type and the strategy of the terrorist group. In this case, there is an asymmetry of the information.

4.1 Nash Equilibria

In static games of complete information, the players simultaneously choose their actions. They don't know the strategy of the other player. To maximize their payoffs, they use the best response functions to determine their strategies. In dynamic games of complete information, the players successively choose their actions. The second player knows the strategy of the first player but the first knows that the second player knows it.

In our case, the government knows the type and the strategy of the terrorist group, but the terrorists ignore that the government knows it. This is a myopic game. Indeed, the terrorist group thinks that his strategy and his type are unknown: terrorists are a myopic player. The government can adjust his strategy according to his knowledge.

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Concerning the moderates and the fanatics, the equilibria are the same than in the previous section, excepted for fanatics facing an average country. Indeed, if the country knows only the type, there is not a pure-strategy Nash equilibrium. Thanks to the knowledge on the strategy, we can determine an equilibrium in pure strategy. First, we have to determine the equilibrium in mixed strategy in the previous case and more particularly the probability for the terrorists to play his strategies:

$$E_T = p[q(dY - S(\overline{C}) - M) + (1-q)(dY - S(\underline{C}) - M)]$$

$$E_G = q[p(S(\overline{C}) - dY - \overline{C} - I) + (1-p)(-\overline{C} - I)] + (1-q)[p(S(\underline{C}) - dY - \underline{C} - I) + (1-p)(-\underline{C} - I)]$$

where p and q are respectively the probability of the terrorists to attack and the probability of the government to play Maximum Protection.

The terrorists are rational, so they choose the strategy where the probability is the highest.

Condition:
They choose "Attack" if $> 1-p \Leftrightarrow 2\overline{C} - 2\underline{C} - S(\overline{C}) + S(\underline{C}) > 0$.

Nash Equilibria in pure strategy:

- If the condition is respected, the Nash equilibrium is (A , P).
- Otherwise, the equilibrium is ($\bar{A}$, P)$

4.2. Analysis

It is obvious that the intelligence service enables the government to have less uncertainty. The government knows the type and the strategy of his opponent. Thanks to the spying, he can determine which action he has to choose. We could conclude that knowing only the type is sufficient. However, it is useful to determine the equilibrium as in the case of no pure strategy.

In the numerical example in the table above, we have p=1/4 and (1-p) = 3/4. The terrorist decide not to attack and the government protect himself at a minimum level.

5. CONCLUSION

This paper focuses on the acquisition of the information in the case of an attacker/defender game. This acquisition is possible thanks to the introduction of an intelligence service. We have seen that spying leads to some modifications on the initial game. Indeed, we begin from a Bayesian game. Then, the spying enables to turn this game into a simultaneous static game without uncertainty on the type of the terrorists. The government knows the type and consequently he chooses his best strategy. However, despite this knowledge, the uncertainty is always present in the game. So, we consider a myopic game where the government has a perfect knowledge on the terrorist group, but this group ignores that the government has this private information.

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This model is very basic because each player has only two strategies. We could consider a level of attack and protection. Moreover, we could study the intelligence service in the case of repeated game and determine the price for which the acquisition of information is useful. An other extension is to include a probability of failure on the infiltration by the secret service. Moreover, spying can be used in other application such as industrial economics. Indeed, the industrial spying enables to know the capacity of production and the costs of the other firms. It can determine the decision of some firms to enter or not in competition.

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