Terrorism, key assets, and critical infrastructures: To protect or to rebuild ? That is the question

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Abstract

Both the choice between "stick" and "carrot" and the tension between the concern for "control" and for the preservation of "civil liberties" characterize the policy debate over counterterrorism. Frey and Rohner (2005) argue for the "carrot" and "civil liberties" point of view. They propose reconstruction as an alternative to protection. They argue that the commitment by the government to rebuild critical infrastructure in case of an attack may be credible if it induces a strong public support.

Our paper aims at providing a comparative analysis of the two policies – to protect or to rebuild – that Frey and Rohner (*ibid.*) describe, without siding with one or the other. First, we model the non cooperative interactions between terrorists and a government by focusing on the *a priori* decision of the government whether or not to protect key assets. Second, we change our model both by including a third player -the public-, and by focusing on the *a posteriori* decision of the state whether or not to rebuild (this model refines that of Frey and Rohner). Next, we study the decision faced by a government who may either choose to make strategic reconstruction or to protect the key assets. We derive conditions under which strategic reconstruction is more efficient than protection in deterring terrorists attacks. Finally, we show that strategic reconstruction may reinforce the efficiency of protection. Hence, there are some cases where the two policies are complements rather than substitutes.

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1 Introduction

Following Enders and Sandler (1995), it is possible to define terrorism "as premeditated use, or threat of use, of extra-normal violence or brutality to obtain a political objective through intimidation or fear directed at a large audience".

In the literature on terrorism, there are three different classes of terrorists, and three types of terrorism. The three different classes of terrorists are the following (Caplan (2006)). Suicidal terrorists kill themselves for their cause. Active terrorists actually belong to a terrorist organization. Sympathizers favour terrorism without doing much about it.
Terrorism comes in three varieties: transnational, international, and domestic terrorism (Rosendorff and Sandler (2004)). Transnational terrorist groups either pursue international goals or move beyond their own frontiers to achieve national goals. Whereas transnational terrorism is carried out by basically autonomous non-state actors, international terrorism is carried out by individuals or groups instigated, controlled, or at least supported by a sovereign state. International Terrorism Attributes of Terrorist Events (ITERATE) records the incident date, type of event, casualties, host country, the terrorist group, and other variables (Mickolus *et al.* (2004)). For transnational or international terrorism, the perpetrators, victims, and audience are all from two or more countries. By contrast, domestic terrorist groups restrict themselves to a particular country, its institutions, citizens, property, and policies. Domestic terrorism is home-grown and not exported abroad. Most terrorist incidents are domestic.

For all nine of the logical possibilities, terrorist action takes different forms. At the one end, there is the use of lethal force involving considerable shooting, injury and death. Al Qaeda, for example, has the character of an active transnational terrorist network using techniques such as suicidal terrorist bombings. At the other end, there is the use of non-lethal force. For example, the Corsican National Liberation Front, which is the predominant home-grown terrorist entity in France, has the character of an active domestic terrorist group, the main method of which is the use of force which is not intended or likely to cause death or great bodily harm. Between these two extremes, there are many different techniques, such as hijackings of planes or ships, hostage takings, and kidnappings.

Since 9/11, the US' s response to terrorism has been focused on Al Qaeda type of terrorism, and the US government has been following a stick and control policy. The USA PATRIOT Act of 2001, signed into law in 2006, is a good illustration of this process in practice. Similar moves have been taken

in the EU, where the fight against terrorist has been recently introduced in the Schengen Information System (SIS 2). At last, it should be noted that United Nations Security Council Resolution 1373 adopted September 28, 2001 obliges all states to criminalize assistance for terrorist activities.

From the law and economics perspective, Garoupa *et al.* (2006) show that such anti-terror measures incorporate three factors: enhancing severity and probability of punishment for terrorist crimes; cutting terrorists off from their funds; making cooperation in terrorist crimes more difficult.

Frey (2004) and (2006), Frey and Luechinger (2003) and (2004), and Frey and Rohner (2005) provide a comprehensive statement of these issues. However Frey (2004) argues for the carrot point of view. He shows that deterrence does not work with respect to terror. Building on this fact, he suggests that we should look at the root causes of terror, and offer potential terrorists an alternative path. Frey and Luechinger (2003) show that counter-terrorism strategies building on the benevolence system are superior to counterterrorism strategies building on the deterrence system. The former tend to produce a positive sum game among the interacting parties. The latter tend to produce a negative sum game interaction. Frey and Luechinger (2004) argue that strengthening decentralized decision-making in the polity and economy provides disincentives for terrorist attacks.

Frey and Rohner (2005) study protection of cultural monuments against terrorism. They highlight the necessity for the government to act without compromising the principles upon which a liberal democracy rests. To solve the dilemma for liberal democracies posed by terrorism, first noted by Wilkinson (1986), they contradict in part the traditional view of existing anti-terrorism literature by proposing reconstruction as an alternative to anti-terror policy. They convincingly argue that such a policy of strategic reconstruction would reduce major direct and indirect utility losses - in particular the possible loss of human rights - due to protective measures, and that, in many cases, by making a firm commitment to rebuild any important monuments destroyed, governments can discourage terrorists from attacking.

The analysis by Frey and Rohner (2005) complements our understanding of antiterrorism policy. In our view, by focusing on the destruction of important monuments with high symbolic meaning rather than on lethal terrorist acts, they also give new insights, which can be useful to fight against the attacks on any critical infrastructure or key asset.

Critical infrastructures are infrastructures that underpin economic strength, national security and society' s welfare (Auerswald *et al.* (2006)). As well as critical infrastructures key assets (notion introduced in the 2003 National

Strategy for the Physical Protection of Cultural Infrastructures and Key Assets) present attractive targets for terrorists.

Key assets include a wide variety of sites and structures that draw large numbers of people and frequent media attention. Their disruption or destruction could result in profound damage to national prestige and have significant impact on public confidence, and the economy.

There are three categories of key assets. The first category includes facilities and structures that represent national economic power and technological advancement. In the second category there are prominent commercial centres, office buildings, and sports stadiums, where large numbers of people regularly congregate. The third category is made up of cultural monuments, prominent historical attractions, symbols, and cultural icons that are symbolically equated with traditional values and political power.

Potentially, the analysis by Frey and Rohner (2005) can also be interesting for dealing with lethal terrorists acts on military or police service men. Indeed, from the state perspective, one can always replace a fallen service man with another (of course, from the point of view of the families of the fallen service men, the loss cannot be compensated). Finally, by relying on a game-theoretical analysis, they contribute to a burgeoning literature that uses game theory to study terrorism.

The application of economic methods to the study of terrorism began with Landes (1978), who applied the economics of crime and punishment to the study of skyjackings in the United States. Among economic methods, game theory is particularly well-suited to provide new insights into terrorism, because, above all, it captures the strategic interactions among various agents as they act based on how they believe that their counterpart will act and react (Sandler and Arce M. (2003)). Since the seminal work of Deutsch (1954), game theoretic methods have been used to analyze and predict political behaviour, and they have been applied by many economists (see, *e.g.*, Azam, (2005), Atkinson *et al.*, (1987), Lapan and Sandler (1988) and (1993), Lee (1988), Overgaard (1994), Sandler (2003), Sandler and Enders (2004), Sandler and Lapan (1988), Scott (1991), and Selten (1988)) to understand issues associated with terrorism. In addition, it should be noted that, for example, the special recent issues entitled "The Political Economy of Terrorism" in *Public Choice* (Volume 128, Numbers 1-2, 2006), "The Political Economy of Transnational Terrorism" in *Journal of Conflict Resolution* (Volume 49, Number 2, 2005) and "The economic Consequences of Terror" in the *European Journal of Political Economy* (Volume 20, Number 2, 2004) include a lot of articles that rely on game theory in their investigation.

The present paper aims at providing a comparative analysis of the (mixes of the) two policies – to protect or to rebuild – that Frey and Rohner (*ibid.*) describe, without siding with one or the other. In our view, it is a very good point to show that strategic reconstruction may be credible. However, it is also important to know whether or not this is a more efficient way than protection. To address these issues we shall rely on game theoretical arguments.

In the next section, we first model the non-cooperative interactions between terrorists and the government by focusing exclusively on the *a priori* decision of the government whether or not to protect key assets (in this section strategic reconstruction is not an option).

In section 3, we change our game-theoretic model of terrorism both by including a third (passive) player -the public-, and by focusing on the *a posteriori* decision of the government whether or not to rebuild (in this section, protection is not an option). This section recasts the analysis by Frey and Rohner (*ibid*) within a more detailed game theoretic framework (by making explicit the interactions of the state and the terrorists, the objective of the latter and by investigating the rationality of the public's expectations). We find that when the cost of not launching an attack for the terrorists is not too high, strategic reconstruction efficiently deters terrorists attacks. Hence, we get the Frey and Rohner result. The only difference is that we have a sightly more detailed description of the multiplicity of equilibria that can arise. However, when this cost is high enough, there will always be an attack (whatever the decisions of the state may be). This case illustrates a limit to the argument by Frey and Rhoner (2005) that credible strategic reconstruction may deter some terrorists attacks.

In section 4, we study the decision faced by a government who may either choose to make strategic reconstruction or to protect key assets. We provide conditions under which strategic reconstruction *alone* is more efficient than protection. Indeed it is not sufficient to show that strategic reconstruction may deter terrorists attacks. For this policy to be chosen, it must be more efficient than other alternatives. We show that the commitment by the government to rebuild critical infrastructure in case of an attack may be credible if it induces a strong public support. Otherwise, protection alone is the optimal choice.

In section 5, we extend our analysis by relaxing our assumption that protection and strategic reconstruction are mutually exclusive choices. First, we analyze the additional opportunities allowed by the use of strategic reconstruction when protection has already been chosen. Second, we endogenize the choice of protection. The main argument for using strategic reconstruc-

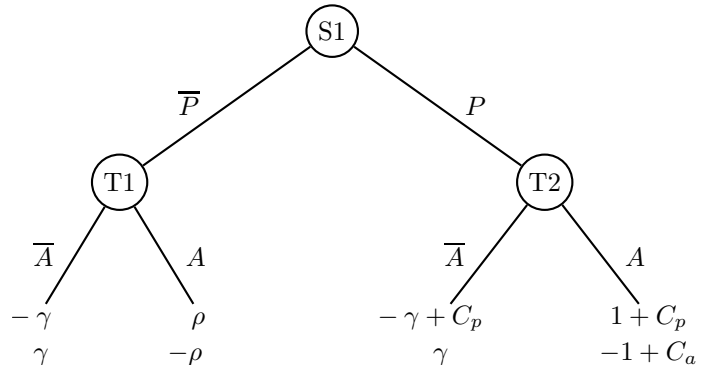

Figure 1: The extensive game with protection choice.

tion *alone* is that it has a weak effect on individual rights. Moreover, if this mechanism is efficient, *i.e.* if its credible, it entails no costs at all[1]. But these two properties also explain why strategic reconstruction can be used together with protection. Indeed, if protection is of some use, it is automatically reinforced by using strategic reconstruction. Hence, protection and strategic reconstruction are in this case complementary rather than substitutes.

Section 6 concludes.

2 A Simple Model of Strategic Protection

In this section, we analyze the efficiency of using protection in deterring terrorists attacks. We model the non-cooperative interactions between terrorists and a state by using the game in extensive form which is displayed in Figure 1. This game has two active players, namely the terrorists and the state.

The first figures of the payoffs at the terminal nodes correspond to the state losses, while the second correspond to the terrorists losses. At node $S1$, the state faces two alternatives: protecting critical infrastructures (P) or not ($\overline{P}$). Then, the terrorists may either attack (A) or not ($\overline{A}$).

Choosing protection is costly (this adds C_p to the loss of the state's payoffs). But this makes an attack more costly to the terrorists (the increase in the costs being equal to C_a).

The structure of the payoffs reflects the zero-sum flavor of the interactions between the state and the terrorists. In this paper, the terrorists want to

[1]Since there is no attack, there are no reconstruction costs.

weaken the state by diminishing its public support. If the terrorists do not attack, they are assumed to be defeated and they incur a loss. Conversely, if the terrorists attack, it is always a success for them and a failure for the state.

We assume that $\rho > 1$ and that $\rho > \gamma$. The variable ρ describes the loss of reputation or of support that the state must bear when there is an attack and if it does not choose to protect. The assumption that $\rho > 1$ implies that the loss of the state in case of an attack is lower when it chooses protection than otherwise. The assumption $\rho > \gamma$ means that the loss of the terrorists is in absolute terms lower when they do not attack than when they attack (and there is no protection).

We now study the subgame perfect equilibria of the Protection game. It is easy to prove the next Proposition[2]:

Proposition 1 *The subgame perfect Nash equilibria of the Protection game are as follows:*

1. *If $C_a < 1+\gamma$, then if $C_p \geq \rho - 1$, the Nash sub-game perfect equilibrium is $(\overline{P}, A)$, if not, the equilibrium is (P, A).*

2. *If $C_a \geq 1 + \gamma$, then if $C_p \geq \rho + \gamma$, the Nash equilibrium is $(\overline{P}, A)$, if not, the equilibrium is $(P, \overline{A})$.*

The Proposition above is somewhat intuitive. If the cost of protection is relatively low and the impact of the later on the terrorists loss is relatively high, protection deters the terrorists from attacking. If not, protection is not chosen and attacking is the best choice for the terrorists[3]. The Proposition 1 is illustrated in Figure 2.

Combining violence with propaganda, terrorism is a confrontation between those seeking power and those maintaining power. Strategy is the essence of terrorism. Before acting, terrorists carefully evaluate the potential implications of different strategies. Terrorists acts are well-planned attacks where the terrorists account for risks and associated costs as well as possible gains. Terrorists take into account their knowledge of their counterparts behaviour. Terrorists choices and actions are influenced by governments counterterrorism policies. In most the cases, understandably, if it is the state' s rule to

[2]Without loss of generality, we assume that whenever an agent is indifferent between acting or not, he chooses not to act.

[3]In fact, Protection may still be chosen in this case if it can induce a lower cost due to the loss of reputation- *i.e.*, when $1 + C_p < \rho$.

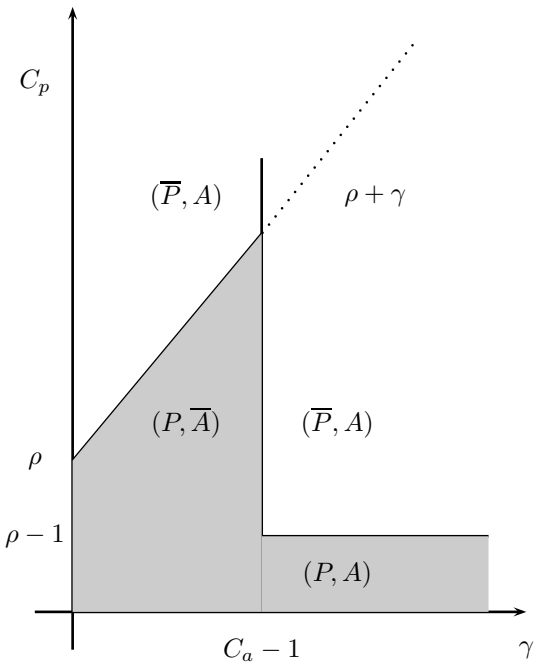

Figure 2: The equilibria of the protection game.

protect critical infrastructures, then the terrorists will gain by adopting the rule not to attack, and vice-versa. However, the cost of protection is twofold. On the one hand, there are the fiscal and other costs of the major homeland security measures. On the other hand, there are the restrictions on civil liberties generated by protection. Concerning this civil liberties cost of protection, it should be noted that rational individuals are prepared to sacrifice some liberty and property to counter terrorist threat. The issue about which there is some disagreement is one of relative magnitude (see Mueller (2004) and Niskanen (2006)). The most visible security measures may be perceived as nuisances by citizens. Screening of visitors, brief-cases and baggage is irritating. Unwarranted intrusion and inconvenience, long lines, searches, and identification requirements are time consuming. All these anti terrorist measures that are becoming an ordinary way of life are moderately effective because it is very difficult to prevent a determined terrorist, even one who is not suicidal, from destroying a critical infrastructure or a key asset. Hence it is clear that the tension between the concern for national security and for the preservation of civil liberties characterize much of the policy debate over how to deal with terrorism.

3 A Simple Model of Strategic Reconstruction

Terrorist attacks are not totally avoidable in practice, and, for example, many American still believe that the right thing to be built at Ground Zero is Twin Towers. Taking such a stylised fact as a starting point, Frey and Rohner (2005) argue that the *a posteriori* decision of the state whether or not to rebuild a particular key asset in case it gets destroyed due to a terrorist attack may influence the *a priori* decision of the terrorists whether or not to attack this key asset. That is, there are several cases where, if the state chooses to be prepared to rebuild identically, it is in the interest of terrorists not to attack. As the authors put it, "an attractive - if somewhat unorthodox strategy is to reduce defensive protection measures to a minimum, but *to be fully prepared for the eventuality and build a rapid and identical reconstruction* once an (unavoidable) terrorist attack has occurred". Above all, Frey and Rohner (*ibid.*) show that it is well possible that "terrorists attack if the government does not seem determined to rebuild the monument, and terrorist do not attack if the government is able to convince them and the public of its determination to rebuild the monument in case of an attack".

In this section, we highlight this stimulating result by providing a recasting of the analysis by Frey and Rohner (*ibid.*) within a more detailed game-theoretic framework. We model the non cooperative interactions between the terrorists and the state by using the game in extensive form which is displayed in Figure 3. There are two differences between our model and the model used by Frey and Rohner (*ibid.*). First, we make explicit the existence of the public: in our model there are two active players, namely the state and the terrorists, and one passive player, the public. Though this player is a passive one, it is important because its reactions and expectations determine the success or failures of a terrorist attack. We take some time studying the rationality of the public's expectations. Second, we make explicit the aims of the terrorists. In particular, we examine the case where the loss of reputation that the terrorists must bear when they do not attack is greater than the loss of reputation that they must bear when they attack, and the state rebuilds. We now analyze the strategic reconstruction game.

The terrorists make a choice at node $T1$. They can either launch an attack or not on critical or cultural infrastructures.

The immediate successor nodes of node $T1$ are in an information set. At nodes $P1$ and $P2$, the public must make an expectation on whether or not the state will rebuild critical infrastructures if there is a terrorist attack. These

nodes belong to an information set since the public is assumed to ignore if there is an attack or not at the moment it must devise its expectations.

Notice that, as indicated by the game, the terrorists must decide to attack without *a priori* knowing the public's expectations.

The symbol $\overline{R}^e$ (resp. R^e) means that the public does not (reps. does) believe that the state will rebuild the infrastructures if there is an attack.

The state takes its decisions at nodes $S1$ and $S2$. In effect, at node $P1$, there has been no attack and there is nothing to rebuild. At nodes $S1$ and $S2$, the decisions of the state are either to rebuild (R) or not ($\overline{R}$)[4].

Let us now discuss the values of the payoffs. The payoffs are shown at each of the terminal nodes of the game. Again, the first figure corresponds to the payoffs of the state, while the second corresponds to the payoffs of the terrorists.

If there is no attack, whatever the public's expectations may be, we assume again that the state is reinforced whereas the terrorists have failed to achieve their aims. This is why the "loss", of the terrorists are the gains of the state (recall that this reflects the zero-sum game flavor of the interactions between the terrorists and the state).

Let us now suppose that the public is pessimistic about the possibility that the state rebuilds infrastructures if there is an attack (formally, the public chooses $\overline{R}^e$). Let us consider the payoffs that are generated at node $S1$. We assume that when there is an attack and when the state does not rebuild the infrastructures, its loss is $\rho > 0$. We still assume that $\rho > 1$ and that $\rho > \gamma$. The variable ρ describes the loss of reputation or of support that the state must bear when there is an attack and if it does not rebuild.

If there is an attack and the state rebuilds, we assume that the loss of support is *weaker* in absolute terms than in the preceding case (hence the assumption that $\rho > 1$). However, to this loss of support, one must add the costs of rebuilding the infrastructures. This is captured by the variable X, $X > 0$.

Let us now suppose that the public chooses R^e (we are then at node $S2$). For the sake of simplicity, we assume that the costs for the state of not rebuilding the infrastructures is the same that at node $S1$. The main difference arises when the state decides to rebuild. This difference is modeled by assuming $0 < \alpha < 1$, *i.e.* that the cost of rebuilding infrastructures is lower than at node $S1$. This is because the public supports the state: it may provide

[4]In this section, protection is not an alternative.

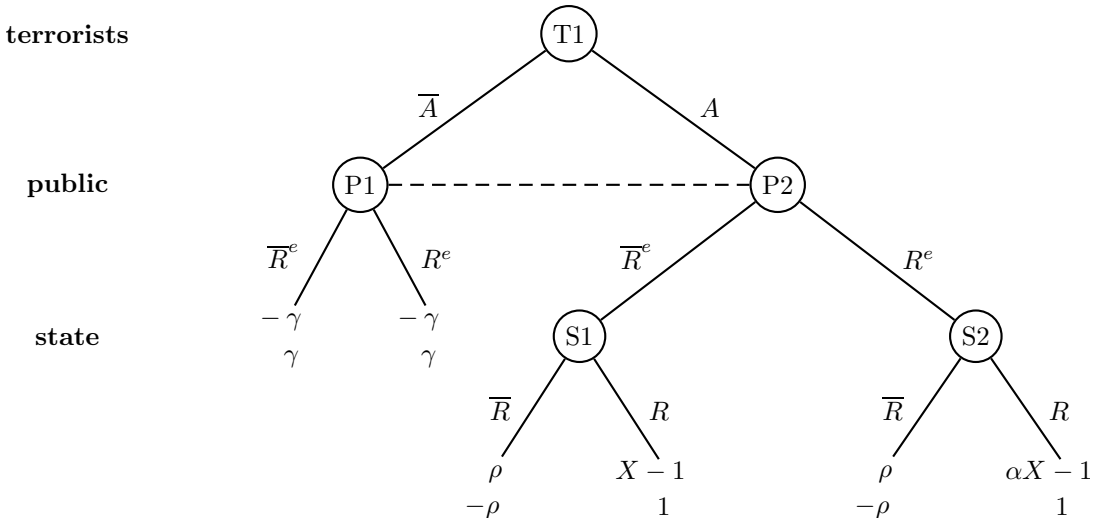

Figure 3: The strategic reconstruction game

the state with free resources, with gifts etc... which will ease the burden of rebuilding infrastructures.

We are now in position to analyze the equilibria of the game. It is most convenient to think that the public "chooses" its expectation according to a random device. Indeed, we shall assume that the public expects that the state will rebuild destroyed infrastructures with probability π ($\pi \in [0,1]$). However, we shall impose a kind of rationality on expectations. To introduce this rationality constraint, let us compute the conditional probability that the state rebuilds infrastructures once there is an attack. Let $D : \{R^e, \overline{R}^e\} \times \{A, \overline{A}\} \rightarrow \{R, \overline{R}\}$, be the function giving the state decision given public expectations and the terrorists decision. Let $\mathbb{1}_{D(R^e,A)=R}$ (resp. $\mathbb{1}_{D(\overline{R}^e,A)=R}$) be the indicator function which takes the value 1 if $D(R^e, A) = R$ (resp. $D(\overline{R}^e, A) = R$)), *i.e.* if the state rebuilds when there is an attack and the public expects R^e (resp. $\overline{R}^e$). Then:

$$\Pi_{R|A} = \pi \mathbb{1}_{D(R^e,A)=R} + (1-\pi)\mathbb{1}_{D(\overline{R}^e,A)=R} \tag{1}$$

We shall say that the public's expectations are rational if whenever there is an attack:

$$\pi = \Pi_{R|A} = \pi \mathbb{1}_{D(R^e,A)=R} + (1-\pi)\mathbb{1}_{D(\overline{R}^e,A)=R} \tag{2}$$

When there is no attack, strictly speaking, the conditional probability is not defined. Thus, we shall not set any constraint on π in this case.

An *equilibrium* for the game whose extensive form is given in Figure 3 will be defined as a pair of strategies (for the terrorists and the state) and public's expectations such that: 1) the strategies are a Nash subgame perfect equilibrium (given the public expectations); 2) public expectations are rational.

Depending on the values of the parameters, there may be several equilibria.

Proposition 2 *Assume first that $\gamma > 1$. Then in any subgame perfect equilibria, terrorists attack and:*

- *If $X - 1 < \rho$, there is a unique equilibrium, with $\pi = 1$, and the state always rebuilds.*
- *If $\alpha X - 1 < \rho \leq X - 1$, there exists a continuum of equilibria indexed by $\pi \in [0, 1]$, where the state rebuilds when the public expects R^e and does not when it expects $\overline{R}^e$.*
- *If $\rho < \alpha X - 1$, there exists a unique equilibrium, with $\pi = 0$, and the state never rebuilds.*

When $\gamma \leq 1$, we have:

- *If $X - 1 < \rho$, there exists a continuum of equilibria indexed by $\pi \in [0, 1]$, and the terrorists never attack.*
- *If $\alpha X - 1 < \rho \leq X - 1$, there are two sets of equilibria. In the first set, $\pi \geq \frac{\gamma+\rho}{1+\rho}$, and the terrorists never attack. In the second, $\pi < \frac{\gamma+\rho}{1+\rho}$, and the terrorist always attack. In both cases the state rebuilds when the public expects R^e and never when the later expects $\overline{R}^e$.*
- *If $\rho < \alpha X - 1$, there exists a unique equilibrium, with $\pi = 0$, the terrorists always attack and the state never rebuilds.*

PROOF. Let π be the probability that the public expects R^e. Again, without loss of generality, we assume that whenever an agent is indifferent between acting or not, he chooses not to act.

Let us now consider the choices made by the state at nodes $S1$ and $S2$. At node $S2$, the state rebuilds whenever $\alpha X - 1 < \rho$. At node $S1$, it rebuilds whenever $X - 1 < \rho$. Hence, if (R_1, R_2) denotes the decisions made by the state at nodes $S1$ and $S2$, we have:

$$(R_1, R_2) = \begin{cases} (R, R) & \text{if } X - 1 < \rho \\ (\overline{R}, R) & \text{if } \alpha X - 1 < \rho \leq X - 1 \\ (\overline{R}, \overline{R}) & \text{if } \rho \leq \alpha X - 1 \end{cases} \tag{3}$$

Now, taking into account the state behavior, the expected loss L_T of the terrorists if there is an attack writes:

$$L_T = \begin{cases} 1 & \text{if } X - 1 < \rho \\ \pi(1+\rho) - \rho & \text{if } \alpha X - 1 < \rho \leq X - 1 \\ -\rho & \text{if } \rho \leq \alpha X - 1 \end{cases} \tag{4}$$

Since the loss of the terrorist is γ if they do not attack, their optimal decisions can be summarized as follows.

- If $X - 1 < \rho$, the terrorists attack iff $1 < \gamma$.
- If $\alpha X - 1 < \rho < X - 1$, the terrorist attack iff $\pi < \frac{\gamma+\rho}{1+\rho}$.
- If $\rho \leq \alpha X - 1$, the terrorists always attacks (since $-\rho < \gamma$).

Now assume that $\gamma > 1$. Notice that:

$$\pi \leq 1 < \frac{\gamma + \rho}{1 + \rho}. \tag{5}$$

So, for all π, the terrorists attack.

If $X - 1 < \rho$, we know that the state always rebuilds when there is an attack. So the only rational public expectations are $\pi = 1$.

If $\alpha X - 1 < \rho \leq X - 1$, the state always rebuilds when the public expectations are R^e and never when they are $\overline{R}^e$. Hence, using the rationality condition (2), one sees that any π in $[0, 1]$ is rational. Thus, there is a continuum of equilibria.

If $\alpha X - 1 \leq \rho$, the state never rebuilds, and the rationality condition (2) implies that π must be equal to zero.

So far, we have proved the first part of the Proposition.

Let us now turn to the case, $\gamma \leq 1$.

If $X - 1 < \rho$, we know that the state always rebuilds when there is an attack. As the Terrorists attack if only if $1 < \gamma$, under our assumptions, there are no attacks and $\pi \in [0, 1]$.

If $\alpha X - 1 < \rho \leq X - 1$ and there is an attack, the state always rebuilds when the public expectations are R^e and never when they are equal to $\overline{R}^e$. There are equilibria at which terrorists attack whenever $\pi < \frac{\gamma+\rho}{1+\rho}$. The rationality constraints is satisfied. There are equilibria without attacks when $\pi \geq \frac{\gamma+\rho}{1+\rho}$ (and the rationality condition does not yield any additional constraints).

If $\alpha X - 1 \leq \rho$, the argument used in the case $\gamma > 1$ still applies. $\square$

The various cases contained in the Proposition are displayed in figure 4.

Let us now compare the previous result with the analysis by Frey and Rohner (2005). Assume first that the cost γ of not launching an attack for the terrorists satisfies $\gamma < 1$. Then, our result that the efficiency of strategic reconstruction depends on the cost ρ for the state of loosing its reputation is very similar to that of Frey and Rohner (2005) (see their Figure 1). The only difference is that we have a sightly more detailed description of the multiplicity of equilibria when $\rho \in]\alpha X - 1, X - 1]$.

However, when $\gamma \geq 1$, our results are slightly different and are drived by the introduction of the opportunity cost of doing nothing for the terrorists (*i.e.* γ). If this cost is high enough, rather intuitively, there will always be an attack (whatever the decisions of the state may be). This case illustrates a limit to the argument by Frey and Rhoner (2005) that credible strategic reconstruction may deter some terrorists attacks.

Still, the Proposition above shows the importance of the support provided by the public in the fight against terrorism. In particular, the Proposition highlights (and, in fact, slightly restates) the case where the argument by Frey and Rohner (2005) is relevant. Indeed, when $\gamma < 1$ and $\alpha X - 1 < \rho \leq X - 1$, the support of the public is not predetermined and if its value is high (i.e. when α is low and π is high), the state is able to deter an attack by the credible threat of rebuilding.

4 Protection or Reconstruction

In the previous section, we have proposed a slight restatement of the argument by Frey and Rhoner that credible strategic reconstruction may deter terrorist attacks.

This result is interesting since strategic reconstruction has a small effect on civil liberties. But this does not mean that such a policy should always be preferred to Protection. Both policies have merits and shortcomings.

In this section, we shall study the conditions under which one policy is better than the other. To do this, we shall assume that these policies are mutually exclusive. That is, we shall assume that protection cannot be used with strategic reconstruction. We postpone the analysis of the joint use of both policies in the next section.

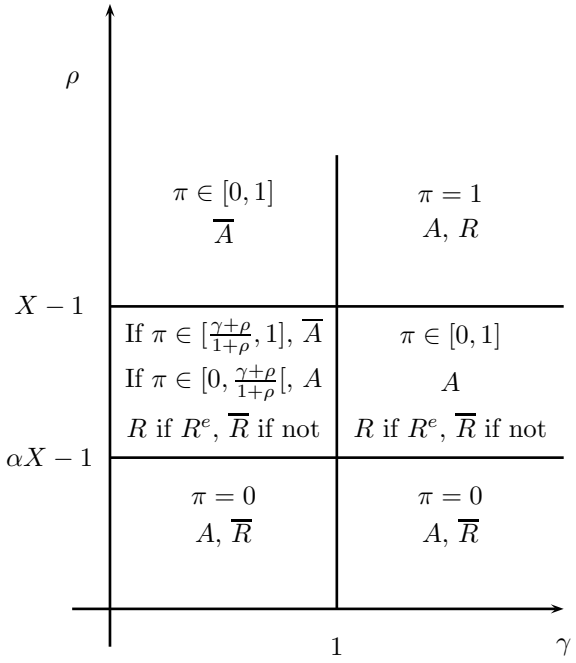

Figure 4: The equilibria of the strategic reconstruction game.

Let us then consider the decision faced by a state who may either choose to use strategic reconstruction or to protect critical infrastructures. The decision process is depicted in Figure 5.

At node $S0$, the state may either choose to use strategic reconstruction (i.e. SR) or to engage in a protection program ($\overline{SR}$). At node $T1$ begins a subgame which is identical to the game studied in the previous section. At node $S3$ begins a subgame which is the protection game.

In the two previous sections we have analyzed the equilibria for these two subgames. The study of the equilibria of the game depicted in figure 5 allows us to make a detailed study of the decision problem faced by the state.

Proposition 3 *Assume first that in the equilibrium of the Protection subgame the state chooses not to protect critical infrastructures. Then:*

- *If $\rho > \alpha X - 1$, strategic reconstructions (SR) is strictly preferred by the state over engaging in the protection game (i.e. $\overline{SR}$) in any Nash subgame-perfect equilibria.*
- *If not, the state is indifferent between the two moves in any Nash subgame-perfect equilibria.*

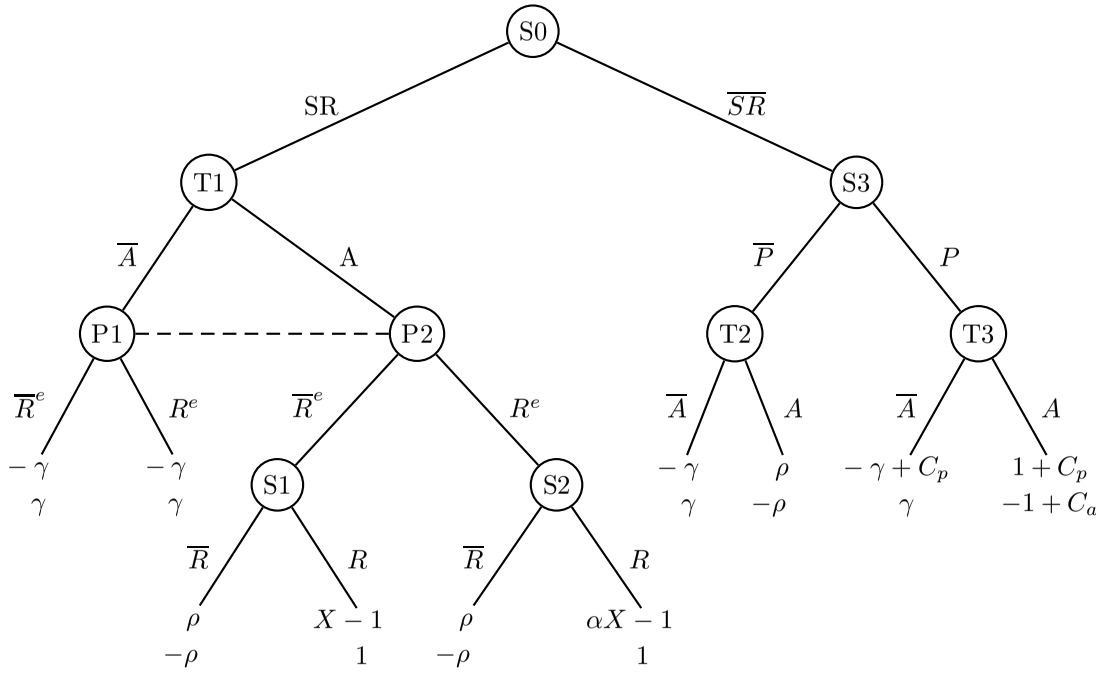

Figure 5: The extensive game with protection and reconstruction choices.

Assume now, that in the equilibrium of the protection subgame, the state chooses to protect critical infrastructures. Then:

- *If in the equilibrium of the strategic reconstruction subgame the state nevers rebuilds (i.e. when $\rho \leq \alpha X - 1$), then protection is always preferred to strategic reconstruction.*

- *When, in the equilibrium of the strategic reconstruction subgame, there is never an attack (i.e. if $\rho > X-1$ and $\gamma \leq 1$ or if $\rho \in (\alpha X-1, X-1]$, $\gamma \leq 1$ and $\pi \in [(\gamma+\rho)/(1+\rho), 1]$), strategic reconstruction will always be preferred to protection.*

- *When, in the equilibrium of the strategic reconstruction subgame there is always an attack and the state always rebuilds (i.e. $\rho > X - 1$ and $\gamma \geq 1$), then : if $\gamma \leq C_a - 1$ (and $C_p \leq \rho + \gamma$), strategic reconstruction is preferred over protection if and only if $\gamma + \alpha X - 1 < C_p$; if $\gamma > C_a - 1$ (and $C_p \leq \rho - 1$), strategic reconstruction is preferred over protection if and only if $\alpha X - 2 < C_p$.*

- *Finally, suppose that in the equilibrium of the strategic reconstruction subgame, there is always an attack and the decision of the state is conditional on the public's expectations. Then, if $\gamma \leq C_a - 1$, the state prefers strategic reconstruction over protection iff $\gamma + \pi(\alpha X - 1) + (1 - \pi)\rho < C_p$. In the case where $\gamma > C_a - 1$, the condition writes: $\pi(\alpha X - 1) + (1 - \pi)\rho < 1 + C_p$.*

Proof. Consider first the case where not protecting is an equilibrium move for the state in the protection subgame. Hence, the loss of the state is ρ.

From Proposition 2, we know what are the optimal moves of the state, depending on the values of the parameters.

Assume then that $\gamma \leq 1$. Then, if either $\rho > X - 1$ or $\alpha X - 1 < \rho \leq X - 1$ and $\pi \in [(\gamma+\rho)/(1+\rho), 1]$, the state's loss is equal to $-\gamma$. Now, if $\pi \in [0, (\gamma+\rho)/(1+\rho)[$, its loss equals $\pi(\alpha X - 1) + (1 - \pi)\rho$. This loss is readily shown to be strictly less than ρ (because we are in the case where $\alpha X - 1 < \rho$). So, in all these cases, the state will prefer strategic reconstruction over protection. When $\rho \leq \alpha X - 1$, the state's loss is equal to ρ so that it is indifferent between SR and $\overline{SR}$.

Assume now that $\gamma > 1$. If $\rho > X - 1$, the state's loss in the strategic reconstruction subgame is $\alpha X - 1$. If $\alpha X - 1 < \rho \leq X - 1$, the expected loss of the state writes $\pi(\alpha X - 1) + (1 - \pi)\rho$. Hence, in these cases, SR will be preferred over $\overline{SR}$. Lastly, if $\rho \leq \alpha X - 1$, the state loss is ρ and it is indifferent between the two moves.

We turn now to the case where protection is the equilibrium choice of the state for the protection subgame.

If in the equilibrium of the strategic reconstruction subgame the state nevers rebuilds (i.e. when $\rho \leq \alpha X - 1$), then whatever may be the value of γ, the state's loss is ρ. But the payoffs of the state in the protection subgame are either $-\gamma + C_p$ or $1 + C_p$. Since protection is the equilibrium choice of the protection subgame, both expressions are strictly less than ρ (see Proposition 1). Hence protection is always preferred to strategic reconstruction.

If in the equilibrium of the strategic reconstruction subgame there is never an attack (i.e. if $\rho > X - 1$ and $\gamma \leq 1$ or if $\rho \in (\alpha X - 1, X - 1]$, $\gamma \leq 1$ and $\pi \in [(\gamma + \rho)/(1 + \rho), 1]$), the loss of the state is $-\gamma$. This value is always less than the losses of the state if protection ($\overline{SR}$) is chosen (because, as was seen above, the state's losses are either $-\gamma + C_p$ or $1 + C_p$).

Suppose now that in the equilibrium of the strategic reconstruction subgame there is always an attack and the state always rebuilds (i.e. $\rho > X - 1$ and $\gamma > 1$). Then, strategic reconstruction yields a loss equal to $\alpha X - 1$. If $\gamma < C_a - 1$ (and $C_p < \rho + \gamma$), then under our assumptions, the loss of the state if protection is chosen is equal to $-\gamma + C_p$. Hence, strategic reconstruction is preferred over protection if and only if $\gamma + \alpha X - 1 < C_p$. If $\gamma \geq C_a - 1$ (and $C_p < \rho - 1$), a similar reasoning shows that strategic reconstruction is preferred over protection if and only if $\alpha X - 1 < 1 + C_p$.

Finally, suppose that in the equilibrium of the strategic reconstruction subgame, there is always an attack and the decision of the state is conditional on the public's expectations. For this to be possible, one must have: $\alpha X - 1 < \rho \leq X - 1$. If $\gamma \leq 1$, this only happens when $\pi \in [0, (\gamma + \rho)/(1 + \rho)[$. The expected loss of the state writes then $\pi(\alpha X - 1) + (1 - \pi)\rho$. Comparing this value to the losses of the state when protection is chosen yields the results. The same reasoning applies when $\gamma > 1$ and the results are the same. □

The first part of the Proposition above is rather intuitive. If, indeed, protection is *not* an equilibrium move for the state in the protection subgame, it is because the cost of doing nothing is relatively low with respect to that of protecting. But the cost of doing nothing (when there is an attack) is the same in the strategic reconstruction subgame. Hence, the state would never lose anything by choosing SR at node $S0$. It can even lower its loss if the cost of rebuilding is relatively low, especially if the support of the public (through the effects of α and π) is high.

As for the second part of the Proposition, protection is assumed to be an equilibrium move for the state in the Protection subgame. This, of course,

happens when the cost of protection is relatively low (*e.g.*, the public does not suffer from a decrease in individual rights).

The case where the arguments by Frey and Rohner is the most persuasive is when there is no attack at the equilibrium of the strategic reconstruction subgame. If the terrorists can be deterred from attacking because of the public support, then, certainly, protection must not be chosen. Indeed, protection is necessarily costly whereas credible strategic reconstruction is not.

In the other cases, the choice between protecting or not involves three elements, the costs of Protection C_p, and the support of the public (π and α). The lower C_p, the higher the probability that protection will be chosen by the state over strategic reconstruction.

What the preceding analysis shows, is that the case made by Frey and Rohner may be a relevant one, that is, credible strategic reconstruction may be an *efficient* way do deter terrorists attack and a superior one in comparison with protection. We have tried to decipher the conditions under which this argument is the most persuasive. Strategic reconstruction is always an option which should be studied even if this option is not always the best (especially if the public tolerates a decrease in civil rights).

5 Protection *and* Strategic Reconstruction

In the preceding section, we have seen that the case made by Frey and Rhoner is relevant. Indeed, in a setting where protection and strategic reconstruction are two separate alternatives, it may be wise to choose the latter.

We shall now extend our analysis by relaxing our assumption that protection and strategic reconstruction are mutually exclusive choices. First of all, in the next subsection, we will analyze the additional opportunities allowed by the use of strategic reconstruction when protection has *already* been chosen. In the second subsection, we shall endogenize the choice of protection. By this, we mean that the state will be able to choose either strategic reconstruction alone or strategic reconstruction *and* protection. By doing this, we shall be able to see if, how, and when protection enhances the strategic reconstruction mechanism.

5.1 Strategic Reconstruction with Protection

In this subsection, we analyze the impact of protection on the choice of strategic reconstruction. More precisely, we assume that the state has already

chosen to spend some resources for protecting critical infrastructures and we examine under which conditions strategic reconstructions are useful.

To analyze this choice, we slightly modify the extensive form of the simple game of strategic reconstruction. The new extensive form is displayed on figure 6. Under our new assumptions, the loss of the state now comprises of protection expenditures (C_p) which impact terrorists losses in case of an attack (C_a).

The Nash subgame perfect equilibria are given in the next Proposition which is a slight repackaging of Proposition 2.

Proposition 4 *Assume first that $\gamma > 1 + C_a$. Then in any equilibria, terrorists always attack and:*

- *If $X - 1 < \rho$, there is a unique equilibrium, with $\pi = 1$, and the state always rebuilds.*
- *If $\alpha X - 1 < \rho \leq X - 1$, there exists a continuum of equilibria, $\pi \in [0, 1]$, where the state rebuilds when the public expects R^e and does not when it expects $\overline{R}^e$.*
- *If $\rho < \alpha X - 1$, there exists a unique equilibrium, with $\pi = 0$, and the state never rebuilds.*

When $\gamma \leq 1 + C_a$, we have:

- *If $X - 1 < \rho$, there exists a continuum of equilibria, whith $\pi \in [0, 1]$, and the terrorists never attack.*
- *If $\alpha X - 1 < \rho \leq X - 1$, there are two sets of equilibria. In the first set, $\pi \geq \frac{\gamma + \rho - C_a}{1+\rho}$, and the terrorists never attack. In the second, $\pi < \frac{\gamma + \rho - C_a}{1+\rho}$, and the terrorist always attack. In both cases the state rebuilds when the public expects R^e and never when the later expects $\overline{R}^e$.*
- *If $\rho < \alpha X - 1$, and $-\rho + C_a < \gamma$ there exists a unique equilibrium, with $\pi = 0$, the terrorists always attack and the state never rebuilds. If $-\rho + C_a \geq \gamma$, the terrorists never attack and $\pi \in [0, 1]$.*

Proof. Easily adapted from that of Proposition 2. □

The Proposition illustrates the impact of protection on the choice of strategic reconstruction. First of all, we notice that once protection expenditures have been decided, they can be thought of as sunk costs, and the choice between

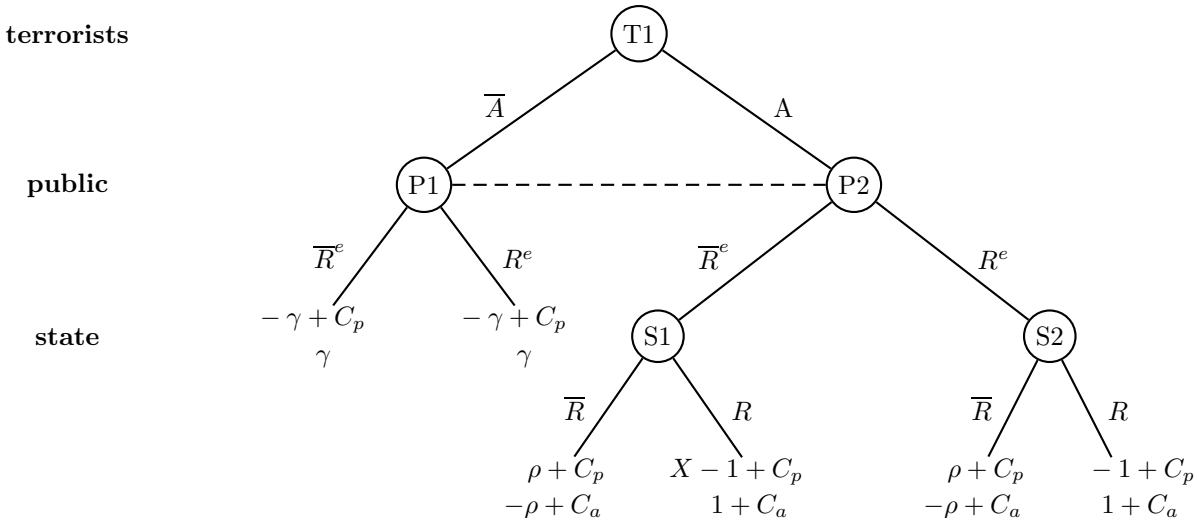

Figure 6: Strategic Reconstruction with Protection

rebuilding or not does not depend on the amount of the former. It the terrorists choice which is affected by the protection expenditures.

Comparing the statements of Proposition 2 and 4, we observe that the higher C_a the lower the probability that the terrorists *always* attack. Moreover, when terrorists may attack, it happens less often when there is protection. Indeed, when there are multiple equilibria (*e.g.* $\gamma \leq 1+C_a$ and $\alpha X - 1 < \rho \leq X - 1$), the set of beliefs for which the terrorists attacks is smaller (the higher C_a the lower $(\gamma + \rho - C_a)/(1 + \rho)$). In the last statement of the Proposition, the terrorists may never attack whereas the state never rebuilds in case of an attack (without protection).

The crucial assumption of this subsection, is that protection expenditures are given. We shall relax this assumption in the next subsection.

5.2 Strategic Reconstruction with or without Protection

In this subsection, we study a game where the state may choose both protection *and* strategic reconstruction. We refine our preceding model: the state's counterterrorism policy is viewed as a game where the state chooses the game that it will play. It chooses if it will try to deter terrorists from attacking critical infrastructures without resorting to protection measures, or if it will play the game studied in the preceding section. The extensive form of this

new game is depicted in Figure 7 of the paper. This game captures nicely the complexity of the policy choices concerning terrorism faced by the state.

It has two subgames, namely one which begins at node $T1$, the other beginning at node $T2$. This latter node is reached whenever the state decides to protect critical infrastructures. The corresponding subgame has been studied in the preceding section. The first subgame corresponds to the game studied in section 3.

We shall not give a complete study of the game (however the various Nash subgame perfect equilibria moves are displayed in figure 8). In effect, we just want to know if protection may sustain and even enhance the mechanism of strategic reconstruction. We can rely on Propositions 2 and 4 to answer to this question.

First of all, there are some cases where protection never sustains nor enhances the mechanism of strategic reconstruction.

Indeed, assume that either $\gamma > 1 + C_a$ or $\gamma \leq 1$ and $\rho > X - 1$. In the first case, from Proposition 4 it is easy to see that the terrorists always attack (whether or not there is protection). Hence, protection is costly and inefficient. So it is never chosen. In the second case, we know from Proposition 2 that the mechanism of strategic reconstruction always deters the terrorists from attacking. Hence, protecting critical infrastructure is again costly and inefficient.

Similar conclusions can be drawn when $\gamma \in [0, 1]$, $\rho \in]\alpha X - 1, X - 1]$ and $\pi \in [0, (\gamma+\rho-C_a)/(1+\rho)[\cup[(\gamma+\rho)/(1+\rho), 1]$. Indeed, when π is high enough, it is enough to use the strategic reconstruction mechanism to deter the terrorists; when π is too low, adding protection does not yield any deterrence. The same reasoning applies to the case where $\gamma \in [1, 1 + C_a]$, $\rho \in]\alpha X - 1, X - 1]$ and $\pi \in [0, (\gamma + \rho - C_a)/(1 + \rho)[$. It also applies to the case where $\gamma \in [0, 1 + C_a]$, $\rho \in [0, \alpha X - 1]$ and when $-\rho + C_a < \gamma$.

But, as was seen in the previous subsection, there are two reasons why choosing protection *and* strategic reconstruction may be useful (and why this may be chosen along a Nash subgame perfect equilibrium path).

First of all, as was already seen, protection increases the cost of an attack for the terrorists. When C_a is high enough and the size of C_p is modest, one can completely deter the terrorists from attacking. For instance, when $\gamma \in [0, 1 + C_a]$, $\rho \in [0, \alpha X - 1]$ and when $-\rho + C_a \geq \gamma$, the terrorists do not attack if protection is chosen. If $C_p < \gamma + \rho$, protection yields a lower loss than strategic reconstruction alone. Moreover, the higher C_a, the lower the

size of the sets of the parameters for which the terrorists *always* attack (see Figure 8).

Second, choosing protection *lowers* the minimum values of π beyond which strategic reconstruction deters attack. Recall that without protection, Proposition 2 asserts that if $\rho \in]\alpha X - 1, X - 1]$ and $\gamma \leq 1$, there are attacks if $\pi < (\gamma + \rho)/(1 + \rho)$. With protection, the threshold is lower and equal to $(\gamma + \rho - C_a)/(1 + \rho)$. So, choosing protection may enhance the mechanism of strategic reconstruction[5]. But this is feasible only if the cost of protection is not too high, *i.e.* whenever $C_p < \gamma + \pi(\alpha X - 1) + (1 - \pi)\rho)$. If this condition is satisfied, protection and strategic reconstruction are complements rather than substitutes.

The gist of the previous results is as follows. The main argument for using strategic reconstruction *alone* is that it has a weak effect on individual rights. Moreover, if this mechanism is efficient, *i.e.* if it is credible, it entails no costs at all[6]. But these two properties also explain why strategic reconstruction can be used *together* with protection. Indeed, if protection is of some use, it is automatically re-inforced by using strategic reconstruction.

6 Conclusion

The present paper aimed at providing a comparative analysis of two anti-terrorists policies - to protect or to rebuild that Frey and Rohner (*ibid.*) describe, without siding with one or the other.

First, we have modelled the non-cooperative interactions between terrorists and the state by focusing on the *a priori* decision of the state whether or not to protect key assets. Second, we have changed our game-theoretic model of terrorism both by including a third (passive) player -the public-, and by focusing on the *a posteriori* decision of the state of whether or not to rebuild. This section has recasted the analysis by Frey and Rohner within a more detailed game theoretic framework. Indeed, we have made explicit the interactions of the state and the terrorists and we have introduced an objective for the latter. We have also defined and studied the rationality of the public expectations. Next, we have studied the decision faced by a state who may either choose to make strategic reconstruction or to protect key assets. We have shown that the commitment by the government to rebuild critical infrastructure in case of an attack may be credible if it induces a strong public support. Otherwise, protection alone is the optimal choice.

[5]The same conclusion obtains when $\gamma \in [1, 1 + C_a]$.

[6]Since there is no attack, there are no reconstruction costs.

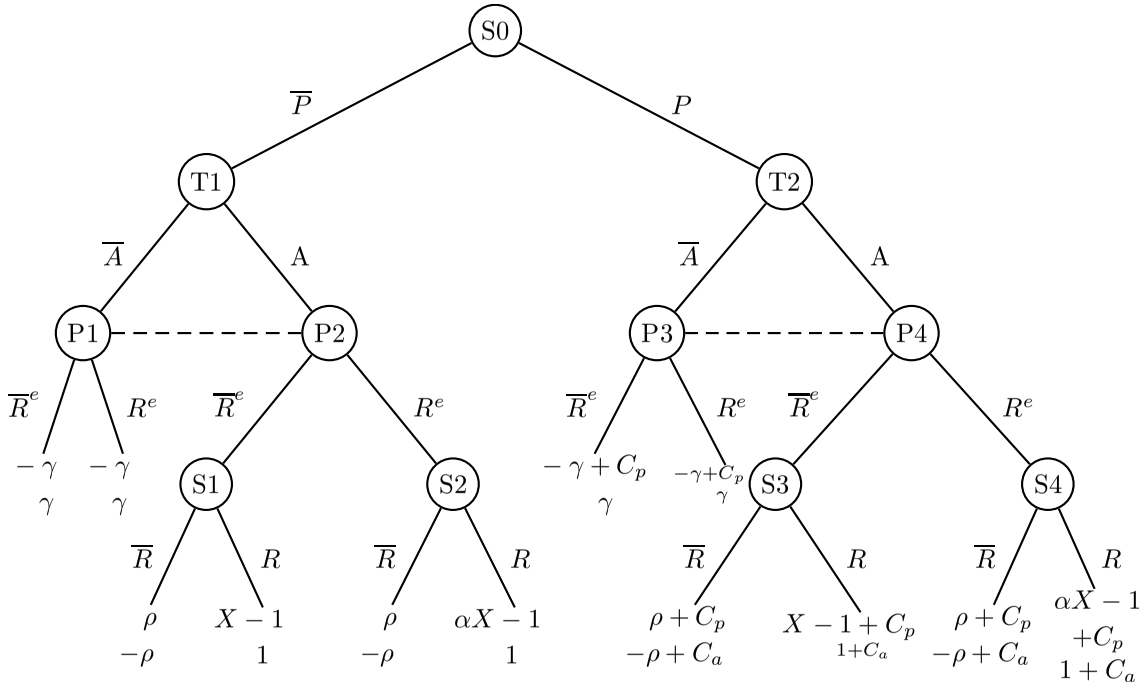

Figure 7: The Game with protection and strategic reconstruction

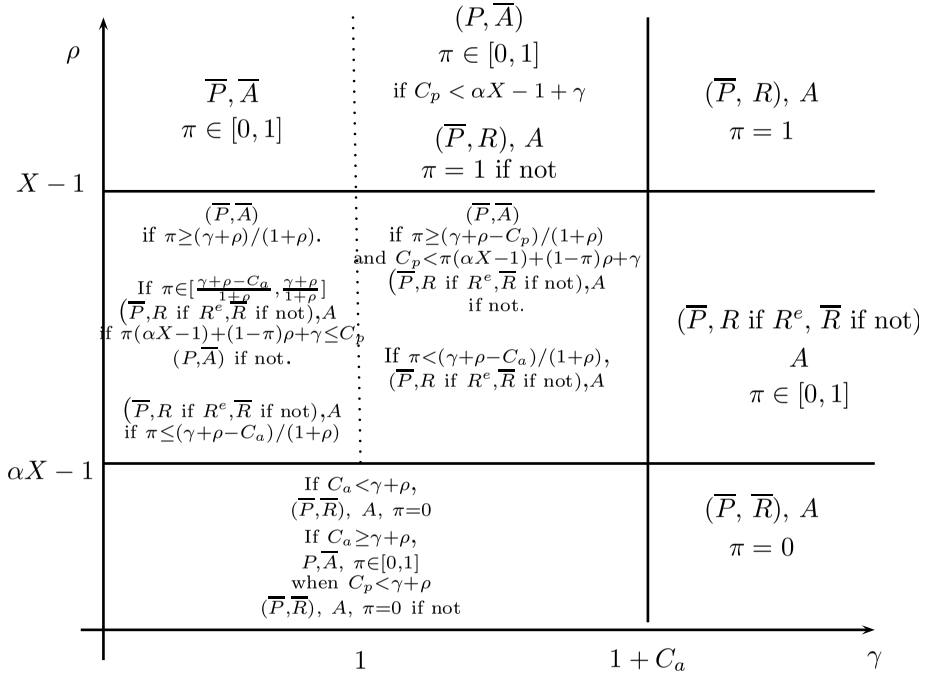

Figure 8: The equilibria of the game whith endogenous protection and strategic reconstruction.

Finally, we have extended our analysis by relaxing our assumption that protection and strategic reconstruction are mutually exclusive choices. First, we have analyzed the additional opportunities allowed by the use of strategic reconstruction when protection has already been chosen. Second, we have endogenized the choice of protection by making the state able to choose either strategic reconstruction or strategic reconstruction and protection. By doing this, we have shown how, and when protection enhances the strategic reconstruction mechanism.

For sure, the results of the paper do not apply to all forms of terrorism. Moreover, in the study of protection we have not assumed that the latter may also enhances public support of the government (for instance, by making the public to felt more secure). The last feature is a natural topic for further theoretical investigations.

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