Countering Terror Cells: Offence versus Defence

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Abstract: The analysis provides insights regarding the suitability of offensive versus defensive measures in countering a terror cell. It is shown that the optimal allocation is more offensive when the cell is aware of which targets have been protected, but unable to distinguish between the values of different targets; than the case where it can neither distinguish between target values nor is the protection conspicuous. Also, the ability of the terror cell to inflict damage is least when it can neither distinguish between target values nor is the target protection conspicuous, and most when it can observe both target values and protection. Hence, from the counter-terrorism (CT) point of view, there seems to be a rationale in making target values and target protection inconspicuous to the extent possible. The paper finally deals with the possibility of diverging target valuations from the CT standpoint and that of the terror cell, and shows that if target protection is conspicuous to the cell and these are common knowledge, then the optimal CT allocation is at least as offensive as the case with identical valuation rankings.

Key words: terror cell; offensive and defensive measures; target value, target protection; counter-terrorism.

JEL Classifications: F52, D74, D78, C70.

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1. Introduction

Sandler (2005) defines terrorism as "*the premeditated use or threat of use of violence by individuals or sub-national groups to obtain a political or social objective through intimidation of a large audience beyond that of the immediate victims*". Terrorists operate both within and across borders, attempting to leave a trail of death and destruction, in order to create a fear-psychosis among people. It is therefore an endeavor of policy-makers and governments all over the world to restrict terrorism. For this purpose, they need to choose suitable counter-terrorism (CT) policies given their financial and operational constraints.

The linkages of global terrorism with income and geography on the one hand, and with politico-economic structures and frameworks on the other, have been analyzed at some length. In the former category, Enders and Sandler (2006) apply an autoregressive intervention model on data spanning 1968-2003 and surprisingly find a lack of evidence of income-based relocation of terror strikes to low-income countries after 9/11, while Barth, Li and McCarthy (2006) find that terrorism adversely impacts overall economic activity. In the latter category, Li (2005) shows that democratic involvement inhibits transnational terrorism, while Sandler and Siqueira (2007)[1] demonstrate that in light of the delegation problem arising in domestic politics where voters strategically choose a representative with preferences potentially different from their own, the *presumed oversupply* of defensive counter-terrorism measures by countries is curtailed.[2]

There have also been numerous works dealing with the co-ordination problem faced by countries when faced with a common terrorist threat. Arce and Sandler (2005) and Sandler (2005) demonstrate the rationale behind each country favoring defensive measures over offensive ones, relying on the nature of externalities generated on others by the type of measures implemented by a country. Das and Roy Chowdhury (2014) apply a game-theoretic model to identify circumstances which may render it logical to respond to increased terrorism with increased pre-emption. Analyzing a framework where the targeted country has interests both at

[1] Siqueira and Sandler (2007) also model the delegation problem arising in domestic politics, to derive similar results.

[2] See Mesquita (2005) for a model which incorporates moral hazard and learning, to illustrate the dynamics between the government and former terrorists.

home and abroad, Sandler and Siqueira (2006) show that leader-follower behavior reduces the inefficiency in deterrence while worsening the inefficiency in pre-emption, compared with the choices in the equilibrium with simultaneous moves. Bandyopadhyay and Sandler (2011) use a two-stage game involving two commonly targeted countries to demonstrate that market failures related to preemption and defense may be collectively mitigated by a handicapped defender.

Countering the scourge of terrorism effectively, however, necessitates an understanding of the organizational structure of terror modules, each operating in multiple hubs through the establishment of a network of terror cells. The present work is cognizant of this, and investigates the nature of the interplay between preemption and defense in CT within a single-defender framework, by focusing on the role of information available with the terrorists and counter-terrorists, and potential divergences in target preferences between the two sides. This is a major departure from the existent literature which, in its focus on multi-country/multi-defender frameworks and the associated issue of co-ordination against a common terrorist threat, largely ignores the salient impacts of information and varying perceptions about target-values even in the absence of co-ordination related dynamics.

Enders and Jindapon (2010) compare alternative network structures of terror outfits – centralized and decentralized – and conclude that because the individual nodes in the latter structure may not make optimal decisions from the group's standpoint, "*the decentralized decision-making process is suboptimal from the overall perspective of the network*". However, with the increased surveillance of the activities of a terror outfit and the purposeful targeting of its leadership, survival may have to be prioritized by the outfit rather than organizational efficiency, thereby forcing it to rely on a decentralized network. Such a trade-off between outfit-safety and intra-outfit correspondence is modeled by Enders and Su (2007), to establish the rationale for the formation of terror cells, which are the smallest units of decentralized networks of terrorists.

A terror cell or terrorist cell comprises of a small and cohesive group of usually three to five members. According to The Free Dictionary by Farlex, ensuring operational safety generally requires that adjoining terror cells be unaware of one another or the headship's identity. Different terror cells operating in a hub may be assigned specialized roles in enabling the smooth execution of a terror attack. *Planning* or *support* or *logistics* cells are responsible for fund-raising and provision of logistical support to *execution* cells. *Sleeper* or *submarine* or *dormant* cells may have resided in the target country for years, living like normal residents until activated. *Execution* cells enter the fray right towards the end, utilizing the resources and intelligence provided by other cells to conduct the attack.[3]

The following analysis seeks to provide insights regarding the optimal utilization of limited resources in thwarting the ability of terror cells to carry out an attack, in a situation where time is of the essence. Therefore, the scenario discussed is likely to describe a situation in which the planning and support cells have already played their part, all concerned sleeper cells have been activated, and the execution cells have entered the fray. Hence to prevent the attack, it would be necessary to either apprehend or eliminate the execution cells before they conduct the attack, or to correctly predict the intended target and provide it protection. The present study intends to compare the optimal resource allocation between attacking the possible hideouts of the terror cell and protecting its potential targets, under different scenarios in respect of the observability of protection afforded to the potential targets, and the ability of the terror cells to distinguish between the values of different targets.

According to Mueller et al. (2006), preemption is probable if adequate intelligence about the terrorists' names, whereabouts, or designs is obtainable. It is, however, important to note that not only is the quantum of intelligence *per se*, important in determining its *actionability* (whether preemption or protection is optimal), but also the quality and nature of inputs. For example, more specific intelligence about the potential whereabouts of the cell drastically reduces the number of potential hideouts which would need to be raided if preemption is chosen, thereby making preemption more likely *ceteris paribus*. Conversely, if the inputs are more specific about potential targets of the outfit, then defense becomes more attractive *ceteris paribus*. This aspect is captured in our framework, and is usually critical in determining the equilibrium allocation of CT resources between offence and defense.

[3] *Slate* (2001).

A retired Commander from the Los Angeles Sheriff's Department, Sid Heal (2011) classifies defensive actions such as vigilance instillation, threat identification, target protection, attack forecasting and damage control under the head of *anti-terrorism* (AT), and the endeavors applied to resist terrorists and determinedly prevent terror strikes under the head of *counter-terrorism*. He concludes that effectively tackling terrorism necessitates the application of both AT and CT. However, our findings suggest that while some amount of allocation to defense is usually optimal, pre-emptive measures may or may not be employed.

In similar vein, Das and Lahiri (2017) construct a three-period game where the terrorists use terror as *a means to an end*, and neither the State nor the terrorists are completely aware of the other's preferences. Hence, they conclude, it is impossible for the State to triumph in the *war on terror* using preemption alone, if the marginal cost of preemption is rising. Although our framework focuses on countering the threat posed by a terror cell, and not on a full-blown war on terror, its robustness lies in its ability to demonstrate the strong rationale underlying the above-stated *impossibility theorem* under different scenarios in respect of the conspicuity of CT target valuations and defensive allocation to the terror cell.

Bier, Oliveros and Samuelson (2007) allow for a divergence of preferences over targets between the defender and attacker such that the defender does not know the attacker's preferences, while the attacker observes the defender's resource allocation. Under these assumptions, they demonstrate that the defender prefers her allocation to be public rather than private. Our study, considers a similar scenario with diverging preferences, but with two key differences. Firstly, our structure allows for pre-emptive strikes against the terror cell (attacker) and secondly, the cell's preferences are common knowledge. Under these assumptions, we show that the optimal CT allocation under diverging preferences is at least as offensive as that under identical preferences, and the expected damage that the terrorists can cause under the diverging preferences does not exceed that under the identical preferences.

The present paper, under different assumptions relating to the observability of target valuations and protection (defensive allocation), attempts to study and compare the nature of optimal resource allocations between offence and defense. It demonstrates that if target valuations from the CT point-of-view cannot be observed by the cell, then the optimal allocation is at least as offensive if the terror cell can observe which targets are protected, than if it cannot. Moreover, it is shown that the terror cell's ability to inflict damage is least when it can neither distinguish between target values nor observe target protection, and most when it can observe both target values and protection.

In Section 2, we provide the basic model and results, given the valuations of the targets. Section 3 addresses the possibility of the terror cell having different target valuations than those from the CT perspective. Section 4 summarizes and discusses the implications of the results. All proofs and calculations are relegated to the appendices.

2. Model

Consider a terror cell located in a specified geographic area, having M possible hideouts and N potential targets T_1, T_2,…., T_N. Let the values of these targets be v_1, v_2,…., v_N respectively from the CT standpoint, such that $v_1 > v_2 > \cdots > v_N$. These valuations may or may not be known to the cell. Suppose the cell requires only one hideout, and has the capability to attack only a single target. Let R be the CT resource endowment, the cost of pre-emptively attacking any hideout be unity (numeraire)[4], and α be the cost of defending any potential target. We assume $R < M$ and $R < \alpha N$, so that the CT resource endowment is such that neither can all possible hideouts be attacked, nor can all potential targets be defended. Then, if m and n denote the number of possible hideouts pre-emptively attacked and the number of potential targets defended respectively, the CT budget constraint is

$$R = m + n\alpha \tag{1}$$

The CT objective is to minimize the expected damage inflicted by the terror cell, by choosing m and n subject to (1). The terror cell's objective is just the converse, which is to inflict the maximum possible damage by choosing an appropriate target. We assume that if the correct hideout is attacked pre-emptively, the terror cell is neutralized before it can carry out an

[4] Hence α, in effect, is the CT cost of defense relative to the CT cost of attack.

attack, and the game ends. Otherwise, the cell conducts an attack on its chosen target. If the designated target is protected, the attack is foiled. If not, the attack succeeds. Moreover, the structure of the strategic interaction is assumed to be common knowledge. We consider the following scenarios:

1. Cell can observe neither target values, nor target protection,
2. Cell can observe target protection, but not target values, and
3. Cell can observe both target values and target protection.

Proposition 1: *The optimal CT allocation is at least as offensive in Scenario 2, as it is in Scenario 1.*

The proof of the proposition is given in Appendix 1. Proposition 1 is a direct consequence of the fact that when target valuation is inconspicuous, if the target protection can be observed by the cell (Scenario 2), then the ability to defend against a terror strike effectively is compromised compared to the case where target protection is inconspicuous (Scenario 1). This is because if target protection is conspicuous to the cell, it will not attack a protected target if it survives the pre-emptive strikes. This ensures a successful terror attack if the cell survives the pre-emptive strikes because, by assumption, the CT resource endowment is not large enough to protect all targets. It is for this reason that pre-emptively attacking hideouts has greater appeal in Scenario 2.

Proposition 2: *Expected damage is highest in Scenario 3, and lowest in Scenario 1.*

The proof is outlined in Appendix 2. In Scenario 1, even if the outfit survives pre-emptive CT strikes, it may end up attacking a defended target due to lack of information on target protection. In Scenarios 2 and 3, such an outfit (which has survived pre-emptive CT strikes) would successfully carry out an attack because target protection is conspicuous. Moreover, in Scenario 3, the outfit would successfully be able to attack the most valuable unprotected target, because it can observe the values of different targets in addition to the protection afforded to each of them. Proposition 2 follows as a consequence.

This result is in sharp contrast to Bier, Oliveros and Samuelson (2007), who argue that making the defensive allocation public may be in the *defender*'s interests. Their result, however, is obtained by assuming that the *attacker* (the terror cell, in the present framework) has a non-trivial *outside option*. If there is no such alternative avenue which can yield higher utility to the terrorists, as in our model, then Proposition 2 holds. The absence of such an *outside option* is in fact a reasonable assumption under the circumstances considered here, given that terror cells can seldom be deactivated at such an advanced stage of a terrorist operation, such as one where the *execution cells* have already entered the picture.

The proposition below rationalizes the ubiquity of defensive CT allocation in real-world scenarios.

Proposition 3: *Let* $\tilde{n}(\leq \left[\frac{R}{\alpha}\right])$ *be a finite number of targets (from the set of all valuable targets arranged in descending order by value, starting from the most valuable) with cumulative value* $\tilde{v}$*, and* m^* *be the optimal number of potential hideouts to be pre-emptively attacked from the CT standpoint. Let the cumulative value of the remaining targets be* $\hat{v}$*, so that* $\sum_{i=1}^{N} v_i = \sum_{i=1}^{\tilde{n}} v_i + \sum_{i=\tilde{n}+1}^{N} v_i = \tilde{v} + \hat{v}$*. If* $\frac{\tilde{v}}{\hat{v}}$ *is high enough, then* $m^* < R$ *in Scenarios 1 and 2. Also, if* $\frac{v_1}{v_{\tilde{n}+1}}$ *is high enough, then* $m^* < R$ *in Scenario 3.*

The proof of the proposition is given in Appendix 3. In scenarios where target values are inconspicuous to the cell, if the targets in a particular subset of targets of value (arranged in descending order, starting from the most valuable) can be protected given the CT resources available, then if the subset is valuable enough compared to its complement, allocating at least some part of the CT resources to defense is optimal. This is because the opportunity cost of not protecting targets which are very valuable compared to other targets, and which can be protected, is very high. To understand this, note that even given a higher CT allocation to offence at the cost of leaving some of such high-value targets unprotected, the cost that the terror cell can inflict if it survives the pre-emptive strikes is prohibitively high, thereby making such an allocation very risky. This ensures the absence of all-out offence in equilibrium. In Scenario 3, a similar result intuitively follows if the value of the most valuable target is sufficiently higher than the value of the most valuable target in the complement of the subset, since target values are conspicuous to the cell in addition to target protection. To understand this, note that if T_1 and other targets of very high value compared to $T_{\tilde{n}+1}$ are not protected for example, then once again we have the possibility of the terror cell inflicting prohibitively high damage if it escapes the pre-emptive strikes. In fact, the opportunity cost here is even higher than that in Scenarios 1 and 2 because both target protection and target values are conspicuous to the cell, thereby ensuring that it will attack the most valuable unprotected target on surviving the pre-emptive strikes.[5]

The omnipresence of defensive measures in combating terrorists, indicated by Proposition 3, is in similar flavor to a significant body of existing literature on terrorism. Although under different frameworks and assumptions than ours, the anecdotal evidence in Heal (2011), the three-stage game characterization of a country's *war on terror* in Das and Lahiri (2017), etc., all point towards the critical role of defensive CT.

We now illustrate the above-stated propositions by constructing numerical examples. We fix the values of various parameters to check the results. Detailed calculations are relegated to Appendix 4.

Example 1: Let $N = 4$, $\alpha = 2$, $R = 4$ and $M = 5$ with $(v_1, v_2, v_3, v_4) = (40, 7, 6, 5)$, then a unique interior solution is obtained in Cases 1 and 3 with $n^* = 1$ and $m^* = 2$, whereas a unique corner solution is obtained in Case 2, where resources are only spent on pre-emptively striking the potential terror hideouts, i.e., $n^* = 0$ and $m^* = 4$. Also, the expected damage caused by the terror cell in Cases 1, 2 and 3 are 2.7, 2.9 and 4.2 respectively. It is immediately evident, therefore, that the results are in conformity with Propositions 1 and 2. Moreover, if $v_1 = 200$ instead of the earlier $v_1 = 40$, then the optimal values of n and m remain unchanged in Cases 1 and 3, but $n^* = 1$ and $m^* = 2$ in Case 2, instead of $n^* = 0$ and $m^* = 4$. The results, therefore, are also in conformity with Proposition 3.

Example 2: Now consider the case where $N = 3$, $\alpha = 2$, $R = 4$ and $M = 5$ with $(v_1, v_2, v_3) = (40, 7, 6)$. A corner solution is obtained in Case 1, where all CT resources are used for defense,

[5] This is in accordance with Proposition 2.

i.e., $n^* = 2$ and $m^* = 0$. The other corner solution is obtained in Case 2, with all CT resources used for offence, i.e., $n^* = 0$ and $m^* = 4$. Finally, a unique interior solution is obtained in Case 3, with $n^* = 1$ and $m^* = 2$. Also, the expected damage caused by the terror cell in Cases 1, 2 and 3 are 2, 3.5 and 4.2 respectively. It is immediately evident, therefore, that the results are in conformity with Propositions 1 and 2. Moreover, if $v_1 = 200$ instead of the earlier $v_1 = 40$, then the optimal values of n and m remain unchanged in Cases 1 and 3, but $n^* = 1$ and $m^* = 2$ in Case 2, instead of $n^* = 0$ and $m^* = 4$. The results, therefore, are also in compliance with Proposition 3.

3. Differing Valuations

In this situation, we consider the possibility that the terror cell's target valuations may differ from those of the CT authorities. However, the valuations of the terror cell are assumed to be common knowledge. We also assume that the protection afforded to the targets is common knowledge.

For the targets T_1, T_2,…., T_N; let the cell's valuations be V_1, V_2,…., V_N where $V_1 > V_2 > \cdots > V_N$. Let v_1, v_2,…., v_N be the CT authority's valuations. If all CT resources are allocated to defense, then let S_0 be the set of targets defended if defensive allocation is granted in descending order of the terror cell's target valuations. It is reasonable to defend targets in descending order of valuation, since the cost of defending each target is the same and equal to α, and therefore the CT focus will be on defending more valuable targets first. So, $S_0 = \left\{T_1, T_2, \dots, T_{\left[\frac{R}{\alpha}\right]}\right\}$, where $\left[\frac{R}{\alpha}\right]$ is the largest integer in $\frac{R}{\alpha}$. Given the CT budget if S_0 is protected, the cell will attack $T_{\left[\frac{R}{\alpha}\right]+1}$, inflicting damage worth $v_{\left[\frac{R}{\alpha}\right]+1}$. Let $T_{min}^{S_0}$ be the least valuable target in S from a CT standpoint, i.e., $v_{min}^{S_0} = min\ v_i$, for all $T_i \in S_0$. Now construct the set $S_1 \subseteq S_0$, with targets in descending order of the terror cell's valuations up to the target $T_{min-1}^{S_0}$. So, $S_1 = \left\{T_1, T_2, \dots, T_{min-1}^{S_0}\right\}$. Let $T_{min}^{S_1}$ be the least valuable target in S_1 from a CT standpoint, i.e., $v_{min}^{S_1} = min\ v_i$, for all $T_i \in S_1$. Let the cardinality of S_1 be n_1, that is, $T^{S_0}_{min-1} = T_{n_1}$. In this way, we can define S_r, $r = 0, 1, 2, \dots$ There are the following two possibilities:

<u>Case 1</u>: $v^{S_0}_{min} < v_{\left[\frac{R}{\alpha}\right]+1}$.

This ensures that defending S_0 is not optimal from a CT standpoint because if S_1 is protected instead, the expected damage will be $\left(\frac{M-R+\alpha n_1}{M}\right) v^{S_0}_{min} < v_{\left[\frac{R}{\alpha}\right]+1}$. Construct $S_2 = \{T_1, T_2, \dots, T^{S_1}_{min-1}\}$, where the cardinality of S_2 is n_2, that is, $T^{S_1}_{min-1} = T_{n_2}$. Compared to defending S_1, $n_1 - n_2$ additional targets are left undefended if S_2 is defended. This leads to an incremental CT resource-saving of $\alpha(n_1 - n_2)$, which can be utilized to preemptively attack $\alpha(n_1 - n_2)$ additional potential hideouts. Since it is optimal to defend fewer than the $\left[\frac{R}{\alpha}\right]$ targets in S_0, the optimal number of targets to defend must be a subset of S_1. This is because the best way to defend fewer targets than in S_0, must begin with leaving $T^{S_0}_{min}$ unprotected. This would therefore become the most valuable undefended target from the cell's perspective. However, all targets in S_0 following $T^{S_0}_{min}$, that is, $T^{S_0}_{min+1}, T^{S_0}_{min+2}, \dots, T_{\left[\frac{R}{\alpha}\right]}$, are less valuable for the cell than $T^{S_0}_{min}$. Hence, these can be left undefended without any additional risk, since the terror cell's optimal target choice would remain $T^{S_0}_{min}$. Moreover, it costs α to defend each of these targets. Therefore, the resources saved can be utilized for preemptively striking potential hideouts. Hence, if defending S_0 is not optimal, then the set of optimally defended targets should either be S_1, or a proper subset of S_1. Similarly, it can be shown that if it is optimal to defend any fewer than the n_1 targets in S_1, then the optimal number of targets to defend must be a subset of S_2, and so on. So the change in expected damage at the margin, on defending S_2 instead of S_1, is $D_2 = \left(\frac{M-R+\alpha n_2}{M}\right) v_{n_2+1} - \left(\frac{M-R+\alpha n_1}{M}\right) v_{n_1+1}$.[6] If $D_2 \geq 0$, then it is optimal to defend S_1. Otherwise, we construct $S_3 = \{T_1, T_2, \dots, T^{S_2}_{min-1}\}$, where the cardinality of S_3 is n_3, that is, $T^{S_2}_{min-1} = T_{n_3}$. Then we check whether $D_3 = \left(\frac{M-R+\alpha n_3}{M}\right) v_{n_3+1} - \left(\frac{M-R+\alpha n_2}{M}\right) v_{n_2+1}$, is non-negative or not, and so on. For some integer r, if $D_1, \dots, D_r$ are negative but $D_{r+1} \geq 0$, then it is optimal to defend S_r. Here,

[6] The expression for D_1, the marginal expected damage on defending S_1 instead of S_0, is given in Case 2 below.

$D_{r+1} = \left(\frac{M-R+\alpha n_{r+1}}{M}\right) v_{n_{r+1}+1} - \left(\frac{M-R+\alpha n_r}{M}\right) v_{n_r+1}, \quad \forall r: 0 < r < \left\lfloor\frac{R}{\alpha}\right\rfloor$. If $D_1, \ldots, D_{\left\lfloor\frac{R}{\alpha}\right\rfloor}$ are all negative, however, then it is optimal to allocate all resources towards offence.

Case 2: $v_{min}^{S_0} > v_{\left\lfloor\frac{R}{\alpha}\right\rfloor+1}$.

In this case, from the CT perspective, the least valuable target in S_0 is more valuable than the most valuable target outside S_0 from the terror cell's perspective. Hence, if defending all targets in S_0 is suboptimal from a CT standpoint, then the set of optimally defended targets should either be S_1, or a proper subset of S_1.[7] The change in expected damage at the margin, on defending S_1 instead of S_0, is $D_1 = \left(\frac{M-R+\alpha n_1}{M}\right) v_{n_1+1} - \left(\frac{M-R+\alpha\lfloor R/\alpha\rfloor}{M}\right) v_{\left\lfloor\frac{R}{\alpha}\right\rfloor+1}$. If $D_1 \geq 0$, then S_0 is the set of optimally defended targets. Else, we check the sign of D_2, and so on. In general, for some integer $r \in [0, \left\lfloor\frac{R}{\alpha}\right\rfloor)$, if $D_0, \ldots, D_r$ are negative but $D_{r+1} \geq 0$, then it is optimal to defend S_r. If $D_1, \ldots, D_{\left\lfloor\frac{R}{\alpha}\right\rfloor}$ are all negative, then as in Case 1, it is optimal to allocate all resources towards offence.

Special Cases:

1. Suppose all targets are valued identically from a CT perspective, that is, $v_1 = v_2 = \cdots = v_N = v$ (say). Then if the terror cell is able to conduct a successful attack on any undefended target, the damage would be the same, that is v. Hence, defending any particular subset of targets is suboptimal, since the cell can observe the CT defensive allocation. Therefore, the optimal allocation is to allocate all CT resources to preemptively striking potential hideouts of the terror cell, that is $(m^*, n^*) = (R, 0)$. This is because a) there are not enough resources to defend all of the equally valuable targets, and b) the damage is limited to v if the cell manages to survive the preemptive strikes.
2. Suppose the valuation-ranking of the targets from the CT standpoint is the same as that from the cell's perspective, that is, $v_1 > v_2 > \cdots > v_N$. If an interior solution exists (where some targets are defended as well as some potential hideouts are preemptively attacked), then the defensive CT allocation is afforded in descending order of value to targets starting from the most valuable, till the marginal utility from defense continues to exceed that from preemptive strikes.

[7] This is as discussed in Case 1.

3. Suppose the target valuation ranking from the CT perspective, is diametrically opposite to that of the terror cell, that is, $v_1 < v_2 < \cdots < v_N$. If the cell survives the preemptive strikes, then it would optimally attack the least valuable target from the CT perspective (T_1), since this is the most valuable target from the cell's perspective. So limited CT resources need not be spent protecting other targets. Moreover, there is no CT incentive in changing the cell's target choice by protecting its most valuable target (T_N), since this is the least valuable target from the CT standpoint. Hence the optimal CT allocation, as when all targets are equally valuable from a CT standpoint, is to use all CT resources for preemptively attacking potential terror hideouts. So, $(m^*, n^*) = (R, 0)$.

In addition to the above extreme cases, we conclude this section with a stronger assertion comparing the cases of identical valuations and differing valuations of potential targets, stated in the proposition below.

Proposition 4: *Suppose the target valuation ranking of the terror cell is different from the CT ranking, target protection is conspicuous to the terror cell, and these are common knowledge. Then the optimal CT allocation is at least as offensive as the case with identical valuation rankings. Moreover, the expected damage does not exceed that in the case with identical valuation rankings.*

The result is novel, and it draws from the three special cases mentioned above. The formal proof is in Appendix 5. If the target valuation rankings differ, the CT authorities may not have to defend certain targets which they would have to under identical preferences, given their own preferences across targets. This is because these targets may not be valuable enough any longer, from a CT perspective. And any resources saved as a result can be optimally utilized for pre-emptive strikes on potential hideouts, thereby entailing a CT allocation which is at least as offensive as that under identical valuation rankings, and with expected damage that is no greater than that under identical rankings.

4. Conclusion

The present analysis attempts to derive insights regarding the optimal utilization of limited CT resources, to counter terror cells, in scenarios where time is of the essence in being able to thwart a successful attack by the terrorist(s). Since the decision to conduct an attack has been taken at an earlier stage, which is not within the scope of this study, it is taken as a *fait accompli*. Consequently, it is observed that in scenarios where the cell is better informed about the targets, the cell is at least as lethal as in scenarios where it has less information about the targets.[8] Hence, there appears to be a CT rationale for suppressing target information from the terror cell, by making target protection wholly or partially inconspicuous for example. In reality however, the ability to suppress target information may be costly, and therefore not achievable to the desired extent. Also, if better intelligence for CT is available in respect of the possible hideouts, as characterized by a lower number of possible hideouts (M) for example, then pre-emptive strikes become more attractive. This is along the lines of Mueller et al. (2006), as alluded to in the introduction. For a framework which determines intelligence endogenously, see Arce and Sandler (2007). The study characterizes terrorist attacks as signals, where the government is uncertain whether it is confronted by a politically motivated or a militant outfit, in order to illustrate the possibility of ex-post regret and the consequent value of intelligence in CT.

The findings of this paper must be viewed in the backdrop of the lack of analyses of counter-terrorism frameworks in general, and terror cells in particular, with specific focus on comparison of different scenarios in terms of the conspicuity of target information. This is despite the existence of a sizeable literature on the broad topic of terrorism, addressing a myriad of issues ranging from the linkages of terrorism to income, geography and politico-economic structures, to the problem of co-ordination failure encountered by countries in the provision of counter-terrorism effort when faced with a common terrorist threat. For instance, the third proposition must be viewed in context of the widespread finding that in the event of almost any terrorist threat, protection is afforded to at least a few potential targets of high enough value. This result provides a theoretical foundation for the ubiquity of defensive measures in countering

[8] The present study therefore illustrates the importance of intelligence regarding the potential targets, in determining the lethality of the terror cell.

terror cells, under different assumptions relating to the conspicuity of target information. This is along the lines of Das and Lahiri (2017), who demonstrate a similar result in the context of a State-waged anti-terror campaign.

Proposition 3 also provides an insight into why the allocation of CT resources may be *suboptimal* from a social perspective, if the number of persons (potential targets) accorded VIP status (high value from the State's perspective) is large. The consequent allocation would tend to divert valuable CT resources to VIP protection, rather than their optimal use in pre-emptive actions against the terror cell, for example. Such allocational inefficiencies are seemingly linked to the kind of delegation problem arising in domestic politics discussed in Sandler and Siqueira (2007) and Siqueira and Sandler (2007). Similarly, CT allocation in an egalitarian society may be more offensive than in a society where there is a minority elite section co-existing with less-privileged masses.

Finally, and most interestingly, the present work provides the rationale for and demonstrates the greater offensive orientation of CT policy, when the CT preferences over the potential targets diverge from those of the terror cell. The framework improves upon that applied by Bier, Oliveros and Samuelson (2007) by providing an additional CT policy lever. This is achieved by allowing for the possibility of conducting pre-emptive strikes on the potential hideouts of the terror cell. This is, in fact, the crucial feature which enables the current structure to demonstrate the increased effectiveness of offensive counter-terrorism under diverging target preferences. An interesting extension would be to check the robustness of this result in a scenario where the preferences of the terrorists are their private information.

Appendix 1: Proof of Proposition 1

In order to prove the first two propositions we characterize a strictly decreasing and differentiable target valuation function $v(.)$, $v'(.) < 0$, defined over the interval $[0, N]$. Let n_1^* and n_2^* be the optimal CT choices in Scenarios 1 and 2, respectively. In Scenario 1, the terror cell neither knows the target values, nor can it observe which targets are protected. So it randomly selects a target. Hence, in order to minimize the expected damage, the authorities will protect the highest-value targets – 1 to n. If the cell attacks any of these n protected targets, then there is no damage because the attack will be thwarted. So the expected damage when the cell randomly chooses a target from the set of all N targets, is $\left(\frac{M-R+\alpha n}{M}\right)\frac{1}{N}\int_n^N v(t)dt$, where $\left(\frac{M-R+\alpha n}{M}\right)$ is the probability that the cell survives the pre-emptive CT strike on hideouts, and $\frac{1}{N}\int_n^N v(t)dt$ is the expected damage from a terror strike if the cell randomizes over all targets of value. The derivative of the expected damage with respect to n is $\frac{1}{N}\left\{\frac{\alpha}{M}\int_n^N v(t)dt - \left(\frac{M-R+\alpha n}{M}\right)v(n)\right\} \equiv C_1$. To ensure that the second order condition (SOC) for convexity holds over the interval of feasible n, we assume $\frac{1}{NM}[-2\alpha v(n) - (M - R + \alpha n)v'(n)] > 0$ for all $n \,\varepsilon\, [0, R/\alpha]$.

In Scenario 2, since the terror cell can observe target protection but is again unable to distinguish between target values, the authorities once again optimally protect the highest-value targets – 1 to n. However, unlike in Scenario 1, the cell randomizes only over the remaining $N - n$ unprotected targets. Hence, the expected damage is $\left(\frac{M-R+\alpha n}{M}\right)\frac{1}{N-n}\int_n^N v(t)dt$, where $\frac{1}{N-n}\int_n^N v(t)dt$ is the expected damage from a terror strike if the cell randomizes over all unprotected targets of value. The derivative of the expected damage with respect to n is $\frac{N}{N-n}C_1 + \frac{N}{(N-n)^2}\left(\frac{M-R+\alpha n}{M}\right)\frac{1}{N}\int_n^N v(t)dt \equiv C_2 > C_1$. The SOC here is $\frac{1}{M}\left[\frac{2\alpha}{(N-n)^2}\int_n^N v(t)dt - \frac{2\alpha}{N-n}v(n) + \frac{M-R+\alpha n}{(N-n)^3}\int_n^N v(t)dt - 2\frac{M-R+\alpha n}{(N-n)^2}v(n) - \frac{M-R+\alpha n}{N-n}v'(n)\right] > 0$ for all $n \,\varepsilon\, [0, R/\alpha]$. If either $C_1 = 0$ or $C_2 = 0$ in $(0, R/\alpha)$, then $n_1^* > n_2^*$. If $C_1 > 0$ at $n = 0$, then $C_2 > C_1 > 0$ at $n = 0$ and hence $n_1^* = n_2^* = 0$. If $C_2 < 0$ at $n = R/\alpha$, then $C_1 < C_2 < 0$ at $n = R/\alpha$ and hence $n_1^* = n_2^* = R/\alpha$. Finally, if $C_2 > 0$ at $n = 0$ and $C_1 < 0$ at $n = R/\alpha$, then $n_1^* = 0 < R/\alpha = n_2^*$. Hence the proof.

Q.E.D.

Appendix 2: Proof of Proposition 2

The expected damage in Scenario 3 is $\left(\frac{M-R+\alpha n}{M}\right)v(n)$. Then comparing the expected damage under different scenarios, we get $\left(\frac{M-R+\alpha n}{M}\right)v(n) > \left(\frac{M-R+\alpha n}{M}\right)\frac{1}{N-n}\int_n^N v(t)dt > \left(\frac{M-R+\alpha n}{M}\right)\frac{1}{N}\int_n^N v(t)dt$, the latter two terms being the expected damages in Scenarios 2 and 1, respectively. Hence the proof.

Q.E.D.

Appendix 3: Proof of Proposition 3

Let $\bar{v}$ be the average value of all targets. Then $\bar{v} = \frac{\tilde{v}+\hat{v}}{N}$. If the CT allocation is purely offensive, the expected damage is $\left(\frac{M-R}{M}\right)\bar{v} = \left(\frac{M-R}{M}\right)\frac{\tilde{v}+\hat{v}}{N}$ in Scenarios 1 and 2, and $\left(\frac{M-R}{M}\right)v_1$ in Scenario 3. If, however, $\tilde{n}$ targets are protected, then the expected damage is $\left(\frac{M-R+\alpha\tilde{n}}{M}\right)\frac{1}{N}\sum_{i=\tilde{n}+1}^{N} v_i = \left(\frac{M-R+\alpha\tilde{n}}{M}\right)\frac{\hat{v}}{N}$ and $\left(\frac{M-R+\alpha\tilde{n}}{M}\right)\frac{1}{N-\tilde{n}}\sum_{i=\tilde{n}+1}^{N} v_i = \left(\frac{M-R+\alpha\tilde{n}}{M}\right)\frac{\hat{v}}{N-\tilde{n}}$ in Scenarios 1 and 2, respectively. Also, the expected damage is $\left(\frac{M-R+\alpha\tilde{n}}{M}\right)v_{\tilde{n}+1}$ in Scenario 3. From the above, it is follows that the necessary and sufficient conditions for $m^* < R$ to hold are $\frac{\tilde{v}}{\hat{v}} > \frac{\alpha\tilde{n}}{M-R}$, $\frac{\tilde{V}}{V} > \frac{1+\frac{\alpha N}{M-R}}{\frac{N}{\tilde{n}}-1}$ and $\frac{v_1}{v_{\tilde{n}+1}} > 1 + \frac{\alpha\tilde{n}}{M-R}$ in Scenarios 1, 2 and 3 respectively.

Q.E.D.

Appendix 4: Calculations of the solutions of the examples in Section 3

The expected damage in Case 1 is given by $\left(\frac{M-R+\alpha n}{M}\right)\frac{1}{N}\sum_{i=n+1}^{N} v_i$. Substituting $N = 4$, $\alpha = 2$, $R = 4$ and $M = 5$ with $(v_1, v_2, v_3, v_4) = (40, 7, 6, 5)$, the expected damage is:

- $\frac{1}{5}.\frac{1}{4}.58 = 2.9$, when $n = 0$,
- $\frac{3}{5}.\frac{1}{4}.18 = 2.7$, when $n = 1$, and
- $1.\frac{1}{4}.11 = 2.75$, when $n = 2$.

Since the expected damage is lowest when $n = 1$, it is the optimal choice.

The expected damage in Case 2 is given by $\left(\frac{M-R+\alpha n}{M}\right)\frac{1}{N-n}\sum_{i=n+1}^{N} v_i$. Substituting $N = 4$, $\alpha = 2$, $R = 4$ and $M = 5$ with $(v_1, v_2, v_3, v_4) = (40, 7, 6, 5)$, the expected damage is:

- $\frac{1}{5}.\frac{1}{4}.58 = 2.9$, when $n = 0$,
- $\frac{3}{5}.\frac{1}{3}.18 = 3.6$, when $n = 1$, and
- $\frac{1}{2}.11 = 5.5$, when $n = 2$.

Since the expected damage is lowest when $n = 0$, it is the optimal choice.

The expected damage in Case 3 is given by $\left(\frac{M-R+\alpha n}{M}\right)\frac{1}{N}\sum_{i=n+1}^{N} v_i$. Substituting $N = 4$, $\alpha = 2$, $R = 4$ and $M = 5$ with $(v_1, v_2, v_3, v_4) = (40, 7, 6, 5)$, the expected damage is:

- $\frac{1}{5}.40 = 8$, when $n = 0$,
- $\frac{3}{5}.7 = 4.2$, when $n = 1$, and
- 6, when $n = 2$.

Since the expected damage is lowest when $n = 1$, it is the optimal choice. The above results conform to Propositions 1 and 2.

On replacing $v_1 = 40$ with $v_1 = 200$, the expected damage in Case 1 is:

- $\frac{1}{5}.\frac{1}{4}.218 = 10.9$, when $n = 0$,
- $\frac{3}{5}.\frac{1}{4}.18 = 2.7$, when $n = 1$, and
- $1.\frac{1}{4}.11 = 2.75$, when $n = 2$.

Since the expected damage is lowest when $n = 1$, it is still the optimal choice.

On replacing $v_1 = 40$ with $v_1 = 200$, the expected damage in Case 2 is:

- $\frac{1}{5}.\frac{1}{4}.218 = 10.9$, when $n = 0$,
- $\frac{3}{5}.\frac{1}{3}.18 = 3.6$, when $n = 1$, and
- $\frac{1}{2}.11 = 5.5$, when $n = 2$.

Since the expected damage is lowest when $n = 1$, it is the optimal choice, instead of $n = 0$ when $v_1 = 40$. It can also be easily verified that the optimal choice remains unchanged in Case 3, just as in Case 1. Hence, the results conform with Proposition 3.

The calculations for the case where $N = 3$, $\alpha = 2$, $R = 4$ and $M = 5$ with $(v_1, v_2, v_3) = (40, 7, 6)$ is similar, and left to the interested reader.

Appendix 5: Proof of Proposition 4

For the targets T_1, T_2,…., T_N; let the cell's valuations be V_1, V_2,…., V_N where $V_1 > V_2 > \cdots > V_N$. Let v_1, v_2,…., v_N be the CT authority's valuations.

Claim: $S_r \subseteq P_r \equiv \left\{T_1, T_2, \dots, T_{\left\lceil\frac{R}{\alpha}\right\rceil - r}\right\}$, $\forall r \in [0, \left\lceil\frac{R}{\alpha}\right\rceil)$, where r is an integer.

Proof: The claim obviously holds for $r = 0$, since $S_0 \subseteq S_0 = P_0$, because every set is a subset of itself. And by construction, for any $r \in (0, \left\lceil\frac{R}{\alpha}\right\rceil)$, $T_{\left\lceil\frac{R}{\alpha}\right\rceil - r + 1}, T_{\left\lceil\frac{R}{\alpha}\right\rceil - r + 2}, \dots, T_{\left\lceil\frac{R}{\alpha}\right\rceil}$ must be excluded from S_0 to obtain S_r. And hence follows the claim.

Suppose the CT valuations share the same ranking as the cell's valuations, that is, $v_1 > v_2 > \cdots > v_N$. Then $S_r = P_r$ $\forall r \in [0, \left\lceil\frac{R}{\alpha}\right\rceil)$, since no target other than $T_{\left\lceil\frac{R}{\alpha}\right\rceil - r + 1}, T_{\left\lceil\frac{R}{\alpha}\right\rceil - r + 2}, \dots, T_{\left\lceil\frac{R}{\alpha}\right\rceil}$ shall be excluded in order to obtain S_r from S_0. For some $r \in [0, \left\lceil\frac{R}{\alpha}\right\rceil)$, if P_r is optimally defended under identical rankings, then differing valuation rankings may enable additional targets belonging from P_r to be left undefended if their CT value does not exceed $v_{\left\lceil\frac{R}{\alpha}\right\rceil - r + 1}$. In other words, these targets are being left undefended without any increase in the damage that the cell can inflict if it survives pre-emptive strikes. This, in fact, is how one arrives at S_r from P_r. And any resources saved in this manner will be optimally utilized offensively. So the set of optimally defended targets under differing rankings must be a subset of S_r, which itself is a subset of P_r. Since $r \in [0, \left\lceil\frac{R}{\alpha}\right\rceil)$ was chosen arbitrarily, it follows from the claim that the set of optimally defended targets under differing valuation rankings is a subset of the set of optimally defended targets under identical rankings, and therefore the optimal CT allocation under differing valuation rankings is at least as offensive as that under identical rankings.

Finally, it can easily be demonstrated that if all-out offence is optimal under $v_1 > v_2 > \cdots > v_N$, then it must also be optimal under all other CT valuation orderings. This is left to the interested reader.

Now we turn our attention to the expected damage. Suppose for some $r \epsilon \left[0, \left[\frac{R}{\alpha}\right]\right)$, defending P_r is optimal under identical valuation rankings. Now consider the possibility of an arbitrary change in the CT valuation ranking. Now since S_r (a subset of P_r) can be defended without risking higher damage if the cell survives pre-emptive strikes, and any resources so saved can be used for additional pre-emptive strikes, the probability of the outfit surviving the pre-emptive strikes shall be no greater than that when P_r is defended. This ensures that the expected damage the terror cell can cause on defending S_r does not exceed that on defending P_r. And as argued above, because the optimally defended set under differing allocations is a subset of S_r, the expected damage associated with this set does not exceed that associated with defending S_r. Since $r \epsilon \left[0, \left[\frac{R}{\alpha}\right]\right)$ was chosen arbitrarily, it follows that the expected damage under differing rankings does not exceed that under identical rankings. This completes the proof.

Q.E.D.

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