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# THE IMPACT OF SOCIETAL RISK ATTITUDES ON TERRORISM AND COUNTERTERRORISM

PAAN JINDAPON* AND WILLIAM S. NEILSON

We analyze decisions made by a group of terrorists and a target government in a zero-sum game in which the terrorists minimize, and the government maximizes, the expected utility of the median voter in the target country. The terrorists' strategy balances the probability and the severity of the attack while the government chooses the level of investment reducing the probability and/or mitigating the severity of attacks. We find that risk aversion affects the strategies of both the government and the terrorists, leading to more severe, less frequent attacks but not necessarily more counterterrorism expenditures.

## 1. INTRODUCTION

THE U.S. GOVERNMENT defines terrorism as the use of either violent attacks or the threat of violent attacks to provoke fear and intimidation among a target population with the ultimate goal of affecting policy change, typically in furtherance of some political, social, or ideological objective.[1] In response to a threat of terrorism, the government of the target country may undertake costly actions that help prevent attacks or mitigate their severity.

In this paper, decisions to commit acts of terrorism and to engage in counterterrorism activities are modeled as a two-person zero-sum game. The terrorists choose the probability and severity of attacks to minimize the expected utility of the median voter in the target country in order to maximize pressure on that government to make a policy change, an assumption we defend in a later section. Opposing them is the government of the target country, which chooses the amount to spend on counterterrorism activities with the objective of maximizing the expected utility of the median voter. These defensive counterterrorism activities can either prevent attacks, mitigate their severity, or both, depending on the setting.

Our game between the government and the terrorist can be thought of as a generalization of the Colonel Blotto game.[2] In the Colonel Blotto game,

*Corresponding author: Paan Jindapon, Department of Economics, Finance and Legal Studies, University of Alabama, Tuscaloosa, AL 35487-0224, USA. E-mail: pjindapo@cba.ua.edu

[1]This definition is based on the ones used by the Department of Defense, the FBI, and the U.S. Code of Regulations. Enders and Sandler (1995) use a definition essentially identical to that of the government, defining terrorism as "the 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." See also the discussion in Krueger and Maleckova (2003).

[2]See Roberson (2006) for a recent discussion on the Colonel Blotto game.

 

two players simultaneously allocate a given level of resources across $n$ locations. The player who allocates more resources in each location wins the battle in that location and earns $1/n$ for each victory. In our game, the terrorist has a fixed quantity of resources to allocate between the two features of terrorism (frequency and severity), while the government chooses the optimal level of counterterrorism. Both games are zero-sum. Unlike the Colonel Blotto game, however, here the level of severity of an attack is continuous and not tied directly to the value of the target being attacked, and here more severe attacks must occur with lower frequency, where in the Colonel Blotto game the probability of attack is determined by a mixed strategy equilibrium. Finally, and importantly, risk attitudes play an important role in this game but not in the Colonel Blotto game.

Once one takes the terrorists' resource constraint and the nature of the government's counterterrorism activities as given, the equilibrium of the game is driven by the risk attitudes of the median voter in the target country.[3] We find that as the median voter becomes more risk averse the terrorists choose to conduct a campaign of more severe, less frequent attacks. If the counterterrorism activity is mitigating, increased risk aversion leads to increased counterterrorism expenditures, but if the activity is preventative the impact of increased risk aversion is ambiguous. Interestingly, though, in the risk-neutral case the terrorists choose a campaign that induces the greatest counterterrorism activity, regardless of whether that activity is mitigating or preventative. Despite the fact that these findings are important empirical predictions, no systematic international comparison of attitudes toward the risks of terrorism exists and the data on counterterrorism policies are not available to the public. Nonetheless, the paper still holds policy relevance. In particular, as the target citizens become more risk averse, counterterrorism activities should focus on more severe attacks as increased safety regulation reduces mortality risks in other aspects of life.

We discuss related literature in section 2. We analyze the terrorists' and the government's strategies in sections 3 and 4, respectively. In particular, section 3 looks at the terrorists' decision in a setting without counterterrorism, which focuses attention on how the terrorists' choices are driven by the risk attitudes of the median voter in the target country and not by a response to any counterterrorism measures. Section 4 examines the target government's counterterrorism activities, taking the terrorists' choices as given. We present the equilibrium of the game between the terrorists and the target government in section 5 and conclude in section 6. All the proofs of our propositions are provided in section 7.

[3]Indeed, the problem faced by the government is similar to Ehrlich and Becker's (1972) self-insurance and self-protection problem.

## 2. RELATED LITERATURE

The first economic analysis to explore the interaction between terrorists and the target government is Sandler et al. (1983), which examines the negotiation process between the government and the terrorists when hostages are seized and demands are issued. While that analysis was appropriate immediately following the Iran hostage crisis, more recent terrorist activities have moved beyond kidnapping. Accordingly, our paper discusses a setting in which terrorists seek to destroy property or lives in the target country and the target government pursues defensive policies to prevent attacks, mitigate their severity, or both. Our analysis of how the terrorists and the government allocate their resources to achieve their goals are related to Bier et al. (2007), Farrow (2007), Lakdawalla and Zanjani (2005), Powell (2007), and Zhuang and Bier (2007).

Lakdawalla and Zanjani (2005) adopt Ehrlich and Becker's (1972) model of self-insurance and self-protection to study how public intervention in the terrorism insurance market affects individuals' decisions to self-protect and the negative externalities associated with self-protection. We also use Ehrlich and Becker's model, but in our model, the levels of self-insurance (damage-reducing activities) and self-protection (probability-reducing activities) are policy choices that the government uses to maximize a representative citizen's expected utility. Farrow (2007) also proposes a model where the government allocates expenditures across damage- and probability-reducing activities to minimize expected loss, and relates the model to some recent reports by the U.S. GAO. In contrast, Powell (2007) assumes that the government allocates resources across two locations vulnerable to terrorist attacks. Given that the resources are limited, the government's goal is to find the optimal allocation that determines the probability of a successful attack in each location so that the overall expected loss is minimized. Bier et al. (2007) also propose a model with two locations in which the probability of a successful attack can be reduced by a costly activity. After the terrorists observe the government choice, they choose a location to attack that maximizes the expected payoff from launching an attack. Zhuang and Bier (2007) extend these models by assuming that the probability of a successful attack depends on both the terrorists' effort and the government's preventive action. The key difference between these games and ours is that we assume that terrorists aim to minimize expected utility of a target citizen by allocating resources between damage scale and probability of success of the attacks; this allows us to link the citizen's fear of terrorism to the terrorists' objective.

While we focus on a game between terrorists and the target government, existing papers explore either the strategies of terrorists or the strategies of target governments, but not both. For example, Arce and Sandler (2005), Sandler (2005), and Siqueira and Sandler (2007) study games in which the two players are governments choosing whether to pursue a pre-emption policy or a deterrence policy against terrorists. In these games a country's payoff from the adopted policy depends on the policy adopted by other countries because the threat of terrorism is global. Siqueira and Sandler (2007) include voters in the first stage of a game and find that a representative voter has an incentive to free ride on the other country's countermeasures and, as a result, each country's proactive measures are undersupplied. Other papers focus on terrorists' strategies. For example, Konrad (2004) applies a simple game of extortion to the investment problem in terrorism and discusses the credibility of terrorist threats in a repeated game, but does not explore any counterterrorism policy. One paper that does look at strategies for both the terrorists and the target government is Jacobson and Kaplan (2007). They study proactive counterterrorism policies by using a multiperiod game where a terrorist group chooses how many suicide bombings to attempt and the government chooses the number of targeted killings to pre-empt planned suicide bombings in each period. The main difference between their paper and ours is the nature of the government's response. We look at how the target government acts to avoid or mitigate the attacks, and risk attitudes play a role in our paper but not theirs. For a complete review of recent developments in game-theoretic analyses of terrorism, see Sandler and Siqueira (2009).

An implicit assumption of game theoretic work on terrorism and counterterrorism is that terrorists respond to government actions, and empirical studies provide evidence that they do. Cauley and Im (1988) apply intervention analysis to data on international terrorist events from 1968 to 1979 and find that the installation of metal detectors has reduced the number of skyjackings but increased other types of terrorist events. Enders and Sandler (2000) use vector autoregressive analysis and find that, over time, terrorists have tried to achieve a greater impact from fewer events. Despite a decline in terrorism since the post-Cold War era, each incident is more likely to result in death or injury. They also find evidence that if the government responds by installing metal detectors, terrorists will substitute to less-protected targets with more deadly consequences.

## 3. THE TERRORISTS' DECISION

Any attempt to specify an objective function for a terrorist organization is bound to meet resistance. The basic premise for an economic model of terrorism, though, is that the terrorist organization has resources at its disposal and allocates those resources in order to optimize its objective function. Any economic model of terrorism must specify both the terrorist organization's choice variables and its objective function. We model the terrorists as choosing the certainty and severity of attacks with the objective of minimizing the expected utility of the target country's median voter. The first task for this section is to justify our approach.

The United States Code of Regulations defines terrorism as "... the unlawful use of force and violence against persons or property to intimidate or coerce a government, the civilian population, or any segment thereof, in furtherance of political or social objectives." The U.S. Department of Defense defines it as "the calculated use of unlawful violence or threat of unlawful violence to inculcate fear; intended to coerce or to intimidate governments or societies in the pursuit of goals that are generally political, religious, or ideological." Terrorist organizations use violent attacks, and the threat of further violent attacks, to provoke fear and intimidation among the target population with the ultimate goal of affecting policy change.

For example, purported political objectives behind al-Qaeda attacks against the United States include ending U.S. military presence in the Middle East, ending U.S. support of Israel, and ending U.S. support for corrupt regimes in the Muslim world (Byman, 2003). Hezbollah's self-stated goals include removing Israeli and American presence from the Middle East and establishing a Muslim state, similar to Iran's, in Lebanon (Harik, 2004; Qassem, 2005).[4] In this paper, we focus on situations in which terrorists try to intimidate or coerce a democratically elected government, because in those cases it makes the most sense for the terrorists to target the population. After all, in a democratic system, policy changes can occur when the electorate becomes dissatisfied with the current policy choices.

The simplest and most commonly used model of majority voting and representative democracy is the median voter model (Black, 1948; Downs, 1957). It states that when there are two candidates and the policy space is single-dimensional, in Nash equilibrium the policy outcome is the one most preferred by the median voter. To that end, suppose that the terrorist organization (referred to simply as the terrorist in the remainder of the paper) believes that if the median voter in the target country becomes sufficiently dissatisfied, a policy change is enacted. The wellbeing of the median voter is measured by her expected utility. The terrorist does not know how far the median voter's expected utility must fall before she votes for a policy change, and therefore uses his resources to minimize the target citizen's expected utility.

Because fear and intimidation work only against those who are not the direct victims of terrorist attacks, the threat of a future attack is the primary terrorism tool. Like everyone else, the terrorist has limited resources to devote to the production of fear. More severe attacks require more resources, and more frequent attacks require more resources. Thus, the terrorist faces a tradeoff between the severity and the frequency of attacks. This is

[4]Krueger and Maleckova (2003) argue that individual members of a terrorist sect do not join for financial reasons, providing evidence that more education and higher income both correspond to a higher likelihood of joining Hezbollah's military wing.

reminiscent of Becker's (1968) classic treatment of a government choosing between the certainty and severity of punishment to deter crime. Borrowing his terminology, the terrorist chooses the certainty and severity of an attack in order to minimize the expected utility of the median voter in the target country.

To capture the tradeoff induced by the terrorist's limited resources, let $p(s)$ be the probability of attack that fully utilizes the terrorist's resources when the chosen severity of attack is $s$. Thus, $p(s)$ describes a production possibilities frontier for the terrorist, with $p_s(s) < 0$ and $p_{ss}(s) < 0$. The negative slope of the production possibilities frontier is the marginal rate of transformation between severity and certainty, which is assumed to be increasing; the terrorist must give up more certainty as the severity level increases and vice versa. There is a least severe attack that can be considered a terrorist attack, and let $\underline{s}$ denote the least severe attack. Also, assume that there is a most severe attack to which the representative citizen assigns positive probability, and denote that level of severity by $\bar{s}$. When coupled with the downward-sloping production possibilities frontier, the existence of a most severe attack implies the existence of a lowest probability of attack, which we denote $\underline{p}$. Note that the lowest probability corresponds to the maximum level of severity, i.e. $\underline{p} = p(\bar{s}) > 0$. Finally, let the maximum probability of attack be $\bar{p} = p(\underline{s}) < 1$. The production possibilities frontier is shown in Figure 1.

The terrorist chooses a combination of certainty and severity to minimize the expected utility of the median voter in the target country. Let her initial wealth be $w$, and let $u(\cdot)$ be her von Neumann–Morgenstern utility function, with $u' > 0, u'' \leq 0$. Then her expected utility is given by

$$EU = (1 - p(s))u(w) + p(s)u(w - D(s)), \tag{1}$$

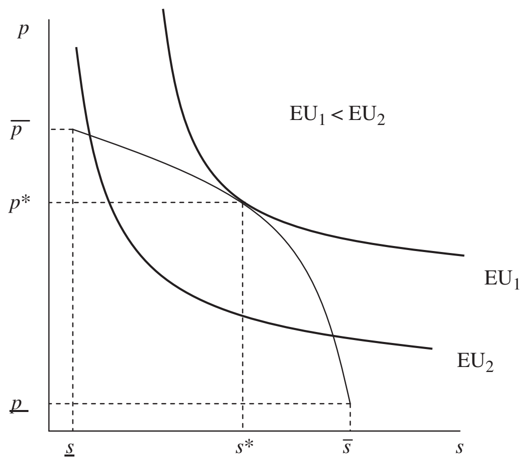


Figure 1. Optimal solution of the terrorist.

where $D(s)$ captures the monetary equivalent of the damage caused by an attack of severity $s$, with $0 < D(s) < w$, $D_s(s) > 0$, and $D_{ss}(s) \leq 0$.[5]

In Figure 1, the terrorist chooses the point on the production possibilities frontier that minimizes the median voter's expected utility. To find the shape of the terrorist's (and the citizen's) indifference curves, fix $\bar{U}$ and let $\pi(s)$ satisfy $(1-\pi)u(w) + \pi u(w - D(s)) = \bar{U}$. Then one can compute

$$\frac{d\pi}{ds} = -\frac{\pi u'(w - D(s))D_s(s)}{u(w) - u(w - D(s))} < 0,$$

and

$$\frac{d^2\pi}{ds^2} = \pi\left[\frac{2[u'(w - D(s))D_s(s)]^2}{[u(w) - u(w - D(s))]^2} + \frac{u''(w - D(s))D_s^2(s) - u'(w - D(s))D_{ss}(s)}{u(w) - u(w - D(s))}\right].$$

If the agent is risk neutral, then $d^2\pi/ds^2 > 0$. Therefore, as long as the agent is not too risk averse her iso-expected-utility curves in $p$–$s$ space are convex, as in Figure 1.

The terrorist chooses $s$ to minimize the agent's expected utility in (1). The first-order condition is

$$\frac{dEU}{ds} = -p_s(s)[u(w) - u(w - D(s))] - p(s)u'(w - D(s))D_s(s) = 0. \tag{2}$$

The second-order condition of the terrorist's minimization problem is

$$\frac{d^2EU}{ds^2} = -p_{ss}(s)[u(w) - u(w - D(s))] - 2p_s(s)u'(w - D(s))D_s(s) + p(s)[u''(w - D(s))(D_s(s))^2 - u'(w - D(s))D_{ss}(s)] \geq 0.$$

If the agent is risk neutral, we have $d^2EU/ds^2 > 0$. Therefore, if the median voter is not too risk averse the value of $s$ that satisfies (2) minimizes the median voter's expected utility. This is exactly the intuition from the graphical approach.

Our first result concerns how the median voter's risk attitudes affect the choice made by the terrorist.

**Proposition 1.** The level of severity chosen by the terrorist is higher when the median voter is more risk averse.

Thus, when compared with a risk-neutral population, a risk-averse population in the target country leads terrorists to commit more damaging, but

[5]Although it is possible to set $D(s) = s$ in this section, in subsequent sections the function $D$ will be modified to allow for mitigating responses by the government.

less frequent, attacks. This result is similar in spirit to Becker's (1968) observation that risk-averse expected-utility-maximizing criminals are more sensitive to changes in the severity than certainty of punishment. Becker argues that, when punishment is no more costly than detection, authorities should deter crime by reducing the likelihood of being caught but increasing the severity of punishment when caught. In the terrorism scenario of Proposition 1, the relative cost of severity vs. certainty is endogenously determined by the slope of the production possibilities frontier, but the basic intuition still holds. Becker's result highlights how increases in severity make criminals worse off than increases in certainty under restrictions on exogenously given enforcement parameters, and Proposition 1 extends the result to a terrorism setting when the enforcement parameters are endogenous.

Ultimately, though, Proposition 1's result that more risk-averse target populations correspond to less frequent but more severe attacks is an empirically testable prediction. Enders and Sandler (2000) find that terrorist attacks have become more severe and less frequent over time, and this finding is consistent with our notion of a downward-sloping production possibilities frontier. However, whether or not the trend toward more severe and less frequent attacks is driven by a worldwide increase in risk aversion requires additional data. The trend is consistent, however, with popular press notions that western societies are becoming more risk averse as government regulation reduces the ambient level of risk.[6]

Another way to look at the relationship between the terrorists' choice of severity and certainty of an attack and societal risk attitudes is by comparing terrorism incidents across countries. In 2004 and 2005, there was one major attack that killed 191 civilians in Madrid and one major attack in London that resulted in 52 fatalities; both attacks are related to Islamic extremism. During the same time period, India experienced 103 terrorist attacks in which Islamic extremists killed at least one person. Only three of these events caused more than 10 deaths. If citizens in developed countries such as the United Kingdom and Spain are more risk averse than those in developing countries such as India, the result of Proposition 1 seems consistent with the terrorist incidents in this period.

## 4. OPTIMAL COUNTERTERRORISM

The analysis of the preceding section covered only part of the story. The government of the target country is unlikely to sit by idly under the threat of terrorist attacks. Instead, the government can undertake costly actions that either help prevent attacks, mitigate their severity, or both. For example, according to the Homeland Security Act of 2002, two of the general goals of the Department of Homeland Security (DHS) are to reduce the vulnerability

[6]See, for example, "A hazardous comparison," *The Economist*, 2008 (Anon., 2008).

of the United States to terrorism and to minimize damage from terrorist attacks that occur within the United States. To that end, we assume in our model that the government can take action $a \geq 0$ to reduce the damage from and/or the probability of a successful attack. Hence, the level of damage and the probability of success are functions of both $a$ and $s$.

We assume that the median voter's share of the cost of the action is $c(a)$, where $c'(a) > 0$ and $c''(a) > 0$. The costs include the financial cost of the action as well as costs associated with any possible loss of liberty and privacy to the agent resulting from the chosen action. The government's objective is to choose $a$ to maximize the median voter's expected utility. In addition, we assume that $D_a(a,s) \leq 0, D_{aa}(a,s) \geq 0, p_a(a,s) \leq 0, p_{aa}(a,s) \geq 0$. These conditions say that increases in $a$ make a given attack both less likely to succeed and less damaging if it does succeed, and that the impact of further increases in $a$ diminishes as $a$ rises. Finally, $D(a,s) > 0$ and $p(a,s) > 0$ for all values of $a$ and $s$, so that the government can never completely eliminate the threat of terrorism.

The median voter's expected utility can be written as

$$EU = (1 - p(a,s))u(w - c(a)) + p(a,s)u(w - D(a,s) - c(a)). \tag{3}$$

The government chooses $a$ to maximize (3). The first-order condition is

$$\begin{aligned}\frac{\partial EU}{\partial a} = &- p_a(a,s)[u(w - c(a)) - u(w - D(a,s) - c(a))] \\ &- (1 - p(a,s))u'(w - c(a))c'(a) \\ &- p(a,s)u'(w - D(a,s) - c(a))[D_a(a,s) + c'(a)] = 0.\end{aligned} \tag{4}$$

If the agent is risk neutral, i.e. $u'(\cdot)$ is constant, then the first-order condition becomes

$$-[p_a(a,s)D(a,s) + p(a,s)D_a(a,s)] = c'(a), \tag{5}$$

which has the standard interpretation that the marginal benefit of the counterterrorism activity equals its marginal cost.

Differentiating the government's objective function a second time yields

$$\begin{aligned}\frac{\partial^2 EU}{\partial a^2} = &- p_{aa}(a,s)[u(w - c(a)) - u(w - D(a,s) - c(a))] \\ &+ 2p_a(a,s)[u'(w - c(a))c'(a) - u'(w - D(a,s) - c(a))(D_a(a,s) + c'(a))] \\ &+ (1 - p(a,s))[u''(w - c(a))(c'(a))^2 - u'(w - c(a))c''(a)] \\ &+ p(a,s)[u''(w - D(a,s) - c(a))(D_a(a,s) + c'(a))^2 \\ &- u'(w - D(a,s) - c(a))(D_{aa}(a,s) + c''(a))].\end{aligned}$$

If the median voter is risk neutral, we have $\partial^2 EU/\partial a^2 < 0$. Therefore, if the median voter is not too risk averse the second-order condition for a maximum is satisfied.

The government's problem is analogous to the self-insurance and self-protection problem introduced by Ehrlich and Becker (1972). The mitigation of the damage from terrorism and the reduction in the probability of a successful attack correspond to self-insurance and self-protection, respectively. Briys and Schlesinger (1990) and Dionne and Eeckhoudt (1985) show that an increase in risk aversion increases the optimal level of self-insurance, but does not always increase the optimal investment in self-protection.

We say that the government's action is purely mitigating if it affects the damages $D$ but not the success probability $p$, i.e. $D_a(a, s) < 0$ but $p_a(a, s) = 0$. In contrast, the action is purely preventive if it affects the success probability $p$ but not the damages $D$. In the United States the mitigation and prevention tasks are assigned to different agencies within the DHS. For example, the Federal Emergency Management Agency (FEMA) has the mission to reduce losses of life and property largely through preparedness, response, and recovery. In contrast, the Transportation Security Administration (TSA) screens airline baggage and passengers with the goal of stopping terrorist attacks. In short, FEMA engages in mitigation activities and TSA engages in preventive activities. We now treat the two cases separately.

### *4.1 Mitigating Activities*

In this subsection assume that the action $a$ affects only the level of damages from an attack but not the probability of success. In particular, assume that $D(a, s) = g(a)D(s)$, with $g'(a) \leq 0, g''(a) \geq 0$, and $p(a, s) = p(s)$. Under these circumstances, we can make the following statement.

**Proposition 2.** Assume that the government's action is purely mitigating. The level of counterterrorism activity chosen by the government rises when the median voter becomes more risk averse.

Proposition 2 states that increased risk aversion leads to increased counterterrorism activities when those activities mitigate the damages of an attack but do not prevent an attack. It is reminiscent of existing results that increased risk aversion leads to increased self-insurance. The intuition behind the result is that by increasing the mitigating activity the government increases the median voter's payoff in the bad state (an attack occurs) but reduces it in the good state (no attack). When the median voter becomes more risk averse, the government desires the two payoff levels to be closer together, which it achieves by spending more on mitigating the damages from an attack.

### 4.2 Preventive Activities

Now assume that the government's actions affect only the attack's success probability and not the extent of damages. In particular, assume that $D(a,s) = D(s)$ and $p(a,s) = f(a)p(s)$ with $f'(a) \leq 0, f''(a) \geq 0$.

**Proposition 3.** Assume that the government's action is purely preventive. If the probability of attack is sufficiently low, the level of counterterrorism activity chosen by the government rises when the median voter becomes more risk averse.

Proposition 3 states that if an attack is not too likely, when the median voter becomes more risk averse the government spends more to prevent an attack. Intuitively, when an attack is not too likely, the expected marginal utility of income is closer to $u'(w - c(a))$ than to $u'(w - D(s) - c(a))$, and the former is smaller than the latter. An increase in risk aversion makes the utility function more concave, which increases marginal utility close to the left endpoint of the interval $[w - D(s) - c(a),\ w - c(a)]$ and decreases marginal utility near the right endpoint. When the probability of attack is small, expected marginal utility decreases as the agent becomes more risk averse. Because the agent values income less, the government finds it optimal to spend more of the income on preventing terrorism attacks.[7]

Conversely, if the probability of attack is high, an increase in risk aversion increases the expected marginal utility of income, and the government spends less on preventing attacks. The ambiguity of the result is consistent with the findings of Briys and Schlesinger (1990) and Dionne and Eeckhoudt (1985) that the optimal level of self-protection may or may not increase with risk aversion, and with the findings of Eeckhoudt and Hammitt (2004) that the amount an individual is willing to pay for a partial reduction in fatality risk may or may not increase with risk aversion.

## 5. EQUILIBRIUM TERRORISM AND COUNTERTERRORISM

This section contains our primary results, which concern the equilibrium of the game between the terrorist organization and the target government. In light of the results of sections 3 and 4, we can begin the analysis with the risk-neutral case and then use Propositions 1–3 to discuss how the equilibrium behavior changes when the median voter becomes risk averse.

In section 4, we found that the impact of increased risk aversion on the government's choice of the level of counterterrorism activity depends on the nature of that activity. In particular, the direction of the effect is unambiguous if the activity is purely mitigating but ambiguous if the activity is

[7] This is similar to the "dead-anyway effect" discussed by Liu and Neilson (2006) and Pratt and Zeckhauser (1996).

purely preventive. To aid in the identification of the counterterrorism activity into one of these two categories, we assume that the probability-of-attack function $p(a, s)$ and the damage function $D(a, s)$ are both multiplicatively separable:

$$p(a, s) = f(a)m(s),$$

and

$$D(a, s) = g(a)n(s),$$

where $f$ and $g$ are decreasing and convex, $m$ is decreasing and concave, and $n$ is increasing and concave. If $f' < 0$ but $g' = 0$ the counterterrorism activity is purely preventive, but if $g' < 0$ and $f' = 0$ it is purely mitigating.

Begin with the terrorist's decision. When the representative citizen is risk neutral, the first-order condition (2) from section 3 becomes

$$p(a, s)D_s(a, s) + p_s(a, s)D(a, s) = 0, \tag{6}$$

which implicitly defines the terrorist's best-response function $s^*(a)$. As the next proposition shows, in the risk-neutral case the terrorist's best-response function is single-valued.

**Proposition 4.** Assume that the median voter is risk neutral and the probability-of-attack function $p(a, s)$ and the damage function $D(a, s)$ can be written as $f(a)m(s)$ and $g(a)n(s)$, respectively. Then the terrorist organization has a dominant strategy, i.e. the severity level it chooses does not depend on the action chosen by the government.

The result that the terrorist's activities are independent of the government's attempts to combat them is surprising. After all, if the government undertakes purely mitigating activities, for example, thereby raising the price of severity, one would expect the terrorist to respond by "purchasing" more certainty and less severity. Proposition 4 shows that this is not the case when the target country's median voter is risk neutral. Instead, the terrorist chooses the same severity level, call it $s^*$, no matter what the target government does.

Turning attention to the target government's decision, when the median voter is risk neutral the first-order condition is given by equation (5). The next proposition describes the shape of the government's best-response function.

**Proposition 5.** Assume that the median voter is risk neutral and the probability-of-attack function $p(a, s)$ and the damage function $D(a, s)$ can be written as $f(a)m(s)$ and $g(a)n(s)$, respectively. Then the government's best-response function $a^*(s)$ is increasing when $s < s^*$ and decreasing when $s > s^*$.

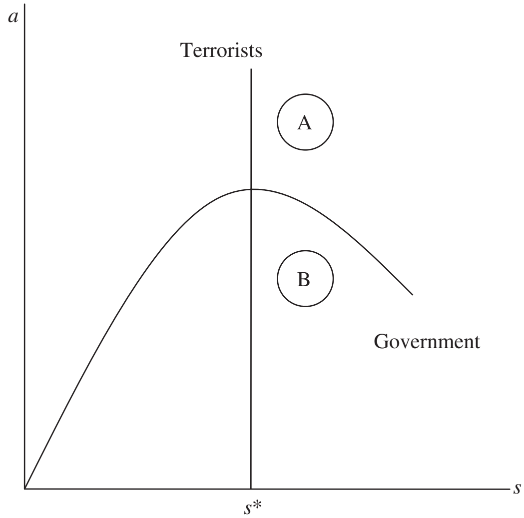


Figure 2. Best-response functions.

Figure 2 shows the best-response curves for the multiplicatively separable risk-neutral case described in Propositions 4 and 5. The terrorist organization's best-response curve is vertical, consistent with the dominant strategy found in Proposition 4. The target government's best-response curve is hump-shaped, and the Nash equilibrium of the game lies at the intersection of the two curves.

As shown in the figure, in equilibrium the terrorist chooses the level of severity that provokes the highest level of counterterrorism activity. At first glance this may seem counterintuitive. After all, if the terrorist wants the attacks to succeed, why would they try to generate a large amount of counterterrorist activity? The answer lies in the nature of the terrorist organization's objective function. The goal of the terrorist is to make the median voter as poorly off as possible, and this can be achieved either through the threat of attack or by making the citizen bear a large counterterrorism burden.

The terrorist attacks of September 11, 2001, led to a huge response by the U.S. government, including both increased preventive and mitigating activities. Preventive activities include stricter airport screenings, tighter border controls, and perhaps the wars in Afghanistan and Iraq. Mitigating activities include such things as terrorism insurance subsidies and the large monetary policy response to the attacks. The model predicts that terrorists take actions that lead to the large responses, and the 9/11 attacks are certainly consistent with this result.

The impact of risk aversion on the levels of terrorism and counterterrorism activities can now be easily derived using the results of Propositions 1–5.

By Proposition 1, when the median voter becomes risk averse the terrorist's best-response curve shifts rightward, and therefore risk aversion leads to more severe attacks. By Propositions 2 and 3, if counterterrorism is purely mitigating or if it is purely preventive but attacks are sufficiently unlikely, risk aversion causes the government's best-response curve to shift upward. Because the risk-neutral equilibrium was at the peak of the government's best-response curve, however, the effect of risk aversion on the level of counterterrorism is ambiguous in this case. The risk-averse equilibrium can be anywhere in the region A of Figure 2. If, on the other hand, counterterrorism is purely preventive and attacks are sufficiently likely, risk aversion causes the government's best-response curve to shift downward, in which case risk aversion unambiguously causes the level of severity to rise and the level of counterterrorism activity to fall. As shown in Figure 2, the risk-averse equilibrium lies in the region B.

## 6. CONCLUSION

We analyze decisions made by a group of terrorists and a government in a zero-sum game where the terrorists minimize the median voter's expected utility and the government maximizes it.[8] The terrorists' strategy balances the probability and the severity of the attack while the government chooses the level of investment reducing the probability and/or mitigating the severity. We find that if the median voter is risk neutral the terrorists choose a level of severity that does not depend on the government's choice of activities but provokes the highest level of counterterrorism activity. We also find that the citizens' risk attitudes affect the strategies of the terrorists and the government. When compared with a risk-neutral population, a risk-averse population in the target country leads the terrorists to commit more damaging, but less frequent, attacks.

When the government's activities mitigate the damages of an attack but do not prevent an attack, increased risk aversion leads to increased counterterrorism activities. However, when the government's activities only prevent an attack but do not mitigate the damages, the effect of risk aversion on counterterrorism activities depends on the probability of an attack. If an attack is not too likely, the government spends more to prevent an attack when the representative citizen becomes more risk averse. If an attack is likely, then the government spends less to prevent an attack when the representative citizen becomes more risk averse.

The analysis is robust to departures from the median voter paradigm. It may be that different groups within a country exert differing degrees of power because of lobbying ability, for example, as in Hettich and Winer (1988). If so, the relevant median voter determining the government's

[8]Since the median voter's expected utility is a gain for the government and a loss to the terrorists, the game is zero-sum regardless of shape of the utility function.

counterterrorism efforts might have different risk attitudes than the relevant median voter determining the government's position on the issue relevant to the terrorist group. The propositions presented in the paper, however, determine how the terrorist's best-response function shifts as its target voter's risk attitudes change, and how the government's best-response function shifts as its most relevant voter's risk attitudes change. Nothing in the model requires that these two voters be the same individual.

While this paper is explicitly theoretical, it contains important empirical predictions. First and foremost, risk attitudes in the target population are an important explanatory variable, both for the severity of attacks and for the level of counterterrorism activities. No systematic international comparison of attitudes toward the risks of terrorism exists, and so casual empiricism is impossible at this juncture.[9] Nevertheless, the paper points toward an important use for such data. The testable hypothesis arising from the paper is a strong one: attacks should be more severe and less frequent in more risk-averse target countries. Furthermore, this is an equilibrium prediction, and not one solely based on the solution to one party's optimization problem.

The paper also holds policy relevance. In particular, the paper establishes as a rule of thumb that terrorists act to provoke the costliest response by the target government, as suggested by the risk-neutral case, and that increases in risk aversion in the target country lead to more severe, but less frequent, attacks. The latter finding suggests that counterterrorism activities should focus on more severe attacks as increased safety regulation reduces mortality risks in other aspects of life. The former finding suggests that target nations may be thinking about terrorism in the wrong way. In particular, it is not necessarily the success of the attack that matters, but instead the amount of spending and other costly activities the threat of attack evokes. Because of this, countries subject to terrorism risks may be able to influence the nature of terrorist attacks by changing the counterterrorism technology.

## 7. PROOFS

*Proof of Proposition 1.* Let $u$ and $v$ be two utility functions with $u$ a concave transformation of $v$. Let $s_u$ and $s_v$ be the values of $s$ that satisfy the first-order condition (2) for the two different utility functions. Normalize the two utility functions so that $u(w - D(s_v)) = v(w - D(s_v)) = k > 0$ and $u'(w - D(s_v)) = v'(w - D(s_v)) = 1$. Define the function $\rho$ to satisfy $u(x) = \rho(v(x))$ for all $x$.

[9]The literature does contain research on the perceived risk of a terrorist attack, as in Sjöberg (2005) and Viscusi and Zeckhauser (2003). However, these papers concern the perceived values of the probability and severity of attack, and not the underlying shape of the median voter's utility function. A useful proxy for risk attitudes might be the value of a statistical life, and Viscusi and Aldy (2003) report several VSL estimates from around the world.

Then by hypothesis $\rho$ is concave, and by construction $\rho'(k) = 1$. Consequently, $\rho'(z) \leq 1$ for all $z > k$. Now note that

$$\begin{aligned} u(w) &= k + \int_0^{D(s_v)} u'(w - D(s_v) + t)dt \\ &= k + \int_0^{D(s_v)} \rho'(v(w - D(s_v) + t))v'(w - D(s_v) + t)dt \\ &\leq k + \int_0^{D(s_v)} v'(w - D(s_v) + t)dt \\ &= v(w), \end{aligned}$$

and therefore, remembering that $p_s < 0$,

$$\frac{dEU}{ds} = -p_s(s_v)[u(w) - u(w - D(s))] - p(s_v)u'(w - D(s_v))D_s(s_v) \leq 0.$$

Since $dEU/ds \leq 0$ at $s = s_v$ and $dEU/ds$ is increasing in $s$ and equal to zero at $s = s_u$, it follows that $s_u \geq s_v$. ■

*Proof of Proposition 2*. The first-order condition (4) can be written as

$$-\frac{[g'(a)D(s) + c'(a)]p(s)}{c'(a)(1 - p(s))} = \frac{u'(w - c(a))}{u'(w - g(a)D(s) - c(a))}. \tag{7}$$

By Pratt (1964), when the representative citizen becomes more risk averse, the right-hand side of (7) falls. Differentiating the left-hand side by $a$ yields

$$\frac{\partial \text{LHS}}{\partial a} = -\frac{[c'(a)g''(a) - c''(a)g'(a)]D(s)p(s)}{(c'(a))^2(1 - p(s))} \leq 0.$$

Therefore, when the representative citizen becomes more risk averse, $a$ must increase to maintain equality in (7). ■

*Proof of Proposition 3*. The first-order condition in (4) can be rearranged to get

$$-\frac{c'(a)}{f'(a)p(s)} = \frac{u(w - c(a)) - u(w - D(s) - c(a))}{(1 - f(a)p(s))u'(w - c(a)) + f(a)p(s)u'(w - D(s) - c(a))}. \tag{8}$$

Consider two utility functions $u$ and $v$ with $u$ more risk averse than $v$. Fix $s$, and let $a_v$ be the value that maximizes $v$'s expected utility. Assume, without loss of generality, that $u(w - c(a_v)) = v(w - c(a_v)) = 1$ and that $u(w - D(s) - c(a_v)) = v(w - D(s) - c(a_v)) = 0$. Furthermore, because $u$ is a concave transformation of $v$, $u'(w - D(s) - c(a_v)) \geq v'(w - D(s) - c(a_v)) \geq v'(w - c(a_v)) \geq$

$u'(w-c(a_v))$. Then there exists $\tilde{p}$ such that

$$(1-\tilde{p})u'(w-c(a_v))+\tilde{p}u'(w-D(s)-c(a_v))$$
$$=(1-\tilde{p})v'(w-c(a_v))+\tilde{p}v'(w-D(s)-c(a_v)),$$

and for any $p<\tilde{p}$,

$$(1-p)u'(w-c(a_v))+pu'(w-D(s)-c(a_v))$$
$$\leq(1-p)v'(w-c(a_v))+pv'(w-D(s)-c(a_v)).$$

Consequently, if $p(s)$ is so low that $f(a_v)p(s)<\tilde{p}$ then

$$\frac{u(w-c(a_v))-u(w-D(s)-c(a_v))}{(1-f(a_v)p(s))u'(w-c(a_v))+f(a_v)p(s)u'(w-D(s)-c(a_v))}$$
$$\geq\frac{v(w-c(a_v))-v(w-D(s)-c(a_v))}{(1-f(a_v)p(s))v'(w-c(a_v))+f(a_v)p(s)v'(w-D(s)-c(a_v))}.$$

Therefore, when $p(s)$ is sufficiently small, the increase in risk aversion from $v$ to $u$ makes the right-hand side of equation (8) rise. The left-hand side of (8) increases in $a$ because both $c$ and $f$ are convex, and it follows that $a_u\geq a_v$. ■

*Proof of Proposition 4*. The first-order condition of the terrorists (6) can be written as

$$f(a)g(a)[m'(s)n(s)+m(s)n'(s)]=0.$$

Implicitly differentiating with respect to $a$ and rearranging yields

$$\frac{ds^*}{da}=-\frac{(f'g+fg')(mn'+m'n)}{fg(m''n+2m'n'+mn'')}$$

and the numerator is zero by the first-order condition. ■

*Proof of Proposition 5*. The first-order condition of the government (5) can be written as

$$-m(s)n(s)[f'(a)g(a)+f(a)g'(a)]-c'(a)=0.$$

Implicitly differentiating with respect to $s$ and rearranging yields

$$\frac{da^*}{ds}=-\frac{(f'g+fg')(mn'+m'n)}{mn(f''g+2f'g'+fg'')+c''(a)}. \quad (9)$$

The terrorist organization chooses $s$ to minimize

$$EU(a,s)=w-p(a,s)D(a,s)=w-f(a)m(s)g(a)n(s).$$

Then $\partial EU(a,s)/\partial s=-fg(m'n+mn')$, and by the second-order condition for a minimum, $m'n+mn'>0$ when $s<s^*$ and $m'n+mn'<0$ when $s>s^*$.

The second-order condition also guarantees that the denominator of (9) is positive, and so the sign of $da^*/ds$ is the opposite of the sign of the numerator of (9). Finally note that, by construction, $f'$ and $g'$ are both negative, and so $da^*/ds$ has the same sign as $m'n + mn'$. ■

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PAAN JINDAPON
*University of Alabama*

WILLIAM S. NEILSON
*University of Tennessee*

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