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# Developing a Game-Theoretic Analysis of Terrorism

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DEVELOPING A GAME-THEORITIC ANALYSIS OF TERRORISM

by

Matthew A. Love

A Thesis Submitted to the Graduate College  
in partial fulfillment of the requirements  
for the Degree of Masters of Art  
Department of Political Science  
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## DEVELOPING A GAME-THEORITIC ANALYSIS OF TERRORISM

Matthew A. Love, M.A.

Western Michigan University, 2013

My research demonstrates the applicability of game theory to analyzing terrorism through consideration of multiple examples. These examples provide a foundation upon which further research involving the application of game theory to terrorism can be explored.

My research contributes to a growing body of literature, especially since the terrorist attacks on the United States on September 11, 2001, in which it has been argued that terrorists are rational agents and, because of that, game theory can be usefully applied to an analysis of terrorism. My research further supports this conclusion.

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Matthew A. Love

## TABLE OF CONTENTS

ACKNOWLEDGMENTS .....	ii
LIST OF FIGURES.....	iv
CHAPTER	
I. INTRODUCTION.....	1
II. DEFINING TERRORISM.....	6
III. TERRORISM AND RATIONALITY.....	18
IV. REVIEW OF GAME THEORY LITERATURE .....	29
V. DEVELOPMENT OF GAME THEORY MODELS.....	37
VI. CONCLUSION.....	51
BIBLIOGRAPHY.....	55

## LIST OF FIGURES

1. Preempt versus do not Preempt.....	36
2. Attack Terminal A or Terminal B using Values.....	40
3. Attack Terminal A or Terminal B using Variables.....	41

# CHAPTER I

## INTRODUCTION

### Introduction of Terrorism to English Lexicon

Since the terrorist attacks of September 11, 2001 on the United States, increasing attention has been directed toward the subject of terrorism. While the term terrorism has not always been used, the use of terror by state and non-state actors as a method of influencing change is age old. During Rome's occupation of Palestine, Jewish Zealots resisted Roman rule through the use of the Sicarii, assassins who killed Romans and their Jewish collaborators and destroyed their property as a means of invoking fear and weakening the occupation. During the Spanish Inquisition, the use of arrest, torture, and execution were implemented as a strategy for strengthening Christian orthodoxy. Hashashins, followers of the Ismaili Shiite power, were notorious assassins with a reputation for spreading terror through the murder of women and children. However, it was not until the French Revolution's Reign of Terror during the late 1700's that the term terrorism was first introduced to the English lexicon by Edmund Burke who chastised the "thousands of those Hell hounds called Terrorists." Since that time, the term's popularity has grown and regularly been used throughout media, literature, education, and popular culture. Interest in the subject has led to analysis of multiple sub-topics; including how to define terrorism, can terrorists be understood as rational actors, and how to approach analyzing terrorism.

## Use of Game Theory in Analyzing Terrorism

If it can be established that terrorists are capable of acting rationally, as I argue, then it is possible to employ the use of game theory in analyzing situations involving terrorism and antiterrorism policies. As a result, researchers and decision makers could predict what a terrorist may do based on an analysis of available strategies and determining the payoffs associated with each combination of strategies. The implications of doing so would mean being able to use game theory to forecast which tactic(s) a terrorist will utilize during an attack, where and when the attack will take place, and which counter measures would provide the best opportunity for prevention of an attack. In addition to using game theory to analyze components involved directly with a terrorist attack, it can also be used to analyze decisions made by governments related to policy, including whether to take a reactive or proactive approach to countering terrorism and how to allocate limited resources in the fight against terrorism. In doing so, our analysis will need to focus on the payoffs and strategies associated with governments and other policy makers, specifically; in the case of the game I develop in this work, security personnel.

Since the terrorist attacks of September 11, 2001 there has been a growing body of literature dedicated to examining terrorism and counterterrorism through the use of game theory. Daniel Arce and Todd Sandler have both contributed significantly to the topic of using game theory to analyze terrorism. In their work *Counterterrorism A Game-Theoretic Analysis* Arce and Sandler consider the question of whether

governments targeted by terrorists should choose proactive or reactive approaches to combating terrorism. In doing so, Arce and Sandler consider the costs and benefits of both alternatives, concluding that “For the pattern of benefits and costs examined here, defensive policies of deterrence and hardening targets generally dominate many proactive policies.” Furthermore, “Many proactive policies yield purely public benefits in which free riding is a problem. In contrast, most defensive policies give private benefits and public costs, with countries competing to match one another’s action to not draw the attack. Governments are predisposed to engage in too little proactive effort and too much defensive effort, thus the general prevalence of the latter.” (Arce and Sandler 2005, 19)

In addition to considering the application of game theory to scenarios involving terrorists and targeted countries, researchers have also used game theory to address interactions between terrorists. In his article *Terrorism and Game Theory: From the Terrorists’ Point of View*, Kevin Chlebik uses game theory to examine the interplay between two distinct terrorist factions of the same terrorist organization. Chlebik develops several models in which he considers the costs and benefits to terrorist cell A and B in analyzing whether it would be in each cell’s best interest to attack or not. According to Chlebik, “by studying decisions terrorists make and understanding why they make them, better counterterrorism policies can be developed.” (Chlebik 2010, 15) In this work, I provide further overview of literature that has advanced the use of game theory in studying terrorism. By doing so, my intention is to demonstrate the potential benefits associated with game theory.

## Game-Theory Model

Many scholars have accepted the premise that terrorists are capable of acting rationally. I share this point of view and argue in favor of it throughout my work. As a result of accepting the conclusion that terrorists are rational actors, game theory has been applied to an analysis of terrorism in a number of circumstances. By contributing to this growing body of literature, my intention is to provide further evidence of game theories value in analyzing terrorism. In doing so, I develop a game-theoretic model involving two players, a terrorist and security personnel. My model is designed as a simultaneous, single shot, imperfect-information game, meaning neither player has information regarding the others player's choice in the game and the game is played only once. Because, as my analysis demonstrates, pure strategies are not the optimum approach for either player, consideration of mixed strategies is necessary and requires the use of probability theory in understanding the outcome of the game. This particular design considers a planned attack against airport security in which the terrorist must decide to attack one of two terminals (terminal A or B) and security must decide to guard one of those two terminals (A or B), resulting in four possible outcomes: Both the terrorist and security choose terminal A, both choose B, security chooses A and the terrorist chooses B, or security chooses B and the terrorist chooses A. In my scenario, security only has enough resources to guard one of the two terminals, leaving the other unprotected and vulnerable to a successful attack by the terrorist and the terrorist only

enough resources to attach one terminal. If both players choose the same terminal, then security wins and the terrorist loses. If, however, both players choose different terminals, then the terrorist wins and security loses. My game involves an analysis of the strategies and associated payoffs for both the terrorist and security. By relaxing my assumption that neither player has information regarding the other player's decision, it is possible to expand my analysis to include discussion regarding the probability of selecting one terminal over the other from the perspective of both players. As a result, I am able to solve the game. The conclusion I draw from my discussion is that the best response of both players is to randomize their selection. My intention is to provide the basic components of developing game theory models in analyzing terrorism. From this basic design, it is possible to expand our analysis to include additional factors that require more advanced techniques.

If my conclusions are correct, then game theory can continue to be advanced in its application to an analysis of terrorism. Given the prevalence of terrorism as a topic of discussion and concern in recent decades, the use of game theory in attempting to develop antiterrorism policies should be considered a valuable resource.

## CHAPTER II

### DEFINING TERRORISM

#### Importance of Defining Terrorism

Defining terrorism has proven to be a difficult task. The challenges of attempting to do so have been realized by law makers and scholars alike. According to Upendra Acharya:

The definition of terrorism has emerged as a central focus of power politics and propaganda. Differential and ideological posturing, the absence of boundaries of conflict and fixed enemies, messages of fear, legal narratives, and creating, remaking and reconfiguring judicial reality have a profound tendency to make terrorism a never-ending battle.....Terrorism is a psychological phenomenon, with criminal acts being used to fight political power or to maintain a political status quo. This particular characteristic of terrorism and the techniques employed to eliminate it, create a narrative, on normative scale, that threatens the potential for global consensus in defining terrorism (Acharya 2009, 653).

The acceptance of a definition of terrorism will have both practical and theoretical implications. The practical consequences of defining terrorism will be felt by policy makers in determining how to approach terrorism at a global level and, maybe most importantly, who and what acts qualify as terrorism. Many researchers have suggested that an objective definition of terrorism can never be agreed upon, concluding that “one man’s terrorist is another man’s freedom fighter.” According to Boaz Ganor, “The question of who is a terrorist, according to this school of thought, depends entirely on the subjective outlook of the definer.” (Ganzor 2002, 287)

However, as Sami Zeidan points out in his article *Agreeing to Disagree: Cultural Relativism and the Difficulty of Defining Terrorism in a Post-9/11 World* “States cannot adequately counteract a phenomenon that they absolutely agree must be eliminated, as long as they fundamentally disagree on its very definition.” (Zeidan 2005, 217) Boaz Ganor agrees, saying “An objective definition of terrorism is not only possible; it is also indispensable to any serious attempt to combat terrorism. Lacking such a definition, no coordinated fight against international terrorism can ever really get anywhere.” (Ganzor 2002, 288) If that is the case, then where should we look for such a definition? It has been suggested that:

A correct and objective definition of terrorism can be based upon accepted international laws and principles regarding what behaviors are permitted in conventional wars between nations. These laws are set out in the Geneva and Hague Conventions, which in turn are based upon the deliberate harming of soldiers during wartime is a necessary evil, and thus permissible, whereas the deliberate targeting of civilians is absolutely forbidden. (Ganzor 2002, 288)

The issue of accepting a universal definition remains contested, and considerations involving civilians and military personnel remain at the forefront of the debate. In the absence of an adequate definition, it proves difficult to develop law or scholarly research on the topic without running the risk of including more or less than a satisfactory definition of terrorism should. Such a conclusion is unsatisfactory for the purposes of scholarly research and policy development. Therefore, further consideration is necessary.

Given the pejorative connotation associated with the term terrorism, I suspect some of the difficulties in accepting a definition of terrorism are a consequence of not

wanting to condemn one's own practices or those of one's allies as terrorism.

According to Kevin Chlebik, the term terrorism is difficult to define "in part because deeming an act "terrorism" depends subjectively on whether a person sides with the attackers or their victims." (Chlebik 2010, 16) In his book "Inside Terrorism", Bruce Hoffman writes "If one identifies with the victim of the violence, then the act is terrorism. If, however, one identifies with the perpetrator, the violent act is regarded in a more sympathetic, if not positive light, and it is not terrorism." In his 2005 interview on Al-Jazeera television, Mahdi Dakhlallah, the former Syrian minister of information, rejected the United States characterization of his country as a sponsor of terrorism, calling it a "selective definition" of terrorism by the U.S. However, as Upendr Acharya concludes, without a definition of terrorism "there is a free and open tendency for the persons using the term, whether states, organized groups or scholars, to define it as suits their purposes at the moment, leading to uncertainty as to how to fashion a legal structure to address terrorism."(Acharya 2009, 655) As a result, it is important for the purposes of creating antiterrorism policies and contributing to scholarly dialogue, including the use of game theory, that the question of how to define terrorism be addressed further.

### Considering Definitions of Terrorism

Definitions of terrorism have traditionally shared common features. At the core of most definitions has been the use of violence or threat of violence. It has also

regularly been accepted that the intended targets of the violence must be *civilians* or *civilian targets*. Earlier definitions were not always as specific regarding the intended targets. At one time many definitions considered terrorism “the deliberate and systematic murder, maiming, and menacing of the innocent to inspire fear for political ends” (Ganor 2002, 293) However, definitions of this type received criticism because of subjective interpretations concerning judgments of innocence and guilt. The inclusion of civilians in the definition had an additional advantage. This characteristic allows one to differentiate between terrorism and other types of political violence, including guerrilla warfare and freedom fighters, in which many of the tactics, methods, and goals are the same as terrorists, but civilians are not being intentionally targeted.

Other definitions have introduced small variations. However, even small variations can contribute significantly to differentiating between terrorists and non-terrorists. Traditional definitions, especially those before the attacks of September 11, had focused primarily on politically motivations. According to the philosopher Per Buhn, terrorism is defined as “The performance of violent acts, directed against one or more persons, intended by the performing agent to intimidate one or more persons and thereby to bring about one or more of the agent’s *political* goals.” (Buhn 1989, 28) However, in a post 9-11 era, it has been argued that political motivations are not the only motivators associated with acts of terrorism, and a broader definition is needed to capture the full scope of terrorism. According to the United States Department of Defense, terrorism is defined 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.*” (Department of Defense 2012) The Federal Bureau of Investigation (FBI) 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.*” (Federal Bureau of Investigation, 2005) The use of “social objectives” by the FBI may cover a host of additions, including religious and ideological motivations. The introduction of religious and ideological motivations has contributed to increases in the number of actions classifiable as terrorism. No longer are political motivations a necessary requirement for classifying terrorism. And acts that are motivated by religious and ideological goals have become a large part of today’s definitions. The inclusion of these two characteristics into the definition of terrorism has provided a new perspective; the absence of political motivations will not automatically eliminate an act as potential terrorism. As a result, religious and ideological terrorism has become a central focus in defining terrorism. Not everyone has agreed with the importance of emphasizing religious and ideological characteristics within definitions of terrorism, suggesting that political motivations are enough to capture the essence of terrorism. After studying 315 cases of suicide attacks, Robert Pape concluded that the suicide bombers actions stem from political conflict, not religion (Pape 2003). Furthermore, “there is little connection between suicide terrorism and Islamic fundamentalism, or any one of the world’s religions.” (Pape 2005, 4) Terry Nardin agrees with the conclusion that religious motivations are over emphasized saying “A basic problem is whether religious terrorism really differs, in character and causes, from political

terrorism.” (Nardin, 2001, 683) If it is the case that religious terrorism doesn’t really differ in “character and causes from political terrorism”, then it may not really be a question of whether or not we include religious motivations in the definition of terrorism so long as we recognize that the character and causes of political and religious motivation are the same. Additional consideration of these characters and causes would be necessary to explore this idea further, however, to do so would take us too far outside the scope of this project.

#### State versus Non-State Terrorism

Debate has also developed over whether or not to include state terrorism in the definition. State terrorism should not be confused with state sponsored terrorism in which a state provides support to a terrorist organization through the supply of resources. These resources could include financial support, weapons, or housing, etc. State terrorism on the other hand is terrorism committed on behalf of the state itself rather than in support of a terrorist organization. State terrorism as defined by Noam Chomsky is “terrorism practiced by states and their agents and allies.” (Chomsky 2002, 2) According to Zeidan, “That there is a form of terrorism that wears uniforms and insignia has prompted thinkers to argue for a definition of terrorism that includes State Terrorism.” (Zeidan 2005, 227) Others have argued for the exclusion of state terrorism from the definition saying there is a “qualitative difference between” state and non-state violence. According to Walter Laqueur, “the very existence of a state is

based on its monopoly of power. If it were different, states would not have the right, nor be in a position, to maintain that minimum of order on which civilized life rests.” (Laquer 2003, 237) Furthermore, as Igor Primoratz point out in his article *State Terrorism and Counterterrorism* it has been argued that a “terrorist state is logically impossible by virtue of the definition of state.” (Primoratz 2002, 7) However, Primoratz points to Nazi Germany and Stalin’s Soviet Union as obvious counterexamples to the claim that states are exempt from being categorized as terrorism (Primoratz 2002).

Other concerns over including states in the definition have focused on the potential for terrorists and their sympathizers to use definitions of this type to argue that there is no difference between terrorist activities and state activities. If violence by the state is recognized as justifiable and non-state actors are acting in accordance with the same guidelines, then violence by non-state actors is also justifiable, or so the argument goes. As Laquer writes, the argument “rests on the deliberate obfuscation between all kinds of violence.” A step in the right direction of eliminating such attempts to “obfuscate between all kinds of violence” is the separation of states and non-states from discussions concerning use of violence by both. (Laquer 2003, 237)

Further explanations concerning the reluctance to accept state terrorism have been attributed to difficulties in recognizing state terrorism in a contemporary setting. Early uses of the term terrorism were almost exclusively used in the context of the state and there are historically obvious examples. The Soviet Union’s period of “the Great Terror” and France’s “Reign of Terror” in the 18<sup>th</sup> century are commonly referenced as clear cases of state terrorism. Over time, state terrorism became less

recognizable and, until it's resurgence more recently, largely absent from the discussion. As Primoratz writes:

In a contemporary setting, state terrorism is apparently much more difficult to discern. Discussions of terrorism in social sciences and philosophy tend to focus on non-state and, more often than not, anti-state terrorism. In common parlance and in the media, terrorism is as a rule assumed to be an activity of non-state agencies in virtue of the very meaning of the word. If one suggests that the army or security services are doing the same thing that, when done by insurgents, are invariably described and condemned as terrorist, the usual reply is, "But these are actions done on behalf of the state, in pursuit of legitimate state aims: the army, waging war, or the security services, fending off threats to our security. (Primoratz 2002, 2)

The belief that these actions are "done on behalf of the state, in pursuit of legitimate state aims..." has not been convincing enough for many contemporaries to eliminate states from the discussion of defining terrorism. As the perspective on terrorism has begun, once again, changing in the direction of considering state terrorism, it has become common to encounter accusations of involvement in state terrorism. Iran and Pakistan have been used as examples of state terrorism throughout much of the debate; however, the west has not remained exempt from consideration. According to Ruth Blakely, "State terrorism, along with other forms of repression, has been an ongoing feature of the foreign policies of democratic great powers from the North and the United States (US) in particular." (Blakely 2007, 228) If states are going to be included in a definition of terrorism, then policies, responses, and analysis of terrorism will require a different approach.

A further objection to including states in the definition of terrorism is that by doing so one ignores the regulations and policies that have already been developed to

address violations by the state, not as an entity of terrorism, but a governing body that is subject to international law during times of abuse. Judicial regulations have been developed for the purpose of protecting international human rights. In the case of violations by the state, their abuse should be treated as a human rights violation and, in some cases, a war crime. Therefore, given the availability of state oversight by judicial bodies, including the United Nations, the addition of states in the definition of terrorism is unnecessary for regulating their actions. There is no need to treat state-violence as an act of terrorism when those actions are already being addressed according to the established rules and regulations governing states. According to Kofi Annan, the seventh Secretary-General of the United Nations, the time has come to “set aside debates on so-called state terrorism. The use of force by states is already regulated under international law.” (Lind 2005, 1)

Conclusions regarding the use of state terrorism in our definition will have a direct impact on discussions concerning the rationality of terrorists. The challenges of establishing rationality as a component of terrorism become increasingly difficult in the case of eliminating state terrorism from our definition. After all, political science assumes states act rationally on a routine basis and is the foundation of rational choice theory as applied to states throughout the literature. To proceed from the conclusion that states act rationally to the conclusion that states act as rational terrorists does not appear nearly as difficult as developing arguments supporting the conclusion that non-state terrorists are rational agents. In the case of dealing with non-state terrorists, it is, I argue, more difficult to determine the motivations and payoffs associated with their particular actions and therefore, subject to miscalculations. As a result, considering the

implications of our outcome, rationality at the level of non-state terrorism must be carefully explored before making any judgments. If it can be established that non-state terrorists are rational agents, then game theory becomes a potentially powerful approach to analyzing the actions of individual non-state terrorists.

### Proposed Definition of Terrorism

The debate over precisely how to define terrorism will certainly continue, however, for the purpose of employing game theory in an analysis of terrorism in this work, it is necessary to settle on a definition. Given the arguments for and against introducing ideological, religious, and, in some instances, social motivations, along with the traditionally accepted political motivations, the definition I use throughout this work will include all as possible motivators. It may be possible, as discussed earlier, to define terrorism using political motivations exclusively by arguing that other motivations, including social and ideological, are reducible to political motives, but, in doing so, it seems to unnecessarily obscure the issue. There appear to be cases of terrorism that are based on religious and ideological motivations. Any attempt to reduce these occurrences to political motivations only detracts from the present situation. By including these motivations in the definition, I believe it accurately captures the circumstances surrounding much of today's terrorism, which is indicative of both religious and ideological goals. According to Upendra Acharya, "At present, the violence that uses terrorism as a tactic includes not only state-sponsored regimes of

fear, but also religious ideology-based terrorism that calls for securing and protecting sacred lands and sacred religious and cultural practices.” (Acharya 2009, 654)

Discussion over the use of state terrorism has led to consideration of arguments for and against adding states to the definition of terrorism. The debate has focused centrally on the question of whether or not the state shares enough characteristics with terrorist organizations to be included as terrorists themselves. Although states can, and have, committed violence acts with the intention of invoking fear for political, religious, or ideological goals, inclusion in the definition of terrorism does not seem necessary. If states and non-states are included in the a definition of terrorism, then the boundaries between the two entities becomes less clear, resulting in several complications that are better avoided through the exclusion of states as potential terrorist. Not only does recognizing state terrorism run the risk of providing non-state terrorists with an argument for identifying themselves with the state and, therefore, justifying their violent actions, but it largely ignores the judicial structure that has already been dedicated to addressing abuses by states. Therefore, for the purpose of my research, the definition of terrorism I use will exclude states. My definition includes these four characteristics:

1. The use of, or threat to use, violence. Any activities that do not include the use of, or threat of, violence will not be included in my definition of terrorism.
2. The targets of the terrorist attack must be civilians or civilian targets.

Cases of guerilla warfare, freedom fighters, or similar populations will not be included because the violence is directed at combatants rather than non-combatants.

Furthermore, acts of violence in which accidental harm to civilians, or collateral damage, occurs do not constitute terrorism.

3. The motivation behind the attack is political, religious, or ideological. In the absence of these motivators, the activity will not be treated as an act of terrorism. Similar acts of violence, without these motivators, is considered criminal, not terrorism.

4. The activity must be committed by non-state actors.

A simplified version of the above characteristics to be applied throughout this research defines terrorism as:

**The intentional use of, or threat to use, violence against civilians or civilian targets by non-state actors for the purpose of accomplishing political, religious, or ideological goals.**

## CHAPTER III

### TERRORISM AND RATIONALITY

The application of game theory to terrorism assumes the rationality of terrorists. Not everyone has acquiesced with characterizing terrorists as rational. Therefore, a defense of this assumption is required before developing models of game theory for the purpose of analyzing terrorism. Unlike colloquial uses of the term rationality that invite numerous interpretations, game theorists define the term more precisely. For game theorists, the term rationality is defined as calculating the benefits and costs of available choices in order to follow the path leading to the greatest net gain.

Economists were the first to utilize the use of game theory for the purpose of developing analytical models. Their successful use has been attributed in large part to the reliable assumption that “people are motivated by money and by the possibility of making a profit.” (Scott 2000, 1). In addition to accepting the assumption that people are motivated by profit, the observability of economic variables has also contributed to embracing the use of game theory for the purpose of analyzing the economy. One can easily observe profit and loss, making determinations regarding rationality much easier than areas where motivations are far less visible. In the case of studying terrorism, costs and benefits have not always been clearly recognizable for the purpose of adjudicating rationality. The result of which has meant attempting to develop a better understanding of the environment surrounding terrorism for the purpose of determining the presence or absence of rationality.

A number of questions regarding terrorists have been addressed in trying to understand their behavior, including what leads terrorists to commit such horrific acts? As determined during our discussion on defining terrorism, terrorists are motivated by political, religious, or ideological goals. However, how does one decide to employ such violent methods as a means of obtaining these goals? After all, aren't alternatives available for pursuing these goals at a lesser cost to the individual? Costs that include loss of time with family, loss of money that could have been earned through employment, disconnection from friends, risk of punitive reactions and, in many cases, loss of one's own life. Additionally, how successful have terrorists been?

So, is the terrorist rational? The question can be analyzed from both a conceptual and historical perspective. In doing so, I frame the discussion in both the context of the individual perpetrator and group. The individual perspective may introduce additional challenges, including how to deal with the free-rider problem. After all, "at a group level, it appears perfectly rational: [terrorists] contention places enormous pressures on adversaries and increases the likelihood that the group will achieve its objective" (Wiktorowicz and Kaltenthaler 2006, 295) However, in the case of the individual wouldn't it be more rational to "free-ride off the efforts of others rather than jeopardize personal self-interest?" (Wiktorowicz and Kaltenthaler 2006, 295) Important to the discussion is the recognition that "we cannot judge an action as irrational simply because we do not agree with the studied actor's preference ordering." (Wiktorowicz and Kaltenthaler 2006, 300) As long as the individual believes he is optimizing his preferences, the individual is acting rationally. The challenge is in identifying his preferences.

## Psychological and Sociological Explanations

Several theories have been developed for explaining the terrorist's choice of action. Some have developed psychological or sociological approaches for dealing with the problem of explaining terrorists decisions. According to Jerrold Post, "political terrorists are driven to commit acts of violence as a consequence of psychological forces." (Post 1998, 25) Furthermore:

It is not my intention to suggest that all terrorist suffer from borderline or narcissistic personality disorders or that the psychological mechanisms of externalization and splitting are used by every terrorist. It is my distinct impression, however, that these mechanisms are found with extremely high frequency in the population of terrorists, and contribute significantly to the uniformity of terrorist." (Post 1998, 27)

Others have not been so inclined towards emphasizing the dominance of psychological forces in explaining the actions of terrorists. According to Martha Crenshaw, "psychology is indeed important in determining such behavior." However, terrorists "resort to violence as a willful choice made by an organization for political and strategic reasons, rather than as the unintended outcome of psychological or social factors." (Crenshaw 1998, 7) Psycho-socio models face further difficulties when presented with developing adequate profiles of terrorists. According to William Shughart:

Scholarly work aimed at developing a composite personality profile of the archetypal terrorist has by and large been unsuccessful, however. Although most terrorists have been young, some very young, and the vast majority have been male, no aspects of race, ethnicity, education, income employment or social status conclusively can be said to

distinguish terrorists from non-terrorists, either now or in the past. Nor, apparently, does terrorism have roots traceable to genetic factors, psychological difficulties in early childhood, a disturbed family life, or identification with the underclass. As a unique personality type, the representative terrorist does not exist: there never was such a person. (Shughart 2006, 1)

In short, terrorists defy categorization based on psychological or sociological profiles. Terrorists are not “mainly poor, uneducated, immature religious zealots or social losers” proceeding irrationally (Pape 2005, 216). If any conclusion concerning the general classification of terrorists is possible, it would be that they “resemble the kind of politically conscious individuals who might join a grassroots movement more than they do wayward adolescents or religious fanatics.” (Pape 2005, 216) Research on terrorism has not only challenged problematic profiles of terrorists, but also reveals the strategic nature of terrorism. Such evidence has provided even greater support for the position that terrorists are capable of acting rationally in the planning and execution of terrorist attacks.

### Why Terrorists Engage in High Risk Behaviors

The costs to terrorists can be high, which begs the question: If the terrorist is a rational agent, why would he decide to pursue actions that come at such a cost, especially when alternative approaches may be available at a lesser cost? According to Martha Crenshaw, “An organization or a faction of an organization may choose terrorism because other methods are not expected

to work or are considered too time consuming, given the urgency of the situation and the government's superior resources (Crenshaw 1998, 16)", which, again, illustrates the capability of terrorists to strategically calculate outcomes. In that case, if it is determined that they chose to engage in terrorism given the view that alternatives to terrorism would provide less benefit, then it may be consistent with rational behavior. However, even if it is determined that no other alternatives are available for accomplishing the goals of the organization, it still needs to be considered whether the benefits of the action outweigh the costs. In the case of terrorism, the costs are plentiful and largely beyond the scope of my work, but mentioning a few does assist in broadening one's understanding of the complexities involved in calculating the costs and benefits involved in making strategic decisions by terrorists.

Acts of terrorism inevitably lead to punitive backlash by the target or those associated with the target, including those receiving benefits from the stability of the country being attacked. However, "the organization may believe that the government reaction will not be efficient enough to pose a serious threat." That may be the case of attacks on targets with limited resources. Even in the case of targets possessing numerous resources, including a robust military, the terrorist may calculate that the benefits of the attack outweigh the costs by taking measures to minimize costs incurred as a result of retaliation "by the advance preparation of building a secure underground" Furthermore, it may be determined that the present sacrifice to the terrorist

organization is worth it if it inspires resistance by sympathizers in the future or creates the circumstances for increases in recruiting. (Crenshaw 1998, 13)

Another potential cost to the terrorist organization is alienation and loss of support by sympathizers as a result of the use of indiscriminate violence towards civilians. Loss of support comes at a cost to the terrorist organization. If sympathizers begin defecting from the cause, the terrorist suffers diminishing resources supplied by allies, including shelter, weapons, money, and food. The terrorists often try “to compensate by justifying their actions as the result of the absence of choice or the need to respond to government violence. In addition, they may make their strategy highly discriminate, attacking only unpopular targets.” (Crenshaw 1998, 15)

As with discussions considering the costs of terrorism, a number of benefits can be pointed out in furthering our understanding of the terrorist’s strategy. In many cases, the explicit demand by the organization is not the only factor in determining success. Saying that “extremist groups resort to terrorism in order to acquire political influence does not mean that all groups have equally precise objectives or that the relationship between means and ends is perfectly clear to an outside observer.” (Crenshaw 1998, 16) A deeper understanding of the individual or group motivators makes a game-theoretic analysis more reliable.

If the violence of terrorists is skillfully articulated it can provide an agenda-setting platform upon which the organization is endowed with a voice that would otherwise not be heard by many. Even in the case of incurring high

costs, the belief may be that “by attracting attention it makes the claims of the resistance a salient issue in the public mind. The government can reject but not ignore an opposition’s demand’s” (Crenshaw 1981, 386) For example, in 1974 the Palestinian Black September organization accepted the costs of sacrificing a base, alienating the Sudanese people, and killing Americans and Belgian diplomats for the benefit of spreading the message of “taking us seriously.”

From the perspective of the individual perpetrator, including suicide attackers, rationality can also be defended. “Even radical movements previously described as unflappable, ideological zealots trapped by rigid adherence to dogma are now analyzed as strategic thinkers.” (Wiktorowicz and Kaltenthaler 2006, 299) In doing so, the suggestion that free-riding would be the rational decision must be challenged. After all, why commit to terrorism when it is possible to benefit from the sacrifices of others at no or little cost to oneself? According to Robert Pape, “The small number of studies addressed explicitly to suicide terrorism tend to focus on the irrationality of the act of suicide from the perspective of the individual attacker.” (Pape 2003, 1) However, it can be argued that the actions of the attacker are based on strategic considerations; even when the attackers own life is among one of the calculated costs. As Crenshaw points out “People realize that their participation is important because group size and cohesion matter. They are sensitive to the implications of free-riding and perceive personal influence on the provision of public goods to be high.” (Crenshaw 1998, 9) It is because of

such personal convictions that the suicide terrorist will conclude the benefits of his actions outweigh the costs. His participation in the collective effort of the terrorist organization is of greater value than his own life, and his commitment to certain death is not, in and of itself, sufficient for dismissing this action as irrational. According to Todd Sandler, “engaging in risky, even deadly, activities is not indicative of irrationality, as firefighters and ordinary people assume such risks daily” (Sandler and Engers 2007, 289) Although I agree with Sandler that risky behavior is not “indicative of irrationality”, the behavior of suicide terrorists is differentiated from risky behavior by commitment to death; two qualitatively different behaviors, however, his point is a salient one: the suicide terrorist is not necessarily irrational because of his commitment to risky behavior and avoidance of free-riding.

Considering religious motivators also provides insight into the rationality of terrorists. Although not all terrorists are motivated by religious goals, it has become a prevalent factor in the modern context of terrorism, and provides an example of how seemingly irrational behavior can be understood as rational from the perspective of some, and why free-riding is seen as better off avoided. Terrorist organizations sometimes espouse their religious ideology “as an efficient (and often exclusive) path to salvation, which serves as a heuristic device for indoctrinated activists to weigh the costs and benefits of certain actions and behaviors.” The result of such a view is that individuals face high costs for not meeting the demands of God, which are framed in the context of commitment to the cause of the terrorist group. The free-riding

dilemma is avoided because individuals are adjudicated “on judgment day according to whether they personally followed the commands of God, [and] free-riding jeopardizes salvation.” (Wiktorowicz and Kaltenthaler 2006,)

### Terrorists Understanding of Efficacy

Other arguments challenging the rationality of terrorism have espoused that terrorism is rarely successful. According to the argument, if terrorism is designed to accomplish specific goals and repeatedly fails to do so, then the terrorist is acting irrationally. After all, would a rational person do the same thing over and over again and expect a different outcome? According to Lutz, “It should be recognized, of course, that the vast majority of terrorist groups fail to achieve any of their goals.” (Lutz 2009, 3) Carr and Abrahms have agreed with Lutz, concluding that whether it is committed during times of war in an attempt to terrorize the civilian population or to target governments in power terrorism will usually fail. (Abrahms 2006 and Carr 2002) Others have not been easily convinced of the failures of terrorism. In his article *Sabotaging the Peace: The Politics of Extremist Violence* Andrew Kydd concludes that “most extremist violence is not indiscriminate or irrational” and “extremists are surprisingly successful in bringing down peace processes if they so desire.(Kydd and Walter 2006)” Alan Dershowitz has argued that Palestinian gains provide evidence for the effectiveness of terrorism, proving that “it works” and is “an entirely rational choice to achieve political objective.”

(Dershowitz 2002, 86) Scott Atran has argued that terrorists organizations generally achieve their objectives. As an example Atran notes that Hezbollah compelled the United States to remove remaining forces from Lebanon in 1984. (Atran 2004) Pape has supported the conclusion in his assertion that over the last twenty years, suicide terrorism has been increasing because terrorists have realized that it pays. Pape provides evidence for his conclusion through research on terrorist campaigns occurring between 1980 and 2003. According to Pape, six of the eleven campaigns involved in his study demonstrated “significant policy changes by the state” and that “a 50 percent success rate is remarkable.” (Pape 2003, 61) Abrahms challenges the position that terrorism has been proven successful based on these events saying “This emerging consensus lacks a firm empirical basis” and that “the notion that terrorism is an effective coercive instrument is sustained by either single case studies or a few well-known victories.” (Abrahms 2006, 45) Drawing conclusions over the successfulness of terrorism from a historical perspective is an important one, however, perception by the terrorist regarding success is one of the most important factors in evaluating his rationality. And if terrorists perceive previous campaigns as successful, then it is likely future campaigns will be forged partially on that basis. And doing so is entirely consistent with the position that terrorists are capable of acting rationally.

A conclusion on the rationality of terrorists is important to the potential development of game-theoretic approaches to analyzing terrorism. Although the debate concerning the terrorist’s ability to rationally weigh out the costs

and benefits of his actions will continue, as we have seen, there are a number of conceptual and historical arguments supporting the position. As a result, a number of researchers have accepted the assumption of rationality and employed the use of game theory in analyzing terrorism.

## CHAPTER IV

### REVIEW OF GAME THEORY LITERATURE

The use of game theory by scholars in analyzing terrorism has grown in popularity since initial applications in the 1980's, especially in the last decade. Applications have included analyzing the choice of target by terrorists, the effectiveness of no-negotiation policy by the U.S. and other countries, cooperation between countries and terrorists, and whether a country should implement proactive or reactive antiterrorism policies. Because of my elimination of state actors from the definition terrorism I developed earlier, non-state terrorism will be the focus of my attention in this chapter with the intention of highlighting particular game-theoretic approaches that have proven valuable and can be further applied to additional circumstances in the following chapter where I develop game-theoretic models.

#### Game-Theory Concepts

Game theory models have been applied to a diverse set of circumstances involving terrorism, but developed over time using general concepts. Any analysis using game theory will include some of these concepts, as they are essential components of game theory models. In considering how models are designed for the purpose of understanding existing literature and developing original models, it is important to keep several concepts in mind.

Will the individual players be aware of one another's move(s) in the game or not? This question is directly related to a couple of concepts used throughout the development of models. Games can be designed as either sequential or simultaneous move games. The primary distinction between the two types involves access to information by one player related to decisions made by the other players. In the case of sequential games, one player will make decisions regarding his actions before the other player makes his. However, it is important to recognize that in the case of sequential games, if no information regarding the other player's decision is gained by the opposing player, then the game is not sequential, but rather simultaneous. In short, if a player's move provides the other with information related to his move, then the game is sequential. If not, then it is simultaneous.

The concepts of sequential and simultaneous games are directly related to the concepts of imperfect and perfect information in game theory. If every player involved in the game observes the move(s) of all other players, then the game is considered one of perfect information. If no players or only some players observe the moves of other players, then the game is defined as an imperfect information game.

An additional concept that is used throughout game theory literature is that of single shot games and iterated games. In the case of single shot games, the players move through each stage of the game until it has terminated with a final decision. The game is not repeated. In the case of iterated games, the games are repeated. The consequence of iterated games is the potential for

continued learning by the players based on previous iterations and therefore adjustments to previous play based on what has been learned through the previous experience.

## Non-Negotiation

A fundamental policy throughout U.S. history has been never to negotiate with terrorists or surrender to their demands. The same stance has been taken by other countries, including Israel. The logic behind the policy is that if target countries commit to the no-negotiation policy, then potential hostage takers will decide not to abduct hostages since there would be nothing to achieve through the act. However, in that case, why do terrorists continue to take hostages? It is clear that countries with even the strictest no-negotiation policy do still renege on their pledge to never “give in” to terrorists. For example, during the 1985-1986 “Irangate” scandal, the Reagan administration was willing to negotiate the release of David Jacobsen, Lawrence Jenco, and Benjamin Weir for arms trade. In 1974, Israel was willing to trade prisoners for the release of schoolchildren taken hostage in Maalot. Game theory models have been designed for the purpose of explaining decisions by players, including terrorists.

Scholars have challenged the completeness of the no-negotiation policy through the development of game-theory models. In their work *To Bargain or Not To Bargain: That Is The Question*, Lapan and Sandler use a game in

extensive form to show that the governments level of deterrence determines the failure or success of terrorists engaging in a hostage mission. According to Lapan and Sandler, if the expected payoffs from taking hostages are positive, then the terrorists will attack. The game can terminate in one of four ways: no attack, an attack that results in a logistical failure, a successful attack that results in no concessions or a successful attack the ends with the terrorists obtaining their demands (Lapan and Sandler 1988). According to Sandler, information in the game is imperfect because “the government does not know the payoffs associated with not capitulating prior to hostage incidents.” (Lapan and Sandler 1988, 3) The ability to determine those payoffs requires quantifying the importance of the person taken hostage. “if a sufficiently important person is secured, then the government may regret its no-negotiation pledge because the expected costs of not capitulating may exceed that of capitulating.” (Lapan and Sandler 1988, 3) That is, the no-negotiation policy is “time inconsistent” if a person of sufficient value is taken hostage. Even when the no-negotiation policy is believed by the terrorists, it is possible that the payoffs associated with a negotiation failure are still higher than the costs because the terrorist organization places a sufficiently high value on the payoffs of popularizing the cause or martyrdom.

Using game-theory, Lapan and Sandler illustrate how the no-negotiation policy hinges on assumptions of the government’s credibility when pledging not to negotiate with terrorists, benefits being exclusively tied to success of negotiation, the presence of complete information, and sufficient

deterrence spending by the government having at risk hostages. Each of these assumptions, when considered from the perspective of real-world practices, is suspect, and the application of game theory contributes to this finding. (Lapan and Sandler 1988)

### Choice of Target

Other game theory models from the literature have been constructed for analyzing the terrorist's choice of target and deterrence expenditures by countries. In this model, a three-player game is developed in which the terrorist must choose between attacking country A or B and country A and B independently decide their deterrence expenditures, which "determines the terrorists' logical failure probability on that nation's soil" (Arce and Sandler 2003, 3; Sandler and Siqueira 2006) The level of deterrence by each country will confer benefits and costs upon each other. For example, when country A's deterrence expenditures are higher than country B's deterrence expenditures, country A will benefit by decreasing the probability of an attack on country A. However, this comes at a cost to country B, since the terrorist will likely decide to attack whichever country is perceived by the terrorist as weaker and therefore, more vulnerable to attack. However, as Sandler points out, deterrence by country A will also provide an "external benefit" to country B when residents from there are living in country A and vice versa for residents of country A living in country B. Absent external benefits, both country will

prefer higher levels of deterrence, since that decreases the chance of an attack on one's own country. "If, for example, attacks in either country lead to no collateral damage on foreign residents of interests, then the countries will engage in a deterrence race as each tries to transfer the potential attack abroad, where it has no residents." (Arce and Sadler 2003, 4) As with the use of game theory when analyzing hostage negotiation involving terrorists, game-theoretic models have revealed important variables involved in deciding the level of expenditures committed to deterrence and what costs and benefits are involved in making that decision. Intuitively, one may commit to the position that higher levels of deterrence are always preferable to lower levels. However, by examining the situation more closely using game theory, it becomes apparent that additional considerations are necessary. For example, upon sufficient deterrence by one country (A), where will the attack occur, and what costs are incurred by country A as a consequence. These costs could include residents living in the attacked country, as already noted. Like the hostage example discussed earlier, the level of importance associated with the individual in danger is also a factor. If attacks are deterred to countries where persons of value to the deterring country are present, then the costs to that country will be higher than in cases where no such person is at risk of being affected.

Although the U.S. has committed numerous resources to deterrence and, aside from the noticeable exception of 9/11, done so successfully on the homeland, approximately 40% of all transnational terrorist attacks have been against the United States. According to Sandler, "U.S. overdeterrence means that it

experiences attacks where it has little authority to do anything about them.”

This may provide evidence for why U.S. embassies have been the target of many attempted and successful attacks.

### Preempt Versus React

Deterrence as a countermeasure against terrorist attacks provides an example of a reactive policy. Other models have been designed with the intention of reviewing reactive versus proactive policies in the fight against terrorism. Proactive policies involve aggressively going after the organization by reducing their resources, whereas reactive policies are designed to limit the consequences of an attack or divert such an attack, as is the case with deterrence.

In their work *Terrorism & game theory*, Sandler and Arce discuss both proactive and reactive policies using game theory as their analytical model for drawing conclusions. Having a closer look at their methods will provide a better understanding as to how game theory can assist with policy development. Given my intention of illustrating the value of game theory to policy makers rather than developing a complete summary of Sandler's work, I am restricting my discussion to only one component of their analysis.

Sandler constructs a two player non-zero-sum game in which each player must decide whether to preempt a common terrorist threat or not. Using game theory, Sandler demonstrates why neither country will preempt under

certain circumstances. For Sandler’s purposes the players in the scenario are the United States and the European Union. There are four possible outcomes to the game: (1) both countries decide to preempt (2) both countries decide not to preempt (3) the U.S. decides to preempt and the European Union decides not to preempt (4) the European Union decides to preempt and the U.S. decides not to preempt. The outcomes are represented in figure 1.

		European Union	
		preempt	Do Not Preempt
U.S.	Preempt	2, 2	-2, 4
	Do Not Preempt	4, -2	0, 0

*Figure 1. Preempt versus do not Preempt*

Sandler supposes that each country receives a benefit of 4 when preemption occurs. Furthermore, a cost of 6 is incurred by the country choosing to preempt. “If, however, both countries preempt, then each receives 2 in net benefits as preemption costs are deducted from gross benefits of 8 (+2x4).” (Arce and Sadler 2003, 8) The resulting outcome is a prisoner’s dilemma in which both countries decide that the logical approach is to not preempt. The reason this occurs is that both countries are trying to maximize their net gain, in this case 4. The only option for doing so is to free ride when the other country preempts. As a result, both countries receive a net gain of 0, consequently remaining at risk for potential attack.

## CHAPTER V

### DEVELOPMENT OF GAME THEORY MODELS

As a review of the literature has demonstrated, the use of game theory has been employed by a number of scholars for the purpose of illustrating its value to decision makers. As with all theory, the intention in developing game theory models for examining terrorism is not to draw definitive conclusions, but rather to provide reasonable predictions and explanations that can then be compared against actual events. The existence of extraneous variables explains the reason for developing only approximations. One cannot account for every variable involved in the formation of preferences in such dynamic environments as those being considered. However, there is still value in developing such an analysis using game theoretic models. As I have argued, provided the assumption of rationality, game theory is a viable approach to analyzing terrorism with the benefit of contributing to policy development. The benefits of its use have been touched on in my discussion of previous work developed throughout the literature. In the current chapter my intention is to add to this body of work by designing game-theoretic models examining the allocation of resources in the fight against terrorism. In doing so, it is possible to contribute further to the body of literature exploring this topic, specifically considering the use of mixed strategy approaches in which it is necessary to take into account that outcomes of the game being considered are not certain,

as some games have been shown to do, but probabilistic. This approach requires additional strategies.

## Airline Security

Mixed strategies are necessary to the analysis of our games when no pure strategies are available. In the game I develop, I consider a mixed strategy zero-sum game, meaning that one player's gain is equal to the loss of the other player. Furthermore, the game is designed to be a single shot game, meaning that each player will make a single choice on one and only one occasion, so that there is no opportunity for repeated play. Because the model is designed as a simultaneous game, it is also characterized as an imperfect information game. The goal of this particular game is to provide further support for the position that game theory can assist policy makers in the process of making decisions by exploring the use of game theory analysis.

The game I develop considers the protection of airport targets and the allocation of limited resources in the protection of those targets. The model can be generalized in its application. That fact is one of the strengths of game theory. An analysis of one game can provide valuable insights into other circumstances fitting the same model. For the purpose of my design, I consider a terrorists planned attack against airport personnel. There are a few assumptions that need to be included for the purpose of the design. First, I assume that security and terrorist resources are limited. This limitation forces

both players in the game to make decisions regarding the placement of personnel. The goal of the terrorist is to breach security for the purpose of attacking airport targets. For the purpose of the game, I consider the target to be a plane, but, again, the particulars in the development of the model are largely intended for illustrative purposes. Second, I limit myself to only two choices for both the terrorist and security. Thirdly, I assume the attack will either succeed or fail according to a single decision made by each the terrorist and security. Fourthly, I assume that an attack on one or the other terminal will occur. Without this assumption, an additional outcome could be added in which security does not guard either terminal and no attack occurs. That would of course be the preferred outcome from the perspective of security since the cost of allocating security to a terminal would be saved without suffering an attack. Lastly, I consider this a game of imperfect information in which neither player knows what decision the other will make. If that were not the case, then obviously the terrorist would decide to attack the terminal absent security or security guard the terminal chosen by the terrorist. I do, however, adjust this assumption as my game progresses in order to introduce probability theory into the analysis. This is done on the basis of players having enough information available to them to assign probabilities to the selection of a terminal by the other player. Real-life circumstances are of course much more complicated than my assumptions allow, but reduction of variables permits one to construct models that can be expanded upon in the future.

A successful attack by the terrorist depends on attacking one of two terminals, A or B. Airport security must decide between protecting one of two terminals, also A or B. Both the terrorist and airport security are restricted to making one of two choices, which, when analyzed reveals four outcomes in the game: (1) The terrorist attacks terminal A and security guards terminal A (2) The terrorist attacks terminal A and security guards terminal B (3) The terrorist attacks terminal B and security guards terminal A (4) The terrorist attacks terminal B and security guards terminal B. The outcomes have been illustrated in figure 2 using a 2 X 2 matrix.

		Terrorist	
		Attack Terminal A	Attack Terminal B
Security	Guard Terminal A	1, -1	-1, 1
	Guard Terminal B	-1, 1	1, -1

Figure 2. Attack Terminal A or Terminal B using Values

By examining the cells of the matrix, we see the payoffs associated with each of the outcomes. In this case, the matrix is designed with ordinal payoffs because the value of the numbers is unimportant to the outcome. The implications of the model would not be affected if we were to multiply each of the values by any positive number N. What is important to our analysis is identifying preference by each of the involved players. In the case of the

terrorist (t), the preferred outcome (PO) is to attack the terminal with no security. An outcome which occurs when security guards terminal A and the terrorist attacks terminal B (AB) or security guards terminal B and the terrorist attacks terminal A (BA):

$$PO_t=AB \quad \text{and} \quad PO_t=BA$$

The airport securities (s) preferred outcome (PO) is to guard the terminal of the attack, which occurs when security guards terminal A and the terrorist attacks terminal A (AA) or security guards terminal B and the terrorist attacks terminal B (BB):

$$PO_s=AA \quad \text{and} \quad PO_s=BB$$

Because of this preferential understanding by both the terrorist and security, a matrix could be constructed by replacing specific values with variables, so long as the preferences of those variables is understood. Figure 3 provides an alternative for doing so and can be used in an analysis of the previously describes scenario as long as it is understood that for both the terrorist and security  $X > Y$ .

		Terrorist	
		Attack Terminal A	Attack Terminal B
Security	Guard Terminal A	X, Y	Y, X
	Guard Terminal B	Y, X	X, Y

Figure 3. Attack Terminal A or Terminal B using Variables

By examining either matrix it is demonstrable that there is no pure strategy Nash equilibrium (NE). To understand why, consider that (AA) can't be a (NE) because the terrorist would want to switch to (B), (BA) can't be a (NE) because security would want to switch to (A), (BB) can't be a (NE) because the terrorist would want to switch to (A), and (AB) can't be a (NE) because security would want to switch to (A). By definition, then, none of the cells contain a (NE). However, this conclusion only applies to pure strategies, so if equilibrium is possible, it must be in mixed strategies. This is normally the case with games in which each player is attempting to outsmart his opponent by keeping him guessing as to what he will do. Unlike pure strategies, mixed strategies require the introduction of probability when analyzing what each player will do given a particular situation.

We can determine best responses to our game using mixed strategies, but only after understanding the use of probability within the context of our scenario and why a mixed strategy approach is necessary under these circumstances. It is here that my assumption of imperfect information requires adjustment. In order to introduce probability into the discussion, players must be permitted availability of enough information to assign probabilities. Let  $p(A)$  be the probability that the terrorist will attack terminal A and  $p(B) = 1 - p(A)$  the probability that the terrorist will attack terminal B. Likewise, we can denote the probability of security guarding terminal A or B using  $q(A)$  as the probability that security will guard terminal A and  $q(B) = 1 - q(A)$  as the probability of guarding terminal B. This is understandable when recognizing

that the sum of our probabilities must equal 1. If the terrorist will attack terminal A with probability  $p(A)$  and security decides to guard terminal B, the terrorist attack will fail with probability  $1 - p(A)$ , which represents the probability that the terrorist will attack terminal B. However, in that case, when security is guarding terminal B the terrorist attack will succeed with probability  $p(A)$ . If security decides to guard terminal A, then the attack will fail with probability  $1 - p(A)$  and succeed with probability  $p(A)$ . Since neither of these choices leads to a certain outcome, we can eliminate a pure strategy from our best response, meaning neither choice is necessarily always the best one.

Because of this conclusion, it is necessary that both players calculate their expected utility from choosing terminal A and terminal B. Unlike pure strategies in which a comparison between the available options yielded enough information for determining what to do, mixed strategies require additional steps. This is the case because a choice can result in more than one outcome. If the terrorist decides to attack terminal A, security may or may not be waiting. Expected utilities are calculated by multiplying the probability of a particular outcome occurring by the payoff associated with that outcome. For example, if security guards terminal A, the attack will fail with probability  $p(A)$  or succeed with probability  $1 - p(A)$ . The payoff to security of a failed attack is 1 and  $-1$  with a successful attack. Therefore, security's expected utility from guarding terminal A is:

$$EU_s(A) = p(A)(1) + (1 - p(A))(-1) = 2p(A) - 1$$

If the terrorist attacks terminal A with probability  $p(A) = \frac{1}{4}$ , then security's EU from choosing A will be:  $(2) (\frac{1}{4}) - 1 = -\frac{1}{2}$ . Security's EU from guarding terminal B is calculated using:

$$EUs(B) = (1 - p(A)) (1) + p (A) (- 1) = 1 - 2p (A)$$

If, again, the terrorist attacks terminal A with probability  $p(A) = \frac{1}{4}$ , the security's EU from guarding terminal B would be  $1 - (2) (\frac{1}{4}) = \frac{1}{2}$ .

Once the EU has been calculated for each possible strategy, the best response can be determined by comparing EUs. The best response is the strategy with the greatest EU. Once the calculations have been completed the utilities can be compared to determine the best course of action. This stage in the process is similar to comparing outcomes using pure strategies. The major difference between the two methods is that a mixed strategy approach calculates EU, which is necessary given the probabilistic component of the game, and requires the additional step of calculating outcomes based on those probabilities. For example, security's best response given probability  $p(A) = \frac{1}{4}$  of attacking terminal A is to guard terminal B because of the EU of  $\frac{1}{2}$ , rather than guarding terminal A, with an EU of  $-\frac{1}{2}$ . That is what one would expect given the situation. The probability of attacking terminal B is  $1 - \frac{1}{4}$ , which is  $\frac{3}{4}$  or 75%. The terrorist is 50% more likely to attack terminal B, so security's best response is to guard that terminal.

Because there are a large number of mixed strategies it is unrealistic to derive a complete set of outcomes. However, it can be generalized that, given

whenever securities EU to guard terminal A is greater than the EU of guarding terminal B, the best response is to guard terminal A:

$$EUs (A) > EUs (B) \text{ or } 1 - 2p > 2p - 1$$

Therefore, it can be concluded that whenever the terrorist attacks terminal B with a probability less than one-half, the security's best response is to guard terminal A or, as one would expect, whenever the terrorist is more likely to attack terminal A, security should guard terminal A. The same can be done in calculating when guarding terminal B would be the optimal choice. Here, the inverse of the above equation will be true:

$$EUs (A) < EUs (B) \text{ or } 1 - 2p < 2p - 1$$

In this case, the solved inequality yields  $p > \frac{1}{2}$ , meaning that whenever the terrorist attacks terminal B with a probability greater than 50%, security's best response is to guard terminal B.

The only other alternative not covered in the previous discussion is the possibility that:

$$EUs (A) = EUs (B)$$

In the case of the equality above, security is indifferent between guarding terminal A and B because the EU between both strategies is equal. So, if the terrorist will attack both terminal A and B with equal probabilities, the expected utility of guarding terminal A equals the expected utility of guarding terminal B and either strategy is as good as the other, so both are considered best responses.

In summary, if the terrorist plays a mixed strategy where  $p < \frac{1}{2}$ , security's best response is to guard terminal A. If the terrorist plays a mixed strategy where  $p > \frac{1}{2}$ , then security's best response is to guard terminal B. And if the terrorist plays a mixed strategy where  $p = \frac{1}{2}$ , then security's best response is to guard either terminal A or B. The cases of  $p < \frac{1}{2}$  and  $p > \frac{1}{2}$  are rather straight forward. If the terrorist is more likely to attack terminal A, then security should guard terminal A and if the terrorist is more likely to attack terminal B, then security should guard terminal B. However, in the case that  $p = \frac{1}{2}$ , security can choose to either guard terminal A as a pure strategy, guard terminal B as a pure strategy, or randomize between guarding terminal A and B as a mixed strategy. As already mentioned, when  $p = \frac{1}{2}$ , security is indifferent to guarding either terminal. The use of randomization can be shown as a viable alternative to using a pure strategy of guarding terminal A or B all of the time. For example, if security were indifferent to either of the two terminals, which is the case under consideration, they could decide to guard terminal A 35% of the time and terminal B 65% of the time and it would not affect our conclusion regarding the situation. Whenever  $p = \frac{1}{2}$ , the expected utility of guarding either terminal is the same, even when deciding to guard terminal A some percentage of the time and terminal B some percentage of the time. In other words, if the terrorists will attack either terminal A or B with equal probability (50%), then security's best response can be either a pure strategy, say always guarding terminal A (or terminal B for that matter) or a mixed strategy in which randomization is implemented by arbitrarily deciding to guard terminal A and

B some percentage of the time. Security's best responses (BR) in deciding which terminal to guard can be summarized in terms of guarding terminal A

(a):

$$\text{BRs} = \begin{array}{lll} q=1 & \text{if} & p < 1/2 \\ q=0 & \text{if} & p > 1/2 \\ 0 \leq a \leq 1 & \text{if} & p = 1/2 \end{array}$$

The first two cases are examples of pure strategies in which, whenever  $p > 1/2$ , security should always choose to guard terminal A and whenever  $p < 1/2$  security should never guard terminal A. In the third case security has an endless number of BR to choose from.

We can determine the terrorist's best responses in much the same way as we did in determining best responses from the perspective of security. Given the redundancy of the process, I provide a condensed outline for determining the terrorist's best responses. We must first calculate the EU associated with attacking terminal A and B from the perspective of the terrorist. The EU of attacking terminal A can be calculated using the equation:

$$\text{EU}_t(\text{A}) = q(-1) + (1-q)(1) = 1 - 2q$$

The EU of attacking terminal B will be calculated similarly, except the encounter with security resulting in a failed attempt occurs at the alternative terminal:

$$\text{EU}_t(\text{B}) = q(1) + (1-q)(-1) = 2q - 1$$

The terrorist will prefer to attack terminal A whenever the expected utility of doing so is greater than the expected utility of attacking terminal B:

$$EU_t(A) > EU_t(B)$$

Therefore, whenever security decides to guard terminal A with a probability of less than 50% ( $q < 1/2$ ), the terrorist's best response is to attack terminal A every time ( $p=1$ ). On the other hand, if  $q > 1/2$ , meaning the probability of security guarding terminal A is greater than 50%, the terrorists should never attack terminal A ( $p=0$ ). If  $q=1/2$ , the terrorist is indifferent in his decision to attack terminal A and B and both choices are best responses. The situation can be summarized as follows:

$$BR_t = \begin{array}{lll} p=1 & \text{if} & q < 1/2 \\ p=0 & \text{if} & q > 1/2 \\ 0 \leq p \leq 1 & \text{if} & q = 1/2 \end{array}$$

As one can quickly see by examining the information from our analysis of the terrorist's and security's circumstances, the mathematical methodology used in determining what to do is identical for both players. The information presented thus far can now be used in determining equilibria.

Our analysis demonstrates the existence of three strategies for both security and the terrorist: Attack or guard terminal A or B all of the time or randomize between the two terminals. Consider the strategy  $(1, q)$  in which the terrorist chooses to attack terminal A. As we can see above, in order for this to constitute a best response, security must select to guard terminal A less than

one-half of the time or if  $q < \frac{1}{2}$ , then  $p=1$ . However, security's best response to the terrorist playing  $p=1$  (attacking terminal A all the time) is  $q=1$  (guarding terminal A all the time). This outcome eliminates the possibility of  $(1, q)$  as a best response which would necessarily require  $q < \frac{1}{2}$ . Therefore, the strategy cannot be an equilibrium.

As an alternative, examine strategy  $(0, q)$ . In this case, the terrorist attacks terminal B every time. However, this turns out to be a best response only if  $q > \frac{1}{2}$ , however, security's best response to  $(0, q)$  is  $q=0$ , which eliminates the required  $q > \frac{1}{2}$  and subsequently cannot be an equilibrium. By extending our analysis to strategies  $(1, p)$  and  $(0, p)$  it can be concluded that neither option can be equilibria either. It has already been determined that there are no pure Nash equilibriums in the form of the game under consideration. Therefore, the only alternative is to examine strategy  $(p, q)$  in which both security and the terrorist rely on mixed strategies.

We discerned from our earlier discussion that players are willing to randomize only in cases where they are indifferent between the other strategies. The terrorist is willing to randomize when security uses a mixed strategy with probability  $q = \frac{1}{2}$ . The same is true of security, which is willing to randomize between guarding terminal A and B only when indifferent to the pure strategy of guarding one or the other. This outcome is indicative of the terrorist randomizing with probability  $p = \frac{1}{2}$ . This can be better understood by recognizing that when security is using mixed strategy  $q = \frac{1}{2}$ , the terrorist is indifferent to either of his available pure strategies and can therefore mix between the two. Likewise, when the terrorist is using mixed strategy  $p = \frac{1}{2}$ , security is indifferent to either of his available pure strategies and can therefore mix between the two. Therefore, it can be concluded that the mixed strategy

equilibrium of this particular game is when both security and the terrorist randomize and  $q$  and  $p$  are equal to one-half.

From this we can conclude that the optimal strategy by both players is randomization for the purpose of preventing one another from guessing what the other is going to do. The outcome of such a game, based on the mutual best responses of randomizing, is that security will sometimes succeed at preventing the terrorist's attack and sometimes fail. The probability can be calculated by recognizing that in equilibrium the terrorist will attack terminal A with probability  $q = \frac{1}{2}$  and security will guard terminal A with probability  $q = \frac{1}{2}$ . Therefore, the probability that both the terrorist and security end up at terminal A can be calculated by multiplying the probabilities of both:  $(.5)(.5) = .25$ . The probability that they both end up at terminal A and the terrorist fails is 25%. Likewise, using identical calculations for determining the probability of both the terrorist and security ending up at terminal B, it can be concluded that there is also a 25% chance. Consequently, it can be calculated that randomization by both players results in the probability that the terrorist will succeed in his attack 50% of the time and fail 50% of the time.

My intention in this chapter has been to demonstrate the application of game theory to analyzing terrorism. I have restricted myself to a basic analysis for the purpose of introducing common characteristics used throughout the field of game theory. Circumstances involving terrorism are generally more complicated than the scenario I have designed. However, through increased usage of game theory in the literature, it has been demonstrated that game theory can be applied successfully to situations involving varying degrees of complexity. Such approaches have provided policy makers with advantages in making decisions regarding how to address terrorism.

## CHAPTER VI

### CONCLUSION

Game theoretic applications to the study of terrorism have been increasingly developed throughout the literature in the last two decades, especially since the September 11, 2001 terrorist attacks on the United States. The strategic interactions between terrorists and targets make game theory an attractive tool for assisting policy makers in the design of antiterrorism policies. Some of the challenges associated with implementing the use of game theory in an analysis of terrorism have been determining what precisely constitutes terrorism and whether or not terrorists are rational agents.

My intention in this work has been to illustrate some of the deeper issues related to defining terrorism and how ones definition affects the range of game theoretic applications. Although debate over a definition will continue, my intention is that consideration of these issues assists those continuing their work on the application of game theory to terrorism in the future.

The application of game theory is based on the assumption that all players involved are rational agents. Given the widespread perception that terrorists behave irrationally, the burden of proof has fallen on the shoulders of those wishing to utilize game theory in their analysis of terrorism. My intention has been to demonstrate the challenges faced by those wishing to do so, especially in the context of considering non-state actors at the individual level where establishing rationality introduces challenges not involved in the

application of game theory to state actors. However, I contend that those challenges can be successfully overcome. By doing so, game theory can assist policy makers and scholars address circumstances involving non-state terrorism.

My development of a game theory model assumes rationality has been established. My intention has been to further demonstrate the value of designing models involving non-state terrorists. In doing so, I consider the use of pure and mixed strategy approaches for finding equilibrium. In my particular game, the outcome of our game reveals mixed strategy equilibrium. One of the values of game theory models are their applicability to multiple circumstances fitting the model. In the case of the model developed in chapter five, it is possible that other situations will arise in the real world that fit a similar design. By being familiar with the models design, conclusions can easily be drawn. These models can be extended to analyze additional areas of terrorism, including interactions between terrorist cells, state terrorism, and involvement by state sponsors with terrorists, to name a few.

#### Future Research

My design can be expanded upon to include additional complexities for the purpose of developing future research. For example, my model has been designed based on the assumption that information is symmetrical, so that both players have available as much or as little information as the other player.

However, it is possible to develop models using asymmetric information instead, whereby, for example, the terrorist has available more information on security than security has on the terrorist. This scenario seems consistent with what we know about the “real-world.” Terrorists are generally in a position to collect information on intended targets through surveillance using, for example, “dry-runs” in which security is tested. As a result, security patterns may be available to terrorists in which it can be determined how often security is guarding one terminal versus the other. Security, on the other hand, would potentially have no information regarding the terrorist’s intended target and would need to assign resources according to that understanding.

I have also assumed that resources for both the terrorist and security are indivisible. Models could be developed in which this assumption is modified. For example, security may have the resources to simultaneously guard multiple terminals or divide their time between terminals. On the other hand, provided sufficient resources, terrorists may be in a position to attack multiple terminals or successfully attack a guarded terminal because of the strength of their resources.

Future research could also be designed to further address the utility associated with a failed attack by terrorists. My design has assigned utilities of +1 and -1 for a successful attack and failed attack, respectively, from the perspective of the terrorist. However, as discussions earlier in my work regarding the motivations of terrorists have touched on, it is difficult to fully account for utility. For example, from the perspective of the terrorist, a failed

attack, because of the platform it provides for espousing his beliefs or other religious motivations, could be assigned a positive utility less than 1. If this is the case, then my original model may have underestimated the payoffs associated with a failed attack. The outcome of this possibility would result in a modified matrix having consequences on our conclusions.

The mathematical design of game theory models provides researchers with an objective component that is absent from many other approaches. Because of this, game theory can add value to the development of antiterrorism policies and the suppression of terrorism and should be considered a viable option for future research.

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