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Interfaces with Other Disciplines

On the value of exposure and secrecy of defense system: First-mover advantage vs. robustness

Mohammad E. Nikoofal[a], Jun Zhuang[b,*]

[a] UCP-Católica Lisbon School of Business & Economics, Palma de Cima, Lisbon 1649-023, Portugal
[b] Industrial and Systems Engineering, University at Buffalo, State University of New York, 317 Bell Hall, Buffalo, NY 14260-2050, USA

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ABSTRACT

It is commonly accepted in the literature that, when facing with a strategic terrorist, the government can be better off by manipulating the terrorist's target selection with exposing her defense levels and thus moving first. However, the impact of terrorist's private information may significantly affect such government's first-mover advantage, which has not been extensively studied in the literature. To explore the impact of asymmetry in terrorist's attributes between government and terrorist on defense equilibrium, we propose a model in which the government chooses between disclosure (sequential game) and secrecy (simultaneous game) of her defense system. Our analysis shows that the government's first-mover advantage in a sequential game is considerable only when both government and terrorist share relatively similar valuation of targets. In contrast, we interestingly find that the government no longer benefits from the first-mover advantage by exposing her defense levels when the degree of divergence between government and terrorist valuation of targets is high. This is due to the robustness of defense system under secrecy, in the sense that all targets should be defended in equilibrium irrespective of how the terrorist valuation of targets is different to government. We identify two phenomena that lead to this result. First, when the terrorist holds a significantly higher valuation of targets than the government's belief, the government may waste her budget in a sequential game by over-investing on the high-valued targets. Second, when the terrorist holds a significantly lower valuation of targets, the government may incur a higher expected damage in a sequential game because of not defending the low-valued targets. Finally, we believe that this paper provides some novel insights to homeland security resource allocation problems.

1. Introduction

Contrary to facing with natural disasters, where the government discloses her defense investments to the public, understanding when and how defensive investment should be disclosed is a challenging issue for governments facing terrorism attacks. Specifically, when government reveals how the targets are defended, the terrorist may have a better knowledge of the effectiveness of the defensive technologies, which increases the probability of a successful attack (Zhuang & Bier, 2010). Powell (2007a) shows that investing more in defense and disclosing to the public could be a signal to the attacker that the heavily defended targets are more vulnerable and/or valuable, and therefore may increase their probabilities of being attacked. On the other hand, for some targets that are well known to the attackers (e.g., the Sears Tower, the Pentagon, and the Golden Gate Bridge), Shapiro and Siegel (2010) show that the government can be better off by revealing defensive information rather than keeping it secret. Zhuang and Bier (2007) also show that, under complete information, the defender should advertize her defensive investments instead of keeping them secret in order to gain the benefits of first-mover advantages. Note that the above results on the advantages of either exposure or secrecy may not necessarily hold if the terrorist has private information, e.g., about his valuation of targets.

In the homeland security literature, it is commonly assumed that the terrorist behaves strategically in the sense that he responds optimally to the government's defensive actions (Jose & Zhuang, 2013). This assumption, which is usually regarded by modeling a sequential defender-attacker game, may mislead the government to a non-efficient allocation of her limited budget. After the terrorism events on September 11, 2001 there has been a dramatic increase in security at the traditional targets, such as embassies and other government properties. Observing strong security levels may lead to different possible outcomes. First, it could be a signal to the terrorist that these

* Corresponding author. Tel.: +17166454707; fax: (716) 645 3302.
E-mail addresses: mohammad.nikoofal@ucp.pt (M.E. Nikoofal), jzhuang@buffalo.edu (J. Zhuang).

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heavily defended targets are more vulnerable and/or more valuable, and therefore may increase their probabilities of being attacked. Second, it may stir the terrorist to switch his attack from *hard (firmly defended)* targets to *soft (weakly defended)* targets. Consequently, the defender may succeed only in deterring the attacker from hard targets, while increasing the threat to soft, but not necessarily less valuable targets. Finally, the terrorist may attack heavily defended targets for some reason that may not be anticipated by the government at the time of attack. For example, he may be looking to demonstrate his organization's power, incurring political and psychological threats, or showing how bold he would be in target selection.

Zhuang and Bier (2010) list some possible reasons for secrecy in the homeland security resource allocation problems. As an example, they pose the advantage of secret anthrax sterilization equipment in the U.S. post office. By announcing that information to the public, potential attackers might use private couriers to deliver anthrax. Consequently, the millions of dollars of defense may just stir the attacker to pay the slightly higher shipping fees charged by the private couriers. In contrast, secret sterilization equipment could have been effective against anthrax attacks. Therefore, the first-mover advantage in a sequential game is not always beneficial for the government. Thus, the demanding scenario is to consider the case where the government hides the defense allocations from the terrorist observation. To model such conditions, one can assume that both the terrorist and the government move simultaneously (Berman, Gavious, & Huang, 2011). Note that this does not actually require both players to decide at the same time; they can be viewed as being engaged in a simultaneous game as long as neither party knows the other's decision at the time he makes his own decision (Zhuang & Bier, 2010). The main goal of this paper is then to answer the following research questions:

Research Question 1: What is the impact of asymmetry in terrorist's attributes between government and terrorist on the government's first-mover advantage?

Research Question 2: Under what conditions can the government be better off by keeping secrecy of defense system rather than exposing it? Which feature of secrecy strategy may dominate the first-mover advantage of exposure strategy?

To answer the above questions, we develop a one-shot game between a government and a strategic terrorist. The government defends two targets and chooses between secrecy and exposure of defense system. To study the decisions under secrecy we assume that the government and terrorist play simultaneously; hence we use the Nash equilibrium approach. However, to analyze the game under exposure policy we assume that the game is played sequentially; hence we use the Stackelberg equilibrium approach. Depending on the government's decision, the terrorist may or may not observe the defense allocation, but in any case he chooses his target and the level of attack. To address research question 1, we show that the government's first-mover advantage under exposure is considerable only when both government and terrorist share relatively similar valuations of targets. In contrast, we find that the government no longer benefits from first-mover advantage by exposing her defense level when the degree of divergence between the government's and the terrorist's valuation of targets is high. To answer research question 2, our analysis shows that the defense system under secrecy is robust to the degree of asymmetry between government and terrorist about terrorist valuation of targets, in the sense that all targets should be defended in equilibrium irrespective of how different the terrorist valuation of targets is to the government. This robustness of defense system under secrecy may dominate the first-mover advantage under exposure. We identify two phenomena that lead to this result. First, when the terrorist holds a significantly higher valuation of targets than the government's belief, the government may waste her budget in a sequential game by over-investing (compared to simultaneous game) on the high-valued targets. Moreover, when the terrorist holds a significantly lower valuation of targets, the government may incur higher expected damage in a sequential game because of not defending the low-valued targets.

The remainder of this paper is organized as follows. Section 2 provides some literature review and clarifies the contribution of this paper. Section 3 presents the model framework. Section 4 provides a benchmark and analyzes the game when the defender and attacker share common valuation of targets. Section 5 explores the impact of asymmetric information on defender's strategy and the budget allocation decision. Section 6 compares the robustness of the defense system of a simultaneous game with that in a sequential game. Section 7 presents an illustrative numerical study to support the analytical results. Section 8 summarizes the main results. Finally, Appendix provides the proofs for all propositions.

2. Literature review

Operations research originated from the efforts of military applications during World War II but has been widely resumed with respect to homeland security after September 11, 2001 (Brown, Carlyle, Salmeron, & Wood, 2006; Hu, Homem-de Mello, & Mehrotra, 2011; Kaplan, Kress, & Szechtman, 2010; McLay, Jacobson, & Nikolaev, 2009; Wright, Liberatore, & Nydick, 2006). Among different techniques of operations research, game theory is a popular tool to capture the strategic interactions between the terrorists and the government on resource allocation problems among multiple targets (Cox, 2009; Hall, 2009; Hausken, 2002; Insua, Rios, & Banks, 2009). See Sandler and Siqueira (2009) for a survey of recent advances in the game-theoretic analysis of terrorism. This literature can be divided into two main streams depending on whether the defender reveals or hides her defense plan.

The literature in the first stream assumes that the attacker behaves strategically by optimally responding to the defender's resource allocation. Under this assumption, the defender, as the Stackelberg leader, can strategically manipulate the attacker's response and predict which target will most likely be attacked (Powell, 2007b; Zhuang & Bier, 2007). Within this stream, several studies explore the impact of uncertainty in the attacker's attributes on defense equilibrium (Bier, Haphuriwat, Menoyo, Zimmerman, & Culpen, 2008; Bier, Oliveros, & Samuelson, 2007; Jeneliusa, Westina, & Holmgrenb, 2010; Kardes, 2008; Nikoofal & Zhuang, 2012; Powell, 2007b; Rios & Insua, 2009; Wang & Bier, 2011; Zhang & Ramirez-Marquez, 2012). A number of studies investigate signaling games where the defender updates her belief about the attacker's attributes (Arce & Sandler, 2007; Harvey & Sandler, 1993; Hausken & Zhuang, 2011; Overgaard, 1994; Zhuang, Bier, & Alagoz, 2010). There is also some research that investigates allocating defensive resources facing both strategic threats (e.g., strategic terrorists) and nonstrategic threats (e.g., natural disasters Golany, Kaplan, Marmur, & Rothblum, 2009; Levitin & Hausken, 2009; Powell, 2007b; Zhuang & Bier, 2007 and nonstrategic terrorists Hao, Jin, & Zhuang, 2009; Nikoofal & Gumus, 2015; Shan & Zhuang, 2013b). The only paper in this stream that investigates the impact of the attacker's private information on the robustness of the defender's budget allocation is Nikoofal and Zhuang (2012); however, it fails to compare the robustness of the defense system in a sequential game with that in a simultaneous game, and thus fails to study the tradeoff between secrecy and exposure.

The second stream of research in this literature, which is not as rich as the first stream, studies the case when the defender and the attacker move simultaneously. Zhuang and Bier (2007) and Hausken, Bier, and Zhuang (2008) propose game-theoretical models to study how the defender chooses tradeoffs between investments in protection against natural disaster and terrorism. Rios and Insua (2009) provide a Bayesian decision analysis to analyze the defender's strategy against an intelligent attacker. Dighe, Zhuang, and Bier (2009) show that partial secrecy about defensive allocations (disclosure of the total level of defensive investment, but secrecy about which resources are