Counterterrorism: A Public Goods Approach

Todd Sandler

1 Introduction

Unfortunately, terrorism occupies an increasing presence in the world with many ghastly events in recent years. Noteworthy attacks include al-Shabaab's attack on Westgate shopping mall in Nairobi, Kenya, on 21 September 2013; Islamic State in Iraq and Syria's (ISIS's) beheadings of hostages beginning in 2014; Boko Haram's kidnapping of 276 schoolgirls from Chibok, Nigeria, on 14-15 April 2014; ISIS's downing of Metrojet flight 9268 en route from Sharam el-Sheikh to St. Petersburg on 31 October 2015; ISIS's armed attacks in Paris at multiple venues on 13 November 2015; and ISIS's suicide bombings in Brussels at the airport and metro station on 22 March 2016. Other noteworthy past terrorism incidents include the suicide truck bombing of the US Marine barracks in Beirut on 23 October 1983; the downing of Air-India Boeing 747 en route from Montreal to London on 23 June 1985; the downing of Pan Am flight 103 en route from London to New York on 21 December 1988; the barricade hostage seizure of Moscow Theater by Chechen rebels on 23 October 2002; and the bombing of commuter trains and station in Madrid on 11 March 2004.

Academic interest in the study of counterterrorism had its roots in the late 1960s at the beginning of the era of transnational terrorism when terrorist attacks had implications for two or more countries (Enders and Sandler 2012; Hoffman 2006). Terrorists resorted to transnational terrorist attacks in order to turn the world's attention to their cause. At first, transnational terrorist groups, such as the Popular Front for the Liberation of Palestine (PFLP), skyjacked commercial flights en route to foreign designations because satellite transmission of the event made everyone

T. Sandler (✉)
Department of Economics, School of Economic, Political and Policy Sciences, University of Texas at Dallas, 800 W. Campbell Rd., Richardson, TX, 75080 USA
e-mail: tsandler@utdallas.edu

W. Buchholz, D. Rübbelke (eds.), *The Theory of Externalities and Public Goods*,
DOI 10.1007/978-3-319-49442-5_11

acutely aware of them and their cause. In addition, terrorist groups sent squads to foreign capital cities, where their attack captured the world's attention—e.g., the abduction of Israeli's athletes at the 1972 Munich Olympics. Recent empirical work on homegrown and home-directed domestic terrorism showed that domestic terrorist groups graduated to transnational terrorist incidents when home campaigns generated little notice (Enders et al. 2011).

Academic analysis of terrorism grew greatly after al-Qaida's four hijackings in the United States on 11 September 2001 (henceforth, 9/11) that resulted in the collapse of the World Trade Center towers, partial destruction of the Pentagon, and a plane crash in Shanksville, Pennsylvania. In total, almost 3000 people perished in these hijackings and many were injured. Subsequent studies applied sophisticated theoretical and empirical methods to the study of terrorism and counterterrorism (Sandler 2014). The former explored the root causes of terrorism and the role played by income (Bandyopadhyay and Younas 2011; Enders et al. 2016; Gassebner and Luechinger 2011; Krueger and Maleckova 2003), globalization (Dreher et al. 2008; Li and Schaub 2004), regime type (Eubank and Weinberg 1994; Eyerman 1998; Gaibulloev et al. 2017; Piazza 2007, 2008; Sandler 1995), and other grievance-causing factors (e.g., economic discrimination). The theoretical study of counterterrorism involves the application of game theory to investigate the interaction among targeted governments or the interface between a terrorist group and one or more targeted governments (Bandyopadhyay and Sandler 2011; Cárceles-Poveda and Tauman 2011; Sandler and Lapan 1988; Sandler and Siqueira 2006; Schneider et al. 2015; Siqueira 2005; Siqueira and Sandler 2006). Noncooperative game theory is an ideal tool to analyze counterterrorism because adversaries or allies are taking independent actions to further their self-interest subject to their constraints and the anticipated response of their counterparts. A government's countermeasures affect a terrorist group's constraint, while terrorist attacks influence a government's objective or constraints. Thus, targeted countries fortify their borders in the hopes of deflecting terrorist attacks to alternative less fortified countries (Gardeazabal and Sandler 2015). Countries targeted by the same terrorist group may do little in the hopes that other attacked countries will take offensive measures to weaken the common terrorist threat. In short, game theory casts the analysis of counterterrorism into one involving strategic rational choice on the part of the agents.

In its game-theoretic formulation, the study of counterterrorism concerns myriad concepts of public goods and externalities. The purpose of this chapter is to underscore the broad-ranging contributions of Richard Cornes and his co-authors by demonstrating how their methods provide a theoretical foundation for better understanding the practice of counterterrorism. To do so, I apply aspects of the private provision of public good model (Bergstrom et al. 1986; Cornes and Sandler 1985, 1986, 1996; Cornes et al. 1999). Throughout the ensuing chapter, I employ the Cornes and Sandler (1984, 1985) graphical device to elucidate numerous insights about counterterrorism in various scenarios. In the case of intelligence gathering, the joint product model plays a role where a single activity yields multiple outputs that vary in their degree of publicness (Cornes and Sandler 1984, 1994).

Public goods and externalities are tied to the two primary types of counterterrorism: proactive and defensive measures. The former are offensive actions intended to reduce the assets or capabilities of the terrorist group. Such actions may involve assassinating terrorist leaders, capturing terrorist operatives, reducing terrorist finances, infiltrating terrorist groups, or gathering intelligence. Effective proactive responses by any targeted country curb the threat for all at-risk countries, thereby providing a public good. In contrast, defensive countermeasures make it more difficult for terrorists to attack successfully. In the event of a terrorist attack, defensive actions limit the resulting damage or loss of lives. As shown later, defensive counterterrorism generates a complex mix of externalities. Even the interaction between terrorists and governments are better understood with methods developed by Cornes and co-authors.

The remainder of the chapter has six sections. Preliminaries concerning the methods applied and the notion of terrorism are presented in Sect. 2. Proactive measures are analyzed in Sect. 3, followed by an investigation of defensive responses in Sect. 4. Section 5 examines the publicness of intelligence gathering. The interplay between a government and a terrorist group is addressed in Sect. 6. Finally, Sect. 7 contains concluding remarks.

2 Preliminaries

Much of the chapter focuses on two-player games where player i chooses to minimize cost, $C_i(q_i, q_j)$, or maximize utility, $U_i(q_i, q_j)$, subject to constraints that include a fixed parameter, q_j, representing player j's choice variable. An analogous problem applies to player j. The respective agents' choice variables are continuously differentiable and often denote counterterrorism actions in the ensuing study. For illustration, we express a few essential definitions in terms of a cost-minimization problem. Player i's best response, BR_i, to agent j's choice, q_j, is

$$q_i = BR_i(q_j) = \arg\min_{q_i} C_i\left(q_i, q_j\right), \quad (1)$$

while player j's best response, BR_j, to agent i's choice q_i, is

$$q_j = BR_j(q_i) = \arg\min_{q_j} C_j\left(q_i, q_j\right). \quad (2)$$

The best-response function for agent i is found by solving $\partial C_i\left(q_i, q_j\right)/\partial q_i = 0$ implicitly for q_i in terms of q_j. Analogously, the best-response function for agent

j is found by solving $\partial C_j\left(q_i, q_j\right)/\partial q_j = 0$ implicitly for q_j in terms of q_i. The simultaneous solution to (1)–(2) gives:

Definition 1 Strategy profile (q_i^N, q_j^N) is a Nash equilibrium if and only if $q_i^N \in \arg\min_{q_i} C_i\left(q_i, q_j^N\right)$ and $q_j^N \in \arg\min_{q_j} C_j\left(q_i^N, q_j\right)$.

At the Nash equilibrium, each agent's choice is a best response to that of the other agent, leaving neither agent to want to change unilaterally its decision variable if offered the opportunity to do so. The problem may include n agents by replacing q_j by $q_{-i} = (q_1, \ldots, q_{i-1}, q_{i+1}, \ldots, q_n)$ and requiring that Definition 1 holds for q_i^N for $i = 1, \ldots, n$. The analysis herein will generally stay with the two-agent case. In places, an additive technology—i.e., $q_i + q_j$—will be applied, indicative of pure public goods and less indicative of general externalities (Cornes and Sandler 1996).

Two other crucial definitions for the two-agent case are:

Definition 2 Strategies q_i and q_j are strategic substitutes if the slopes of the best-response curves are negative—i.e., $\partial BR_i/\partial q_j < 0$ and $\partial BR_j/\partial q_i < 0$; and

Definition 3 Strategies q_i and q_j are strategic complements if the slopes of the best-response curves are positive—i.e., $\partial BR_i/\partial q_j > 0$ and $\partial BR_j/\partial q_i > 0$.

These definitions are due to Bulow et al. (1985). Strategic substitutes indicate that one agent's action replaces the need for the other agent's action, whereas strategic complements mean that one agent's action encourages this action on the part of the other agent. Generally speaking, contributions to a pure public good represent strategic substitutes, while exploitation efforts in an open-access commons represent strategic complements. In the latter case, harvesting efforts result in a race to exploit the openly available common property resource (Cornes and Sandler 1983). Arms race constitutes another instance of strategic complement, where one adversary's buildup of forces induces further buildup by the rival country.

Another important notion is that of plain substitutes and plain complements, as defined by Eaton (2004) and Eaton and Eswaran (2002). These concepts correspond to the cross-partials of the objective function, unlike strategic substitutes and complements which correspond to the cross-partials of the marginal function, as previously expressed in Definitions 2 and 3. For plain complements and cost minimization, $\partial C_i/\partial q_j < 0$, so that increased effort by one's counterpart reduces one own's cost, which is a good thing. In contrast, plain substitutes involve $\partial C_i/\partial q_j > 0$, or greater costs resulting from the actions of one's counterpart. For maximizing utility or profit, $\partial U_i/\partial q_j > 0$ denotes a plain complement, while $\partial U_i/\partial q_j < 0$ indicates a plain substitute.

Next, I turn to background on terrorism. Terrorism is the premeditated use or the threat to use violence by individuals or subnational groups to obtain a political objective through the intimidation of a large audience beyond that of the immediate victim (Enders and Sandler 2012). An essential ingredient of terrorism is the political objective, without which a kidnapping is an act of extortion and a bombing is a criminal act. The wider audience, which is typically a political constituency, is needed to pressure a government to concede to a terrorist group's political demands. Terrorism can be further subdivided into domestic and transnational terrorism (Enders et al. 2011). Domestic terrorism is homegrown where the perpetrator and victims are citizens from the venue country of the attack. Generally, a central government can internalize the externalities that terrorism in different provinces or locations in the same country implies. Transnational terrorism involves two or more countries owing to the nationalities of the perpetrators or victims in regards to the venue country. A skyjacking that originates in one country and concludes in another country is an instance of transnational terrorism. The beheadings of Western hostages by ISIS terrorists are acts of transnational terrorism, as are armed attacks by terrorists in a foreign capital. This chapter focuses on transnational terrorism, which involves the presence of transnational externalities from the practice of counterterrorism. Unless countries cooperate with one another, these externalities will not be internalized. Proactive countermeasures often result in underprovision compared to a Pareto-efficient ideal, while defensive action may imply overprovision or underprovision depending on the mix of externalities.

3 Proactive Measures

Consider a scenario where countries i and j are targeted by the same terrorist network that can strike at each country's interests at home and abroad. The common terrorist threat confronting the two countries can be reduced through proactive measures (e.g., drone attacks against the terrorist network's assets). Such measures have strong elements of publicness—i.e., nonexcludability and nonrivalry of benefits. Without loss of generality, I examine country i's viewpoint since the equations are symmetric for country j. Proactive measure, q_i, results in three cost and benefit components: the cost of the action, potential losses to i from a terrorist attack at home, and potential losses from a terrorist attack on i's interests in country j. Proactive cost is denoted by $G(q_i)$ with $G'(q_i) > 0$ and $G''(q_i) > 0$, so that this cost increases at an increasing rate. The expected loss from a home attack on i is $\pi_i l(q_i)$ where $l'(q_i) < 0$, so that i's proactive measures reduces its potential losses by weakening the terrorists' ability to inflict harm in country i on i's home interests.[1] The likelihood of an attack in country i is $\pi_i(q_i, q_j)$ with $\partial\pi_i/\partial q_i < 0$, $\partial\pi_i/\partial q_j < 0$, and $\partial^2\pi_i/\partial q_i \partial q_j > 0$. Proactive measures by either country reduce the likelihood of an attack on i as the terrorists' capabilities are weakened. The cross-partial of π_i is positive, indicative of substitutes and diminishing returns to effort. In addition, i's proactive response limits its expected losses in j, which is denoted by $\pi_j v(q_j)$,

[1] In a more general model, we could write i's loss as $l(q_i, q_j)$, so that j's proactive efforts also limit i's losses at home. This would provide more publicness and externalities. Because the likelihood of attack depends on both countries' proactive measures, the model has plenty of externalities without this further complication.

where $\pi_j(q_i, q_j)$ has negative first-order partials and positive cross-partial analogous to π_i. Country i's losses in country j are denoted by $v(q_j)$ with $v'(q_j) < 0$, so that these losses are limited by j's proactive response. Offensive measures by i protects its interests abroad by reducing the likelihood of an attack abroad.

Country i chooses its proactive level to minimize its cost, C_i, as follows:

$$\min_{q_i} C_i = \left[G(q_i) + \pi_i\left(q_i, q_j\right) l(q_i) + \pi_j\left(q_i, q_j\right) v(q_j)\right], \quad (3)$$

where the second term is the expected cost of an attack in country i on its home interests and the third term is the expected cost on i's interests of an attack in country j. The associated first-order condition (FOC) is:

$$\frac{\partial C_i}{\partial q_i} = G'(q_i) + l(q_i)\frac{\partial \pi_i}{\partial q_i} + \pi_i l'(q_i) + v(q_j)\frac{\partial \pi_j}{\partial q_i} = 0, \quad (4)$$

with second-order condition (SOC), $\partial^2 C_i/\partial q_i^2 > 0$ or strict convexity of cost function.[2] In (4), there are three marginal benefits and one marginal cost. By increasing its offensive measures, country i reduces not only the likelihood of a home attack, but also the damage of a home attack. This corresponds to the second and third right-hand terms of (4), which are negative marginal losses or marginal benefits. This proactive measure also decreases the likelihood of an attack in country j, thereby guarding i's foreign assets. Thus, the fourth right-hand term in (4) is also a marginal benefit. The three marginal benefits are traded off against the increased cost of taking such action, which is the first right-hand term in (4). An analogous objective and FOC hold for country j and are not displayed. A mere switch of the i and j subscripts is required. Equation (4) implicitly indicates i's best response, $BR_i = q_i$, in terms of q_j. To establish that this is a case of strategic substitutes, I apply the implicit function rule to (4) to get:

$$\frac{\partial BR_i}{\partial q_j} = \frac{-l'(q_i)\frac{\partial \pi_i}{\partial q_j} - v'(q_j)\frac{\partial \pi_j}{\partial q_i} - l(q_i)\frac{\partial^2 \pi_i}{\partial q_i \partial q_j} - v(q_j)\frac{\partial^2 \pi_j}{\partial q_i \partial q_j}}{\partial^2 C_i/\partial q_i^2} < 0. \quad (5)$$

The negative sign, indicative of strategic substitutes, follows because all four terms in the numerator are negative and the denominator is positive by the SOC. Similarly, we can show that $\partial BR_j/\partial q_i < 0$ for j's best-response function.

The Cornes-Sandler diagram can now be instructive for this case of strategic substitutes. In Fig. 1, I revert to $i, j = 1, 2$ with q_1 on the horizontal axis and q_2 on the vertical axis. IC_1 represents country 1's isocost curve for alternative proactive responses for the two countries, which corresponds to a constant level of C_1 in the bracketed expression in (3). IC_1's U-shaped contour follows because small q_1

[2]Throughout the analysis, I ignore corner solutions where all attacks are avoided, $\pi_i + \pi_j = 0$, or where only one country takes offensive measures.

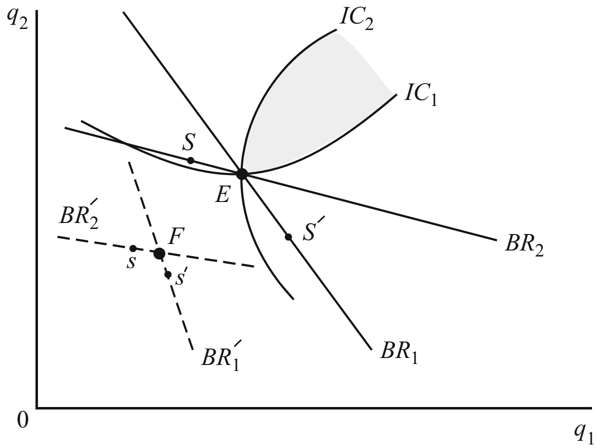

Fig. 1 Proactive counterterrorism measures

is associated with marginal proactive benefits overwhelming marginal proactive cost, while large q_1 is associated with marginal proactive cost exceeding marginal proactive benefits.[3] The minima of IC_1 satisfies (4) and is on the Nash reaction path or best-response curve, BR_1, of country 1. Partial differentiation of C_1 with respect to q_2 gives

$$\frac{\partial C_1}{\partial q_2} = l(q_1)\frac{\partial \pi_1}{\partial q_2} + v(q_2)\frac{\partial \pi_2}{\partial q_2} + \pi_2 v'(q_2) < 0. \tag{6}$$

This expression tells us that the area above country 1's isocost curve denotes reduced cost for country 1 for greater q_2. This, in turn, implies plain complements, where 2's proactive effort increases 1's well-being. In Fig. 1, IC_2 represents one of country 2's C-shaped isocost curves, for which the area to the east of a given curve corresponds to reduced cost and, thus, greater well-being. Equation (5), tailored to country 2, indicates that 2's best-response path, BR_2, is also negatively sloped, indicative of strategic substitutes. BR_2 connects infinite-sloped points on the IC_2 contours where 2's FOC is satisfied. For simplicity, the two best-response paths (BR_1 and BR_2) are drawn in a linear fashion; however, these paths may be curvilinear. To satisfy stability and uniqueness of equilibrium, the slope of BR_1 must be less than –1 and greater than $-\infty$ and the slope of BR_2 must be greater than –1 and less than zero (Cornes et al. 1999; Cornes and Sandler 1996).

In Fig. 1, the Nash equilibrium, E, occurs at the intersection of the two best-response paths where the slope of IC_1 is zero and that of IC_2 is infinite. At this intersection, both countries satisfy their FOC and, hence, Definition 1 holds. The

[3] The slope of IC_1 is found by the implicit function rule applied to C_1 to give an expression for $\partial q_2/\partial q_1$ for a constant C_1. The numerator of this partial derivative is the FOC in (4). The second-order partial is positive.

shaded lens-shaped region denotes Pareto superior points to E, where both countries experience smaller cost. The total provision of proactive efforts at E can be found by drawing a line with slope –1 from E to the q_1 axis (not shown). Drawing a similar line from any point in the shaded area results in greater provision of proactive measures. Thus, the Nash equilibrium implies underprovision.

This underprovision can be shown rigorously by first finding the minimization of total cost, C^T, for the two targeted countries:

$$\min_{q_i, q_j} C^T = G(q_i) + G(q_j) + \pi_i(\mathbf{q})\left[l(q_i) + v(q_i)\right] + \pi_j(\mathbf{q})\left[l(q_j) + v(q_j)\right], \quad (7)$$

where $\mathbf{q} = (q_i, q_j)$. The FOC for country i is:

$$\frac{\partial C^T}{\partial q_i} = G'(q_i) + \pi_i\left[l'(q_i) + v'(q_i)\right] + \left[l(q_i) + v(q_i)\right]\frac{\partial \pi_i}{\partial q_i} + \left[l(q_j) + v(q_j)\right]\frac{\partial \pi_j}{\partial q_i} = 0. \quad (8)$$

A similar expression holds for $\partial C^T / \partial q_j$. Evaluation of the FOC in (8) at the Nash equilibrium, $\mathbf{q^N} = \left(q_i^N, q_j^N\right)$, which satisfies (4), yields:

$$\pi_i v'\left(q_i^N\right) + v\left(q_i^N\right)\frac{\partial \pi_i}{\partial q_i} + l\left(q_j^N\right)\frac{\partial \pi_j}{\partial q_i} < 0. \quad (9)$$

Equation (9) follows because four expressions on the right-hand side of (8) must sum to zero when evaluated at the Nash equilibrium, thereby leaving just three terms. Each corresponds to reduced marginal external cost, thus a marginal external benefit. The first term is the marginal external benefit conferred by i's proactive efforts on limiting j's losses in country i, while the second term is the marginal external benefit conferred by i's proaction on reducing the likelihood of home attacks that damage j's assets in country i. In (9), the third term is the marginal external benefit stemming from i's proactive measures reducing the likelihood of attacks on j's interests at home. The sign of the inequality indicates underprovision of proactive measures. A similar analysis and conclusion applies to country j's offensive efforts.

3.1 Leadership and Unilateral Action

Next, consider leadership scenarios where country 1 first chooses q_1. The follower acts like a Nash player and abides by its best-response path, BR_2. Country 1 then chooses its q_1 using BR_2 as a constraint so that it seeks the tangency of its highest isocost curve to BR_2 at point S in Fig. 1. To limit clutter, I do not display the tangent IC. At this leader-follower equilibrium, the leader shifts some of the proactive burden onto the follower as $q_2^S > q_2^N$ and $q_1^S < q_1^N$. By extending a 45° line with slope –1 from S to the horizontal axis, one sees that the leader-follower equilibrium implies less overall proactive provision than the Nash equilibrium.

Analogously, if country 2 is the leader, then S' is the leader-follower equilibrium where 2's isocost curve (not shown) is tangent to BR_1. Once again, one sees that this outcome results in a smaller provision level than the Nash equilibrium at point E. This leadership cannot address underprovision when both best-response paths are negatively sloped since the leader accounts for the follower's negative conjectural variation. If, however, the leader's proactive measures induce further action by the follower owing to a behavioral response of wanting to match the leader's proactive efforts, then leadership can reduce underprovision (Buchholz and Sandler 2017). This alternative scenario requires a positive conjecture or positively sloped best-response path for the follower.

In a seminal piece, Hoel (1991) showed that unilateral action in a pure public good situation (e.g., removal of pollution) does not benefit the agent taking this action. If, say, country 1 assumes an altruistic attitude and internalizes some of the external protection that it provides so as to shift BR_1 in the northeast direction, then the new equilibrium on BR_2 implies greater cost for country 1. Moreover, country 2's efforts are lowered, which works against country 1's intentions. The shortfall of proactive measures is difficult to address without a fundamental change in the underlying model.

3.2 Backlash

Backlash occurs when proactive measures result in further terrorist grievances, which induce more terrorist recruitment and attacks (Rosendorff and Sandler 2004). ISIS wants the United States and Europe to take aggressive actions against the group in Iraq and Syria, so that ISIS can solicit more recruits. Attacks against innocent Muslims in the United States and Europe after the Paris and San Bernardino attacks play into ISIS's plan to recruit more converts.

Let $B(q_i)$ denote backlash cost, which is added to the objective in (3). The new FOC will have an additional marginal cost to weigh against the three marginal benefits, thereby resulting in smaller q_i for each q_j. As a consequence, country 1's best-response path shifts down and becomes steeper—i.e., BR_1' in Fig. 1, while country 2's best-response path shifts down and becomes flatter—i.e., BR_2' in Fig. 1. The new Nash equilibrium is at F where the two dashed best-response paths intersect in Fig. 1 in the light of backlash. With backlash, there is less of a gain to leadership because of the enhanced cost of assuming an offensive stance by drawing an attack. The leader-follower equilibrium for backlash will be nearer to the Nash equilibrium (see points s and s' in Fig. 1). Backlash can also be captured through a *smaller ability* to reduce the likelihood of the attack through proactive effort. This latter consideration also makes BR_1 steeper and BR_2 flatter and shifts both paths down.

4 Defensive Measures

Next, I tailor the model to account for defensive measures, intended to reduce the likelihood of a terrorist attack and to limit the resulting damage of successful attacks. Defensive actions imply an interesting set of opposing externalities since a country must be cognizant of its interests at home and abroad. Greater defense at home may merely deflect an attack abroad, where its assets are targeted and the country must depend on the venue country to protect these assets. Although I limit these opposing externalities to a bare minimum, many additional externalities could be introduced.

The primary modeling difference concerns the likelihood of attack, $\pi_i(q_i, q_j)$, for which own defense reduces terrorist attacks at home, $\partial\pi_i/\partial q_i < 0$, but increases these attacks abroad, $\partial\pi_j/\partial q_i > 0$ for i and j and $i \neq j$. There is diminishing marginal returns to defensive efforts, $\partial^2\pi_i/\partial q_i^2 > 0$ and $\partial^2\pi_j/\partial q_i^2 < 0$. Moreover, country j's defense reduces (increases) the marginal impact of country i's action to limit terrorist attacks at home if j's defense is larger (smaller) than that of i, so that

$$\frac{\partial^2\pi_i}{\partial q_i \partial q_j} \gtreqless 0 \quad \text{and} \quad q_i \lesseqgtr q_j. \tag{10}$$

The likelihood of attack function is assumed symmetric between the two countries, such that $\pi_i\left(q_i, q_j\right) = \pi_j\left(q_j, q_i\right)$.

For defensive measures, the objective function is still (3) and the FOC is still (4); however, the fourth term in (4) is now a marginal cost as defense in country i deflects the attack to country j where i's foreign assets are jeopardized—i.e., $v(q_j)\left(\partial\pi_j/\partial q_i\right) > 0$. This change means that two marginal cost expressions are traded off against two marginal benefit terms. These benefits arise from greater safety stemming from home defense. The all-important slope of i's best-response curve has the same form as (5); however, its sign is now anticipated to be positive. At a symmetric solution where $q_i = q_j$, the cross partials, $\partial^2\pi_i/\partial q_i \partial q_j$ and $\partial^2\pi_j/\partial q_i \partial q_j$, in the numerator are zero.[4] The first two terms in the numerator are now positive because of attack transference (i.e., $\partial\pi_i/\partial q_j > 0$ and $\partial\pi_j/\partial q_i > 0$). Since the denominator is also positive, the best-response curves are now positively sloped in the neighborhood of the symmetric equilibrium, indicative of strategic complements. Even without the symmetry assumption, this is the likely outcome

[4]Without symmetry, these cross partials differ in sign so that the last two terms may offset to some degree. If q_i exceeds q_j, then the net difference is positive and reinforces the positivity of the numerator.

given that i's interests at home are generally greater than those abroad. Thus, defensive measures results in a fortification race, analogous to an arms race.

Evaluation of the FOC for the cooperative problem at the Nash equilibrium yields an inequality with the same terms as (9); however, this inequality cannot be signed owing to opposing externalities given each country's interests at home and abroad. Thus, more structure is required, which is provided by two special cases.

4.1 Host-Country Specific Assets

This case rules out each country having foreign assets, so that

$$v(q_i) = v'(q_i) = 0 \quad \text{for} \quad i = 1, 2. \tag{11}$$

The evaluation of the FOC that characterizes the cooperative solution at the Nash equilibrium implies,

$$\partial C^T / \partial q_i = l\left(q_j^N\right)\left(\partial \pi_j / \partial q_i\right) > 0, \quad i, j = 1, 2, \quad \text{and} \quad i \neq j, \tag{12}$$

so that independent behavior results in overprovision of defense as both countries ignores the transference externality that its fortification causes. Without foreign assets, there is no inhibiting factor that can attenuate the motive to deflect the attack abroad. If, say, country 1 has no foreign assets, while country 2 has assets in country 1, then country 1 will pursue transference to a greater extent than country 2.

In Fig. 2, the two solid best-response curves are displayed along with the Nash equilibrium at point E. Country 1's isocurve is now an inverted U-shaped contour

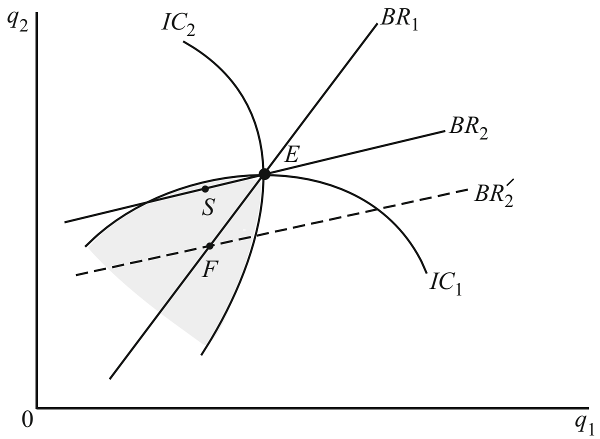

Fig. 2 Defensive race: no foreign assets

for which cost is smaller below the contour, given that

$$\frac{\partial C_i}{\partial q_j} = l(q_i)\frac{\partial \pi_i}{\partial q_j} > 0, \quad i,j = 1,2, \quad \text{and} \quad i \neq j. \tag{13}$$

Equation (13) indicates that i's cost increases with q_j as there is transference to country i. In Fig. 2, country 2's isocost contours are inverted C-shaped curves, where cost falls to the west of the contours. Equation (13) is consistent with plain substitutes. BR_1 joins the maxima of 1's isocost curves, while BR_2 joins the infinite-sloped points of 2's isocost curves. The intersection of these best-response paths results in the Nash equilibrium at E. The shaded lens-shaped region indicates Pareto improvement over the Nash equilibrium. Consistent with (12), these improvement points involve reduced defense on the part of the two countries.

This situation of strategic complements and plain substitutes implies a different outcome for leadership than was true for proactive measures. In Fig. 2, leadership by country 1 gives equilibrium S, at which 1's isocost curve is tangent to BR_2. S implies reduced levels of defensive measures by both countries. Because the reduction in q_1 is relatively greater than that of q_2, there is a second-mover advantage for the follower. Suppose that country 2 assumes unilateral action and account for some of the transference externality by reducing its defense for each level of q_1. This gives rise to the downward shift in BR_2 to the dashed BR_2' locus and the new equilibrium at F where both countries are better off. Ideally, unilateral behavior on the part of both countries could achieve a Pareto optimum provided that each internalizes the transference externality when deciding its defense. Obviously, some protection is required to limit consequences when attacks succeed, which may include first-responder resources among other things.

4.2 Case 2: Globalized Threat

This globalized threat scenario is where each country's losses from a terrorist attack are the same at home and abroad, so that

$$l(q_i) = v(q_j) \quad \text{and} \quad l(q_j) = v(q_i), \quad \text{if} \quad q_i = q_j. \tag{14}$$

As such, countries lose as much from a home attack as from an attack abroad. Globalization diffuses countries' assets worldwide and in the limit would achieve this scenario, which eliminates countries' incentive to divert attacks abroad. The countries' best-response paths are still positively sloped, indicating strategic complements. However, the isocost curves in Fig. 3 change their orientation as compared to the host-country-specific asset case. At a symmetric equilibrium where $q_i = q_j$ and $\partial\pi_i/\partial q_j = -\partial\pi_j/\partial q_j$, the following holds:

$$\frac{\partial C_i}{\partial q_j} = \pi_j v'(q_j) < 0 \quad \text{for} \quad i,j = 1,2, \quad \text{and} \quad i \neq j. \tag{15}$$

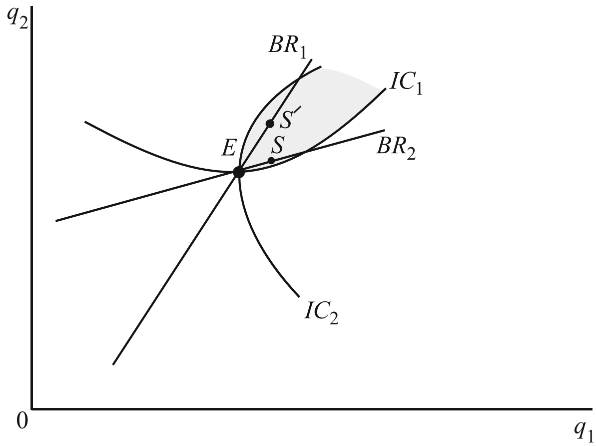

Fig. 3 Defensive countermeasures: generalized threat

Equation (15) indicates that the areas above IC_1 and to the east of IC_2 are lower (greater) levels of cost (well-being) for countries 1 and 2, respectively. Each country's defense protects both countries' interests on the defender's home soil. This justifies the U-shaped and C-shaped isocost contours for countries 1 and 2, respectively, in Fig. 3. If I were to distinguish between the loss functions within each country—i.e., $l_i(q_i) \neq l_j(q_j)$ and $v_i(q_i) \neq v_j(q_j)$, then a symmetric equilibrium would not be applicable. Nevertheless, the outcomes indicated next still hold.

The generalized or globalized threat case is one of strategic and plain complements. In Fig. 3, the Nash equilibrium is at E. In relation to E, Pareto improvement involves the shaded lens-shaped region, defined by IC_1 and IC_2 associated with the Nash equilibrium. An evaluation of C^T at the Nash equilibrium gives

$$\frac{\partial C^T}{\partial q_i} = \pi_i v'\left(q_i^N\right) < 0, \quad i = 1, 2, \tag{16}$$

which indicates underprovision of defense as external benefits that home protection affords foreign interests at home are not internalized. This supports the undersupply displayed in Fig. 3.

Unlike proactive measures, leadership can reduce this underprovision. In Fig. 3, leadership by country 1 results in outcome S, while leadership by country 2 results in outcome S'. Leader-follower behavior leads to larger aggregate provision of defense, which improves both countries' well-being by boosting defense. There appears to be a second-mover advantage as the follower increases its defense by a smaller amount than the leader, which is reflected by the relative shifts of the isocost curves. Unilateral effort in terms of a rightward shift of BR_1 or an upward shift of BR_2 improves general well-being *if not taken too far*.

This is not an aggregative game since there is no additive structure for q_i and q_j (Cornes and Hartley 2007). An aggregative game structure could be introduced for some proactive and defensive counterterrorism scenarios. Thus far, a two-country scenario is assumed. Increasing the number of countries results in a complex set of opposing and reinforcing externalities. Terrorist preferences and grievances result in some subset of countries facing no terrorist threat and, thus, no need for any counterterrorism measures. Corner solutions become relevant for these countries. In contrast, the United States confronts a huge terrorist threat [5] and is more motivated to take proactive measures (Bandyopadhyay and Sandler 2011). Without these measures to reduce terrorist capabilities, US defensive efforts must be large and never able to protect all potential targets.

5 Intelligence Gathering

The gathering of intelligence against a terrorist threat is a proactive measure that can be modeled in many ways, depending on how the two targeted countries' intelligence gathering adds to a country's knowledge of the terrorist threat.

5.1 Intelligence With Congestion

In this case, intelligence is analogous to a commons' crowding (and uncoordinated gathering) that jeopardizes each country's independent action in the field (Cornes and Sandler 1983). Consider a scenario where targeted countries are independently infiltrating a terrorist group. Given the reciprocal secrecy, each intelligence agent has no way of knowing that the other country's agent is not a terrorist in the infiltrated group. This failure of coordination may limit the true intelligence ascertained. In some instances, these independent actions may result in a tragic outcome where agents are accidently killed. Even without this extreme outcome, each country's agent jeopardizes the safety of the other country's agents in an infiltration situation.

Let x_i and x_j denote the level of intelligence gathering in the respective countries. Country i faces the following utility, U_i, optimizing problem:

$$\max_{x_i} U_i \left[w_i - px_i, I\left(x_i, x_j\right) \right], \tag{17}$$

where the budget constraint, $w_i = y_i + px_i$, is substituted for the private numéraire good, y_i, whose price is unity. U_i increases with greater levels of the private good and intelligence, I, but at a diminishing rate of increase.[6] The private good and i's intelligence are assumed to be Edgeworth complements, so that $\partial^2 U_i / \partial y_i \partial I > 0$.

[5] Almost 40 % of all transnational terrorist attacks were directed at US interests during 1968–2010 (Enders and Sandler 2012).

[6] To limit superscripts, I assign $\bar{I}$ to denote j's intelligence.

In (17), the country's unit cost of intelligence collecting is p. Given the crowding assumption, i's intelligence level rises with x_i and falls with x_j, so that $\partial I/\partial x_i = I_i > 0$ and $\partial I/\partial x_j = I_j < 0$. Moreover, crowding implies that the cross-partial I_{ij} is negative. In this first representation, intelligence is not a public good, given excludability due to secrecy and rivalry due to crowding.

The FOC for (17) is

$$-p\frac{\partial U_i}{\partial y_i} + I_i\frac{\partial U_i}{\partial I} = 0. \tag{18}$$

The corresponding slope of i's best-response path to changes in x_j is

$$\frac{\partial BR_i}{\partial x_j} = -\frac{\left[-p\frac{\partial^2 U_i}{\partial y_i \partial I}I_j + I_i I_j\frac{\partial^2 U_i}{\partial I^2} + I_{ij}\frac{\partial U_i}{\partial I}\right]}{\partial^2 U_i/\partial x_i^2} > 0, \tag{19}$$

where the SOC requires $\partial^2 U_i/\partial x_i^2 < 0$, which is a short-hand notation for the first derivative of the left-hand side of (18) which respect to x_i. Provided the first two terms in the numerator exceed the absolute value of the third term, Equation (19) indicates strategic complements, while

$$\frac{\partial U_i}{\partial x_j} = I_j\frac{\partial U_i}{\partial I} < 0 \tag{20}$$

is consistent with plain substitutes. The latter means that beneath an income-constrained isoutility contour, IU, i's utility increases as j's intelligence decreases. If IC_1 and IC_2 are relabeled as IU_1 and IU_2 and the axes are relabeled with x_2 and x_1, then Fig. 2 would serve to illustrate this intelligence congestion scenario.[7] As such, both leadership and unilateral action by either country improves both countries' well-being by recognizing the self-defeating intelligence race that ensues.

If, however, the countries were to share intelligence and jointly participate in such operations, then the form of the intelligence function is $I\left(x_i + x_j\right)$. As a consequence, the model corresponds to the private provision of a pure public good. This sharing ends targeted countries working at cross-purposes, but it does not ensure optimality because of free-riding incentives. Countries sometimes share intelligence on terrorist groups, but are loath to conduct joint intelligence operations; hence, the crowding scenario is generally appropriate.

[7] Implicit differentiation of the constrained utility function in (17) gives the slope of these isoutility functions, denoted by $\partial x_2/\partial x_1$. The partial derivative of this slope with respect to x_1 establishes the inverted U-shape to the contours. Similarly, 2's isoutility contours are inverted C-shaped curves.

5.2 Joint Products and Intelligence

The crowding representation of intelligence can be broadened to allow country-specific benefits and purely public crowding externalities. The latter is denoted by $\widehat{C}\left(x_i + x_j\right)$, where $X = x_i + x_j$, $d\widehat{C}/dX > 0$, and $d^2\widehat{C}/dX^2 > 0$. The income-constrained utility objective is

$$\max_{x_i} U_i\left[w_i - px_i, x_i, \widehat{C}(X)\right], \tag{21}$$

where $\partial U_i/\partial y_i > 0$, $\partial U_i/\partial x_i > 0$, and $\partial U_i/\partial \widehat{C} < 0$. Marginal utility for y_i and x_i diminishes; marginal disutility for crowding also diminishes $\left(\partial^2 U_i/\partial \widehat{C}^2 < 0\right)$. Finally, I assume $\partial^2 U_i/\partial y_i \partial \widehat{C} < 0$ and $\partial^2 U_i/\partial x_i \partial \widehat{C} < 0$.

The FOC is

$$-p\frac{\partial U_i}{\partial y_i} + \frac{\partial U_i}{\partial x_i} + \frac{\partial U_i}{\partial \widehat{C}}\frac{d\widehat{C}}{dX} = 0, \tag{22}$$

for which $\partial U_i/\partial x_i$ must equal the sum of the other two negative terms (Cornes and Sandler 1984, 1996).[8]

Implicit differentiation of (22) gives

$$\frac{\partial BR_i}{\partial x_j} = -\frac{\left(-p\frac{\partial^2 U_i}{\partial y_i \partial \widehat{C}}\frac{d\widehat{C}}{dX} + \frac{\partial^2 U_i}{\partial x_i \partial \widehat{C}}\frac{d\widehat{C}}{dX} + \frac{\partial^2 U_i}{\partial \widehat{C}^2}\left(\frac{d\widehat{C}}{dX}\right)^2 + \frac{\partial U_i}{\partial \widehat{C}}\frac{d^2\widehat{C}}{dX^2}\right)}{\partial^2 U_i/\partial x_i^2} < 0, \tag{23}$$

where $\partial^2 U_i/\partial x_i^2 < 0$ is again a short-hand expression for the SOC, which is negative. Every term in the numerator is negative, consistent with strategic substitutes and a negatively sloped best-response path. The analogous expression, $\partial BR_j/\partial x_i$, is also negative, so that this is a situation of strategic substitutes. This is also an instance of plain substitutes, since $\partial U_i/\partial x_j = \left(\partial U_i/\partial \widehat{C}\right)\left(d\widehat{C}/dX\right) < 0$ for i and $j = 1, 2$ and $i \neq j$; hence i's (j's) isoutility curves are inverted U-shaped (C-shaped) contours.

This intelligence scenario is displayed in Fig. 4, along with the isoutility contours (IU_1 and IU_2) associated with the Nash equilibrium, E. The shaded lens-shaped area denotes Pareto superior points relative to E. Leadership by either country increases its intelligence operation relative to that of its counterpart (see S and S'), thereby improving its well-being at the expense of the other country. The same is true of unilateral action (not shown) that increases BR_1 and BR_2 provided the shifts are not too far—e.g., a shift in BR_1 to an intersection beyond where IU_1 crosses BR_2.

[8] A characteristic approach can be used to investigate this case—see Cornes and Sandler (1994).

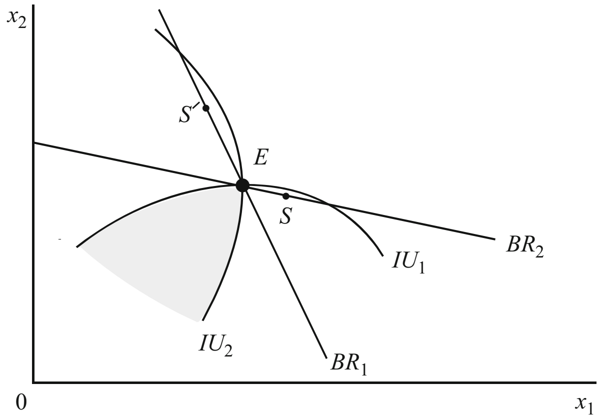

Fig. 4 Intelligence provision

The two cases of intelligence congestion are interesting because the first implies strategic complements and the second implies strategic substitutes. As a consequence, one instance gains from leadership and unilateral action, while the other selectively gains from leadership and unilateral action. Thus, even slight modeling changes can drastically influence strategic and policy aspects for congestion-based models. This lesson can be applied to a host of nonterrorism scenarios, such as congestion-based tolls for highways where the form of the congestion function assumes an essential role (Cornes and Sandler 1996).

Thus far, asymmetric information has not been built into the above representations. This can be done and the terrorist group can be brought in as active informed agent (Arce and Sandler 2007).

5.3 *Final Cases*

Finally, consider the following intelligence representation:

$$\max_{x_i} U_i\left[w_i - x_i c_i\left(x_j\right), I\left(x_i, x_j\right)\right], \tag{24}$$

where i's unit price of intelligence is $c_i(x_j)$ with $dc_i/dx_j > 0$ indicating congestion. A similar representation holds for country j. Intelligence is no longer exclusive so that each country gain not only from its intelligence but also from that of its counterpart—i.e., $I_i > 0$, $I_j > 0$, and $I_{ij} < 0$. With standard procedures, this can be shown to be a case of strategic substitutes with negatively sloped best-response paths. Unlike the previous model, this case can be consistent with plain substitutes or complements depending on marginal crowding cost $\left(-x_i \frac{\partial U_i}{\partial y_i} \frac{dc_i}{dx_j}\right)$ relative to i's marginal gain from j's intelligence effort $\left(\frac{\partial U_i}{\partial I} I_j\right)$. If, say, marginal crowding cost is the stronger influence, $\partial U_i/\partial x_j < 0$, indicative of plain substitutes. This then means that Fig. 4 still applies; otherwise, Fig. 1 is relevant with relabeling of the *IC* curves. In either case, leadership and/or unilateral action is not helpful to both countries.

There are other scenarios. For example, the following formulation,

$$\max_{x_i} U_i \left[w_i - c_i x_i, x_i, I\left(x_i + x_j\right)\right], \tag{25}$$

where c_i is the price parameter. This formulation permits positive private and public joint products to be derived from *i*'s intelligence. For intelligence, the aggregator technology can also come into play (Cornes 1993). Obtaining intelligence on a terrorist group is a best-shot public good, dependent on the greatest effort, while maintaining the secrecy of gathered intelligence is a weakest-link or weaker-link public good, more dependent on the smaller concealment efforts. This aggregator technology affects the form of the *I* function and presence of strategic or plain substitutes and/or complements.

6 Terrorists Versus Government

I conclude with an analysis of adversaries—a targeted government (g) and the terrorist group (t)—for which there can be a rich set of counterterrorism externalities (Gaibulloev et al. 2017). The model is stripped down to its bare essentials. However, even in its primitive form, there is a hybrid case of strategic substitutes and strategic complements.

The terrorist group's problem is to maximize utility (u) minus costs (c):

$$\max_a \left[u\left(a, \varphi\right) - c\left(a, e\right)\right], \tag{26}$$

in which a denotes terrorist attacks, e represents the government's counterterrorism efforts, and φ is the group's radicalization parameter. Terrorists' utility derives from their induced casualties and property damage, which increase with attacks, so that $u_a > 0$ and $u_{aa} < 0$. Increased radicalization augments the marginal utility of attacking, so that $u_{a\varphi} > 0$. Terrorists' cost satisfies the following: c_a, c_e, c_{aa}, c_{ee}, and $c_{ea} > 0$, for which the first four partials indicate that cost rises at an increasing rate in terms of increased attacks or enhanced counterterrorism measures. The cost cross-partial is positive because greater counterterrorism measures lift the marginal cost of attacks. With this set of assumptions, the slope of the terrorist best-response path, BR_t, is

$$\frac{\partial BR_t}{\partial e} = \frac{c_{ae}}{u_{aa} - c_{aa}} < 0, \tag{27}$$

indicative of strategic substitutes. The denominator of (27) is the SOC, which is negative. This can be shown to be a situation of plain substitutes because $\partial (u - c) / \partial e = -c_e < 0$, based on the objective associated with (26). Hence, the terrorists' isoprofit curve, IPC_t, is an inverted C-shape. Unilateral efforts at increased radicalization implies

$$\frac{\partial BR_t}{\partial \varphi} = \frac{-u_{a\varphi}}{u_{aa} - c_{aa}} > 0, \tag{28}$$

or an upward shift in the terrorists' best-response path.

The adversarial government's problem is

$$\min_e \left[\psi l\left(e, a\right) + C(e)\right], \tag{29}$$

or to choose its counterterrorism to minimize the sum of attack-induced loss, l, plus counterterrorism cost, C. The government puts a ψ weight on losses, so that more democratic governments are anticipated to weigh such losses greater. The loss function abides by the following reasonable assumptions: $l_e < 0$, $l_{ee} > 0$, $l_a > 0$, $l_{aa} > 0$, and $l_{ea} < 0$. The cross-partial indicates that the marginal loss from an attack is ameliorated by counterterrorism measures that may involve enhanced first-responder capabilities.

The slope of the government's best-response curve, BR_g, is

$$\frac{\partial BR_g}{\partial a} = \frac{-\psi l_{ea}}{\psi l_{ee} + C''} > 0, \tag{30}$$

where the denominator is positive owing to the satisfaction of a minimum's SOC. Thus, the government's best-response function is positively sloped indicative of strategic complements. Differentiation of the objective in (29) with respect to attacks is consistent with plain substitutes, so that the government's isocost contours, IC_g, are inverted U-shaped curves.

This mixed case of strategic substitutes and complements possesses interesting implications for leadership and unilateral action that differ from all previous cases. The Nash equilibrium, E, is at the intersection of BR_g and BR_t in Fig. 5, where the shaded lens-shaped region consists of Pareto-superior points to E. Leadership by the government result in S_g, for which the government's well-being is improved at the expense of the terrorist group. However, leadership by the terrorist group results in S_t, for which the well-being of both adversaries improves. In Fig. 5, terrorist leadership ratchets down the hostilities, leading to fewer attacks and less counterterrorism measures, which improve both adversaries' well-being. This scenario occurs when terrorists lead by limiting attacks—e.g., Fuerzas Armadas Revolucionarias de Colombia (FARC) in recent times. Mixed cases imply asymmetric leadership outcomes.

Unilateral action by the terrorist group is harmful to the government if it involves increased radicalization, which shifts BR_t in the northeast direction. This

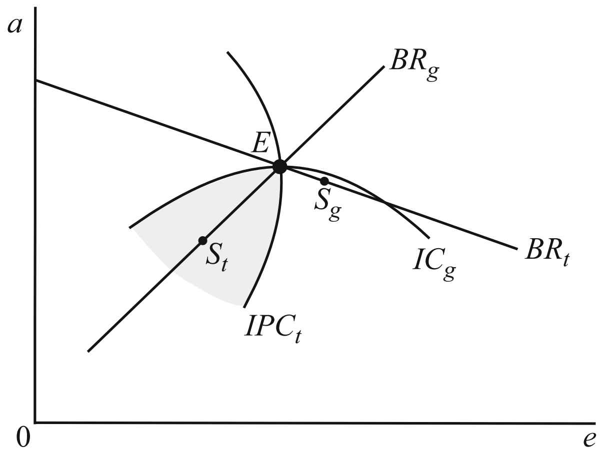

Fig. 5 Mixed case: terrorist versus government

augmented radicalization changes the position of all of the terrorists' IPC_t curves due to a change in the group's utility function; hence, comparison to the IPC_t through E in Fig. 5 is not informative. If, however, unilateral action corresponds to decreased radicalization owing to new leadership or government concessions, then the government's well-being improves.

For the government, unilateral action corresponds to changes in ψ or the value it places on citizen's safety. The effect of this parameter on BR_g is

$$\frac{\partial BR_g}{\partial \psi} = \frac{-l_e}{\psi l_{ee} + C''} > 0, \tag{31}$$

or an eastward shift in BR_g in Fig. 5, which improves the government's well-being at the expense of the terrorists. The mixed strategic scenario allows leadership and unilateral action to imply different outcomes. Unlike the case examined here, there may exist terrorist groups that augment their attacks in response to greater government counterterrorism, so that BR_t is positively sloped. This may correspond to risk-loving groups. Throughout the chapter, terrorists are assumed to be risk neutral, but this implicit assumption could be altered.

Thus far, only one stage to the game is permitted. Multiple stages prove useful when the counterterrorism game is extended to more agents, such as voters or additional targeted governments (Sandler and Siqueira 2009; Siqueira and Sandler 2007). For example, the recruitment of terrorist operative may constitute the first stage; the interaction between the terrorist group and the government characterizes the second stage; and the voter's reaction to government success or failure involves the third stage.

7 Concluding Remarks

Cornes and his co-authors greatly enriched the theoretical foundations of the private provision of public goods and the analysis of externalities. In a modest way, this chapter highlights the practical importance of these contributions by applying a tiny portion of them to the study of terrorism and counterterrorism. The variety of applications underscores the richness of this work. These principles can be applied to the study of regional and global public goods, including the study of transfrontier pollution (Peinhardt and Sandler 2015; Sandler 2004). As such they have much to say about climate change, ozone-shield depletion, acid rain, and deforestation. The work of Cornes and associates also enlightens us about global health, world security, global governance, and knowledge generation.

References

Arce, D. G., & Sandler, T. (2007). Terrorist signaling and the value of intelligence. *British Journal of Political Science, 37*(4), 573–586.
Bandyopadhyay, S., & Sandler, T. (2011). The interplay between preemptive and defensive counterterrorism measures: A two-stage game. *Economica, 78*(3), 546–564.
Bandyopadhyay, S., & Younas, J. (2011). Poverty, political freedom, and the roots of terrorism in developing countries: An empirical assessment. *Economics Letters, 112*(2), 171–176.
Bergstrom, T. C., Blume, L., & Varian, H. (1986). On the private provision of public goods. *Journal of Public Economics, 29*(1), 25–49.
Buchholz, W., & Sandler, T. (2017, forthcoming). Successful leadership in global public good provision: Incorporating behavioral approaches. *Environmental and Resource Economics.*
Bulow, J. L., Geanakoplos, J. D., & Klemperer, P. D. (1985). Multimarket oligopoly: Strategic substitutes and complements. *Journal of Political Economy, 93*(3), 488–511.
Cárceles-Poveda, E., & Tauman, Y. (2011). A strategic analysis of the war against transnational terrorism. *Games and Economic Behavior, 71*(1), 49–65.
Cornes, R. (1993). Dyke maintenance and other stories: Some neglected types of public goods. *Quarterly Journal of Economics, 108*(1), 259–271.
Cornes, R., & Hartley, R. (2007). Aggregative public good games. *Journal of Public Economic Theory, 9*(2), 201–219.
Cornes, R., Hartley, R., & Sandler, T. (1999). Equilibrium, existence and uniqueness in public goods models: An elementary proof via contraction. *Journal of Public Economic Theory, 1*(4), 499–509.
Cornes, R., & Sandler, T. (1983). On commons and tragedies. *American Economic Review, 73*(4), 787–792.
Cornes, R., & Sandler, T. (1984). Easy riders, joint production, and public goods. *Economic Journal, 94*(3), 580–598.
Cornes, R., & Sandler, T. (1985). The simple analytics of pure public good provision. *Economica, 52*(1), 103–116.
Cornes, R., & Sandler, T. (1986). *The theory of externalities, public goods, and club goods*. Cambridge: Cambridge University Press.
Cornes, R., & Sandler, T. (1994). The comparative static properties of the impure public good model. *Journal of Public Economics, 54*(3), 403–421.
Cornes, R., & Sandler, T. (1996). *The theory of externalities, public goods, and club goods* (2nd ed.). Cambridge: Cambridge University Press.
Dreher, A., Gaston, N., & Martens, P. (2008). *Measuring globalization—Gauging its consequence*. New York: Springer.

Eaton, B. C. (2004). The elementary economics of social dilemmas. *Canadian Journal of Economics, 37*(4), 805–829.
Eaton, B. C., & Eswaran, M. (2002). Asymmetric equilibria and strategic behavior in oligopolistic markets. In B. C. Eaton (Ed.), *Applied microeconomic theory*. Cheltenham, UK: Edward Elgar.
Enders, W., Hoover, G. A., & Sandler, T. (2016). The changing nonlinear relationships between income and terrorism. *Journal of Conflict Resolution, 60*(2), 195–225.
Enders, W., & Sandler, T. (2012). *The political economy of terrorism* (2nd ed.). Cambridge: Cambridge University Press.
Enders, W., Sandler, T., & Gaibulloev, K. (2011). Domestic versus transnational terrorism: Data, decomposition, and dynamics. *Journal of Peace Research, 48*(3), 319–337.
Eubank, W. L., & Weinberg, L. B. (1994). Does democracy encourage terrorism? *Terrorism and Political Violence, 13*(1), 155–164.
Eyerman, J. (1998). Terrorism and democratic states: Soft targets or accessible systems? *International Interactions, 24*(2), 151–170.
Gaibulloev, K., Piazza, J. A., & Sandler, T. (2017, forthcoming). *Regime types and terrorism. International Organization*, Richardson, TX.
Gardeazabal, J., & Sandler, T. (2015). INTERPOL's surveillance network in curbing transnational terrorism. *Journal of Policy Analysis and Management, 34*(4), 761–780.
Gassebner, M., & Luechinger, S. (2011). Lock, stock, and barrel: A comprehensive assessment of the determinants of terror. *Public Choice, 149*(3–4), 235–261.
Hoel, M. (1991). Global environmental problems: The effects of unilateral actions taken by one country. *Journal of Environmental Economics and Management, 20*(1), 55–70.
Hoffman, B. (2006). *Inside terrorism* (revised ed.). New York: Columbia University Press.
Krueger, A. B., & Maleckova, J. (2003). Education, poverty, and terrorism: Is there a causal connection? *Journal of Economic Perspectives, 17*(4), 119–144.
Li, Q., & Schaub, D. (2004). Economic globalization and transnational terrorism. *Journal of Conflict Resolution, 48*(2), 230–258.
Peinhardt, C., & Sandler, T. (2015). *Transnational cooperation: An issue-based approach*. New York: Oxford University Press.
Piazza, J. A. (2007). Draining the swamp: Democracy promotion, state failure, and terrorism in 19 Middle Eastern countries. *Studies in Conflict and Terrorism, 30*(6), 521–539.
Piazza, J. A. (2008). Do democracy and free markets protect us from terrorism? *International Politics, 45*(1), 72–91.
Rosendorff, B. P., & Sandler, T. (2004). Too much of a good thing? The proactive response dilemma. *Journal of Conflict Resolution, 48*(5), 657–671.
Sandler, T. (1995). On the relationship between democracy and terrorism. *Terrorism and Political Violence, 7*(4), 1–9.
Sandler, T. (2004). *Global collective action*. Cambridge: Cambridge University Press.
Sandler, T. (2014). The analytical study of terrorism: Taking stock. *Journal of Peace Research, 51*(2), 257–271.
Sandler, T., & Lapan, H. E. (1988). The calculus of dissent: An analysis of terrorists' choice of targets. *Synthese, 76*(2), 245–261.
Sandler, T., & Siqueira, K. (2006). Global terrorism: Deterrence versus preemption. *Canadian Journal of Economics, 50*(4), 1370–1387.
Sandler, T., & Siqueira, K. (2009). Games and terrorism: Recent developments. *Simulation & Gaming, 40*(2), 164–192.
Schneider, F., Brück, T., & Meierrieks, D. (2015). The economic survey of counterterrorism: A survey. *Journal of Economic Survey, 29*(1), 131–157.
Siqueira, K. (2005). Political and militant wings within dissident movements and organizations. *Journal of Conflict Resolution, 49*(2), 218–236.
Siqueira, K., & Sandler, T. (2006). Terrorists versus the government: Strategic interaction, support, and sponsorship. *Journal of Conflict Resolution, 50*(6), 878–898.
Siqueira, K., & Sandler, T. (2007). Terrorist backlash, terrorism mitigation, and policy delegation. *Journal of Public Economics, 91*(9), 1800–1815.