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Jerry Cromwell and Edward M. Drozd

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**About the Authors**

**Jerry Cromwell**, PhD, is an RTI Senior Fellow in health economics based in RTI's Waltham, Massachusetts, office.

**Edward M. Drozd**, PhD, is a senior research economist at RTI International specializing in healthcare financing and payment. He, too, is based in RTI's Waltham office.

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RTI International
3040 Cornwallis Road
PO Box 12194
Research Triangle Park, NC
27709-2194 USA

Tel: +1.919.541.6000
Fax: +1.919.541.5985
E-mail: rtipress@rti.org
Web site: www.rti.org



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# Target-Based Model of Efficient Allocation of Federal Resources to the States for Emergency Preparedness

Jerry Cromwell and Edward M. Drozd

## Abstract

In In the wake of the September 11, 2001, terrorist attacks, Congress provided a fund to help states offset costs for protecting against terrorist attacks and for emergency preparedness. More than one-third of this money is shared equally by all states, with the rest distributed based on the states' population share, regardless of the potential targets in each state. This paper develops a rational public finance framework for distributing money to states for protecting against terrorist attacks.

We propose two allocation criteria: (1) an efficiency criterion that equalizes the marginal expected loss (human and monetary) across all targets and (2) an equity criterion that adjusts payments to states based on their ability to pay for their own protection. These criteria imply a much more concentrated distribution of protection spending in a few highly populated, target-rich states than is now the case. We then explore the additional information required to protect against all types of terrorists. Limiting the set of protected targets to a few that are highly valued by well-funded terrorist groups produces an even more geographically concentrated funding portfolio. Terrorist insurance is preferable for low-likelihood, difficult-to-protect targets, or targets attractive to individual terrorists.

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## Introduction

The costs of a successful terrorist attack on American soil are both very high and multifaceted, including societal psychological costs as well as loss of human life and property. Yet the costs of protecting the homeland against attacks may even be higher (Hobijn, 2002; Zycher, 2003).[1] A cogent argument has been made for public terrorism insurance to cover losses after the fact and avoid an uncoordinated spending rush that deflects but does not significantly reduce the likelihood of an attack (Lakdawalla and Zanjani, 2004; US Office of Management and Budget [OMB], 2003; Weaver et al., 2001).[2] Nevertheless, soon after the 9/11 attack on the World Trade Center, Congress established the Department of Homeland Security (DHS) and legislated that three-quarters of 1 percent (0.75%) of the federal security budget go to each state, with the rest (99.25%) distributed based on each state's population. Since then, Congress has modified the allocation of funding. First, additional funds were provided exclusively to urban areas. However, nearly 60 percent of protection funds were based on the three-quarters of 1 percent formula, so that 22.5 percent was allocated as a flat amount to each state, 37.5 percent was allocated based on state population, and 34 percent was allocated to 50 specific urban areas. For fiscal year 2007, the state equal-allocation portion rose to 31 percent, and the portion allocated to specific urban areas rose to 66 percent.[3] The amounts that each prespecified urban area may receive are capped, and states still largely determine the projects that receive these funds.

Consequently, sizable resources are being devoted to protecting a wide range of targets,[4] almost none of which are targets ever considered by most terrorist groups and even fewer that would actually be attacked.[5] In its rush to harden targets, Congress allocated security funds to the states using a method that had two major flaws, which are addressed in this paper. Even now, the formula includes a significant allocation (nearly one-third) that does not account for the geographic maldistribution of targets. If some form of protection is *prima facie* cost-effective,[6] given the fact that the public demands some protection before an attack occurs, the first policy question becomes:

> **What is the efficient allocation of security funds across potential targets?**

The second flaw is that the formula makes no allowance for the varying per capita wealth of the states. We argue that the federal government should take state ability to pay into consideration when sharing the cost of protection. Not all types of targets and losses are universally federal. Some are more specific to state and local populations (e.g., local power plants, commercial buildings), and federal funding to protect such targets should be based primarily on fiscal federalism considerations of states "insuring" each other and relative abilities of states to self-insure. Hence, once a protection strategy is formulated, the logical follow-up question is:

> **What is the most equitable federal-state sharing of the cost of protection?**

In this paper, we lay out a structure, or way to think about, answers to these two questions. As a technical exercise, we diverge from the political constraints placed on efficient funding by giving decision makers

1 Some research addresses the more global costs of war itself (Hess, 2003).

2 Congress did pass the Terrorism Risk Insurance Act (P.L. 107-297) on November 26, 2002 (more than a year after 9/11) to ensure the availability of affordable risk insurance for businesses. It supposedly is a temporary federal program to "allow ... for the private insurance markets to stabilize, resume pricing of such insurance, and build capacity to absorb future losses ... " (OMB, 2003, p. 66).

3 These allocation percentages are the authors' calculations based on state- and urban area–specific amounts published by the US Department of Homeland Security (DHS 2005, 2007)

4 In spite of the billions of dollars now being spent by the Department of Homeland Security, Congress has criticized the underfunding of security locally, due to state budget cuts due to the recession (Abel, 2003). As evidence, representatives cite the 640,891 potential weapons confiscated from airline passengers in July 2003, almost 2 years after the 9/11/2001 attack, and the failure to adequately screen airplane cargo or harbors.

5 The press is replete with examples of "questionable" federal funding of local "protection" investments (Hall, 2003).

6 For a rationale for public provision of some forms of protection, see OMB (2003). The Department of Homeland Security's 2004 Budget in Brief (DHS, 2003) cites areas of public expenditures on counterterrorism and homeland security: border and transportation security ($18.1 billion), which includes $3.5 billion for the Office of Domestic Preparedness to give to state/local governments for protection; US Coast Guard ($6.8 billion), emergency preparedness and response ($6 billion) primarily for biodefense drugs; information analysis and infrastructure protection ($829 million), primarily to provide an accurate map of all potential targets and to develop state/local protection strategies; and science and technology ($803 million) funding to develop countermeasures for nuclear, biological, chemical, and other modes of attack.

some appreciation of factors that at least should be considered. Our algorithms also highlight how key decision parameters interact to produce substantial deviations from Congress' simplistic approach. We also assume that total spending on homeland security is determined outside the allocation model. We leave for others to quantify the opportunity costs of greater homeland security spending (e.g., less spending on roads and schools).

After we are done, many challenging technical and political tasks remain, such as estimating gains from greater protection spending on specific targets, how to value small versus large losses of life, and the proper federal-state sharing of security costs. Our hope is that technical advisors to policy makers can begin to use our framework to ask the right questions and to better understand how the pieces of the protection puzzle fit together.

The rest of this paper is in four sections. The first section develops algorithms for efficiently allocating total US expenditures on protection across targets and states, taking into consideration attack probabilities and the value society would place on human and property losses from a successful attack. The next section addresses the equity issues involved in federal-state sharing of protection costs within each state. In this section, we illustrate likely congressional over- and under-spending on protection in various states. The third section addresses a serious complication to the initial model by considering multiple terrorist groups with different goals, popular targets, and attack capabilities. This section also discusses terrorist reactions to protection that engender the inter-state "spending rush" displacement effect. The last section provides concluding observations regarding Congress' allocation formula and limitations of the model.

## An Efficient Protection Strategy

The efficient allocation of public spending on homeland protection requires equalizing the marginal expected loss from a successful terrorist attack across all targets by a given method of attack. To see this, let $L_{tmj}$ be the government's (and society's) value (in dollar equivalents) of the different types of expected losses from a successful attack on a target of type *t* using the method *m* in state *j*. Losses from a single attack can be decomposed into those related to property and to humans, both measured in dollars:

$$L_{tmj} = G[T_{tmj}] + V[H_{tmj}] \quad (1)$$

where $G[T_{tmj}]$ = the functional valuation (G) of tangible property losses, $T_{tmj}$, and $V[H_{tmj}]$ = the value (V) that government and society place on human losses, $H_{tmj}$, in state *j* from a successful attack (e.g., destruction of a nuclear plant). Property losses may be approximated by replacement costs plus any substantial spillover economic and psychological costs in terms of productivity declines, inconveniences (e.g., airline security checkpoints), and national morale (e.g., loss of the Statue of Liberty). Expected property losses for a given target type (e.g., nuclear plant) likely are independent of state—at least within target type—but human losses will depend on how densely populated a state is relative to the number of potential targets.

The value (V) placed on human life is very complex and worthy of a separate discussion. Pay-outs to victims' families for the 9/11 tragedy are complete yet remain controversial in certain aspects, such as how to adjust, if at all, for human losses covered by insurance (such coverage was deducted from government payouts). Also, should individual lives be recompensed equally or based on earnings capacities? How society values the loss of 10 versus 100 versus 1,000 lives is not clear—hence our use of the generalized V function. Does the government consider a 10 percent likelihood of losing 10 persons equivalent to a 0.1 percent likelihood of losing 1,000 persons? If so, would the government be indifferent in allocating protection funds, all other things equal?

Our guess is that the valuation function rises at a slower rate with the increase in the possible number of lives lost. That is, government and society, we believe, would err on the side of protecting, first, against higher probabilities of losing even a few lives. But one can certainly argue that a large loss of life in a single attack has a disproportionate psychological effect on all citizens as a whole and, therefore, deserves disproportionate protection. We have no definitive answers to these essentially political and social questions and leave them to our political representatives to determine. Our model simply attempts to put their valuations into a general modeling framework.

To begin, the government, having determined some valuation of human losses, is assumed to allocate its protection spending, C, to minimize the aggregate expected value of losses, E[L], across all target types and methods of attack:

$$\text{MIN: } E[L] = \Sigma_j \Sigma_t \Sigma_m \, p_{tmj} L_{tmj} \quad (2)$$

where $p_{tmj}$ = the probability of a successful attack on target type *t* using method of attack *m* in state *j*. The probability of attack also varies with the type of terrorist group, a complication we address later in this paper. The full first-order conditions for minimizing Equation 2 require allocating spending across targets and methods until the marginal expected losses to protection spending are equalized. Differentiating Equation 2 with respect to C (ignoring the state subscript for simplicity) and setting the results equal to zero gives a series of first-order loss-minimizing conditions:

$$\partial E[L]/\partial C_{11} = (\partial p_{11}/\partial C_{11})L_{11} + p_{11}(\partial L_{11}/\partial C_{11}) + \Sigma_g \Sigma_h [(\partial p_{gh}/\partial C_{11})L_{gh} + p_{gh}(\partial L_{gh}/\partial_{11})] = 0 \quad (3)$$

$$\partial E[L]/\partial C_{22} = (\partial p_{22}/\partial C_{22})L_{22} + p_{22}(\partial L_{22}/\partial C_{22}) + \Sigma_g \Sigma_h [(\partial p_{gh}/\partial C_{22})L_{gh} + p_{gh}(\partial L_{gh}/\partial C_{22})] = 0$$

$$\partial E[L]/\partial C_{tm} = (\partial p_{tm}/\partial C_{tm})L_{tm} + p_{tm}(\partial L_{tm}/\partial C_{tm}) + \Sigma_g \Sigma_h [(\partial p_{gh}/\partial C_{tm})L_{gh} + p_{gh}(\partial L_{gh}/\partial C_{tm})] = 0$$

where $\partial$ = marginal change, $C_{tm}$ = total federal and state government spending to protect the *t*th target type from the mth method of attack, $\Sigma_g$ = summation across all *g* targets other than *t*, and $\Sigma_h$ = summation across all *h* methods other than *m*. The marginal effect of protection spending against a specific target-method has four components: (1) the direct effect of reducing the likelihood of a successful attack, $(\partial p_{tm}/\partial C_{tm})$; (2) mitigating losses in the event of a successful attack, $(\partial L_{tm}/\partial C_{tm})$; (3) increasing the likelihood of a successful attack on all other target types (*g*) with all other methods (*h*) (the displacement effect), $(\partial p_{gh}/\partial C_{tm})$; and (4) any greater losses from successful "displaced" attacks, $(\partial L_{gh}/\partial C_{tm})$. Although part of Homeland Security spending mitigates losses from a successful attack, we simplify the analysis by concentrating on the crucial part of government spending that thwarts a successful attack, that is, all $(\partial L_{tm}/\partial C_{tm}) = (\partial L_{gh}/\partial C_{tm}) = 0$. We also assume at this point in the paper that spending to protect one target has no spillover, or displacement, effects on the likelihood of a successful attack on other targets, that is, all "cross-partial" $(\partial p_{gh}/\partial C_{tm}) = 0$. We return to this assumption in the last part of this paper when we consider terrorist reaction functions.

To further simplify the presentation, we focus the analysis by comparing the first-order loss-minimizing condition between just two targets, *t* and *u*, and two methods of attack, *m* and *v*:

$$[\partial p_{tm}/\partial C_{tm}] \bullet L_{tm} = [\partial p_{uv}/\partial C_{uv}] \bullet L_{uv} \quad (4)$$

or

$$[\partial p_{tm}/\partial C_{tm}] / [\partial p_{uv}/\partial C_{uv}] = L_{uv}/L_{tm} \quad (5)$$

where $C_{tm}$ is the total national dollar outlays (federal and state) for protecting the *t* targets from method *m* attack and $C_{uv}$ is the total national dollar outlays (federal and state) for protecting the *u* targets from method *v* attack. For the country to minimize the expected loss from a successful attack on a particular type of target, policy makers should spend first on protecting targets where the risk reduction is greatest, taking into consideration the loss from a successful attack. If the efficiency criterion (Equation 4) were in disequilibrium, policy makers could reduce overall expected loss to the country by reallocating security funds toward the target with the higher marginal reduction in the probability of attack weighted by expected loss. We assume the *t* and *m* targets are spread evenly across the country, with no geographical differences in attack risk or expected loss. This assumption is relaxed shortly. Also, to make the discussion more concrete, assume that target *t* is a chemical plant, that method of attack *m* against the plant is a rocket-propelled grenade, that target *u* is the Golden Gate Bridge, and that the method of attack against the bridge is a set of underwater explosives. Our later section Multiple Terrorists' Targets and Reactions includes a table with more examples of possible targets.

Next, assume the following negative exponential successful attack probability functions:

$$p_{tm} = A_{tm}(E_{tm})e^{[-\beta_{tm} C_{tm}]} \quad (6)$$

$$p_{uv} = A_{uv}(E_{uv})e^{[-\beta_{uv} C_{uv}]} \quad (7)$$

where $A_{tm}(E_{tm})$ and $A_{uv}(E_{uv})$ are the probabilities of a successful attack (based on expected terrorist effort, E) with no homeland security spending on protection; and $e^{[-\beta_{tm}C_{tm}]}$ and $e^{[-\beta_{uv}C_{uv}]}$ = the (hypothetical) negative exponential attack probabilities as a function of protection spending. The unprotected attack probabilities are assumed to be a positive function of terrorist effort, E, on each target by each method. We introduce terrorist reaction functions later in this paper.

The marginal probabilities of a successful attack decline as spending to protect that target rises—that is, $\partial p_{tm}/\partial C_{tm} = -\beta p_{tm} < 0$—implying that, holding terrorist effort and losses fixed, targets facing an elevated likelihood of a successful attack should have higher levels of protection spending. Additional protection gains to spending are reduced, however, as more is spent on one target and method (*tm*), that is, $\partial^2 p_{tm}/\partial C_{tm}^2 = \beta^2 p_{tm} > 0$.

Inserting the marginal probability functions into Equation 4 gives

$$-\beta_{tm}\, p_{tm}\, L_{tm} = -\beta_{uv}\, p_{uv}\, L_{uv}\,. \qquad (8)$$

Using a total (federal plus state) homeland security budget constraint,

$$C^* \equiv C_{tm} + C_{uv} \qquad (9)$$

where C* is a fixed total amount that DHS determines ought to be spent by all public jurisdictions together on homeland protection, the allocation algorithm, Equation 8, can be solved for the optimal total expenditures on the two types of protection:

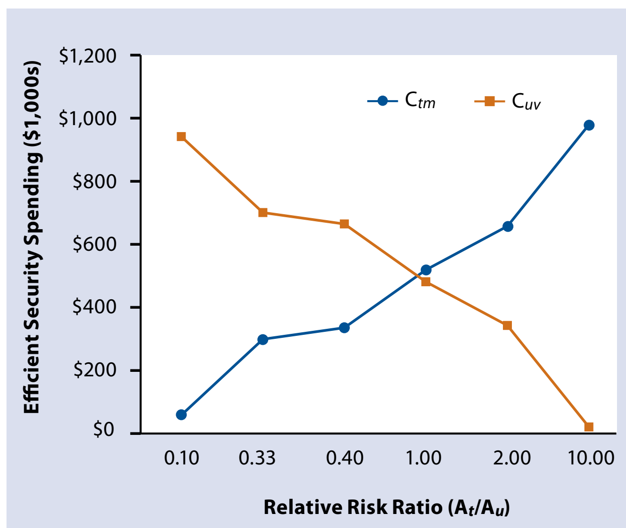
$$C_{tm} = [\log(\beta_{tm}/\beta_{uv}) + \log(A_{tm}/A_{uv}) + \log R + \beta_{uv}C^*]/(\beta_{tm} + \beta_{uv}) = bC^* + fQ + f(\log R) \qquad (10)$$

$$C_{uv} = C^* - C_{tm} = (1 - b)C^* - fQ - f(\log R) \qquad (11)$$

where $\log R = \log(L_{tm}/L_{uv})$ the natural log of the ratio of losses to $_{tm}$ and $_{uv}$ from a successful attack; $b = \beta_{uv}/(\beta_{tm} + \beta_{uv})$, $f = 1/(\beta_{tm} + \beta_{uv})$; and $Q = [\log(\beta_{tm}/\beta_{uv}) + \log(A_{tm}/A_{uv})]$. The amount of money to be spent protecting type *t* targets attacked in the method *m* way would depend positively on the total homeland security (federal and state) budget. The amount would also be higher if the expected loss from a successful attack or the expected unprotected risk was higher for target *t* than for target *u*.

Figures 1 and 2 show the sensitivity of the efficient spending mix to variations in expected losses and unprotected risks for a successful attack on targets *t* and *u*. The figures assume total protection spending equal to $1 billion. Unprotected risks of a successful attack on the type *t* targets equal to 2 percent and on type *u* targets equal to 5 percent (i.e., $A_t/A_u = 0.40$), and equal loss values from successful strikes on both types of targets ($R = L_{tm}/L_{uv} = 1$).[7] In Figure 1, $340 million should be spent protecting type *t* targets and $660 million spent protecting type *u* targets. As the relative risk to type *t* targets rises, more money should be spent protecting type *t* targets and less on type *u* targets, given a fixed total budget. For targets of equal relative risk and loss (i.e., $A_t/A_u = 1.00$), $1.10 should be spent protecting type *t* targets for every $1.00 spent protecting type *u* targets because of the lower marginal gain in protection per dollar spent on type *t* targets; that is, type *t* targets are more

**Figure 1. Sensitivity of security spending by type of target to unprotected target risk: relative expected loss ($R = L_{tm}/L_{uv} = 1$)**




7 Assuming equal valued loss from a successful attack on the chemical plant and the Golden Gate Bridge takes into consideration the expected actual loss in property and human life from the attack, adjusted by policy makers' valuation of, and expected differences in, lives lost. It also incorporates losses to the national psyche associated with the bridge that would not extend to the plant. R = 1 does not presume, therefore, that the number of lives lost in each catastrophe are equal. Only 20 lives might be lost in a successful attack on the bridge versus 100 lives for the chemical plant. The valuation of differences in property and lives are assumed equal after all factors are taken into consideration. Rarely, of course, would two successful attacks be considered exactly equal in value.

difficult to protect. More must be spent on type *t* targets to accomplish the same reduction in relative risk. Figure 2 gives the optimal spending mix when type *t* targets have 10 times the expected loss from a successful attack than type *u* targets. Both target types begin with nearly equal optimal spending. Although a successful attack on *t* is 10 times more costly, it is also assumed that *t* is 10 times more likely to be attacked than *u* (i.e., $A_t/A_u = 0.10$). Note that when type *t* targets are highly valued, *no* spending on type *u* targets is efficient for relative unprotected risks much above 1:1—for instance, if *t* = the Golden Gate Bridge and *u* = a one-story state municipal building. This conclusion, however, is based on C* = $1 billion. Higher overall national spending levels would justify some spending on protecting *u*.

The means by which efficient spending would be distributed across the two types of targets is shown in Figure 3. In Quadrant I, optimal total national baseline spending on protecting type *t* targets is plotted on the vertical axis, and spending on type *u* targets is plotted on the horizontal axis. One national 45° isoexpenditure line (A–B) is plotted, showing the baseline 1:1 dollar trade-off of spending for protecting the two targets. Two positively sloped linear "efficient spending" rays are shown for R = 1 (equal expected losses; X–A) and R = 10 (i.e., target *t* valued at 10 times target *u*; Y–B). The rays are based on the formula in Equation 12:

$$C_t = [f/(1 - b)]Q + [f/(1 - b)]\log R + [b/(1 - b)]C_u \quad (12)$$

derived by substituting Equation 9 into Equation 10 and solving for $C_t$ with respect to $C_u$ (and dropping the method-of-attack subscript for convenience).

Efficient spending in protecting *t* targets is log linear in the ratios of marginal reductions to risk reduction and the unprotected risk rates, embedded in Q, and in the relative losses from a successful attack that would be associated with *t* versus *u* targets, logR. Using the baseline parameters, for R = 1, $C_t = 1.5C_u$ - \$0.66 billon, whereas for R = 10, $C_t = 1.5C_u$ + \$0.49 billion. The nation's efficient spending mix protecting the two kinds of targets is found where the efficiency ray intersects the DHS budget constraint, C*. Point A indicates spending \$660 million protecting *u* targets and \$340 million protecting *t* targets, almost a

**Figure 2. Sensitivity of security spending by type of target to unprotected target risk: relative expected loss ($R = L_{tm}/L_{uv} = 10$)**

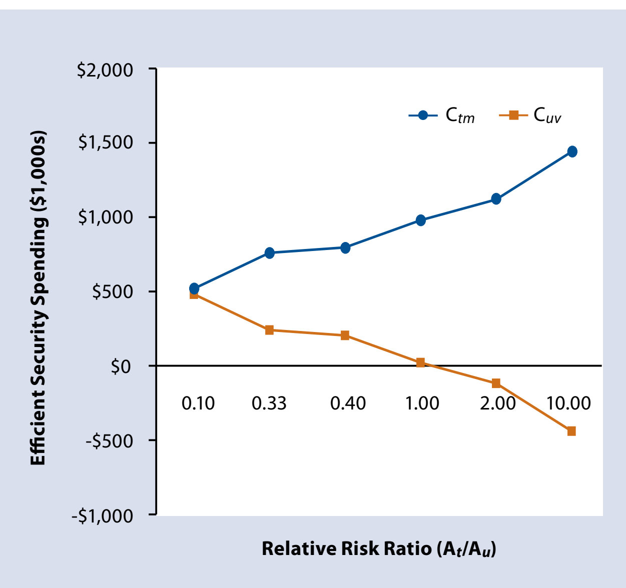
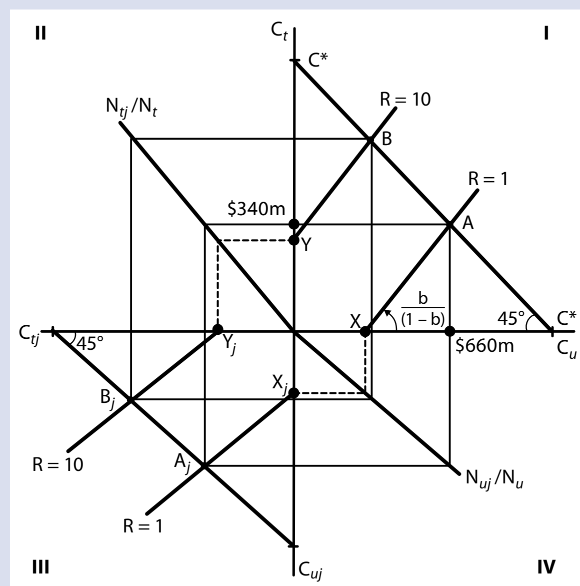



**Figure 3. Efficient homeland security funding regarding two target types for the nation and *j*th state**




**Legend**

C* = a fixed, hypothetical, total US spending in protecting targets

$C_{tj}$, etc. = spending to protect target type *t* in the *j*th state

$N_{tj}$, etc. = the number of type *t* targets in the *j*th state

X, Y = spending levels at which positive spending begins on the alternative target

b = $\beta_{uv}/(\beta_{tm} + \beta_{uv})$

2:1 ratio. Although potential targets of type *t* are more likely to be actual targets, more is spent on type *u* targets since the likelihood that an attack on type *u* targets is higher and the marginal gain to protecting type *u* targets is higher.

The X and Y intercepts of the two rays indicate zero spending levels on *t* targets (X intercept) and *u* targets (Y intercept). For targets of equal loss value (R = 1), $440 million (point X in Quadrant I) should be spent on protecting *u* targets before spending antiterrorism money on *t*. The reason is the same as in the case described above: (1) the unprotected likelihood of a successful attack is higher for *u* targets and (2) the greater marginal gain to protection of *u* versus *t* targets. Eventually, the risk to type *u* targets should be reduced to the point where the marginal attack risks (i.e., attack likelihood times expected loss) are equalized. Conversely, a positive Y intercept implies no spending on protecting *u* targets until $Y is spent protecting *t* targets because a loss of *t* is worth 10 times the loss of *u*. Once spending any money on protecting *t* targets becomes efficient, then $1.50 should be spent (optimally) on *t* for every marginal $1 spent protecting *u*.

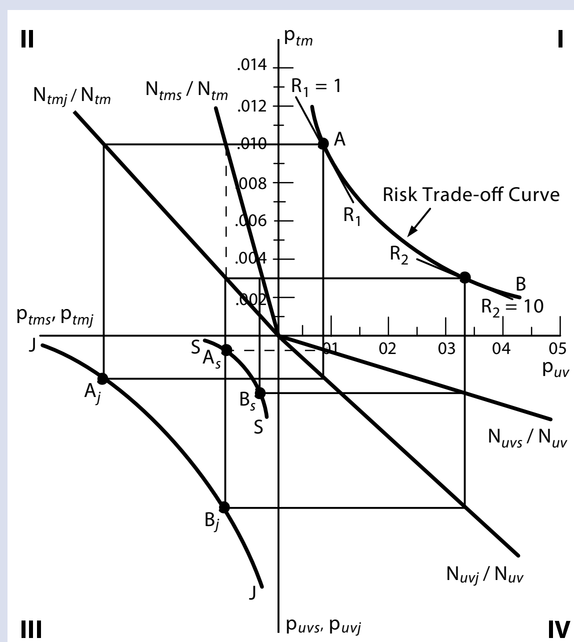
Total desired spending to protect the *t* and *u* targets in state *j* depends on the geographic distribution of the two types of targets. Quadrants II and IV show lines from the origin reflecting the (assumed) proportions of targets found in state *j*; namely, 3-in-4 for type *t* targets, $N_{tj}/N_t$, and 5-in-6 for type *u*, $N_{uj}/N_u$. (Only one other state is assumed, with one-quarter of the *t* targets and one-sixth of the *u* targets.) Two spending rays specific to state *j* are shown in Quadrant III, with slopes corresponding to those in Quadrant I.[8] The efficient spending mix in state *j* depends upon nationally efficient mixes. For national spending levels of C*, points $A_j$ and $B_j$ represent efficient spending levels in the *j*th state, given the geographic distribution of targets. The two points trace out a linear efficient spending trade-off curve for state *j*. Note that the state-specific relative spending levels will generally differ from the nation's as a whole because of a different target mix in each state. Consequently, efficient total spending levels $A_j$ ($805 million) and $B_j$ ($753 million) in state *j* will not fall on the same 45° spending line in the state as in the nation as a whole in Quadrant I. In the example, $B_j$ in Quadrant III represents slightly lower total budgeted spending in state *j* than $A_j$ because there are relatively more *u* targets than *t* targets in state *j*.

[8] This assumes expected loss ratios are uncorrelated with states, which is not likely due to differences in population densities.

Figure 4 plots the spending trade-offs in successful attack probabilities between the two target types for a given parameter set. The nonlinear attack probability curve is derived by solving Equation 7 for $C_{uv}$ and inserting the result into Equation 6 where $C_{tm} = C^* - C_{uv}$:

$$p_{tm} = A_{tm} e^{[-\beta_{tm}\,(C^* - (\log(p_{uv}/A_{uv})/-\beta_{uv})]} = De^{[(\beta_{tm}/\beta_{uv})\,\log(p_{uv}/A_{uv})]}\,, \quad (13)$$

**Figure 4. Attack risk curves regarding two target types for the nation and states *j* and *s***




**Legend**

$p_{tm}$, $p_{uv}$ = probability of a successful attack on *t* or *u* target type with *m* or *v* method

$p_{tmj}$, $p_{uvj}$, $p_{tms}$, $p_{uvs}$ = probability of successful attack on *t* or *u* type by method *m* or *v* in states *j* and *s*

$N_{tm}$, $N_{uv}$, $N_{tmj}$, $N_{uvj}$, $N_{tms}$, $N_{uvs}$, = Number of t or u targets available to be attacked by method *m* or *v*, nationally, and for states *j* and *s*

$R_1$ = Relative loss ratio where the loss associated with target types *t* and *u* is of equal value

$R_2$ = Relative loss ratio where the loss associated with target type *t* is 10 times greater than loss of target type *u*

$A_j$, $B_j$, $A_s$, $B_s$ = *tm* and *uv* attack-method probability combinations for states *j* and *s* where D is $A_{tm}e^{[-\beta_{tm} C^*]}$ = the lowest achievable probability of a successful attack on *t* if the entire security budget was spent in its defense. The more that is spent protecting against a *uv* attack and the less spent on *tm*, the lower will be $p_{uv}/A_{uv}$ and the greater will be the attack probability on target *tm* for a fixed security budget. Two downward-sloping linear relative loss lines are shown in Quadrant I, reflecting differences in relative losses due to a successful attack. Point A reflects attack probabilities that correspond to the efficient spending solutions in Figure 1 for $R_1 = 1$; namely, 0.0101, or 1.01 percent for target *t* and 0.0069, or 0.69 percent, for target *u*. The $R_2 = 10$ relative loss line places a much higher loss weight on a successful attack on target *t*. As a result, the efficient spending mix shifts toward protecting target *t*, thereby substantially reducing the probability of attack on target *t* with method *m* ($p_{tm}$), while the probability of an attack on target *u* with method *v* ($p_{uv}$) rises.

Quadrants II and IV translate the national risk profiles into profiles for two states, *j* and *s*, in Quadrant III. In Quadrant II, state *s* is assumed to have one-quarter of all type *t* targets, $N_{tms}/N_{tm}$, and state *j* is assumed to have three-quarters of all type *t* targets. Quadrant IV makes the same assumption about the distribution of type *u* targets. Quadrant III shows two successful attack profiles, mimicking the national profile in the first quadrant. State *j* exhibits a much higher risk profile (the curve described by points $A_jB_j$) because it has a disproportionate number of potential targets. While it is certainly possible, the state attack profiles do not cross in this example because state *j* has proportionally more of both target types. Also, nothing has been said at this point about the population size of the two states. It is conceivable that state *j* has a lower risk exposure on a per capita (versus a per-target) basis.

## An Equitable State Protection Strategy

Besides an efficiency goal in lowering successful attack likelihoods, the federal government also has an equity goal in sharing the burden of protection with states. Targets are not equally distributed across the states, nor are states equally capable, financially, to fund terrorism protection programs. Homeland security, like welfare and health care for the poor, transcends state boundaries. All Americans share in the economic and physical security of others, either directly by avoiding negative physical spillovers from a successful attack on, say, interstate electrical grids or nuclear power plants or indirectly through psychological spillovers (e.g., loss of the Golden Gate Bridge). Security, again like health and welfare, also is a “merit” good to the degree that the less protected our neighbors are, the less satisfied we are.

Traditional federal health and welfare programs share costs with states. Poorer states have both higher percentages of persons in poverty and less ability to pay for their needs; hence, the federal government shares a higher percentage of their costs. Logically, the same is true for homeland security, where the percentage of likely targets is analogous to poverty rates. However, in one respect, federal homeland security cost sharing with states is quite different from the federal matching algorithms used in allocating federal welfare and Medicaid funds. In those programs, the federal government matches any state expenditures at a rate varying with state per capita income (US General Accounting Office [GAO], 2003). Although all states would certainly spend some of their own private and tax monies on protection without federal grants, poorer states would likely put their own citizens at greater risk than wealthier states, thereby also putting citizens in other states at increased risk because of negative spillovers. Conversely, wealthy states with few targets might overspend on their own protection relative to other states. Although they should be free to do so, interpersonal equity suggests that they also contribute significantly to protection in other, poorer, states. In some instances, this may require earmarked protection subsidies across states. As we show later, this approach would call for a much different funding algorithm than Congress currently uses to fund homeland protection.

Once the federal government decides upon the appropriate total amount to be spent on protection by all public jurisdictions ($C^*$), and how that amount should be apportioned between protecting targets of type *t* and *u* across the country, or $C_s$ and $C_j$ in our two-state model, it should set its cost sharing with each state so as to equalize each state's own financial burden per state dollar of tax capacity.[9] For states *s* and *j*, this rule is defined by Equation 14:

$$(1 - k_s)(C_s/TC_s) = (1 - k_j)(C_j/TC_j) \quad (14)$$

where $C_s/TC_s$ and $C_j/TC_j$ equal the total federal plus state spending on protection in states *s* and *j* divided by state total tax capacity; and $k_s$ and $k_j$ are the federal portion of spending in states *s* and *j*.

The equity criterion Equation 14 can be rearranged as shown in Equation 15:

$$(1 - k_j)/(1 - k_s) = (C_s/TC_s)/(C_j/TC_j) = (C_s/C_j)(TC_j/TC_s) \quad (15)$$

implying that the ratio of state-sharing responsibilities determined by DHS should be set equal to state relative tax capacities ($TC_j/TC_s$) times the inverse ratio of efficient total antiterrorism protection costs in the two states, ($C_s/C_j$). States facing high protection costs per taxable dollar should have more federal sharing (i.e., higher k factors) and lower state spending obligations.

The amount, in total, that should be spent in states *s* and *j* can be considered a weighted sum of the number of *t* and *u* targets in each state, aggregated across all methods of attack (*m* and *v*), with weights equal to the national average optimal protection cost per target type:

$$C_s = \Sigma_m N_{ts}(C_{tm}/N_{tm}) + \Sigma_v N_{us}(C_{uv}/N_{uv}) \quad (16)$$

$$C_j = \Sigma_m N_{tj}(C_{tm}/N_{tm}) + \Sigma_v N_{uj}(C_{uv}/N_{uv}) \quad (17)$$

where $N_{ts}$ and $N_{us}$ equal the total number of *t* and *u* targets in state *s*, and $N_{tj}$ and $N_{uj}$ equal the corresponding numbers in state *j*. Average protection costs per target depend upon target type but are assumed to be unaffected by the state in which the target is located. (More population-dense states could have higher C/N ratios if human losses are higher from a successful attack.)

While the number and geographic distribution of targets are presumably known,[10] and the efficient protection spending in each state identified (once the efficiency goal is determined), more information is needed to solve Equation 15 for equitable federal sharing in each state. It seems reasonable to assume that the federal government sets its own overall spending level on protection that will be distributed to each state. Thus, total national spending can be decomposed as $C^* = C^f + C^s$, where $C^f$ is the predetermined total federal spending on homeland security and $C^s$ = the residual portion of optimal national spending that is the states' responsibility. The federal allocation to each state is

$$C^f = k_s C_s + k_j C_j , \quad (18)$$

which can be solved for $k_j$ and inserted into Equation 15 and solved for $k_s$:

$$k_s = [F + (C^f/C_j) - 1] / [F + (C_s/C_j)] \quad (19)$$

where $F = (C_s/TC_s) /(C_j/TC_j) = (C_s/C_j)(TC_j/TC_s)$ is the relative target cost of efficient and equitable protection per state dollar of taxable capacity. The federal share of spending in state *s* ($k_s$) depends positively on F. For states with equal tax capacities, those with greater security needs should enjoy greater federal sharing. Also, if the (predetermined) federal outlays on homeland security, $C^f$, are increased, then more funds are available to support state *s*. (The same is true of state *j*, as federal spending flows to both states.)

The sensitivity of efficient and equitable federal security grants to the two states is shown in

9 State taxable capacity, or total taxable revenues, is a preferred measure of state wealth, rather than per capita income. Taxable capacity is a weighted measure of a state's tax base that includes taxes on sales, property, corporate profits, minerals, etc. The weights are a national set of tax rates on each base. Per capita income understates a state's ability to raise taxes from certain sources such as corporate profits and minerals. Wyoming and Delaware are two states with tax capacities well in excess of their per capita incomes given the mineral (Wyoming) and corporate profit bases (Delaware) in each state. For examples of the use of taxable capacity in evaluating the distribution of federal Medicaid funds, see GAO (2003); Cromwell, Hurdle, Schurman (1987); and Cromwell et al. (1995).

10 This is obviously a debatable assumption. The vector of potential targets in the US, stratified by different means of attack, likely runs into the hundreds of thousands, if not millions. All tall buildings can be attacked in several ways (e.g., planes, bombs, aerosols in air conditioning, fires). All bridges and government buildings can be attacked using explosives or planes. Plus there are the monuments (e.g., Statue of Liberty, Mt. Rushmore). Part of infrastructure funds in DHS' budget is to be devoted to such a mapping of potential targets. Further complicating the problem are the varying sets of targets depending upon type of terrorist. These issues are addressed in the last part of the paper.

Figures 5 and 6 for varying distributions of targets and state tax capacities.[11] Relative losses to attacks on *t* and *u* targets are assumed to be equal in both figures, and the federal government will pay for one-half of target hardening. Figure 5 assumes that state *s* has 25 percent of the *t* targets and 20 percent of the *u* targets, whereas state *j* has 75 percent of the *t* targets and 80 percent of the *u* targets. If wealthier state *j*'s tax capacity is 2.5 times that of state *s*, for example, $50 billion versus $20 billion, then DHS should grant state *s* $0.17 for every $1 granted to state *j* (i.e., $74 million to state *s* versus $426 million to state *j*) because state *j* has so many more targets than state *s*.

Federal protection grants are a *positive* function of (1) a state's share of all targets, $\%N_s$, (2) national total efficient spending on the two target types, $C^*$, and (3) the federal share of total efficient spending, $(C^f/C^*)$, and a *negative* function of a state's relative tax capacity. Even if the tax capacity of state *j* was five times that of state *s*, the federal government should grant state s only $0.37 for every $1 spent protecting targets in state *j* ($134 million to state *s* versus $366 million to state *j*) because of the uneven distribution of targets between the two states. In fact, if tax capacities were equal between the two states, that is, $TC_j/TC_s = 1.0$, state *s* should receive no federal security grant at all given its modest number of targets and relative wealth per target.[12]

If the two states had equal numbers of targets, Figure 6, optimal federal grants would change radically. If wealthier state *j*'s tax capacity is 2.5 times that of state *s*, poorer state *s* should receive $2.50 for every $1 of federal security funding awarded to state *j* (i.e., $357 million for state *s* versus $143 million for state *j*).[13] Federal grants to the two states would be equal only if both states had identical numbers of targets and tax capacities (indicated by intersection of the two grant spending lines in Figure 6).

**Figure 5. Sensitivity of federal security grants, $k_sC_s/k_jC_j$, to state distribution of targets and taxable capacity: % $N_{ts}$ = 0.25; % $N_{us}$ = 0.20**

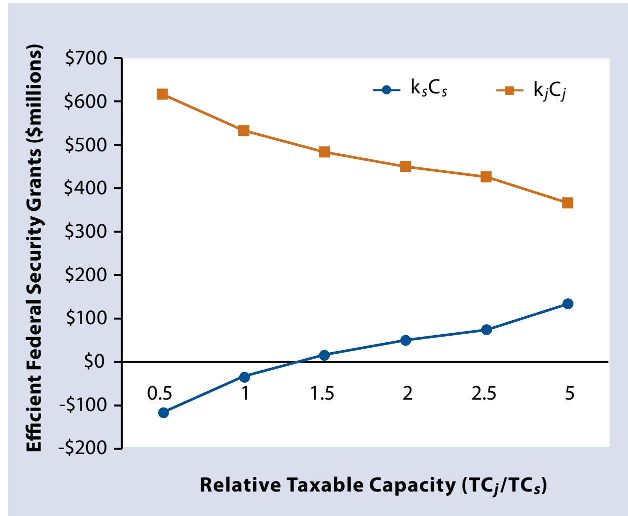
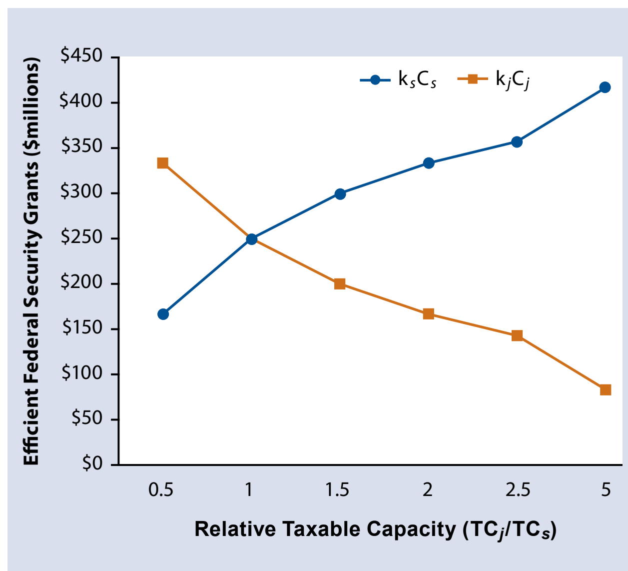



**Figure 6. Sensitivity of federal security grants, $k_sC_s/k_jC_j$, to state distribution of targets and taxable capacity: % $N_{ts}$ = 0.50; % $N_{us}$ = 0.50**




[11] Figures 5 and 6 are based on solving for $k_sC_s$ by multiplying Equation 19 by Equation 16 and simplifying, that is, $k_sC_s = C^*N_s + C^*[(C^f/C^* - 1)/[1 + (TC_j/TC_s)]$ , where $N_s = \%N_{ts}(C_t/C^*) + \%N_{us}[1 - (C_t/C^*)]$ and where $\%N_{ts}$ and $\%N_{us}$ denote state's share of *t* and *u*, respectively.

[12] State *s* would have 6.5 targets per billion dollars of tax capacity versus 11.75 targets per billion dollars for state *j*.

[13] The disproportionate increase in the federal grant for state *s* over the baseline (i.e., $357 million versus $74 million) is due to $[(C^f/C^*) - 1] < 0$.

These allocations can be contrasted, in illustrative fashion, with the allocation that might have occurred using the congressionally mandated formula that guaranteed to each state 0.75 percent of the federal security budget, with the rest allocated according to state population; for example,

$$k_j C_j / C^f = (0.0075) + (1 - 0.385)(POP_j / POP_{US}) \quad (20)$$

where $k_j C_j / C^f$ is the share of federal homeland security spending allocated to the $j$th state; $(1 - 0.385) = [1 - 50(0.0075)] = 0.615$; $POP_j$ equals the state population; and $POP_{US}$ = total US population. To illustrate this, our efficient and equitable federal spending level in state $s$ (see Footnote 11) first must be rewritten in terms of a state's population share.[14] We also ignore multiple target types for ease of comparison with the congressional formula by collapsing them into a single type:

$$k_j C_j / C^f = (POP_j / POP_{US})\{(C^* / C^f)[(N_j / POP_j) / (N_{US} / POP_{US})] - [(C^* / C^f) - 1)](TC_j / TC_{US})\} \quad (21)$$

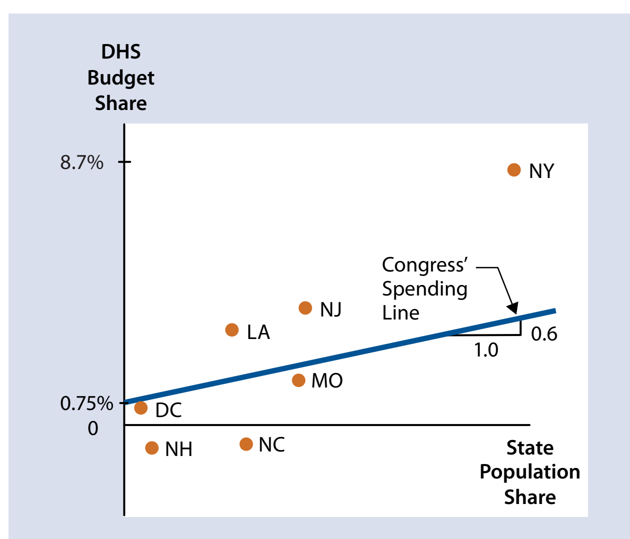
where $N_j$ is the number of all targets in state $j$, and $N_{US}$ is the number of all targets in the United States.

Using our allocation algorithm (Equation 21), it is possible for states with relatively few targets and states that are very wealthy to have negative claims on federal homeland security dollars. A negative share implies that state residents would have to "donate" to the federal security fund to simultaneously achieve efficient and equitable protection of potential targets throughout the country.

Figure 7 illustrates possible differences in the distribution of homeland security funds between the formula that Congress mandated and one based on efficiency and equity principles. Congress' bolded spending line begins at 0.75 percent for each state and rises at a rate of 0.0615 percentage points for every 0.1 percent increase in the state's share of the US population (Department of Homeland Security, 2004, 2005, 2006). Several states are plotted in the figure, based on illustrative assumptions of ours regarding their relative intensity of targets using Equation 21. Information from established sources (US Census Bureau, 2002; GAO, 2003) was used to estimate state population shares and relative tax capacity.

According to the congressional allocation formula, New York (NY), with 6.8 percent of the US population, would have received 4.9 percent of federal homeland security protection funds. However, if we assume that New York had 25 percent more targets per capita than in the country as a whole, and that DHS covered one-half of all protection costs in states, on average, then New York should have received 8.7 percent of all DHS funds, despite its higher (21 percent) relative tax capacity. Part of the reason for the discrepancy is that no funds in our formula are automatically allocated to states, regardless of their target intensity. New Jersey (NJ) would also receive higher funding if its targets per capita were 25 percent above the national average, even though New Jersey's

**Figure 7. Department of Homeland Security (DHS) budget shares for selected states**




[14] Dividing both sides of the equation in footnote 11 by $C^f$, canceling terms, and expanding to consider $g$ types of targets gives

$$k_j C_j / C^f = [(\Sigma_g (N_{gj} / N_g)(Cg / C^f)] + (1 - C^* / C^f) / [(TC_j / TC_j) + 1] .$$

Equation 20 can be restated in terms of state $j$'s population share by rewriting $(TC_j / TC_j)$ in terms of average national tax capacity,

$$TC_{US} = (POP_j / POP_{US})(TC_j / POP_j) + (POP_s / POP_{US})(TC_s / POP_s).$$

Dividing through by $(TC_j / POP_j)$ and solving for $(TC_j / TC_j)$,
$$(TC_s / TC_j) = (POP_j / POP_{US})(POP_{US} / POP_s)[TC_{US} / (TC_j / POP_j)] - 1 ,$$

then substituting this result for $(TC_s / TC_j)$ into $k_j C_j / C_f$ and expressing the first bracketed term in terms of state $j$' population share gives

$k_j C_j / C^f = (POP_j / POP_{US})\{(\Sigma_g (POP_{US} / N_g)(N_{gj} / N_g)(C_g / C^f) - [(C^* / C^f) - 1)](TC_j / TC_{US})\}$, where $(TC_j / TC_{US})$ = the ratio of tax capacities in the $j$th state versus the US as a whole. Thus, the share of the federal security budget going to state $j$ depends positively on $(N_{gj} / N_g)$ and the share of targets in the $j$th state, and negatively on $(TC_j / TC_{US})$, the relative wealth of the state (i.e., $(C^* / C^f - 1) > 0$).

tax capacity was 30 percent above average. If we assume that Louisiana (LA) has 50 percent more targets per capita than nationally, but that its tax capacity is 8 percent below average, then it would see a doubling of its federal funding share to 3.3 percent instead of 1.7 percent under the congressional formula. New Hampshire (NH) and Missouri (MO) are shown (hypothetically) as having negative efficient and equitable shares of the federal budget. This is based on the assumption that they have only one-half to one-third the number of targets per capita found elsewhere in the US. New Hampshire also has above-average tax capacity.

## Multiple Terrorists' Targets and Reactions

Our allocation model so far has made the simplifying assumption of fixed (unprotected) probabilities of a successful attack based on constant terrorist effort levels for specific targets. More realistically, the rational terrorist group would shift its attack efforts depending upon the government's defense strategy (the displacement effect).[15]

A generalized terrorist reaction function for the *t*th target likely includes several major factors. Effort, and hence likelihood of success, is a positive function of the group's maximum resource capabilities, relative preference for a given target, and perceived improvement in attack success from investing more in attacking one target relative to others. Effort and likely success are negative functions of the government's investment against an attack (i.e., the displacement effect). The reaction function would have to be inserted into the attack likelihood functions (Equations 6 and 7) in place of E, and the system resolved for efficient and equitable spending levels.[16] The three positive effects would be considered exogenous to the model and, obviously, very difficult to calibrate accurately. Spending is endogenous and would require solving the model in iterative fashion, as greater spending to harden one target would raise the likelihood of an attack on another target, which, in turn, would require yet another reallocation of spending to protect other targets.

Protecting against a terrorist attack is complicated even further in recognizing multiple terrorist groups with varying goals and capabilities. Table 1 presents some examples of target and terrorist groups that the US government might consider in determining its allocation of counterterrorism protection spending.

Estimates of the magnitudes of losses from terrorist attacks are in Hobijn (2002) and Zycher (2003). For example, a successful attack on a government building (e.g., the Murrah Federal Building in Oklahoma City) will generally require reconstruction and may result in the loss of hundreds of lives (US Federal Bureau of Investigation [FBI], 2000). The attack also presumably creates at least a medium level of terror across the country. By contrast, an attack on a monument (such as the Statue of Liberty) may result in far less loss of life but may feel like an attack on the country as a whole and thereby create far more of a feeling of terror. A terrorist attack on an individual (e.g., a physician who performs abortions) involves relatively low monetary and human life losses but can cause a moderate amount of terror. An anthrax or sarin attack in a large city could kill thousands and spread terror fears throughout the country.

The middle panel of Table 1 gives three examples of types of terrorist groups (see Smith, 1998; FBI, 2000; US Department of State, 2002). International terrorists (e.g., Al Quaeda) in the United States would presumably select relatively large, high-profile targets—such as monuments, unique government structures (e.g., the Pentagon), and famous structures (e.g., the World Trade Center) that would have international news value—as well as large population centers. By contrast, domestic antigovernment groups (e.g., the Montana Freemen, Timothy McVeigh and associates) are far more likely to target government buildings and symbols of government power rather than commercial targets or general population centers. Single-issue terrorist groups (e.g.,

[15] The notion of the "rational terrorist" is a common assumption in the literature on terrorist decision making (e.g., see Cauley and Im, 1988; Weaver, et al., 2001). For a more detailed discussion of terrorist reactions and US counter-actions, see Sandler and Arce (2003) and Arce and Sandler (2005).

[16] A detailed description of Nash equilibrium reaction functions is available from the authors. For a discussion of the general methodology, see Fudenberg and Tirole (1991).

**Table 1. Hypothetical US losses versus terrorist utilities from attacks on various targets**

| | General Government Buildings | Monuments | Famous Structures | Public Infrastructure | Private Commercial | Individuals | General Population |
|---|---|---|---|---|---|---|---|
| | **US Losses From Successful Attack** | | | | | | |
| Monetary | Medium | Medium | High | High | Medium | Low | Medium |
| Human Life | Medium | Low | High | Medium | Medium | Low | High |
| General Terror | Medium | High | High | High | Low | Medium | High |
| Overall Loss | Medium | Medium | High | High | Medium | Low | High |
| | **Terrorist Utility** | | | | | | |
| International (Al Qaeda) | Low | High | High | High | Medium | Low | High |
| Domestic Anti-Govt. (Tim McVeigh) | High | High | Low | Medium | Low | Medium | Medium |
| Domestic Single-Issue (Ecoterrorist) | Low | Low | Low | Low | High | High | Low |
| | **Examples and Distribution of Targets** | | | | | | |
| Examples | Murrah Building | Mt. Rushmore | World Trade Center | Airplane | Research lab | Abortion MD | Anthrax |
| | Schools | Statue of Liberty | Golden Gate Bridge | Power plant | Refinery | Animal researcher | Sarin |
| Number of Targets | Thousands | Hundreds | Tens | Hundreds of thousands(?) | Tens of thousands(?) | Thousands | Thousands |
| Concentration of Targets | Many cities | Many states | Few cities | All states | All states | All states | Many cities |

antiabortionists; ecoterrorists) will generally place high value on commercial companies or individuals that produce products to which the group is opposed.

Table 1 provides general guidance about the optimal distribution of protection spending across target types and states. For example, overall losses from successful attacks on famous structures are quite high, and there are relatively few such high-profile targets. Furthermore, they are highly favored by international terrorist groups that have relatively greater resources at their disposal. This suggests that a substantial amount should be spent to protect this type of target. Since these targets are highly concentrated in a handful of states, protection spending would be concentrated geographically as well. This effect would be mitigated by spending on geographically dispersed infrastructure and population center targets that are also favored by large terrorist groups.

Table 1 suggests that little, if any, homeland security protection spending is optimal for some target types. For example, noninfrastructure commercial and individual person targets are ubiquitous and are the primary focus of single-issue groups, who may have relatively few resources. (Private nuclear plants are clearly an exception.) As a result, any amount of protection spending will likely have a minimal effect on the already low probability of attack. Protecting such targets should more logically be in the purview of the criminal justice system rather than the Department of Homeland Security. Terrorist insurance is also a more cost-effective "protection" alternative for such targets.

## Conclusion

Algorithms presented in this paper provide a rational policy for allocating public spending on protecting various targets around the country from terrorist attacks. The model easily incorporates different kinds of terrorists and targets and shows how allocation decisions change depending upon the perceived type of terrorist. What changes are the key parameters, namely, the likelihoods that terrorists will attack certain targets and the marginal gains of spending to harden targets. Efficiency requires allocating protection funds across targets so as to equalize the marginal societal value of expected losses. This is easier said than done. If the goal is to protect all potential targets from all methods of attack, an enormous amount of information is required—all of the terrorist groups that might want to attack each target, the resources they have at their disposal, the relative value of each type of target to all others, each group's abilities to use different methods of attack and to deploy their resources across target types, and the estimated loss of life and property from a successful attack. A policy that aims to protect a comprehensive range of potential targets appealing to all types of terrorist groups will very likely not be able to collect all of the necessary information, resulting in an inefficient allocation of protection spending.

Even if sufficient information were available to policy makers, almost any feasible level of protection spending for all types of targets would provide only a miniscule level of protection for most targets. While seemingly counterintuitive and controversial, efficient allocation rules would leave many "potential" targets only marginally protected, if at all. Efficient protection budgeting, therefore, depends crucially on the relationship between successful attack probabilities and protection spending. This paper uses rather simple exponential attack curves, which imply sizable reductions in risk from modest expenditures. While this might be the case for some targets, especially those susceptible to a displacement effect, it is unreasonable to expect substantially lowered risk "on the cheap." Much more research is needed on the technical efficiency of the "diversified minimalist" spending strategies now in vogue.

With these considerations in mind, our analysis suggests that a relatively limited set of target types should be identified, particularly those that (1) are of relatively high value to well-funded terrorist groups, (2) would produce large economic and psychological losses if an attack were successful, and (3) are relatively few in number. By restricting the set of federally protected targets, the government can focus the public's resources with lower expected losses. Low-grade domestic terrorism is best left to local police and FBI intelligence. Private insurance also is capable of reimbursing for the fairly nominal losses involved without simply deflecting the terrorist to another target. If human loss is less insurable because of the high psychological cost to society from a successful, large-scale attack on persons (e.g., widespread emotional empathy, fear, and possible panic), then the argument for active protection of certain targets before an attack occurs is reinforced and narrows the range of targets, at least somewhat.

The original congressionally mandated formula for distributing funds for protection spending (the State Homeland Security Program) was far too uniform across states, with 37.5 percent allocated equally across states regardless of the distribution of targets. The recent (FY 2007) allocations continued to allocate a significant portion (31 percent, nearly $355 million) of homeland security grants to states in a nearly equal-allocation fashion. Despite the shift to 60 percent of grants to states with 45 key urban areas, hardening a relatively small set of internationally attractive targets implies that protection spending should be concentrated in even fewer states. The current congressional formula for distributing protection spending remains too uniform across all states and has produced "earmark irrationality" in state spending (e.g., ambulances capable of penetrating concrete walls in Vermont). Nor has Congress made any allowance for each state's ability to pay for its own protection—even though it routinely uses state per capita income (we prefer tax capacity) to cost share on welfare, Medicaid, and other public services. Considering each state's ability to pay for local protection, adjusted for the number and type of target, would produce a more efficient and equitable distribution of homeland security funds. Adjusting federal sharing for New York's higher tax capacity might also address the resentment in rural states that New York is unduly favored by Washington.

The model incorporating federal-state sharing of protection costs also recognizes the likely incongruence of federal and state security priorities. The Congress and DHS should protect targets of a national character, such as monuments, federal buildings, and strategic electricity grids, and leave protection of more local targets (e.g., commercial buildings) to states. Our allocation model captures federal protection preferences in R, the perceived losses of Congress and the Administration to successful attacks on different targets. Assuming negative exponential returns to more spending in protecting targets, targets valued at, say, 10 times greater than others, would see their spending protection increase only 2.3-fold. This explains why protection spending differentials are far narrower than perceived differences in societal value for different targets.

It is important to note that this paper considers spending only on physically protecting potential targets. Spending on intelligence gathering or border protection is not tied to specific targets and may be more cost-effective than most physical protection spending, especially for the geographically dispersed targets of disgruntled domestic citizens and small groups. Both surveillance and actual physical protection makes the most sense for obvious large targets of national character, with or without huge potential loss of life. Sandler and Arce (2005), using a game theory model, also demonstrated the benefits of proactive attacks on terrorist groups that do not experience displacement effects.

## References

Abel, D. (2003, September 2). Senators rap state security readiness. *Boston Globe.*

Arce, D. G. & Sandler, T. (2005). Counterterrorism: A game-theoretic analysis. *Journal of Conflict Resolution, 49*(2), 183–200.

Cauley, J. & Im, E. I. (1988). Intervention policy analysis of skyjackings and other terrorist incidents. *American Economic Review, 78*(2), 27–31.

Cromwell, J., Adamache, K., Ammering, C., Bartosch, W.J., & Boulis, A. (1995). The equity of the Medicaid program to the poor versus taxpayers. *Health Care Financing Review, 16*(3), 75–104.

Cromwell, J., Hurdle, S., & Schurman, R. (1987). Defederalizing Medicaid: Fair to the poor? Fair to the taxpayers? *Journal of Health Politics, Policy and Law, 12*(1), 1–34.

Fudenberg, D., & Tirole, J. (1991). *Game theory.* Cambridge, MA: MIT Press.

Hall, M. (2003, July 14). Anti-terror funding questioned. *USA Today,* p. 3A.

Hess, G. D. (2003, January). An economic welfare cost of conflict: An empirical assessment. Claremont Colleges Working Papers in Economics. Retrieved January 15, 2008, from http://www.claremontmckenna.edu/econ/papers/2002-08.pdf

Hobijn, B. (2002). What will homeland security cost? *Federal Reserve Board of New York Economic Policy Review,* 21–33. Retrieved January 15, 2008, from http://www.ny.frb.org/research/epr/02v08n2/0211hobi/0211hobi.html

Lakdawalla, D. N., & Zanjani, G. (2004). Insurance, self-protection, and the economics of terrorism. Santa Monica, CA: RAND Institute for Civil Justice. Retrieved January 15, 2008, from http://works.bepress.com/cgi/viewcontent.cgi?article=1011&context=darius_lakdawalla

Sandler, T. & Arce, D. G. (2003). Terrorism and game theory. *Simulation Gaming, 34*(3), 319–336.

Smith, G. D. (1998). Single issue terrorism. Commentary No. 74, Canadian Security Information Service. Retrieved January 15, 2008, from http://www.csis-scrs.gc.ca/en/publications/commentary/com74.asp

US Census Bureau (2002). Statistical abstract of the United States: 2001. Available at http://www.census.gov/prod/2002pubs/01statab/stat-ab01.html

US Department of Homeland Security (DHS). (2004). Fiscal year 2005 Homeland Security Grant Program: Program guidelines and application kit. Retrieved January 15, 2008, from http://www.ojp.usdoj.gov/odp/docs/fy05hsgp.pdf

US Department of Homeland Security (DHS). (2005). Fiscal year 2006 Homeland Security Grant Program: Program guidelines and application kit. Retrieved January 27, 2008, from http://www.ojp.usdoj.gov/odp/docs/fy2006hsgp.pdf

US Department of Homeland Security (DHS). (2006). Overview: FY 2007 Homeland Security Grant Program. Retrieved January 27, 2008, from http://www.dhs.gov/xlibrary/assets/grants_st-local_fy07.pdf

US Department of Homeland Security (DHS). (2003). Budget in brief: Fiscal year 2004. Retrieved January 15, 2008, from http://www.dhs.gov/xabout/budget/

US Department of State. (2002). Patterns of global terrorism 2001. Retrieved January 15, 2008, from http://www.state.gov/s/ct/rls/crt/2001/pdf/

US Federal Bureau of Investigation (FBI). (2000). Terrorism in the United States 1999. Retrieved January 15, 2008, from http://www.fbi.gov/publications/terror/terror99.pdf

US General Accounting Office (GAO). (2003 July). Medicaid formula: Differences in funding ability among states often are widened (GAO-03-620). Washington, DC: Author.

US Office of Management and Budget (OMB). (2003). Regulations related to homeland security and recovery from the attacks of September 11, 2001. In *Informing regulatory decisions: 2003 report to Congress on the costs and benefits of federal regulations and unfunded mandates on state, local and tribal entities.* Washington, DC: Office of Management and Budget, Office of Information and Regulatory Affairs.

Weaver R., Silverman, B. G., Shin, H., & Dubois, R. (2001 May). Modeling and simulating terrorist decision-making: A "performance moderator function" approach to generating virtual opponents. Paper presented at the 10th Conference on Computer Generated Forces and Behavioral Representation, SISO. Retrieved January 15, 2008, from http://www.seas.upenn.edu/~barryg/HBMR.html

Zycher, B. (2003). A preliminary benefit/cost framework for counterterrorism public expenditures. Santa Monica, CA: RAND. Retrieved January 15, 2008, from http://www.rand.org/publications/MR/MR1693/

## Additional Resources

Blomberg, S. B., Hess, G. D., & Weerapana, A. (2002 August). *Terrorism from within: An economic model of terrorism.* Claremont Colleges Working Papers in Economics.

Grossman, H. I. (1991). A general equilibrium model of insurrections. *American Economic Review, 81*(4), 912-921. Retrieved January 15, 2008, from http://www.jstor.org/view/00028282/di971053/97p0014t/0.

Hess, G. D., & Orphanides, A. (1995). War politics: An economic, rational-voter framework. *American Economic Review, 85*(4), 828–846.

Hess, G. D., & Orphanides, A. (2001). Economic conditions, elections, and the magnitude of foreign conflicts. *Journal of Public Economics 80*, 121–140.

Lee, D. R. (1988 May). Free riding and paid riding in the fight against terrorism. *AEA Papers and Proceedings: The Political Economy of Terrorism, 78*(2), 22–26.

Smith, G. D. (1985). Political violence in animal liberation. *Contemporary Review, 247*(1434).