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The Benefit-Cost Analysis of Security Focused Regulations

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Abstract

Security focused regulations have been largely exempt from the benefit-cost type of analysis required for major Federal regulations and done routinely in areas such as transportation, environment and safety. Among the reasons offered for exemption are the analytical difficulties of security issues involving complex or poorly understood probabilities and consequences. This paper investigates the magnitude of security focused regulations, a framework for developing an expected cost analysis of regulations, and the current "break-even" analysis used by the Department of Homeland Security. Key assumptions implicit in the current analysis are identified and suggestions are made for the difficult evolution of security regulations toward a more explicit benefit-cost analysis.

KEYWORDS: homeland security, regulation, benefit-cost, risk, consequences

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I. Introduction

Security investments and regulation focused on anti-terrorism have increased dramatically since the attacks of September 11, 2001 (9/11). This is particularly true for federal regulations where security quickly earned an importance similar to environmental protection, food safety and transportation. When federal regulations expanded rapidly in the 1960s and 1970s, it prompted a reaction from opposing forces that included the adoption of benefit-cost analysis as a means of assessing regulations and assisting in the centralized control of laws based on agency regulations (McGarity 1993). In the current era, security rules create unique challenges for benefit-cost analyses. While there are numerous problems in calculating the costs of these regulations, the primary challenges are to measure the benefits and associated probabilities of security rules. Because much of the information required to assess the value of preventing terrorist attacks is not only highly uncertain but also classified, rules on security have generally escaped serious economic analysis. Although many of these rules are issued by components of the Department of Homeland Security (DHS), some are issued by other agencies such as the Food and Drug Administration and the Department of Agriculture.

Minimal components for the benefit-cost analysis of a homeland security regulation are: benefits using estimates of costs avoided; probabilities; and costs to industry, citizens and government to implement a regulation. However, there is no established template or model for applying benefit-cost analysis to homeland security issues where the probabilities, and to a lesser extent the avoided costs, are poorly understood. Standard benefit-cost texts do not cover the topic A search of the economics literature using the words terror, homeland, benefit and cost in various combinations results in a total of 19 citations, of which most were tangential to actually applying benefit-cost analysis to security issues.

Some benefit-cost issues are discussed at a macro level, as in Enders and Sandler (2006) and Sandler, Arce and Enders (2008) which model a balancing based on a target's expected value and ease of protection. A few others focus on individual actions including self-protection, insurance, and value of homes, and consider the usefulness of response to risk from natural disasters as a model for security expenditures (Smith and Hallstrom 2005; Lakdawalla and Zanjani 2006). Finally, a few authors consider the homeland security allocation problem of an organization such as DHS, from which some benefit-cost implications can emerge (Farrow 2007; Bier, et al. 2008). More of the literature focuses on case studies relating to individual components of the benefit-cost analysis for security regulations.

In response to these issues, this paper investigates a particular type of analysis, break-even analysis, used by DHS for several homeland security regulations, and summarizes a benefit-cost framework for investing in security that is designed to be consistent with benefit-cost guidance from the U.S. Office of Management and Budget (OMB 1992, 2003). The review of DHS' analysis and conceptual framework is then used to suggest further steps in the use of benefit-cost analysis for security regulations.

The paper proceeds as follows. Central issues surrounding analysis of homeland security costs and benefits are described in Section II. Section III presents the DHS break-even analysis and conceptual framework mentioned above. In Section IV, the recent DHS analyses are critiqued using the conceptual framework. Section V offers recommendations for improving security based benefit-cost analyses and related conclusions.

II. Costs, Consequences and Probabilities

Every year, the Office of Management and Budget (OMB) reports to Congress on the annual benefits and costs of regulations. In the area of homeland security, OMB says "Because the benefits of homeland security regulation are a function of the likelihood and severity of a hypothetical future terrorist attack, they are very difficult to forecast, quantify, and monetize." (OMB 2009). However, OMB does keep track of the implementation costs of a subset of homeland security regulations. This subset consists of those regulations that are "economically significant" under Executive Order 12866. These regulations each have an impact on the economy of more than $100 million in at least one calendar year. Since 2002, there have been fourteen such regulations. Most of these have been issued by components of DHS, but several have been issued by the Food and Drug Administration (FDA) to prevent bioterrorist attacks. These fourteen regulations have been estimated to "impose a total cost on the economy of between $3.4 billion to $6.9 billion a year." (OMB 2009).

There are two reasons that this number is likely to be an understatement. One reason is that OMB does not include all regulations in its estimate. The other reason is that there are omissions in the calculations of the costs of individual regulations. There have been far more than fourteen rules issued since 2002 that impact homeland security. OMB has never estimated the cost of rules not deemed "economically significant" but has stated that the rules included in their totals, "economically significant" rules, likely make up the bulk of regulatory costs. However, Hahn and Cecot (2006) noted that even economically insignificant rules can have significant costs.

Forty-nine other final security rules have been promulgated by agencies between 2002 and 2008 in addition to the fourteen identified as economically significant. A list of these rules from the Unified Agenda (Regulatory Information Service Center 2002-2008) appears in Appendix 1. Although many of these rules are not counted because the promulgating agency estimates that they cost less than $100 million per year, technically the rules should be counted if the benefits exceed $100 million in any given year. However, because benefits are never counted it is likely that some rules that should be in the OMB total are not included. Even so, if each of these rules only cost $25 million per year, their inclusion would add another billion dollars to the costs. There is good reason to think that for these rules in particular the costs may be large, perhaps even greater than the $100 million per year threshold.

Of those security rules with costs estimated at less than $100 million annually, many make it more difficult for immigrants to enter the United States. Since there is no analysis on rules with costs below $100 million annually, it is impossible to ascertain whether the agency considered the broader effect on the economy of immigration rules even if the direct effect on immigrants is excluded because they are not U.S. citizens. Such rules may have large effects on sectors such as agriculture, which employ large numbers of immigrants. These indirect costs are likely much greater than the direct costs that agencies usually estimate in benefit-cost analyses. While these broader effects may not make the cost of any of these rules rise above $100 million, it is also unlikely that the rules have trivial costs.[1]

Many homeland security rules also restrict individual liberties and privacy. While the rules may mention these costs, there is no attempt to quantify them. In fairness to DHS, the academic literature has only touched on this issue. Viscusi and Zeckhauser (2003) have analyzed the tradeoff between civil liberties and the prevention of terrorism and noted that people are willing to trade off some liberties and convenience for increased safety. However, such costs certainly exist and their absence from the analyses justifying homeland security regulations means that the estimated costs are certainly lower than the true costs.

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Benefits and Risks for Assessing Regulation

A necessary element of a benefit-cost analysis is the determination of the benefits. For safety-type regulations, the typical framework is that benefits are primarily generated by expected costs avoided as a result of the regulation. Avoided expected costs include elements of both probability (sometimes referred to as risk) and consequences. Delving deeper, changes in probability are typically associated with prevention measures, and changes in consequence (conditional cost) are associated with mitigation measures. The complexity of each of these elements, probability and consequence, is limited “only” by the analyst’s

[1] An entire literature exists on the costs and benefits of immigration to the United States (see for example Borjas 2005).

imagination and analytical tools. For instance, discussions of resiliency as a characteristic of a system (Rose et al. 2007, Sheffi 2005) can be viewed as the challenge for modeling how various expenditure alternatives affect the costs avoided. If a system is resilient the cost avoided may be large with respect to several different types of attacks or types of hazards.

An anchoring point for avoided cost is the economic cost of the 9/11 attacks for which various estimates exist. The DHS uses a mean figure of $375 billion for damages from the 9/11 attacks on New York and on the airline system (DHS 2007a). Other studies, such as that by the GAO (2002) isolate the effect on New York city and state. The Congressional Budget Office concludes that the macroeconomic effects were slight (CBO 2002).

Table I Costs of Various Terrorist Attacks

Author	Attack	Cost Estimate
Gordon et al 2007	Aviation system	$ 214 to 421 billion (not counting lives)
Rose, Oladosu, Liao 2007	L.A. blackout	$ 2.8 to 20.5 billion, depending on resilience (defined by the author as ability to respond to the attack)
Rosoff and Winterfeldt 2007	Dirty Bomb in LA/Long Beach ports	$ 130 million to $ 100 billion, depending on length of shutdown. (Assumes zero lives lost.)
Gordon et al. 2005	LA, Long Beach ports	from $1.1 billion (or 10,061 person-years of employment) to $34 billion (or 212,000 person-years of employment)
Park 2008	Dirty bomb in LA/Long Beach ports	$34 billion in import/export losses. No estimate based on lives or property lost.
Cheng, Stough, and Kocornik-Mina 2006	Power plant attack in DC	$1.18 billion
Abt 2005	Bioterrorist attack	from $200 billion to $3 trillion; deaths from 500,000 to 30 million
Bae, Blaine, Bassok 2005	Seattle highways	from $1.2 to $1.5 billion

The terrorist attacks spurred substantial work on the potential costs of various types of terrorist attacks in the United States such as: bioterrorism (Abt 2005), targeted at the Washington, DC area (Cheng et al. 2006), Seattle (Bae et al. 2005), the ports of Los Angeles and Long Beach (Gordon et al. 2005), the aviation system (Gordon et al. 2007), and at the power system for Los Angeles (Rose et al. 2007).

The above scenarios and their associated cost estimates appear in Table 1. The costs are total costs, not annual costs. Where the articles include sensitivity analyses for various scenarios, the value cited as the central estimate or most likely estimate is used in the table for illustrative purposes. More generally, the Federal Emergency Management Administration (FEMA) has developed HAZUS (FEMA 2009) a nationwide inventory and model of the built environment, geographic features, and population to predict damages from natural disasters such as floods and wind. The model can also be adapted to assess damages from security-related events.

Estimating Probabilities in Security Based Benefit-Cost Analysis

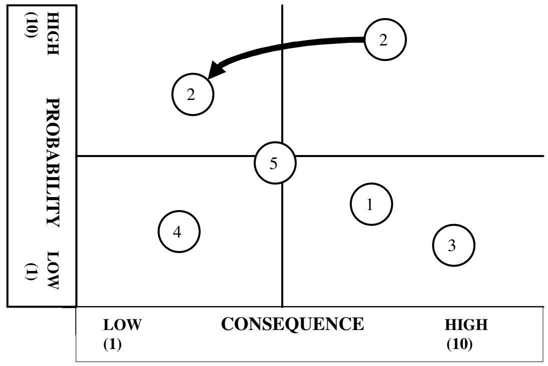
With the many issues involved in estimating the costs avoided, the benefits become even more complex when determining the probability of an attack at various sites and of various types. At times, implicitly, cost estimates such as those above involve assumptions about attack mode and severity given that an attack occurs. For instance, a private company, "Risk Management Solutions," has developed a model for insurance companies to use to measure the risk of terrorist attacks. DHS has also used this model to generate probabilities for various attacks; these can, in turn, be fed into a benefit-cost analysis. The model is available for private purchase but does not appear to have been subject to peer review; additionally, the assumptions underlying it are not obvious to the outside researcher.[2]

Other approaches use a single step to consider probability and consequence. Likelihood and consequence are frequently mentioned as a risk-based approach to security issues. Sheffi (2005), among others, has a diagram similar to Figure 1 below where analysts are encouraged to place potential events in a subjective location in the two dimensional diagram (based on probability and consequence). An explicit third dimension is missing from Figure 1, namely some function of probability and consequence. The whole theory of utility and risk may be invoked so that the missing function depends on the preferences of each individual decision-maker.

The diagram illustrates five possible events, with arbitrary divisions between high and low. The diagram illustrates that some action may move event 2 from the upper right quadrant, high probability and high consequence, to the upper left quadrant with somewhat lower probability and significantly lower consequence.

[2] See http://www.rms.com/Terrorism/Solutions/ProbabilisticTerrorismModel.asp. Accessed: 2008-07-15. (Archived by WebCite® at http://www.webcitation.org/5ZL0ak9mv).

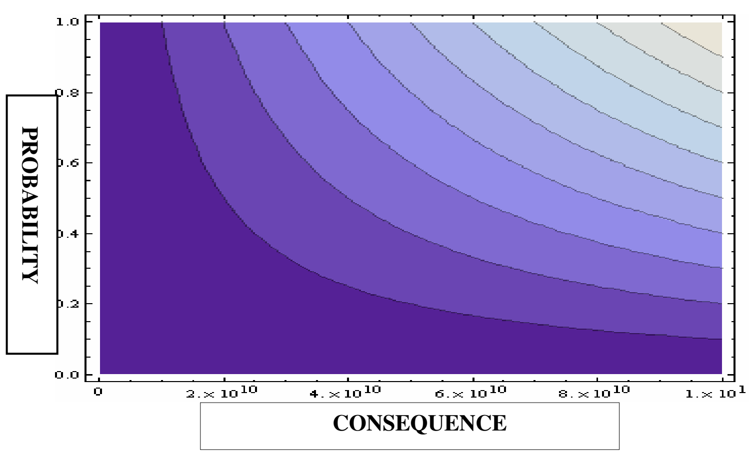
Figure 1: Example of risk matrix



Adapted from Alexander and Marshall (2006)

In contrast, Figure 2 is based on computing the missing third dimension as probability times damage, the expected value, which is a common anchoring point for evaluating risks (OMB 2003). The level curves show values of equal expected damage. While both diagrams agree that the upper right-hand corner is of high risk (also high expected value), the scaling in Figure 2 depends on the case at hand and may seem to dip more toward major disasters than does the standard box diagram of Figure 1.

Figure 2: Contours of equal expected cost (P*C):



Probability (0 to 1) and Damages (0 to 100 Billion)
Source: Author's calculations using Mathematica (Wolfram 2007)

Does populating Figure 2 with approximate information on specific risks, probability and consequence pairs, constitute a benefit-cost analysis? No. Information potentially presented in Figure 2 is the initial "exposure" of the level of expected cost. Information for benefit-cost analysis focuses on the *change* in the expected benefit (avoided cost) as a result of an action, say the expenditure of homeland security funds or the requirement of private expenditures resulting from regulation. The reduction in expected cost, the benefits, can be caused by either a change in probability or a change in consequences given that an event occurs. This is equivalent to the movement of risk number 2 in Figure 1. Further, the implementation cost of an alternative is not represented in Figure 2. The analytical tasks to rank utility and bound consequences appear barely less stringent than the tasks for a benefit-cost analysis.

However, beyond standard issues of estimating or eliciting probabilities, homeland security appears to involve a greater degree of uncertainty about such estimates making "level curves" as in Figure 2, more like vague bands. Weitzman (2009), in studies of climate change, discusses how such uncertainties can swamp concerns about the timing of events. Although there is no agreed upon approach, Posner (2004) discusses some methodologies. While Posner focuses on cases of catastrophic risks, some of his suggestions, most notably "inverse cost-benefit analysis," are potentially applicable to homeland security questions. Posner's approach asks how large the (unknown) probability would have to be in order to equate benefits and costs. Several authors have suggested that it may be possible to develop threshold probabilities for action as a residual, to which rules of reason, external information, or consistency may be brought to bear. Fundamentally however, the available data are unlikely to provide "bright lines" that divide action from inaction. In three recent regulations, DHS has utilized this inverse benefit-cost analysis, renaming it "break-even analysis."

III. Using Benefit-Cost Analysis for Homeland Security Regulations

DHS-funded research led to published work on the benefits and costs of security expenditures by LaTourette and Willis (2007; Willis and LaTourette 2008) that focused on developing an empirically applicable type of break-even analysis to link a minimum measure of risk (defined more precisely below) with a break-even level of benefits and costs. Their model is summarized here in order to contrast and compare its simplifying assumptions with the still simplified benefit-cost models of Farrow (2007). The comparison suggests caution in interpreting current break-even estimates of security regulations and identifies areas for improvement.

Willis and LaTourette (2008) define their break-even benefit-cost estimator using an annualized baseline loss (L_b) without the regulation and a new loss (L_n) with regulation. Assuming there is reliable information on the annualized regulatory cost, I, they identify the change (reduction) in losses as the benefit and state that a benefit-cost test requires L_b-L_n > I. By dividing each side by the baseline loss and using an equality, they define the break-even minimum "Risk" (R) as:

$$R= (L_b-L_n)/L_b = I/L_b \quad (1)$$

When DHS is able to estimate the cost of the regulation, I, and the baseline loss, L_b, then equation 1 can be used to estimate the break-even level of risk necessary for the benefits to just equal the costs. In several homeland security regulations, DHS has used variations on this approach to investigate this definition of risk as a function of the baseline level of loss, L_b and other factors. Clearly the larger the baseline loss in the absence of a regulation, the smaller is the break-even R (risk) necessary to justify the regulation.

This break-even analysis is a step forward in synthesizing quantitative benefit and cost information for informed decision-making. However, there are assumptions implicit in the measure as written in comparison to models that include concerns such as the ability of attackers to shift targets, symbolic targets, and other concerns.

Understanding the assumptions implicit in the break-even analysis begins with recognizing that the measure R refers to a change in losses that is not known with certainty in advance. Guidance on regulatory analysis recommends the use of expected values (OMB 1992, 2003). Define a basic expected value as probability times consequence (P*C), that is the measure of loss (L) in equation 1. After substitution, the equation becomes: $P_bC_b - P_nC_n \geq I$. Some of the difficulty in the interpretation of R as a probability is investigated by considering three cases (after changing the inequality to equality in order to find the minimum change to determine a break-even amount).

Case 1: The regulation is probability reducing and does not change the consequence so that C_b=C_n=C, then P_b-P_n = I/C. If DHS uses its regulatory cost estimate, I, and the dollar valued consequence of an attack, C, to estimate R; then the estimate is the required *change* in probability to break-even, not a percentage change. This is one interpretation used in DHS regulations.

Case 2: The regulation is consequence reducing only and does not change the probability so that P_b=P_n=P, then P=I/(C_b-C_n). If DHS uses the change in consequence, C, with and without the regulation, then the right-hand side yields an estimate of the probability of attack necessary to equate the benefits and costs.

Case 3: When both probability and consequence change due to the regulation, one might divide by the base expected value, then $(P_bC_b-P_nC_n)/ P_bC_b = I/P_bC_b$. If DHS has data on the cost of the regulation, I, and the initial expected loss of an attack, $P_b{*}C_b$, then the result is an estimate of the proportional change in risk and appeared to be used in some DHS regulations. However, the denominator in the right-hand side is the expected value, which presumes estimation of probabilities, the lack of which was the initial motivation for a simpler approach.

While the above indicates some complications in interpreting exactly what DHS estimates in its regulations, a set of expected value models presented in Farrow (2007) illustrates additional concerns as below.

Framing Benefit-Cost Analysis: Expected Cost Minimization Models

Guidance from the U.S. Office of Management and Budget (OMB 1992, 2003) defines expected value estimates as the foundational analysis. Such analyses may be extended by simulation approaches or methods that incorporate more complex aspects of decision-making under uncertainty. Farrow (2007) used an expected value, social cost minimization framework in a series of benefit-cost structured models to provide guidance on defining benefit and costs and in allocating security expenditures. Social cost minimization, by including costs avoided through security investments, is a benefit-cost framing of the problem. Implicit in the recommendations for optimal allocation of security expenditures is that the benefits exceed the costs until the recommended allocation is achieved, at which time the benefits just equal the costs, breaking even, if the model is correct.

Although based on the decomposition of risk into its probability and consequence components as in the above section, each of the social cost-minimization models is more complex than that of Willis and LaTourette (2008) because a constraint on the amount of expenditures on homeland security is assumed. Such a constraint on expenditures would seem to better capture the real problem of government investment than assuming an unlimited amount of funds is available. Table II summarizes benefit-cost criteria and data as increasingly complex issues are considered, such as a constraint on the total expenditures available for security investments, or that improving security at one location may increase the probability of attack at another.

Consider the situation where security expenditures at a particular target may encourage terrorists to switch to another target. Lakdawalla (2003) and Woo (2003) both point out that homeland security rules can be thought of as falling into two categories that are designed to prevent either a specific type or a general type of attack. Examples of security rules in the specific category include FDA rules designed to protect the food supply (see example, Federal Register 69 FR 71561) and Transportation Security Administration (TSA) rules designed to protect air travel. General security rules are designed to make it harder for terrorists to conduct any type of attack; rules that make it harder to enter the United States are in this category.

Table II: Benefit-cost models and criteria adapted from Farrow (2007)

Issue/model	Recommended Action and Break-even result	Key Variables Required for Estimation
1. Allocating a Fixed Expenditure Amount among Independent Sites	Equate the marginal expected social costs avoided (MESCA)	Social costs avoided and their change with expenditures, probabilities, and costs of implementation
2. Displacement of Probability of Attack	Determine the net MESCA, net of probability increasing effects at other sites	As above, plus adjustments in probability for diverted attacks
3. Constraint on Probability or Cost Reduction	Results in an optimal inequality among sites even where investment occurs	As above, but break-even will be different at sites with constraints
4. Both Prevention and Mitigation Reducing Activities	Equate the marginal social cost avoided of each type of expenditure	As above, but also separates effect of each activity
5. General rules: Public Goods	Invest until the sum of marginal damages avoided equals the individual site MESCA	As above, but identify the multiple sites that are positively linked.
6. All Hazards: Multiple Sources of Probability and Cost	The form of decision is the same (e.g., equate MESCA), but all costs and probabilities taken into account	As above, but more complex probabilities
7. Dynamic Uncertainty and Irreversibility	There can be an optimal ‘‘overinvestment’’ in safety	More complex uncertainties

For the first category of rules or "specific security rules," one likely assumes that rational terrorists will alter their behavior in the wake of new restrictions. Model 2 in Table II captures this complication. Therefore, the net benefit for a specific security rule should be the differential or net value between the benefit of preventing the specific attack (or reducing its likelihood) and the cost of a "replacement level" attack (the type of attack that a terrorist would turn to if their first choice attack was made too difficult). In some cases where attacks are particularly deadly, the differential benefits between the specific attack and the replacement attack may be significant. Protecting nuclear facilities or large chemical plants may very well fall into this category.

On the other hand, "general security rules," designed to make it harder for terrorists to enter this country, or to make it easier to apprehend terrorists, may have the effect of reducing the likelihood of all attacks. Immigration rules fall into this category and are examples of Model 5 in Table II involving public goods. Such rules impact the probability of attacks at numerous locations, and analysis should account for this by perhaps focusing on the reduction of probabilities across all types of attack including particularly high consequence attacks. An additional complication is that general security rules may encourage terrorists to attack our allies rather than the United States. Benefit-cost analyses typically are concerned only with benefits and costs accruing to this country but it should keep in mind that for immigration rules, a global benefit-cost analysis would make some general security rules appear like specific security rules. Indeed, one may argue that the tightened immigration rules issued since 9/11 have played a role in the numerous attacks in Europe since 2001.

Other models in Table II lead to similar adaptations of a general benefit-cost framework including attention to the way in which some investments may, for instance, reduce the consequences from multiple types of hazards.

IV. Homeland Security Regulations and Break-Even Analysis

The discussion in earlier sections indicated the increasing use by DHS of break-even analysis for economically significant security regulations. None of the break-even analyses include issues such as the diversion of attack from one site to another, a limited budget, or other issues summarized in Table II.

The assumptions in DHS' break-even analysis can be illustrated in more detail with regard to the cases identified in the preceding section. The first economically significant regulation to use the probability break-even approach was the Minimum Driver License/REAL ID (DHS 2007a, p. 127), which requires minimum standards for state-issued identification documents such as driver's licenses. The DHS approach assumed that there is no change in damages given that an event occurs. The analysis then proceeds by finding the minimum change in probability to make net benefits equal to zero, assuming no budget constraint. This is equivalent to Case 1 of the preceding section. The assumed cost was based on the 9/11 New York terrorist attack. The assumed consequence is an important analytical assumption for which some justification, based on target selection or distribution of consequences, should be carried out.

A second recent analysis concerned the Secure Flight Program regulation (DHS 2007b) which transfers responsibility from the airlines to TSA in order to compare passenger flight lists against watch lists and other information. This TSA regulation is to provide essentially real-time decisions on passenger access to different areas in the airport system. The analysis was stated as being based on LaTourette and Willis (2007) and used a similar consequence scenario as the Real ID program, the 2001 attack on New York. However, the interpretation of the analysis is less clear than in the Real ID program. A break-even frontier was developed but the baseline measure is now stated as the "likelihood of terror attack and loss" (DHS 2007b, p. 77). Material in the text discusses "the reduction in the expected loss." These interpretations appear different than in the Real ID program and point more to a regulation that is both probability and consequence reducing, as in Case 3 of the preceding section which implies knowledge of the expected value. Also, The Secure Flight rule is a specific security rule, protecting only against attacks using aircraft as weapons. DHS should have adjusted their value of C accordingly.

A third regulation that affects importers requires advanced notice of information about ship-based cargo in order to better perform risk-based targeting of inspections. The key distinction in this analysis (IEc. 2007) is that analysts used three different consequences in their analysis of a break-even change in probability to reflect a distribution of possible outcomes. They evaluated alternative consequence scenarios based on: 1) a West Coast port shut-down based on a historical event, 2) a nuclear attack at a port or major Eastern U.S. city center, and 3) a bioterrorism attack in a major city. Given the interpretation in the text, the regulation appears to be assuming that its purpose is only to change the probability of an adverse outcome, not its consequence, consistent with Case 1 in the preceding section.

The analyses conducted by DHS are, without question, improvements on the analyses conducted prior to 2007 which largely ignored benefits and presented only implementation costs. However, there are numerous ways in which these break-even analyses remain incomplete substitutes for a true benefit-cost analysis. Some incompleteness is due to the implicit assumptions as above but also is due to further complications, such as the potential displacement of attacks from one site to another or the existence of budget limitations.

V. Directions for Improvement

Analysis of homeland security regulations is roughly analogous to the state of analysis of environmental regulations 25 years ago. Benefit-cost analysis is now required and conducted routinely for all significant environmental regulations and the quality of the analysis has improved with time. As one analytical challenge is surmounted, new depths are opened for further analysis. There is no reason that the analysis of homeland security regulations cannot evolve in a like manner, but it will take sustained effort and a reasonable degree of openness on general models.

The analytical steps to a benefit-cost analysis are similar to those implicit in apparently simpler risk based methods. Somewhat heuristically, the comparison between risk matrices in Figures 1 and 2, making clear the underlying assumptions in a break-even analysis, and extensions involving probability shifting among sites lead one close to a benefit-cost analysis. The challenge is to understand and evolve the subjective mental maps of probability and consequence into a more replicable and data based source of information. Evolving models in both the public domain, such as HAZUS with its data inventories, and those in the private or classified domain contain key elements for assessing the benefits of an avoided terrorist attack.

Benefit-cost analysis should not be seen as something that is inherently different than analyses that are being done, but rather should be seen as seeking to make modeling more explicit and replication more likely. Further, with infrequent occurrences of some (not all) security events there will be an element of subjective or assumed probabilistic structure even in explicit models. The direction for improvement lies in the standard evolution of scientific modeling which tends to replace hidden assumptions with explicit modeling or information.

Such improvements will require commitment on the part of both government practitioners and academics. The Office of Management and Budget (and to a lesser degree Congress) should hold agencies that promulgate security regulations to meaningful analytical standards and work with them to improve their analyses whether they ultimately appear in the public domain or not. The communication of an analysis is a separate issue from its development, although limits to the public communication of modeling efforts will likely impede their development, at times justifiably.

Relevant agencies should respond by hiring interdisciplinary teams to develop measures of both the cost and benefits of security regulations. Some effort has already been made to engage the academic community as well, through longer term grant funding and centers of excellence, but at this stage wide-spread seed funding may be the most productive way to generate a wide set of possible approaches. It should be expected that methods of analysis are likely to proceed, gradually accumulating information and models. Discussions of strategy and tactics will not slow in the absence of benefit-cost analysis.

Whether the evolution of benefit-cost analysis can keep up with increasingly sophisticated text-based discussions is a challenge, but it is not unique to the issue of security. For instance, text discussions of a precautionary principle in environmental regulation have spurred the development of more complex models of decision-making under uncertainty. As an example in the security context, resiliency (Sheffi 2005) may be viewed as greater breadth of multiple hazards being considered, or resiliency may also be viewed in the interconnections within and among organizations. The benefit-cost framework allows such concerns in concept, generally in the identification of alternatives being considered and their consequences.

There appears to be no magic template to immediately implement benefit-cost analysis of security-based regulations that involve impacts, probabilities, and valuation. At the same time, the discipline of explicitly modeling complex linkages can be expected to bring new and additional insight to the attention of policy makers as it has in other areas.

Appendix I. Homeland Security Rules Issued Since September 11, 2001.

Source: The Unified Agenda of Regulatory and Deregulatory Actions (Regulatory Information Services Center 2002-2008).

The Unified Agenda is published semiannually and contains agency descriptions of all of the regulations they plan on issuing over the next six months and all those that they have issued in the previous six months.

A. Rules Included in the OMB Total Cost Estimate

Rule Title	Agency
Establishment and Maintenance of Records Under the Public Health Security and Bioterrorism Preparedness and Response Act of 2002	HHS-FDA
Registration of Food Facilities under the Public Health Security and Bioterrorism Preparedness and Response Act of 2002	HHS-FDA
Prior Notice of Imported Food under the Public Health Security and Bioterrorism Preparedness and Response Act of 2002	HHS-FDA
Required Advance Electronic Presentation of Cargo Information	DHS-CBP
Area Maritime Security	DHS-USCG
Vessel Security	DHS-USCG
Facility Security	DHS-USCG
Authority To Collect Biometric Data From Additional Travelers and Expansion to the 50 Most Highly Trafficked Land Border Ports of Entry (US-VISIT)	DHS-BTS
Electronic Transmission of Passenger and Crew Manifests for Vessels and Aircraft	DHS-CBP
Air Cargo Security Requirements	DHS-TSA
Chemical Facility Anti Terrorism Standards	DHS-OS
Passenger Manifest for Commercial Aircraft and Vessels Arriving In and Departing From the United States	DHS-CBP
Documents Required for Travel Within the Western Hemisphere	DHS-CBP
Transportation Worker Identification Credential (TWIC) Implementation in the Maritime Sector	DHS-TSA

B. Rules Not Included in the OMB Total Cost Estimate

Rule Title	Agency
Agricultural Bioterrorism Protection Act of 2002; Possession, Use and Transfer of Biological Agents and Toxins	USDA-APHIS
India and Pakistan: Lifting of Sanctions, Removal of Indian and Pakistani Entities, and Revision in License Review	DOC-BIS
Possession, Use and Transfer of Select Agents and Toxins	HHS-CDC
Screening of Aliens and Other Designated Individuals Seeking Flight Training	DOJ
Attorney General's Evaluations of the Designations of Belgium, Italy, Portugal, and Uruguay as Participants under the Visa Waiver Program	DOJ-INS

Rule Title	Agency
Requirements for Biometric Border Crossing Identifications Cards (BCCs) and Elimination of Non-Biometric BCCs on Mexican and Canadian Borders	DOJ-INS
Authorizing Collection of Fee Levied on F, J, and M Nonimmigrant Classifications under Illegal Immigration Reform and Immigrant Responsibility	DOJ-INS
Custody Procedures	DOJ-INS
Review of Custody Determinations	DOJ-INS
Requiring Change of Status from B to F-1 or M-1 Nonimmigrant Prior to Pursuing a Course of Study	DOJ-INS
Release of Information Regarding INS Detainees in Non-Federal Facilities	DOJ-INS
Requiring Certification of All Service Approved Schools for Enrollment in the Student and Exchange Visitor Information System (SEVIS)	DOJ-INS
Passenger Data Elements for Visa Waiver Program	DOJ-INS
Reduced Course load for Certain F and M Nonimmigrant Students in Border Communities	DOJ-INS
National Security: Prevention of Acts of Violence and Terrorism	DOJ-BOP
Protective Orders in Immigration Administrative Proceedings	DOJ-EOIR
Student and Exchange Visitor Information System (SEVIS) Rule -- 22 C.F.R. Part 62, Subpart F	State
Aviation Security Infrastructure Fees	DOT-TSA
Civil Aviation Security Rules	DOT-TSA
Security Programs for Aircraft With a Maximum Certificated Takeoff Weight of 12,500 Pounds or More	DOT-TSA
Transportation of Explosives from Canada to the US Visa Commercial Motor Vehicle and Railroad Carrier	DOT-TSA
Aviation Security: Private Charter Security Rules	DOT-TSA
Threat Assessments Regarding Citizens of the US Who Hold or Apply for a Federal Aviation Administration Certificate	DOT-TSA
Aircraft Security under General Operating and Flights Rules	DOT-FAA
Flight Crew Compartment Access and Door Designer	DOT-FAA
Flight Crew Compartment Access and	DOT-FAA
Door Designer	
Enhanced Security Procedures for Operations at Certain Airports in the Washington, DC Metropolitan Area Special Flight Rules Area	DOT-FAA
Security Considerations for the Flight deck on Foreign-Operated transport Category Airplanes	DOT-FAA
Picture Identification Requirements	DOT-FAA
Ineligibility for an Airman Certificate Based on Security Grounds	DOT-FAA
Limitation on Construction or Alteration in the Vicinity of the Private Residence of the President of the United States	DOT-FAA
Limitation on the Issuance of Commercial Driver's Licenses with a Hazardous Materials Endorsement	DOT-FMCSA

Rule Title	Agency
U.S. Locations Requirement for Dispatching of United States Rail Operation	DOT-FRA
Hazardous Materials: Security Requirements for Offerors and Transporters of Hazardous Materials	DOT-RSPA
Administrative Detention of Food for Human or Animal Consumption under the Public Health Security and Bioterrorism Preparedness and Response Act of 2002	HHS-FDA
Evidence Requirement for Assignment of Social Security Administration Numbers (SSNs) and Assignment of SSNs for Non-work Purposes	SSA
DNA Sampling of Federal Offenders Under the USA Patriot Act of 2001	DOJ
Screening of Aliens and Other Designated Individuals Seeking Flight Training	DOT-FAA
Retention and Reporting of Information for F, J, and M Non-immigrants; SEVIS	DOJ-INS
Registration and Monitoring of Certain Non-immigrants	DOJ-INS
Procedures for Handling Critical Infrastructure Information	DHS
Automatic Identification System Carriage Requirements	DHS-USCG
Threat Assessments Regarding Alien Holders of, and Applicants for, FAA Certificates	DHS-TSA
Transportation Worker Identification Credential (TWIC) Implementation in the Maritime Sector; Hazardous Materials Endorsement for a Commercial Driver's License	DHS-USCG
Hazmat Fee Rule: Fees for Security Threat Assessments on Hazmat Drivers	DHS-TSA
Notification of Arrival in U.S. Ports; Certain Dangerous Cargoes; Electronic Submission	DHS-USCG
Regulations Implementing the Support Anti-Terrorism by Fostering Effective Technologies Act of 2002	DHS
Documents Required for Travelers Departing From or Arriving in the United States at Air Ports-of-Entry From Within the Western Hemisphere	DHS-BCBP
Minimum Standards for Driver's Licenses and Identification Cards Acceptable to Federal Agencies for Official Purposes	DHS-OS
The U.S. Munitions Import List and Import Restrictions Applicable to Certain Countries	DOJ-ATF
Letters and Documents; Advanced Electronic Presentation of Cargo Data	DHS-BCBP
Documents Required for Travelers Entering the United States at Sea and Land Ports-of-Entry From Within the Western Hemisphere	DHS-BCBP
Establishing Procedures for Recertification of Schools Approved by the Student and Exchange Visitor Program (SEVP) To Enroll F or M Nonimmigrant Students	DHS-ICE
Long-Range Identification and Tracking of Ships	DHS-USCG

References

Alexander, Corianne and Maria Marshall. 2006. "The Risk Matrix: Illustrating the Importance of Risk Management Strategies," *Journal of Extension*, 44(2):2T0T1.

Abt, Clark C. 2005. "Current and Improved Biodefense Cost-Benefit Assessment" in Richardson, 2005.

Bae, Chang-Hee Christine, Larry Blaine and Alon Bassok. 2005. "The Transportation Implications of a Terrorist Attack on Seattle's Highway Network" in Richardson 2005.

Belacore, Jamie and Jerry Ellig. Forthcoming. "Homeland Security and Regulatory Analysis: Are We Safe Yet?" *Rutgers Law Journal*.

Bier, Vicki M., Naraphorn Haphuriwat, Jaime Menoyo, Rae Zimmerman and Alison M. Culpe. 2008. "Optimal Resource Allocation for Defense of Targets Based on Differing Measures of Attractiveness," *Risk Analysis*, 28(3):763-770, June.

Borjas, George J. 2005. "The Labor Market Impact of High-Skill Immigration," *American Economic Review*. 95:56.

Cheng, Shaoming, Roger R. Stough, and Adriana Kocornik-Mina. 2006. "Estimating the Economic Consequences of Terrorist Disruptions in the National Capital Region: An Application of Input-Output Analysis," *Journal of Homeland Security and Emergency Management*: 3(3), Article 12.

Congressional Budget Office (CBO) 2002. "The Economics Effects of 9/11: A Retrospective Assessment," G. Makinen coordinator, CBO Order Code RL 31617, Washington, D.C.

Department of Homeland Security (DHS). 2007a. "Regulatory Evaluation, Real ID," 6 CFR Part 37, RIN: 1601-AA37, Docket DHS-2006-0030, February 28.

_________________2007b. TSA, "Secure Flight: Regulatory and Economic Analysis," 49 CFR Part 1560, RIN: 1652-AA45, Docket TSA-2007-28572-0001, August 7.

Enders, Walter and Todd Sandler. 2006. *The Political Economy of Terrorism*. Cambridge University Press, Cambridge.

Farrow, Scott. 2007. "The Economics of Homeland Security Expenditures: Foundational Expected Cost-Effectiveness Approaches," *Contemporary Economic Policy*, Jan., pp. 14-26.

Federal Emergency Management Administration (FEMA). 2009. HAZUS-MH, accessed at http://www.fema.gov/plan/prevent/hazus/index.shtm, Jan. 18.

GAO (U.S. Government Accountability Office). 2002. "Review of Studies of the Economic Impact of the September 11, 2001 Terrorist Attacks on the World Trade Center," GAO report, GAO-02-700R, Washington, D.C. 2002.

Gordon, Peter, James Moore II, Ji Young Park and Harry Richardson. 2007. "The Economic Impact of a Terrorist Attack on the U.S. Commercial Aviation System," *Risk Analysis* 27:505.

Gordon, Peter, James Moore II, Henry Richardson and Qisheng Pan. 2005. "The Economic Impact of a Terrorist Attack on the Twin-Ports of Los Angeles-Long Beach," in Richardson 2005.

Hahn, Robert. and Caroline Cecot. 2006. "The Economic Significance of Insignificant Rules," Working Paper 06-06, AEI-Brookings Joint Center for Regulatory Studies.

IEc (Industrial Economics). 2007. "Importer Security Filing and Additional Carrier Requirements: prepared for U.S. Customs and Border Protection," RIN: 1651-AA70, Docket USCBP-2007-0077-0001, December.

Lakdawalla, Darius and George Zanjani. 2006. "Insurance, Self-protection, and the Economics of Terrorism," *Journal of Public Economics* 89(9-10):1891-1905.

Lakdawalla, Darius. 2003. "Comment on Cost-Benefit Analysis of Homeland Security Regulation" at http://www.whitehouse.gov/omb/inforeg/2003report/16.pdf .

LaTourrette, Tom and Harry Willis. 2007. "Using Probabilistic Terrorism Risk Modeling for Regulatory Benefit-Cost Analysis: Application to the Western Hemisphere Travel Initiative Implemented in the Land Environment," Rand Working Paper WR-487-IEC, Center for Risk Management and Policy, Rand Corporation, Santa Monica, CA., May.

McGarity, Thomas. 1993. *Reinventing Rationality*. Cambridge University Press.

OMB (U.S. Office of Management and Budget). 2009. "2008 Report to Congress on the Benefits and Costs of Federal Regulations and Unfunded Mandates on State, Local, and Tribal Entities," January; accessed at http://www.whitehouse.gov/omb/assets/information_and_regulatory_affairs/2008_cb_final.pdf .

___________. 1992. "Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs" OMB Circular A-94, Washington, D.C.

___________. 2003. "Regulatory Analysis" OMB Circular A-4, Washington, D.C.

Park, Ji Young. 2008. "The Economic Impacts of a Dirty- Bomb Attack on the Los Angeles and Long Beach Port: Applying Supply-driven NIEMO (National Interstate Economic Model)," *Journal of Homeland Security and Emergency Management*: 5(1), Article 21.

Posner, Richard. 2004. *Catastrophe*. Oxford University Press. New York.

Regulatory Information Service Center, U.S. General Services Administration. Semiannually. "The Unified Agenda of Regulatory and Deregulatory Actions," accessed at http://www.reginfo.gov/public/do/eAgendaMain .

Richardson, Harry, Peter Gordon, and James Moore eds, 2005. *The Economic Impact of Terrorist Attacks*. Edward Elgar Publishing Limited. Cheltenham U.K.

Rose, Adam, Gbadebo Oladosu and Shu-Yi Liao. 2007. "Business Interruption Impacts of a Terrorist Attack on the Electric Power System of Los Angeles: Customer Resilience to a Total Blackout," *Risk Analysis* 27:513.

Rosoff, H. and D. von Winterfeldt. 2007. "A Risk and Economic Analysis of Dirty Bomb Attacks on the Ports of Los Angeles and Long Beach," *Risk Analysis* 27:533.

Sandler, Todd, Daniel Arce, and Walter Enders. 2008. "Transnational Terrorism: Copenhagen Consensus 2008 Challenge Paper," February; accessed at http://www.usc.edu/dept/create/assets/003/58253.pdf .

Sheffi, Yossef. 2005. *The Resilient Enterprise: Overcoming Vulnerability for Competitive Advantage*, MIT Press, Cambridge.

Smith, Kerry V. and Daniel G. Hallstrom. 2005. "Designing Benefit-Cost Analysis for Homeland Security Policies" in Richardson, 2005.

Viscusi, Kip and Richard Zeckhauser. 2003. "Sacrificing Civil Liberties to Reduce Terrorism Risks," *Journal of Risk and Uncertainty* 26:99.

Wetizman, Martin L. 2009. "On Modeling and Interpreting the Economics of Catastrophic Climate Change," *Review of Economics and Statistics* 91(1):1-19.

White House, Executive Orders 12866, 13258, and 13422. Accessed April, 2008 at http://www.whitehouse.gov/omb/inforeg/eo12866/index_eo12866.html

Willis, Henry and Tom LaTourette. 2008. "Using Probabilistic Terrorism Risk-Modeling for Regulatory Benefit-Cost Analysis: Application to the Western Hemisphere Travel Initiative in the Land Environment," *Risk Analysis* 28:325.

Wolfram Research Inc. 2007. *Mathematica6* (software). Available at http://www.wolfram.com/ .

Woo, Gordon. 2003. "The Benefits And Costs Of Homeland Security Rules. Comments prepared for the Office of Management of Budget" (can be found at: http://www.whitehouse.gov/omb/inforeg/2003report/15.pdf)