The Benefit-Cost Analysis of Public Safety[1]

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This monograph provides an initial compilation of proposed principles and standards for benefit-cost analysis (BCA) of public safety policies. Public safety issues cover a wide range of governmental activities in general categories such as security, physical safety, health, natural hazards, and consumption of goods. Each of these areas of potential risk exposure has specific components such as crime, terrorism, food products, water, floods, and transportation accidents. Fundamental to each component is the element of risk of a bad outcome, including risks arising from nature as well as those that are the result of actions of people. Typically, there are also decisions that affect one's exposure to the risk as well as possibilities to either alter the risk or its consequences, such as through the purchase of insurance.

Markets play a fundamental role in many risk contexts but in a manner that is less direct than for standard consumption goods. In general, markets do not directly buy and sell commodities such as "floods." However, the risk of flood may be purchased as part of a bundled commodity when one buys a house in a flood plain. Given that floods are undesirable, the presence of flood risks will reduce the purchase price. It is often possible to buy, sell, and manage risk in various ways so as to change probabilities, reduce damages, and shift the cost associated with adverse outcomes. Agencies involved in implementation range from local police and health departments, to state offices and national agencies such as the Federal Emergency Management Agency (FEMA), the U.S. Coast Guard, the Transportation Security Administration (TSA), portions of the U.S. Environmental Protection Agency (EPA), the Consumer Product Safety Administration (CPSC), the Food and Drug Administration (FDA), the U.S. Army Corps of Engineers,

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and the U.S. Department of Transportation (DOT). Agencies at different levels of government use formal benefit-cost analysis with varying frequency in all these applications, where the role of BCA in the decision making process ranges from being a minor component to defining a key test that the policy must pass.

The applications of benefit-cost analysis to policy decisions involving public safety are diverse. The different contexts for BCA are associated with different literatures, communities of practice, and outlets for publication. What is similar across the applications in public safety is that there is an element of risk involving a probability of some negative outcome. An antonym for safety is danger and in modern parlance, the likelihood of a bad outcome or risk. Notwithstanding the systematic policy concern with risk, it's not surprising that we don't have Departments of Public Danger or Public Risk, both because of the broad scope associated with such names and the fact that agency names tend to be cast in positive advocacy terms. Designating an agency as promoting environmental protection stresses the constructive function of the agency in a way that designations such as the environmental hazard agency does not. Nevertheless, attending to general concepts such as public danger and public risk provides an important clue to the principles and standards that may be common across areas of public safety. Consequently, this monograph focuses on principles and standards for applying BCA where the unifying theme is that public safety directed at reducing risk to the public. How risks should be incorporated theoretically and empirically into BCA is the focus of the proposed principles and standards[2].

In general, theoretical economic analysis of uncertain outcomes such as those involved with public safety begins with expected utility theory (e.g. Luce and Raiffa 1965; Raiffa 1968; Pratt, Raiffa, and Schlaifer 1995; Hirshleifer and Riley 1992; Just, Hueth and Schmitz, 2004; Eeckhoudt, Gollier, and Schlesinger 2005). Although models of choice under uncertainty have proliferated in recent decades, the expected utility model remains the standard reference point for normative decisions. The expected utility model is based

[2] Like externalities, the concern here is "real" as opposed to pecuniary or financial risk; although real risks are sought to be ultimately expressed in monetary terms.

on a series of assumptions that establish a rational basis for decision, such as the assumption that increasing the probability of an adverse outcome makes the "lottery" less attractive. Thus, expected utility theory is the generally accepted economic reference point for how people should make decisions under uncertainty. How people actually may make such decisions may be quite different than what expected utility theory predicts. For example, making decisions involving very small probabilities of catastrophic outcomes may be quite difficult. However, for purposes of providing guidance with respect to how the government should make decisions involving public risks the expected utility framework provides the standard default framework for decisions in the economics literature.

The expected utility model values the different outcomes by their utility, which is a measure of individual preferences for the outcome, and weights the utility values by the value of the probabilities associated with those outcomes. Such analyses focus on probability and the utility of outcomes without a distinction, except sign, regarding good or bad probabilistic outcomes. In other words, in the theoretical literature "risk" is not necessarily linked to a negative outcome, only a probabilistic one in which the dispersion of possible outcomes has utility implications. The chance that you will win the lottery is consequently a "risk" but a risk with favorable implications, unlike the adverse risks that are the focus of public policy efforts.

What role expected utility theory should play in policy decisions involving risk depends on who is affected and to what extent. When asking how much beneficiaries of flood control projects value the reduction in flood risks, there should be recognition of the preferences over uncertain outcomes of those who will be protected by the policy. Thus, individual risk preferences may be quite germane in constructing society's willingness to pay for the benefit. However, some policy risks, such as the uncertain cost of the flood control project, can be spread across the entire population with little financial consequence for any particular individual. How risk enters the social aggregate depends on the distribution and amount of the outcomes. Most applied benefit-cost analyses, consistent with standard practice for analyzing expected value outcomes, undertake the analysis in a manner so that it is possible to reduce expected utility to expected value. This approach is typical both for individuals and aggregates based either on reasoning that projects have a small impact on individual income either directly or through the availability of insurance, or that society effectively holds a portfolio of policy investments that insures against individual risk (OMB, 1992; 2004; Boardman et al., 2006, p. 213-215; Arrow and Lind, 1970). In some cases, ex-ante measures of the willingness to pay of individuals based on risk aversion, such as an option price can be incorporated into the analysis (Just, Hueth, Schmitz 2004; Fisher and Pindyck 2000; Boardman et al., 2006, p. 200-213). People's willingness to pay to avoid personal catastrophic losses from natural disasters could, for example, enter the analysis, but note that even here the valuation of the risk can be converted to a certain monetary equivalent. Where risk borne by the social aggregate are more collective or systematic, perhaps such as those involving large interrelated systems such as finance or broadly scaled public health, then a stronger case made be made for departures from expected value (Boardman et al., 2006, p. 213-215).

The varying practices on treatment of uncertainty at the individual and aggregate level can be confusing, as when one advises use of the expected value of a measure of risk aversion. Table 1 below provides a conceptual framework for the four ways in which individual and social preferences about risk aversion and risk neutrality are categorized. In each cell are the combinations of measures with the first for the individual and the second for societal decision-maker. In the table "E" is the statistical expectations operator, V is a measure of value without consideration of risk aversion, and RA is a measure including risk aversion. For instance, in the cell where both the individual and the societal decision-maker is risk neutral, then both values are the statistical expected value without consideration of risk aversion. In the cell where the individual is risk averse but the social decision-maker is risk neutral, perhaps because of an ability to spread risk across many projects, then the individual values are reported based on risk aversion by the individual (where appropriate) but the social decision-maker considers the expected value of that measure of risk aversion. In the remaining cells, where the social decision-maker is risk averse, there may be consideration of additional risk aversion at the societal level. As indicated, typical analytical practices lie in the first column while the social risk aversion is seldom invoked directly, due to inability to define social welfare functions. Instead, and implicitly, a not uncommon practice is to present statistical distributions to decision-makers who may well incorporate some degree of risk aversion—or possibly even risk loving behavior.

Table 1: Distinguishing Individual and Social Risk Neutrality and Risk Aversion

		SOCIETY Risk Neutral	SOCIETY Risk Averse
INDIVIDUAL	Risk Neutral	E(V), E(V) Typical BCA	E(V),RA Advanced Decision-maker
INDIVIDUAL	Risk Averse	RA, E(RA) Advanced BCA	RA, RA Advanced Decision-maker

E: expectations operator; V: value without risk aversion; RA: value with risk aversion

Some outcomes do not entail financial harms but nevertheless merit inclusion in the benefit-cost analysis. Irreplaceable health losses and damage to scarce natural resources are two prime examples. But even for the seemingly intractable outcomes it is usually possible to establish a monetary valuation of the benefit by ascertaining the willingness to pay for the risk reduction. Thus, considerable literatures have emerged to address the valuation of risk to life and health and risks to the environment.

Even if the underlying policy context does not involve an element of risk, the empirical analysis of the policy choice may introduce aspects of uncertainty. Most obviously there can be measurement error of theoretically correct components of the benefit-cost analysis, as well as variability across responses in the system and random error. Morgan and Henrion (1990, p. 56-69) elaborate on the various sources of uncertainty in quantitative analysis and list the following categories:

1. Random error and statistical variation
2. Systematic error and subjective judgment
3. Linguistic imprecision
4. Variability
5. Inherent randomness and unpredictability

6. Disagreement
7. Approximations

Debate could, and has, gone on for centuries about distinctions between and among these categories and others, in part because there some uncertainties may be associated with more than one category. The purpose of this listing is not to establish a framework to compartmentalize the different sources of uncertainty but to point out that a variety of issues about risk and uncertainty occur at both theoretical and empirical levels of a policy analysis.

Risk and uncertainty are here used synonymously, based on a subjective risk framework where there may be few classical risks that are known with precision (Hirshleifer and Riley, 1992, p. 9-10; Raiffa (1968)). Probabilities such as the average motor-vehicle fatality risk are precisely understood risks because we have a great deal of information about the probabilities based on observing a large population. In contrast, hazards such as the dangers of climate change or newly identified diseases, such as swine flu, are not as well understood and fall into the category of uncertainties. Where a distinction between risk and uncertainty appears useful, the latter representing unknown randomness, then it will be used. However, for purposes of policy decisions, we will treat probabilities of an adverse outcome symmetrically whether they are precisely understood risks or dimly understood uncertainties. Perhaps the most important distinction is that in situations of uncertainty there is often the opportunity to learn more about the level of the probabilities, creating opportunities for information acquisition. Because elements of risk are important in areas outside of public safety, many of the same concerns surveyed here also may be relevant in other application areas.

Principles and Standards: Purposes and sources

The principles and standards developed in this document are meant to be most useful in the practice of benefit-cost analysis. Policy analysts may most lack the time to survey the pertinent literature and may also be under the most pressure to deliver an analysis in a specified time frame subject to a particular budget (Committee to Evaluate Measures 2006). It is in applied work where standardization of methods may increase the replicability, credibility, and usability of analyses. Researchers of benefit-cost analysis are assumed to be more active in conducting their own literature reviews and defending their own research choices. Similarly, assessments of large or complex projects may require the creation of new methods or may push standard practice in ways that go beyond even the emerging principles partially developed here.

What this document provides are the authors' interpretations resulting from teaching, consulting, research, and government practice. It is not the result of a committee or a specific broad based literature review. Nor is it based on an explicit hierarchy of sources such as used in Accounting (U.S. GAO, 2005) as there are no existing standard setting organizations for benefit-cost analysis. The result is a dependence on textbooks, professional articles, and current government guidance.

Common sources of standards for the benefit-cost analyst in Government are guidance documents issued by the U.S. Office of Management and Budget (OMB, 1992, 2004). In these and supplemental guidance issued by individual agencies, expectations about benefit-cost analysis are described in text although individual standards not easily separated. The guidance applies to government projects and regulation. A number of prominent benefit-cost authors published their consensus on principles and standards (Arrow, et al., 1996), and recent texts on benefit-cost analysis and applied welfare analysis include those by Boardman et al. (2006), Jones (2005), Brent (1998), Zerbe and Dively (1994), Hanley and Spash (1993), Gramlich (1990), Stokey and Zeckhauser (1978), and collections of major articles such as those in Schmitz and Zerbe (2009), Zerbe (2008) and Layard and Glaister (1994).

The areas of application that may be considered public safety and that involve risk and uncertainty include but are not limited to

1. Security: crime, terrorism, defense
2. Safety: traffic, building codes, crowd control
3. Natural hazards and environment: waterway control, fire, wind, flood, earthquake, tsunami, climate change
4. Health: water, hazardous waste products, disease, pollution, occupational risk
5. Consumption: Food, consumer products, drugs

Essentially all applications of ex-ante or forecasting benefit-cost analysis involve many common issues of risk and uncertainty. While the focus of this white paper excludes detailed discussions of such applications, material subsequent to the principles and standards below briefly illustrate some of the pertinent concepts using examples from crime, terrorism, floods, and hazardous waste.

Principles are here intended to be general, few in number, and to provide a touchstone for more detailed standards. Standards are meant to be specific guidance for modeling or empirical estimation in benefit-cost analysis. While the standards are not explicitly linked to principles in the presentation here, their development included that link. Theoretical and empirical issues related to risk and public safety as covered may be usefully combined with principles and standards for other issues such as those related to general versus partial equilibrium, the cost of public funds, or other topics. The standards are separated into theoretical and empirically oriented standards, and each with sections devoted to established and emerging standards.

PROPOSED PRINCIPLES

Principles for the benefit-cost analysis of public safety

1. Represent reality: the analysis should faithfully represent economic reality based on behavioral responses and uncertainty as it is currently understood. Where components of the analysis are not well understood, there should be an explanation of the lack of understanding due, for example, to resource limitations or inherent uncertainties that cannot be resolved.

2. Applied welfare economics is the theoretical foundation. The foundational principles defining what is to be measured are those that are generally accepted in professional economics literature. There is explicit recognition that such foundational elements are not unanimous and evolve, often through interaction with other disciplines.

3. Do not let the ideal analysis be the enemy of the useful: Analyses may be informative even if not consistent with all principles of welfare economics or other theoretical tools. It is often possible to adopt theoretical refinements in an analysis but doing so may not alter the overall policy assessment or optimal policy choice.

4. Do not usurp the decision-makers: Generate information that is valuable to decision-makers using a range of decision approaches involving uncertainty. Do not usurp the decision-maker's role unless the decision-maker has previously given approval or if abiding by the results of the benefit-cost analysis is a requirement by which the decision-maker must abide.

5. Do not usurp the analysts: Technical issues should not be decided by political forces nor should initial investigations by the analyst of feasible alternatives be unduly limited as informed from a possibly wide array of stakeholders.

6. Strive to report monetized outcomes: Qualitative, quantified, and monetized measures are all useful but the goal is a series of numerical analyses that allow a decision-maker to understand the impacts of a decision in a monetary or equivalent metric while also being able to view key quantities and values that lead up to the monetization. Establishing a single monetary metric for policy benefit and cost components facilitates comparisons. While it some policy impacts by necessity may remain in qualitative terms, if there are too many such components the analysis tends to become unwieldy and with an accompanying danger that the policy choice will be made independent of the objective economic merits of the policy.

7. Assume statistical randomness: If a numerical value is considered important and not analyzed as a random variable, one should explain why not. Discussing uncertainties is an essential component, but the existence of uncertainties with respect to parameters in a policy analysis should not be a barrier to identifying the policy that maximizes the difference between the level of expected benefits and expected costs.

8. Avoid false accuracy: The modeling assumptions and reporting of numerical values should convey information about the accuracy of the estimates.

9. Proportionality: Analytical effort should expended to the extent it might change the policy decision whether formally or informally reflecting a value of information. Many policy decisions hinge on a single key component. Identifying the critical parameters and ascertaining their value is a critical aspect of judgment required for effective policy analysis.

10. Choose the appropriate scope of analysis. Ultimately some element of judgment is required in selecting the breadth and temporal dimension of the analysis that is pertinent for the policy decision, but the scope is often dictated by what factors are relevant for the BCA. For example, the time period for analyzing policy decisions may be different than the time period for assessing policy effects. Longer term technology uncertainties may make it infeasible to analyze decisions affecting toxic exposures for more than the next few decades. But even if no decisions beyond some near term date are being assessed, due to the latency periods for many illnesses the analysis should assess the longer term consequences of the decisions and should not be truncated so as to coincide with the period over which policy decisions are being made.

11. Responsible information acquisition. Acquire information about key uncertainties, but do not let the existence of uncertainties paralyze the analysis. The presence of uncertainty rather than well known risks creates a potential for acquiring information that will foster more precise understanding of the probabilities. Doing so is often desirable, but it should be recognized that failure to act often has important opportunity costs.

PROPOSED STANDARDS

Proposed Established Standards (S): Theoretical and Empirical

THEORY

S-THEORY-1

Issue: Does the potential exist to increase economic efficiency?
Standard: Identify some type of market failure or government failure
Discussion: The focus of welfare economics and hence of benefit-cost analysis is determining whether an action increases economic efficiency. In the absence of theoretical or empirical evidence suggesting a market or government failure there is little expectation for positive net benefits from action. For example, the existence of externalities from pollution and transaction costs that establish barriers to bargained solutions to externalities imply that private actions by consumers or firms will be inefficient and so it is possible for an action to increase efficiency compared to market outcomes. If the analysis claims that the policy will raise individuals' welfare or firms' profits, then a useful check on the analysis is to inquire what market failure currently prevents these gains from being realized.
References: U.S. OMB (1992), most texts.

S-THEORY-2

Issue: What are the benefits of increased safety?
Standard: The standard benefit is the willingness to pay to reduce the risks of the bad outcomes that would have occurred compared to the base case. Thus, the willingness to pay value is an ex ante valuation measure for the reduction in the probabilities of the adverse outcome rather than an assessment of these values after the fact.
Discussion: Public safety issues generally involve probabilities of outcomes perceived as socially "bad", e.g. floods, crimes, illness and which may or may not be inefficiently provided. As the primary outcome of concern is a "bad," benefits are achieved by reducing the frequency or severity of the bad outcome. The problem can be framed as a trade-off between two types of cost: reduced value (cost) of harm and the implementation cost of avoiding the harm. Those benefiting from the forecasted reduction in harm are assumed to treat such reductions symmetrically with more standard benefits.
Examples include reductions in pollution that reduce bad health outcomes and reductions in damage from natural disasters or terrorist attacks.
References: Freeman (2004, p. 324-336)

S-THEORY-3

Issue: What welfare measure should be used?
Standard: Use Marshallian demand based on willingness to pay.
Discussion: Welfare measures based on consumer surplus typically use Marshallian (uncompensated) demand functions. Willig (1976) developed bounds on the error from the use of Marshallian consumer surplus instead of that based on a compensated (Hicksian) demand. The Willig article has been reprinted in a number of places including Zerbe and Dively (1994, p. 111-113; Jehle and Reny, 2000, p. 170). The error in using the Marshallian demand can be larger if only the deadweight loss is being measured (Hausman, 1981; Haveman, et al., 1987).
Exceptions: See frontier practice standard for exact measures of surplus.
References: Boardman et al. (2006); Freeman (2003, p. 53-68); Zerbe and Dively (1994).

S-THEORY-4

Issue: Benefit or cost transfer: when to use a point estimate developed in one location or decision context or with other assumptions and apply these estimates to a new analysis?
Standard: To the extent possible, the point estimate should be adjusted for conditioning factors using a benefit transfer function. Whether such adjustments are made or not, the analyst should explain the reasons why the data and results obtained elsewhere are applicable to the new analysis.
Discussion: The underlying statistical population should be similar between the initial study site and the new analysis. For example, the use of recreational benefits in one area, such as a beachfront, may not be appropriate in another. There also may be differences in the population characteristics, and these often can be recognized through the use of the pertinent elasticities of demand with respect to these characteristics, such as income. Also, the value of a statistical life based on workers may not be appropriate in other settings in which deaths occur, such as those due to terrorism, or to other populations, such as the elderly.
Exception: Sensitivity analysis or other uncertainty methods may investigate the implications of a point estimate transferred by one location to another.
References: Boardman et al. (2006, p. 429-432); Freeman (2003, p. 453-456), Desvousges, Johnson, and Banzhaf (1998).

S-THEORY-5

Issue: How to incorporate model uncertainty?
Standard: Use of linear or constant coefficient approximations to welfare outcomes
Principle: Use appropriate welfare theoretic measurement concepts but some functional specification for demand and supply is necessary with its associated model uncertainty.
Discussion: Linear forms allow relatively easy closed form solutions and allow basic analytic geometry to be used to form estimating equations. More advanced work often deals with more general functional forms such as constant elasticity or "exact" surplus measures. For example, while estimating welfare measurements related to cell-phones, Hausman (1997) used a linear approximation to an estimated constant elasticity demand function as total surplus measures with that measure become infinite at quantities close to zero.

Exceptions: More advanced applications may estimate welfare measures with more complex functions, "exact" surplus measures, or use numerical methods to integrate more complex functions. Further, there can be concern for modeling variability but omitting random error (Farrow, 2008).
Source: Textbooks such as Boardman, et al. (2006) or Zerbe and Dively (1992).

EMPIRICAL

S-EMPIRICAL-1

Issue: What value should be used for point estimates?
Standard: Use the statistical expected value (mean) for point estimates or lacking that, a measure of central tendency.
Discussion: There are two justifications:

1. Numerical: The fundamental operation for benefit-cost analysis is addition and subtraction. The addition or subtraction of expected values is also the expected value which is not true in general of other measures of a random variable. Further, first-order approximations of functions of random variables such as products or division use expected values
2. Decision analytic: A risk-neutral individual or social decision-maker makes decisions based on expected values (e.g. Boardman et al., 2006; Arrow and Lind, 1970). If the decision has a small effect on income or other major determinants of preferences, then the decision-maker may be risk neutral. In situations of risk aversion, the expected willingness to pay values for benefits should recognize the influence of risk aversion so that from the standpoint of making the policy choice the expected benefits and costs should be the guide.

For Example:

1. A sample is available of the change in education due to a program. The mean change should be used if only point estimates are reported.
2. Regression analysis generates an estimate of the expected value conditional on factors in the model. A predicted value is the expected value evaluated at the mean of the conditioning factors.

Exceptions to the standard: If more than a point estimate is being reported, then other standards apply, such as Empirical Standard 3 and Frontier Empirical Standard 1 below.
References: Arrow, et al. (1996), U.S. OMB (1992)

S-EMPIRICAL-2

Issue: When should some number be used instead of no number?
Standard: In contexts in which there is available data to assess the precision of a number, that number can be used when the mean is significantly different from zero, where statistical significance is usually taken to be a 5 percent level of confidence where computable. In some contexts, one must rely on judgmental probabilities as there is

either no data or insufficient data to calculate these probabilities. Specifying these values and incorporating them in the analysis can promote sound analyses that systematically recognize the decision maker's estimates of the likely effects. Often such judgmental probabilities can be provided in the context of a sensitivity analysis, e.g., how large must the probability of a terrorist attack be for a particular precaution to pass a benefit-cost test?

Discussion: The role of significance tests depends on whether the information available for the analysis makes this a situation in which principles of classical statistical inference are pertinent, or whether by necessity judgmental probabilities and valuations must be used following Bayesian decision theory. Since numbers are assumed to be random variables, if the point estimate can be tested and a null hypothesis of zero is rejected then the number should be used in the classical statistics case. Perhaps the greatest danger is to abandon quantitative analyses altogether because of the imprecision of available data. Systematic thinking about policy effects is generally assisted by analyses in concrete numerical terms even when such numbers may be imprecise so that the best estimates of the distribution must be relied upon when undertaking the analysis.

Exception:

1. Sensitivity analysis or other uncertainty methods may investigate the implications of the standard.
2. Although an estimate (coefficient) may be insignificantly different from zero, theory may indicate that the estimate is unbiased and the best available (e.g. minimum variance among linear unbiased estimates). The lack of significance may be viewed as an issue of more information or sample size. Analysts may wish to investigate the robustness of their results using insignificant estimates.
3. Classical measures may be unknown or poorly understood, as with terrorism risk, and so Bayesian methods for elements of a statistical distribution may be used.

References: Standard Econometrics textbooks, Raiffa (1968), and Pratt, Raiffa, and Schlaifer (1995).

S-EMPIRICAL-3

Issue: How to assess the variability in outcomes due to parameter assumptions?

Standard: Investigate the sensitivity of the point estimate result at least with respect to key alternative values as might exist in the literature. In addition, consider a systematic adjustment of key variables in the analysis by changing their value by a common amount, such as 25 percent (stress testing).

Discussion: Sensitivity analysis as a "what if" investigation of empirical alternatives can investigate specific issues in the literature or policy debate; systematic variation in parameter values improves comparability of outcomes.

References: Boardman, et al. (2006, p. 175-184).

S-EMPIRICAL-4

Issue: What is the link, if any, between the discount rate and uncertainty?

Standard: Use the appropriate real or nominal discount rate as specified by the sponsoring agency, or do not add uncertainty into the discount rate. Various

justifications for different levels of the discount rate implicitly include some return for risk when private sector crowding out is assumed; and the risk-free rate has been supported based on risk pooling across governmental investments. Lower interest rates are often based on pure time preference rates.
Discussion: Consider a typical discounting term as involving a value, the numerator; and a discount rate term, the denominator. Some initial approaches in the literature suggested adjusting the discount rate using information on the price of dispersion (risk) and the quantity of risk associated with the project (Zerbe and Dively, 1994, p. 332-333). More recently, the focus has been on adjusting the numerator for risk and discounting at rates believed to be associated more directly with time. Thus, the role of risk can be incorporated in the expected benefits at any point in time rather than through the discount rate, which imposes a mathematical structure on the influence of uncertainty over time that may not be reflective of the temporal influence of uncertainty.

What is being discounted are the monetized values-- the expected benefits and costs at different points in time-- not physical units. If the unit dollar benefit value is constant over time, then discounting physical units is appropriate. But often there is a growth in these unit benefit values due, for example, to increases in income or greater scarcity of resources. If the unit benefit value is growing at a rate g and the discount rate is r, where $r>g$, then it is appropriate to discount the value of physical units over time or the benefit value based on current unit benefit amounts using a discount rate of r-g.
Exception: See frontier standard on discounting.
References: Boardman et al. (2006, p. 264-269), U.S. GAO (1991), Lind (1982), Portney and Wyent (1999), Viscusi (2007), Summers and Zeckhauser (2008), and Dasgupta (2008)..

S-EMPIRICAL-5

Issue: When to use shadow prices or transfer values?
Standard: Numerous values related to risk are in frequent use even if there is not complete agreement. Issues include the value of a statistical life, valuing the risks of injury, and determining the economic costs of crime. Some surveys of shadow prices exist such as are reported in Boardman, et al. (2006).
Exception: Analysts are typically encouraged to consider whether the shadow price can be adapted for the specific population at hand. See Theoretical Standard 4.
References: Boardman et al (2006, p. 403-429); Desvousges, et al. (1998).

S-EMPIRICAL-6

Issue: What characteristics of random variables should be reported?
Standard: The mean, median, and measures of dispersion such as the range, the interquartile range, and standard deviation of key outcomes such as benefits, costs, net present value.
Discussion: In practice, the social welfare function is not known nor is that of the decision-maker. It is useful to provide to stakeholders and decision-makers information about the variability in the outcomes so that the decision-maker(s) can be informed about elements that theory suggests may influence their choice.
Exception/improved practice: The range, meaning the minimum and maximum, leaves interpretation to the decision maker of the probability within that range. To the extent

possible additional information such as a 95 percent confidence range or full information about the distribution should be presented. Further, the visual display of quantitative information can be valuable. Probability density and cumulative distributions have been used with varying success to communicate uncertainty to decision-makers. There may of course be values at the extreme of a particular distribution that may imply quite different policy choices than derived from the mean values. This may provide a reason for further assessment of the key parameter values, but the potential influence of extreme values on the policy choice does not imply that the decision based on the means is incorrect.
References: Arrow, et al., (1996); Krupnick, et al. (2006)

Proposed Frontier Standards (FS) Theoretical and Empirical

THEORY

FS-Theory-1

Issue: How to value uncertain outcomes?

Standard: Monetize individual values using an ex-ante measure that explicitly accounts for uncertainty

Discussion: Current thinking is that elements of uncertainty are appropriately captured in people's valuations of ex-ante costs and benefits taking into consideration risk preferences such as risk aversion. The value of statistical life is one such ex-ante measure that reflects the structure of individual preferences with respect to reducing risks of death. Addressing the value of uncertain outcomes more generally, such as valuing the chance that one might be interested in using a natural resource at some future date, has turned out to be empirically difficult although substantial theory exists. Approaches include obtaining the option price which is the monetary metric linking the expected utility of the gamble with the utility of the certainty equivalent; adjusting expected damage (ex-post measure) using theoretical adjustments; using the larger of expected surplus or option price if fair insurance is available; and using quasi-option or real option values if the decision-maker can adapt to new information and decisions are irreversible. For example, committing to irreversible capital investment today may give up the option value of investing tomorrow as new information arrives, which is a real option value. Alternatively, people may be willing to pay to purchase sprinkler irrigation, a form of (approximately) state independent payment consistent with option price, which incurs a certain cost but may stabilize income in either wet or dry years.

References: Boardman et al. (2006, p. 200-213); Freeman (2006, p. 209-252), Dixit and Pindyck (1994).

FS-Theory-2

Issue: What welfare measure should be used?

Standard: Use "exact" consumer surplus based on compensated demand.

Discussion: Duality theory provides methods for exactly calculating compensating or equivalent variation measures of consumer surplus given estimated parameters. Methods are based either on integrating an estimated Marshallian demand curve back to underlying expenditure and indirect utility functions, or to assume a known utility function to derive appropriate Marshallian demands. If econometric methods are used to estimate the parameters, the variance of the estimate can be computed given the known, but generally non-linear, structure of the exact consumer surplus measure. Under some conditions, non-market valuation linked to market observables can be carried out.

Exceptions: Failure of integrability, separability, or some non-market conditions may invalidate exact estimation.

References: Freeman (2003 p. 69-72, 101-122), Hausman (1981).

FS-THEORY-3

Issue: How to include insurance in benefit-cost analysis?
Frontier standard: Use to inform an ex-ante evaluation based on premiums or an ex-post measure of damages based on insurance claims paid.
Discussion: If insurance were actuarially fair, then by definition insurance premiums would equal the expected loss. Notwithstanding the practical difference between insurance premiums and losses, risk-averse people often purchase insurance and the premiums they pay would provide an estimate of the ex-ante willingness to pay for the level of risk reduction. With insurance loading and multiple risks, the estimate is biased. Many people may forego the purchase of insurance even though they are risk-averse if the premiums are too high so that their valuations will not be captured by insurance premiums. When an insured event occurs, there is a transfer of funds based on a partial estimate of damages given the degree and extent of coverage. For example, voluntary risk premiums paid to avoid flooding may inform estimates of the value of structural improvements to reduce flooding.
References: Boardman, et al. (2006, p. 208-211), Freeman (2003, p. 210-221), Krutilla (1966), Schleisinger (2000)

FS-Theory-4

Issue: Does a budget constraint change the recommended decision rule?
Standard: With constrained budgets the incremental net welfare measure, usually expected net present value, should equal or exceed a threshold value larger than zero.
Discussion: Equality constrained optimization problems typically yield the result that the change in the objective function due to a choice variable (the first order condition identifying the incremental impact) should equal the shadow price of the constraint, the Lagrangian multiplier. As all first order conditions equal the same shadow price for a budget constraint, the standard follows. The implication is that some projects that may pass an unconstrained benefit-cost test (EPVNB greater than zero) will fail the test based on limited resources. Regarding homeland security expenditures for example, investments should occur across sites until (ideally) the marginal expected social costs avoided are equal to the shadow price. Variations of this budget constrained problem can alter the outcome as indicated in the table below in which government investments can affect either or both of probabilities and outcomes. A related standard based on benefit-cost ratios is discussed in Bellinger (2007, p. 157)

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

Source: Farrow (2009)

References: Farrow (2007)

EMPIRICAL

FS-Empirical-1

Issue: How does one estimate the statistical distribution of outcomes?
Frontier standard: Implement Monte-Carlo simulation analysis using information on the statistical distribution of input assumptions and their inter-relations in the model.
Discussion: Many software applications now allow Monte Carlo simulation when the user specifies input distributions and inter-relations. The output of such simulation can be reported via tables, graphs, and interpretive data such as the correlation of inputs with outcomes, tornado diagrams, and similar diagnostics. For example, models such as BENMAP (EPA URL) or FERET (2001) utilize different simulation tools to estimate the benefits or net benefits of pollution reduction based on distributions for concentration-response functions and for the value of various health outcomes.
References: U.S. OMB (2003); Boardman, et al. (2006).

FS-EMPIRICAL-2

Issue: What is the appropriate discount rate with uncertainty?
Frontier standard: As indicated in S-Empirical-4, the discount rate for near term effects is generally specified by agency or OMB guidance. Very long-term effects will play a very minor role in the analysis unless the valuation of the magnitudes being discounted also increases over time due to a positive income elasticity or increasing scarcity of the good being valued. Thus, if the discount rate is 3% and benefits are increasing in value by 2.5%, then the net discount rate of 0.5% has a much more modest effect on discounted long-term benefit values than would a 3% rate.

How effects for future generations should be discounted remains a matter of continuing debate. Such long term effects have been primarily of academic interest and are included in very few benefit assessments. The most fundamental task is to include longer term consequences when they are potentially important to the policy assessment. Selecting the discount rate or the sequence of discount rates to be used in assessing effects on future generations is a matter of continuing debate. Some economists have advocated preferential, lower discount rates for future generations based on intergenerational equity concerns. Suggestions that a zero discount rate be used have been widely rejected since a permanent $1 annual loss would have an infinite value and would swamp all other concerns in the analysis. Others have advocated discounting of future benefits in the same manner as effects for the current generation. A less future-oriented position is based on an assumption that future generations will be more affluent than the current generation so that there should be no preferential treatment of future generations. Should differential discount rates be used, such as a declining rate of discount over time, there is also a potential problem of time inconsistency. For example, will the discount rate sequence being applied to policies that have effects on future generation effects be in line with the preferences of that generation, which may have more present-oriented within generation preferences than suggested by a steadily declining discount rate over time?
References: Dasgupta (2008), Summers and Zeckhauser (2008), Boardman et al. (2006), and Viscusi (2007).

FS-EMPIRICAL-3

Issue: How can distributional weights be incorporated?

Standard: The basic standard is no adjustment (weighting) is made for who receives the benefit or pays the cost. The frontier standard is that sensitivity analysis be carried out of this assumption.

Discussion: The aggregation of individual benefits is problematic, both because individual marginal utility of incomes are not known and because there is no agreement on a social welfare function. The basic standard assumes a constant marginal utility of income across all people and no income inequality aversion as a society. These assumptions should be investigated if there are important distributional implications of the action (e.g. income, race, age, gender). For example, an analyst could adjust impacts by income categories of those affected using "Atkinson" values published by the Bureau of the Census which imply relative marginal utilities of income based on differing incomes. This adjustment is formally equivalent to a risk aversion to income inequality. In the absence of a consensus on distributional weights, a more limited approach is to provide information on the distribution of benefits in policy contexts where that is an important concern.

References: Boardman et al. (2006), Layard and Walters (1978).

Illustrations of BCA issues to public safety in the areas of flood control, crime, hazardous wastes, and terrorism

These wiki-type "stubs" are introductions in several areas to illustrate basic BCA and risk issues in an application specific context.

Floods

Floods, with or without accompanying wind storms such as hurricanes, are regularly among the most damaging events. The historical involvement of the U.S. Army Corps of Engineers (COE) and the U.S. Department of Interior's Bureau of Reclamation was a key setting for the development and application of benefit-cost analysis (Porter, 1995). These agencies built structures on waterways that may have multiple uses such as flood control, power generation, recreation, transportation, irrigation, and municipal and industrial water supply. The diversity of these issues and the central role of BCA in the efforts made the area a fruitful one for application. Before undertaking these water resource projects, the agencies were required to show that the economic benefits of the efforts exceeded the costs. Over the past half century, the COE and Bureau of Reclamation have created and periodically update their own guidance and standards for water projects that are the Federal standards in the area in place of OMB guidance (US Water Resources Council, 1983; U.S. Executive Office of the President, 2009). Early development of benefit-cost methods also owed much to issues associated with flooding and control of water systems (e.g., Krutilla and Eckstein, 1957).

In addition to structural approaches, there are important non-structural policies related to flooding that are subject to benefit cost analysis. The National Flood Insurance Protection program (US GAO, 2005) was in part motivated by a conceptual benefit-cost type of analysis (Krutilla, 1966). The recent evaluation of the program generated a number of documents that could inform a benefit-cost analysis (AIR, 2006). The flooding of large parts of New Orleans following Hurricane Katrina brought new attention to the risks associated with built structures such as levees and to distributional issues.

Among the issues involved with uncertainty in flooding and water control projects are: 1) probabilities of flooding at different scales, 2) individual level damages, 3) regional or collective damages, 4) the extent of capitalization of risk and various policies on property values, 5) the extent of market failure, 6) the financial impacts of floods, 7) the behavioral response to a recent event, 8) construction cost uncertainty, 9) the estimation of long term power, agricultural production impacts, recreational, or transportation benefits of multi-purpose structures.

Crime

The economic analysis of crime begins with modeling behavior based on expected utility and gets increasingly complex involving portfolio and other models (Eide, 2004; Eide, Rubin, and Shepherd, 2006). A main issue in framing a BCA for crime is benefits and costs to whom—the potential criminal, the victim, or society at large. Starting with the potential criminal's benefit-cost calculus provides an opportunity to assess the points of leverage that can be used to discourage criminal behavior. The criminal's decision involves an intrinsic element of risk. With respect to the potential gains from crime, such as financial rewards, there is some probability that the crime will not be successful. For example, burglar alarms and other forms of self protection may decrease the probability that the crime will have a reward to the criminal. The costs of crime likewise have an important probabilistic component, as there is some probability that the criminal will be arrested, a subsequent probability of conviction conditional on arrest, and a distribution of possible sanctions. Understanding the criminal's choice calculations may assist in designing the most effective anti-crime policies.

Criminal justice policies can also be subject to BCA as criminal justice resources can be analyzed for their efficient allocation. Such concerns have led economists focus on the relative efficacy of different anti-crime measures. For example, increasing the strength of the police force to generate a higher probability of arrest may have a greater deterrent effect per dollar expended than increased sentence length with its attendant costs of imprisonment.

Hazardous Waste

Hazardous waste policy assessments involve less precisely understood risks than do flood control projects or criminal justice policies and also involve an important time dimension as many of the most severe health effects of hazardous waste take decades before they are manifested. The hazardous waste policy context provides an ideal setting for exploring how such probabilistic dimensions should be incorporated in the analysis. The costs of hazardous waste cleanup involve relatively straightforward assessments of the costs associated with the particular policy action, whether it involves removal and incineration of the waste or zoning restrictions to limit access to the contaminated area.

The main benefit component driving cleanup decisions is the risk of cancer, which can be valued using value of statistical life estimates or the counterpart values for the risk of cancer. How great the individual risk of cancer is depends on the duration of exposure, the frequency of exposure, the ingestion rate, the contaminant concentration, the toxicity of the chemicals, and various normalization factors to capture the units of analysis. Calculating the cancer risk consequently involves the multiplication of five different variables, each of which as some associated distribution. The appropriate benefit-cost approach is to use the mean value of each distribution when calculating the overall cancer risk level. The EPA approach, as well as that of many other federal risk regulation agencies, is to use various worst case assumptions for the parameter, such as upper bound values or the 95th percentile of the distribution. Such so called "conservatism" leads to upwardly biased risk assessments. If, for example, the 95th percentile of each distribution is used to calculate the risk level, then the probability that the actual risk is as great as the calculated value is 0.05x0.05x0.05x0.05x0.05, or under one in a million if the different components of the calculation are independent. Use of such conservatism adjustment approaches distorts the probabilities, places undue emphasis on imprecise risks as opposed to real known risks, and hides information about the actual risk level from the decision maker.

If there is a desire for the policy to be protective, then that concern can be addressed by setting a suitably high value on the benefit amount for the health outcome averted, which in this case is cancer. The cancer benefits will, however, not occur immediately but only after a latency period. As a consequence, these amounts must be discounted, as outlined above, reducing their role in the analysis. However, since income levels are rising over time, with a positive income elasticity of the value of cases of cancer, the unit benefit amount will also be rising over time after it is recognized that what is being discounted is not the number of cases of cancer in each year but rather society's willingness to pay to reduce this risk.

Current agency practices do not, however, focus on a comprehensive assessment of the benefits, or what agencies term a "population risk" approach, but instead take what they term and "individual risk" approach. So long as there is an actual or potential future cancer risk to some individual that is at some critical level of lifetime risk, such as 1/10,000, then cleanup is justified. In contrast, the BCA formulation by necessity takes a population risk approach. The mean risks reduced to all people, not just the risk to a hypothetical maximally exposed individual, must be taken into account in calculating the total risk reduction benefits. The use of a population risk approach also takes into account the exposure to large, dense populations near hazardous waste sites. Because such exposed populations are often lower income or minority groups, ignoring these population exposures creates a distributional bias against protecting these individuals. Thus, rather than using a preferential distributional weight for benefits affecting the poor, the individual risk approach in effect gives these large populations zero weight. Because of the emphasis of benefit-cost analysis on a comprehensive assessment of all benefits to those exposed to the risk, cleanup policies based on a BCA approach would target cleanups in a manner that would be more protective than those based on the current methodology. The frequent assertion that BCA is biased against the poor is simply not true.

For further discussion and analysis of hazardous waste policies, see Hamilton and Viscusi (1999).

Terrorism

The benefit-cost analysis of terrorism has links to the literature on crime but the behavior of the attacker's and the frequency of events are elements adding additional complexity. Unlike criminal behavior, for which there is available data on thousands of criminal actions of each type, the U.S. fortunately has been the victim of very few terrorist attacks. As a result, the BCA of terrorism policies emphasizes the appropriate structure of decisions often coupled with subjective assessments of some probability components. 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 the Department of Homeland Security (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.

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:

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

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. Since the risk level is likely to be the most difficult component to quantify, framing the analysis in this manner focuses attention on what the critical risk level must be for a policy to be justified. It may be conceptually easier to assess whether the risk is above or below a particular value than to pinpoint the probability value. 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. Various implications emerge as discussed in Farrow and Shapiro (2009) when the expected value of the loss is substituted for loss in the above equation. The interpretation of the break-even point then depends on whether the regulation is probability reducing, damage reducing, or both.

Risk neutral models using expected values and a budget constraint can also be informative. When probability of attack depends on the amount invested in defensive expenditures, then the stage is set for game theory types of approaches as well. Minimizing expected social cost of defensive expenditures subject to a budget constraint leads to a variety of models summarized in Table 1.

Table 1: 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

Other social objective functions are frequently investigated such a minimizing the maximum loss and the incorporation of a game theoretic response. Such formulations should not, however, be a substitute for a comprehensive BCA that takes into account the entire distribution of possible outcomes, not just the maximum loss.

A wide range of benefit-cost related topics are under investigation in this areas including: 1) risk aversion and adjustments to expected damage measures, 2) valuation of collective risks, 3) the resiliency of systems to recover from attacks, 4) general equilibrium modeling, and 5) behavioral and other responses to rare but large events.

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Appendix I: Government guidance on uncertainty as of December, 2009.

Source: U.S. OMB, 1992. *Circular A-94.* p, 10-11

9. **Treatment of Uncertainty**. Estimates of benefits and costs are typically uncertain because of imprecision in both underlying data and modeling assumptions. Because such uncertainty is basic to many analyses, its effects should be analyzed and reported. Useful information in such a report would include the key sources of uncertainty; expected value estimates of outcomes; the sensitivity of results to important sources of uncertainty; and where possible, the probability distributions of benefits, costs, and net benefits.

a. Characterizing Uncertainty. Analyses should attempt to characterize the sources and nature of uncertainty. Ideally, probability distributions of potential benefits, costs, and net benefits should be presented. It should be recognized that many phenomena that are treated as deterministic or certain are, in fact, uncertain. In analyzing uncertain data, objective estimates of probabilities should be used whenever possible. Market data, such as private insurance payments or interest rate differentials, may be useful in identifying and estimating relevant risks. Stochastic simulation methods can be useful for analyzing such phenomena and developing insights into the relevant probability distributions. In any case, the basis for the probability distribution assumptions should be reported. Any limitations of the analysis because of uncertainty or biases surrounding data or assumptions should be discussed.

b. Expected Values. The expected values of the distributions of benefits, costs and net benefits can be obtained by weighting each outcome by its probability of occurrence, and then summing across all potential outcomes. If estimated benefits, costs and net benefits are characterized by point estimates rather than as probability distributions, the expected value (an unbiased estimate) is the appropriate estimate for use.

> Estimates that differ from expected values (such as worst-case estimates) may be provided in addition to expected values, but the rationale for such estimates must be clearly presented. For any such estimate, the analysis should identify the nature and magnitude of any bias. For example, studies of past activities have documented tendencies for cost growth beyond initial expectations; analyses should consider whether past experience suggests that initial estimates of benefits or costs are optimistic.

c. Sensitivity Analysis. Major assumptions should be varied and net present value and other outcomes recomputed to determine how sensitive outcomes are to changes in the assumptions. The assumptions that deserve the most attention will depend on the dominant benefit and cost elements and the areas of greatest uncertainty of the program being analyzed. For example, in analyzing a retirement program, one would consider changes in the number of beneficiaries, future wage growth, inflation, and the discount rate. In general, sensitivity analysis should be considered for estimates of: (i) benefits and costs; (ii) the discount rate; (iii) the general inflation rate; and (iv) distributional assumptions. Models used in the analysis should be well documented and, where possible, available to facilitate independent review.

d. Other Adjustments for Uncertainty. The absolute variability of a risky outcome can be much less significant than its correlation with other significant determinants of social welfare, such as real national income. In general, variations in the discount rate are not the appropriate method of adjusting net present value for the special risks of particular projects. In some cases, it may be possible to estimate *certainty-equivalents* which involve adjusting uncertain expected values to account for risk.

Source: U.S. OMB, 2003. *Circular A-4.* pages 38-42

Treatment of Uncertainty

The precise consequences (benefits and costs) of regulatory options are not always known for certain, but the probability of their occurrence can often be developed. The important uncertainties connected with your regulatory decisions need to be analyzed and presented as part of the overall regulatory analysis. You should begin your analysis of uncertainty at the earliest possible stage in developing your analysis. You should consider both the statistical variability of key elements underlying the estimates of benefits and costs (for example, the expected change in the distribution of automobile accidents that might result from a change in automobile safety standards) and the incomplete knowledge about the relevant relationships (for example, the uncertain knowledge of how some economic activities might affect future climate change).[25] By assessing the sources of uncertainty and the way in which benefit and cost estimates may be affected under plausible assumptions, you can shape your analysis to inform decision makers and the public about the effects and the uncertainties of alternative regulatory actions.

footnote 25

In some contexts, the word "variability" is used as a synonym for statistical variation that can be described by a theoretically valid distribution function, whereas "uncertainty" refers to a more fundamental lack of knowledge. Throughout this discussion, we use the term "uncertainty" to refer to both concepts.

The treatment of uncertainty must be guided by the same principles of full disclosure and transparency that apply to other elements of your regulatory analysis. Your analysis should be credible, objective, realistic, and scientifically balanced.[26] Any data and models that you use to analyze uncertainty should be fully identified. You should also discuss the quality of the available data used. Inferences and assumptions used in your analysis should be identified, and your analytical choices should be explicitly evaluated and adequately justified. In your presentation, you should delineate the strengths of your analysis along with any uncertainties about its conclusions. Your presentation should also explain how your analytical choices have affected your results.

In some cases, the level of scientific uncertainty may be so large that you can only present discrete alternative scenarios without assessing the relative likelihood of each scenario quantitatively. For instance, in assessing the potential outcomes of an environmental effect, there may be a limited number of scientific studies with strongly divergent results. In such cases, you might present results from a range of plausible scenarios, together with any available information that might help in qualitatively determining which scenario is most likely to occur.

When uncertainty has significant effects on the final conclusion about net benefits, your agency should consider additional research prior to rulemaking. The costs of being wrong may outweigh the benefits of a faster decision. This is true especially for cases with irreversible or large upfront investments. If your agency decides to proceed with rulemaking, you should explain why the costs of developing additional information—including any harm from delay in public protection—exceed the value of that information.

For example, when the uncertainty is due to a lack of data, you might consider deferring the decision, as an explicit regulatory alternative, pending further study to obtain sufficient data.[27] Delaying a decision will also have costs, as will further efforts at data gathering and analysis. You will need to weigh the benefits of delay against these costs in making your decision. Formal tools for assessing the value of additional information are now well developed in the applied decision sciences and can be used to help resolve this type of complex regulatory question.

"Real options" methods have also formalized the valuation of the added flexibility inherent in delaying a decision. As long as taking time will lower uncertainty, either passively or actively through an investment in information gathering, and some costs are irreversible, such as the potential costs of a sunk investment, a benefit can be assigned to the option to delay a decision. That benefit should be considered a cost of taking immediate action versus the alternative of delaying that action pending more information. However, the burdens of delay—including any harm to public health, safety, and the environment—need to be analyzed carefully.

[26] When disseminating information, agencies should follow their own information quality guidelines, issued in conformance with the OMB government-wide guidelines (67 FR 8452, February 22, 2002).

[27] Clemen RT (1996), Making Hard Decisions: An Introduction to Decision Analysis, second edition, Duxbury Press, Pacific Grove.

1. Quantitative Analysis of Uncertainty

Examples of quantitative analysis, broadly defined, would include formal estimates of the probabilities of environmental damage to soil or water, the possible loss of habitat, or risks to endangered species as well as probabilities of harm to human health and safety. There are also uncertainties associated with estimates of economic benefits and costs, such as the cost savings associated with increased energy efficiency. Thus, your analysis should include two fundamental components: a quantitative analysis characterizing the probabilities of the relevant outcomes and an assignment of economic value to the projected outcomes. It is essential that both parts be conceptually consistent. In particular, the quantitative analysis should be conducted in a way that permits it to be applied within a more general analytical framework, such as benefit-cost analysis. Similarly, the general framework needs to be flexible enough to incorporate the quantitative analysis without oversimplifying the results. For example, you should address explicitly the implications for benefits and costs of any probability distributions developed in your analysis.

As with other elements of regulatory analysis, you will need to balance thoroughness with the practical limits on your analytical capabilities. Your analysis does not have to be exhaustive, nor is it necessary to evaluate each alternative at every step. Attention should be devoted to first resolving or studying the uncertainties that have the largest potential effect on decision making. Many times these will be the largest sources of uncertainties. In the absence of adequate data, you will need to make assumptions. These should be clearly identified and consistent with the relevant science. Your analysis should provide sufficient information for decision makers to grasp the degree of scientific uncertainty and the robustness of estimated probabilities, benefits, and costs to changes in key assumptions.

For major rules involving annual economic effects of $1 billion or more, you should present a formal quantitative analysis of the relevant uncertainties about benefits and costs. In other words, you should try to provide some estimate of the probability distribution of regulatory benefits and costs. In summarizing the probability distributions, you should provide some estimates of the central tendency (e.g., mean and median) along with any other information you think will be useful such as ranges, variances, specified low-end and high-end percentile estimates, and other characteristics of the distribution.

Your estimates cannot be more precise than their most uncertain component. Thus, your analysis should report estimates in a way that reflects the degree of uncertainty and not create a false sense of precision. Worst-case or conservative analyses are not usually adequate because they do not convey the complete probability distribution of outcomes, and they do not permit calculation of an expected value of net benefits. In many health and safety rules, economists conducting benefit-cost analyses must rely on formal risk assessments that address a variety of risk management questions such as the baseline risk for the affected population, the safe level of exposure or, the amount of risk to be reduced by various interventions. Because the answers to some of these questions are directly used in benefits analyses, the risk assessment methodology must allow for the determination of expected benefits in order to be comparable to expected costs. This means that conservative assumptions and defaults (whether motivated by science policy or by precautionary instincts), will be incompatible with benefit analyses as they will result in benefit estimates that exceed the expected value. Whenever it is possible to characterize quantitatively the probability distributions, some estimates of expected value (e.g., mean and median) must be provided in addition to ranges, variances, specified low-end and high-end percentile estimates, and other characteristics of the distribution.

Whenever possible, you should use appropriate statistical techniques to determine a probability distribution of the relevant outcomes. For rules that exceed the $1 billion annual threshold, a formal quantitative analysis of uncertainty is required. For rules with annual benefits and/or costs in the range from 100 million to $1 billion, you should seek to use more rigorous approaches with higher consequence rules. This is especially the case where net benefits are close to zero. More rigorous uncertainty analysis may not be necessary for rules in this category if simpler techniques are sufficient to show robustness. You may consider the following analytical approaches that entail increasing levels of complexity:

- Disclose qualitatively the main uncertainties in each important input to the calculation of benefits and costs. These disclosures should address the uncertainties in the data as well as in the analytical results. However, major rules above the $1 billion annual threshold require a formal treatment.

- Use a numerical sensitivity analysis to examine how the results of your analysis vary with plausible changes in assumptions, choices of input data, and alternative analytical approaches. Sensitivity analysis is especially valuable when the information is lacking to carry out a formal probabilistic simulation. Sensitivity analysis can be used to find "switch points" -- critical parameter values at which estimated net benefits change sign or the low cost alternative switches. Sensitivity analysis usually proceeds by changing one variable or assumption at a time, but it can also be done by varying a combination of variables simultaneously to learn more about the robustness of your results to widespread changes. Again, however, major rules above the $1 billion annual threshold require a formal treatment.

• Apply a formal probabilistic analysis of the relevant uncertainties B possibly using simulation models and/or expert judgment as revealed, for example, through Delphi methods.[28] Such a formal analytical approach is appropriate for complex rules where there are large, multiple uncertainties whose analysis raises technical challenges, or where the effects cascade; it is required for rules that exceed the $1 billion annual threshold. For example, in the analysis of regulations addressing air pollution, there is uncertainty about the effects of the rule on future emissions, uncertainty about how the change in emissions will affect air quality, uncertainty about how changes in air quality will affect health, and finally uncertainty about the economic and social value of the change in health outcomes. In formal probabilistic assessments, expert solicitation is a useful way to fill key gaps in your ability to assess uncertainty.[29] In general, experts can be used to quantify the probability distributions of key parameters and relationships. These solicitations, combined with other sources of data, can be combined in Monte Carlo simulations to derive a probability distribution of benefits and costs. You should pay attention to correlated inputs. Often times, the standard defaults in Monte Carlo and other similar simulation packages assume independence across distributions. Failing to correctly account for correlated distributions of inputs can cause the resultant output uncertainty intervals to be too large, although in many cases the overall effect is ambiguous. You should make a special effort to portray the probabilistic results—in graphs and/or tables—clearly and meaningfully.

New methods may become available in the future. This document is not intended to discourage or inhibit their use, but rather to encourage and stimulate their development.

2. Economic Values of Uncertain Outcomes

In developing benefit and cost estimates, you may find that there are probability distributions of values as well for each of the outcomes. Where this is the case, you will need to combine these probability distributions to provide estimated benefits and costs.

Where there is a distribution of outcomes, you will often find it useful to emphasize summary statistics or figures that can be readily understood and compared to achieve the broadest public understanding of your findings. It is a common practice to compare the "best estimates" of both benefits and costs with those of competing alternatives. These "best estimates" are usually the average or the expected value of benefits and costs. Emphasis on these expected values is appropriate as long as society is "risk neutral" with respect to the regulatory alternatives. While this may not always be the case, you should in general assume "risk neutrality" in your analysis. If you adopt a different assumption on risk preference, you should explain your reasons for doing so.

Source: U.S. Environmental Protection Agency, 2000. *Guidelines for Preparing Economic Analysis* (the agency is considering revisions in 2010).

5.5 Analyzing and Presenting Uncertainty

This section contains guidance on dealing with uncertainty in regulatory economic analyses, focusing on characterizing the precision of estimated economic outcomes such as net benefits. It provides specific recommendations for describing and presenting problems arising from uncertainty, and suggestions for carrying out sensitivity analyses. This section concludes with a discussion of the welfare considerations related to risk and uncertainty.[5] These considerations are largely distinct from those associated with characterizing precision. The use of certainty equivalents for addressing these problems is addressed briefly, but detailed treatment is beyond the scope of this discussion.[6] Issues related to differences in risk perceptions and the provision of information are described, and the role of quasi-option values in decisions characterized by irreversible consequences is addressed briefly.

5.5.1 Guiding Principles for Uncertainty Analysis

Uncertainty is inherent in economic analyses, particularly those associated with environmental benefits for which there are no existing markets. The issue for the analyst is not how to avoid uncertainty, but how to account for it and present useful conclusions to those making policy decisions. Treatment of uncertainty, therefore, should be considered part of the communication process between analysts and policy makers.

Transparency and clarity of presentation are the guiding principles for assessing and describing uncertainty in economic analyses. Although the extent to which uncertainty is treated and presented will vary according to the specific needs of the economic analysis, some general minimum requirements apply to most economic analyses. In assessing and presenting uncertainty the analyst should, if feasible: present outcomes or conclusions based on expected or most plausible values; provide descriptions of all known key assumptions, biases, and omissions; perform sensitivity analysis on key assumptions; and justify the assumptions used in the sensitivity analysis.

The outcome of the initial assessment of uncertainty may be sufficient to support the policy decisions. If, however, the implications of uncertainty are not adequately captured in the initial assessment then a more sophisticated

[5] Stemming from definitions given in Knight (1921) economists have distinguished risk and uncertainty according to how well one can characterize the probabilities associated with potential outcomes. Risk applies to situations or circumstances in which a probability distribution is known or assumed, while uncertainty applies to cases where knowledge of probabilities is absent. Note that the economic definitions for these terms may differ from those used in other disciplines.

[6] Several other issues associated with uncertainty are also beyond the scope of this brief discussion, including verification, validation, and plausibility checks. Analysts will need to consult other sources for additional information on these topics. analysis should be undertaken.

The need for additional analysis should be clearly stated, along with a description of the other methods used for assessing uncertainty. These methods include decision trees, Delphi-type methods[7], and meta-analysis. Probabilistic methods, including Monte Carlo analysis, can be particularly useful because they explicitly characterize analytical uncertainty and variability. However, these methods can be difficult to implement, often requiring more data than are available to the analyst.[8]

Confidence intervals are generally useful to describe the uncertainty associated with particular variables. When data are available to estimate confidence intervals they can serve to characterize the precision of estimates and to bound the values used in sensitivity analysis.

5.5.2 Performing Sensitivity Analysis

Most analytical base cases, or primary analyses, generally do not address uncertainty and present expected or most plausible outcomes. Regardless of the basis for the primary analysis, point estimates alone do not provide policy makers with information about the full range of potential outcomes. Additional information is needed if the decision-maker is to have a more complete view of the potential impacts of the policy alternatives. It is always useful to see how net benefit estimates or other outputs of the economic analysis change with assumptions about input parameters. Sensitivity analysis provides a systematic method for making these determinations. Keeping in mind some basic principles can enhance sensitivity analysis.

Focus on key variables. For most applied economic analyses, a full sensitivity analysis that includes every variable is not feasible. Instead the analyst must limit the sensitivity analysis to those input parameters that are considered to be key or particularly important. In determining which parameters are key, the analyst should carefully consider both the range of possible values for input parameters and each one's functional relationship to the output of analysis. The analyst should specify a plausible range of values for each key variable, including the rationale for the range of values tested.

Present the results clearly. Results of the sensitivity analysis should be presented clearly and accompanied with descriptive text. The most common approach to this sort of partial sensitivity analysis is to estimate the change in net benefits (for a benefit-cost analysis) or other economic outcome while varying a single parameter, leaving other parameters at their base value. A more complete analysis will present the marginal changes in the economic outcome as the input parameter takes on progressively higher or lower values. Varying two parameters simultaneously can often provide a richer picture of the implications of base values and the robustness of the analysis. Analysts should consider using graphs to present these combined sensitivity analyses by plotting one parameter on the x-axis, the economic outcome on the y-axis, and treating the second parameter as a shift variable.[9]

Identify switch points. "Switch point" values for key input parameters can be very informative, especially in benefit-cost analyses. Switch points are defined as those conditions at which the recommended policy decision changes (e.g., when the estimation of net benefits changes sign). While switch points are not tests of confidence in the statistical sense, they can help provide decision-makers with an understanding of how robust the analysis is.

Assess the need for more detailed analysis. Finally, sensitivity analyses can also be useful as a screening device to determine where more extensive treatment of uncertainty may be needed. In some cases the plausible range of values for the parameter may be narrowed with further research or data gathering, or the analyst may be able to better characterize the parameter's uncertainty. If several parameters appear to have a large impact on the results of the analysis then a more sophisticated treatment of uncertainty may be necessary.

[7] There a number of such techniques, but all of these methods focus on the use of eliciting and combining expert judgment to inform analysis. See Chapter 7 of Morgan and Henrion (1990) for more detail on the use of these methods.

[8] Morgan and Henrion (1990) is a useful general reference that includes descriptions of many methods to assess uncertainty.

[9] When the analysis contains many highly uncertain variables, presentation may be facilitated by noting the uncertainty of each in footnotes and carrying through the central analysis using best point estimates.

U.S. Department of Housing and Urban Development, 2006.
Housing Impact Analysis

Appendix B: Quantitative Analysis of Uncertainty

One aspect of subdividing markets is the increase in uncertainty or volatility in the elasticity estimates. Over broad markets at the regional or national level, the local variation tends to average out. Even at the national level, however, there is uncertainty, especially over time. Ideally, a housing impact analysis in concert with an RIA would estimate a probability distribution of outcomes. For each economic outcome, there would be a probability of that outcome. The expected value outcome, then, is the sum of each projected outcome multiplied by its predicted probability. The probability of each endogenous outcome is based on the probability distributions for each exogenous input in the estimation model. We recognize that estimating probabilities requires a much more detailed level of analysis, which can be justified for regulations exceeding $1 billion economic impact.

A middle-ground approach, particularly when it is difficult to quantify the uncertainties, is to provide a range of outcomes and associated scenarios. Another compromise approach is to do a sensitivity analysis. Even if all the uncertainties are not accounted for in the model, it can be very helpful to the policymaker to see how much the final outcome varies with changes in key parameters. Typically, one parameter is varied at a time to make explicit the impact of that sole change. In reality, parameters are jointly determined and a more complete sensitivity analysis would test the variation of correlated parameters changing in coordination. For example, interest rates and regional house prices could be projected over a range of combinations and then the model could estimate regulatory impacts for the submarket of interest, such as affordable housing.

Hoesli (2005) provides an example of how Monte Carlo simulations can be used to cope with the risk and uncertainty of future cash flows and discount rates on commercial property. The basic concept is to create a model that calculates the present discounted value for a property based on expected rents and ultimate resale value. A single valuation requires estimates for parameters including the discount rate. Estimate the distribution for each of those parameters and then run the model for different draws of the parameters. Each simulation produces a point estimate of the present discounted value. If the simulation is repeated enough times, it produces a smooth distribution of point estimates. The mean point estimate has a standard error as an indication of reliability and the extent of the distribution can highlight the range of possible values with corresponding probabilities. Rodda et al. (2004) provides another example of stochastic modeling applied to FHA-insured reverse mortgages.

White Paper Prepared
For the University of Washington Benefit-Cost Center

The Benefit-Cost Analysis of Crime

John R. Lott

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I. Overview

Criminal justice involves many trade-offs. Are we spending enough on police? What are the levels of penalties for different crimes? Are there trade-offs between different types of penalties? For example, does greater reliance on criminal penalties reduce the reliance on reputational penalties?

One complicated example is the death penalty. There is still some debate over the deterrence effect of the death penalty. But even if one accepts that such deterrence exists, how large does that effect have to be to out weigh the costs? The legal process for the death penalty is costly. What are the costs of accidentally convicting innocent individuals? The death penalty might save imprisonment costs after a certain point, but executions are so delayed that the present value of those costs might be small. Numbers cannot easily be assigned to all these costs and benefits, but it is still possible to give examples of how large different values have to be for people to change their decisions on whether the death penalty passes a cost-benefit type test.

Prison provides another interesting trade-off. Crime is overwhelmingly committed by young men. The incapacitation effect of prison is thus likely to decline with the prisoner's age. If criminals have a high discount rate (and there is considerable evidence that is true),[1] after a certain point lengthening prison sentences might not have much of an impact on deterring criminals. If society uses a different discount rate for the cost of imprisonment than criminals do for the penalty that they face, long prison terms might

[1] Michael K. Block and Vernon E. Gerety (1995), "Some Experimental Evidence on Differences Between Student and Prisoner Reactions to Monetary Penalties and Risk," *Journal of Legal Studies*, 24, 123-138.

impose very little penalty on criminals despite imposing a very large financial burden on society.

There are many possible alternative methods of deterring crime. Longer prison terms are just one option. There are also issues of increasing the probability of arrest or conviction for those who are arrested. There are also private actions that can deter crime. Private reputations are one example. Take also putting locks on doors, car alarms, or people owning guns. Some of these actions involve possible externalities and we will discuss how those externalities might be measured and evaluated.

Though the range of possible estimates for many of these actions will be too large to definitively say whether the actions pass a cost-benefits test, that is not an unusual result. It is still useful to know what actions can be said to pay for themselves and which ones don't.

Cost benefit analysis is a technique designed to determine the feasibility of a project or plan by quantifying its costs and benefits. Below is a brief rough outline of what is involved with measuring and calculating these costs and benefits.

II. Four types of Penalties

A. Prison, Fines, Reputations, and Collateral Penalties

There are generally four types of criminal penalties, all of which have significant costs and benefits: prison, fines, reputations, and so-called collateral penalties, the loss of the ability to hold different jobs or various rights. All these punishments deter crime, though with the exception of prison and fines there is no evidence of their different abilities to deter crime. The costs of these penalties vary dramatically. The two most costly are prison and collateral penalties. For prison, there is the obvious cost of running the prison, but there is another cost: anything beneficial that the criminal could have been produced outside of prison. Many criminals might have continued spending most of their time committing crime, but others would have produced benefits that people pay for. Michael Milken might have been charged with stock parking crimes, a violation that would normally have been punished with a $10,000 fine, but presumably there was some reason why companies were willing to pay Milken $500 million per year to help them get financing. During the mid-1980s the average person convicted of insider trading was making $365,000 per year in legal income prior to conviction.

Just as women's human capital depreciates when they leave the labor force to have children, putting people in prison also leads to depreciated human capital. It is possible their human capital that facilitates their ability to commit crime increases, but there is a clear drop in earnings that occurs the longer the criminals are in prison.

In 2001, annual prison operating costs averaged $22,600 per inmate, ranging from $8,128 in Arkansas to $44,379 in Maine.[2] Much of this range depends on factors beyond the control of correctional officials: differences in the cost of living, the mix of high and low security prisoners, variation in prevailing wage rates, climate, building codes, as well as other factors.[3] For example, prisoners who are serving life sentences are very difficult to maintain. The only additional penalty that could restrain the behavior of these criminals is the threat of a death penalty. But there is no reduced prison time for good behavior.

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[2] James J. Stephan, "State Prison Expenditures, 2001," Bureau of Justice Statistics, June 2004.
[3] Ibid, p. 5.

Inmate Prison Expenditures by State in 2001					
State	Annual Cost Per Inmate	State	Annual Cost Per Inmate	State	Annual Cost Per Inmate
Alabama	$8,128	Kentucky	$17,818	North Dakota	$22,415
Alaska	$36,780	Louisiana	$12,951	Ohio	$26,295
Arizona	$22,476	Maine	$44,379	Oklahoma	$16,309
Arkansas	$15,619	Maryland	$26,398	Oregon	$36,060
California	$25,053	Massachusetts	$37,718	Pennsylvania	$31,900
Colorado	$25,408	Michigan	$32,525	Rhode Island	$38,503
Connecticut	$26,856	Minnesota	$36,836	South Carolina	$16,762
Delaware	$22,802	Mississippi	$12,795	South Dakota	$13,853
District of Columbia	$26,670	Missouri	$12,867	Tennessee	$18,206
Florida	$20,190	Montana	$21,898	Texas	$13,808
Georgia	$19,860	Nebraska	$25,321	Utah	$24,574
Hawaii	$21,637	Nevada	$17,572	Vermont	$25,178
Idaho	$16,319	New Hampshire	$25,949	Virginia	$22,942
Illinois	$21,844	New Jersey	$27,347	Washington	$30,168
Indiana	$21,841	New Mexico	$28,035	West Virginia	$14,817
Iowa	$22,997	New York	$36,835	Wisconsin	$28,622
Kansas	$21,381	North Carolina	$26,984	Wyoming	$28,845
				Average by Prisoner	$22,600
				Average by State	$24,105
Source: James J. Stephan, "State Prison Expenditures, 2001," Bureau of Justice Statistics, June 2004.					

Fines don't have many of the costs involving prison. Paying the fine doesn't interfere with criminal's ability to continue working. There can be costs to collecting the fine, but those are similar to the costs of trying to put the criminal in prison. The question is whether it is easier to hide assets or the individual. However, while fines have many desirable attributes, they are not simply applicable for most criminals since the harmed caused by the criminal vastly outweighs the most criminals' assets.

Collateral penalties share aspects of both prison and fines. For collateral penalties, the loss of business and professional licenses, the inability to work for many unions or to work for the government, as well as the loss of the ability to own a gun all have their own costs. A criminal conviction because of debarment is likely to result in lawyers loosing their licenses, executives in defense sellers being forbidden from working in the defense industry, and stockbrokers being banned from working in the securities industry.[4] The penalties involving jobs are similar to those faced by people in prison. Even banning convicted felons being able to own guns can have its costs. The question is whether the felons will be more likely to use their guns for self-protection (many felons will presumably live in high crime areas) or whether they use the guns to commit yet more crimes. Presumably these risks vary by the type of crime the criminal was convicted of. White-collar criminals seem unlikely to be the people who are at risk of using a gun in a crime.

The debate over these collateral penalties goes back decades and the types of penalties are indeed very broad. Ex-convicts face many other forms of penalties such as being prevented from inheriting property, suffering partial or complete divestment of their assets, loosing life and automobile insurance, and losing pension funds and face the discontinuance of pension payments even if the individual is already retired.[5] Since the loss of inheritance and pension funds and divestment of assets undoubtedly impose a larger absolute penalty on the well-to-do than it will on the poor, the estimates presented

[4] The National Advisory Commission on Criminal Justice Standards and Goals (1973, p. 592) notes that, "every State and the Federal government make it difficult for persons convicted of a felony to obtain licenses to practice occupations regulated by the government. In many instances conviction of a felony is automatic grounds for denial of a license. In others, it is in practice impossible for a former offender to obtain a license."

[5] Grant *et al.*, 1970, p. 1109-1143.

here will underestimate how much penalties increase as a function of pre-sentence income. Conviction also affects voting, parental rights, divorce, public employment, ability to serve as a juror, and holding public office. Several Presidential Task Forces have emphasized the importance of these collateral penalties and expressed concern over how ignoring collateral penalties will create inequities in criminal penalties (e.g., President's Commission, 1967, p. 88).

Many of these collateral penalties, such as the loss of property or other assets, are the same as fines. Losing assets in a divorce is no different than losing assets in the form of a fine. The only differences is that these collateral penalties transfer assets to a spouse or someone else instead of as restitution to the crime victim or as a fine to the government.

Finally reputational penalties have similarities to all the other penalties. As with prison and collateral penalties, reputational penalties can mean that employment is ended. Those who commit a crime may find that people are unwilling to hire the criminal because they no longer trust him. While the government imposes collateral penalties, reputations involve voluntary exchange. But there is another difference between prison and collateral penalties versus reputational penalties. As noted earlier, a cost of prison and collateral penalties could involve the loss of productive labor. Reputational penalties seem less likely to have the same problem since reputational penalties are only imposed voluntarily. Jobs where reputations are important in ensuring the worker's behavior will be foreclosed to those workers. Jobs where reputations aren't important won't be foreclosed.

Reputations also have another similarity to fines and collateral penalties in that they apply most to the highest income criminals. People who lose professional licenses tend to be relatively well to do. Reputations, where individuals are paid a premium, almost by definition mean that the criminal is earning a higher income.

B. Comparing the penalties in real life

A criminal's income plays a major role in how he is penalized. Penalties thus end up being extremely progressive. If optimal penalties mean that two criminals who commit the exact same crime should face the same penalty, this penalty structure could mean that prison penalties are right for low-income criminals are too high for high-income criminals. Similarly, penalties that are right for high-income criminals would be too low for low-income criminals. If the later case is closer to the truth, it implies that we are able to get closer to the right penalty simply because fines and reputations, which are readily available for high-income criminals, are lower cost ways of imposing penalties.

Take the case of a bank embezzler from California in the mid-1980s shown in the accompanying table.[6] The total criminal monetary penalty that a person bears from conviction consists of the reduction in legitimate income, the lost income while in prison, fines, legal costs, and the lost time resulting from the legal process leading up to conviction. Assuming the exact same crime in terms of the amount taken and the circumstances under which it was committed, an embezzler with an income one standard deviation above the mean faces a total monetary penalty that is 4.94 times greater than that for an average income embezzler. The analogous bank larcenist faces

[6] John R. Lott, Jr., "Do We Punish High Income Criminals too Heavily?" ***Economic Inquiry***, Vol. 30, no. 4, October 1992: 583-608 and John R. Lott, Jr., "An Attempt at Measuring the Total Monetary Penalty from Drug Convictions: The Importance of an Individual's Reputation," ***Journal of Legal Studies***, Vol. 21, no. 1, January 1992: 159-187.

a 2.1 to 1 ratio over the one with the mean income. Therefore, if the low- and high-income criminals in both cases are to face the same expected penalties from conviction, the high-income embezzler must face a probability of conviction that is only 20.7 percent of that of the mean income embezzler and the high income larcenist a probability that is only 47 percent of that of mean income larcenist. When the corresponding values for two standard deviations above the mean are used, the relative probability of convictions fall to only 11 and 30 percent.

These numbers can underestimate the true differences across criminals. For example, if the real reduction in earnings persisted for five years beyond the last year of probation or parole and the real interest rate was two percent, the present value of lost earnings for an average bank embezzler is $31,020 and for embezzlers with income one and two standard deviations above the mean the present values are $190,818 and $364,028.

Crime Category	Income Level	Income 12 Months prior to Sentencing ($)	Expected Monetary Reduction in Postsentence Income ($)	Expected Percentage Reduction in Postsentence Income (%)	Expected Fine† ($)	Expected Imprisonment Times Presentence Income ($)	Expected Restitution ($)	Total Monetary Penalty ($)	Reduction in Postsentence Income Divided by Total Monetary Penalty (%)	Probability of Conviction as a % of that for the Mean Income if Expected Monetary Penalties to be Equal (%)
1) Bank	1/2 Mean	$8,406	$1,315.21	15.6%	$175	$897	$1,133	$3,520	37.4%	284%
Embezzlement	Mean	$16,813	$6,591.12	39.1%	$260	$1,769	$1,299	$10,010	65.7%	100%
	Plus 1 Std Dev	$49,362	$40,483.72	82.0%	$1052	$4,914	$1,929	$48,370	83.7%	20.7%
	Plus 2 Std Dev	$81,911	$77,231.67	94.3%	$1670	$7,699	$2,500	$89,130	86.7%	11.2%
2) Bank	1/2 Mean	$4,127	$597.07	14.5%	$313	$673	$1,883	$3,468	17.2%	200%
larceny	Mean	$8,255	$3,407.88	41.3%	$334	$1,302	$1,908	$6,932	49.0%	100%
	Plus 1 Std Dev	$14,986	$10,106.95	67.4%	$364	$4,914	$1,948	$14,654	69.0%	47%
	Plus 2 Std Dev	$21,717	$17,678.32	81.4%	$391	$7,699	$1,984	$23,117	76.5%	30%
3) Heroin/	½ Mean	5,580	5,059	91	0	1,077	5	6,140	82	100
cocaine	Mean	11,161	10,260	95	0	2,032	5	12,657	84	49
distribution	Plus 1 S.D.	22,613	22,049	98	90	3,893	6	26,039	85	24
	Plus 2 S.D.	34,065	33,477	98	776	6,100	7	40,360	83	15
4) Heroin/	½ Mean	6,537	5,778	88	24	788	3	6,593	88	100
cocaine	Mean	13,074	12,285	94	0	1,426	3	13,713	90	48
possession	Plus 1 S.D.	24,792	23,989	97	278	2,528	4	26,779	90	25
	Plus 2 S.D.	36,510	35,654	98	1078	4,108	4	40,843	87	16
5) Narcotics,	½ Mean	3,483	3,276	94	162	112	1	3,550	92	100
District of	Mean	6,967	6,751	97	78	166	1	6,998	96	51
Columbia	Plus 1 S.D.	7,329	7,113	97	71	169	1	7,354	97	48
	Plus 2 S.D.	7,692	7,475	97	66	171	1	7,714	97	46

C. Understanding the Trade-off between Government Imposed Penalties and Reputational Penalties.

Government imposed penalties are not simple substitutes for reputational penalties. Increasing government-imposed penalties will reduce the use of reputational penalties, but the trade-off is not one-to-one.

Consider a simple case in which a single person is selling a product to consumers. Consumers value reducing the probability of being defrauded, but reducing that probability is costly. In the absence of government penalties, consumers can reduce the probability of fraud by having sellers face larger reputational losses or higher civil penalties for fraud.[7] Reputational penalties are costly because they arise from the quasi-rents established when consumers pay high prices for high quality-assurance.[8] Civil (and criminal) fines are also costly. In addition to administrative and enforcement costs, fines produce higher prices to customers of even legitimate sellers because higher fines increase legitimate sellers' returns from protecting themselves against false charges of fraud.

At some total penalty level, the cost to consumers of extra fraud deterrence exceeds the incremental expected cost of the fraud. When the cost of fraud is low or when customers have lower cost alternative methods of insuring themselves against fraud, sellers will invest less in reputation and provide little quality-assurance. People who buy cars at flea markets are probably not making systematic mistakes -- they simply value additional quality-assurance less than do people who buy from new car dealers. Flea market customers are more likely to be defrauded, but they also pay lower prices for their cars. They also are probably people who can better evaluate car quality.

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[7] Common law prohibits privately negotiated penalty clauses in civil cases. But if existing efficiency prohibitions are valid, they would seem to apply to government-determined criminal penalties as well. That is, if frauds are not punished sufficiently because civil fines are restricted, the efficient reform is to change the common law prohibition, not to increase criminal penalties.

We also distinguish between two issues: the mix of fines and reputation to police fraud, and whether private parties or government agents are better suited to determine the fine levels through civil or criminal procedures. To address the latter issue, one must examine whether the government has lower costs of determining the fine levels than do parties directly involved in the transactions. Block has argued that criminal fines involve a much more costly process than that involved with civilly imposed fines. Michael K. Block, "Optimal Penalties, Criminal Law, and the Control of Corporate Behavior," 71 Boston University Law Review, (March 1991): 395-419 and John R. Lott, Jr., "The Optimal Level of Criminal Fines in the Presence of Reputation," United States Commission Working Paper (August 1988).

[8] In the Klein-Leffler model sellers either cheat or not with certainty. Lott extends this model by admitting the stochastic nature of the seller's decision to cheat. The size of the reputational bond is set so that the marginal value consumers obtain from a lower probability of fraud is equal to the marginal cost of increasing the bond. Benjamin Klein and Keith B, Leffler, "The Role of Market Forces in Assuring Contractual Performance," 89 Journal of Political Economy, (August 1981): 615-641 and Lott *supra* note 5. See also Michael R. Darby and Edi Karni, "Free Competition and the Optimal Amount of Fraud," 16 Journal of Law and Economics, (April 1973): 67-88.

This argument clarifies why the optimal amount of fraud is not zero: at some point the costs of reducing the probability of fraud exceed the expected benefits. Furthermore, and despite the presence of fraud, there is no externality in this case. Fraud deterrence is purchased until the marginal cost equals the marginal benefit.

A role for criminal penalties arises when a fraud imposes external costs on other parties. However, not all frauds that directly affect third parties represent negative externalities. Suppose a fraud committed by one seller causes the customers of other similar sellers to invest more resources to assure quality and detect fraud. These extra costs *may* represent external costs of the fraud. But they *may not*. The fraud may simply reveal that the net gain to fraud is higher than the customers previously realized, and that greater investments in quality-assurance and fraud detection are optimal. Such customers may demand greater investment in reputation to ensure quality. Learning that it paid for the seller to commit fraud represents an external benefit, not a cost, because the detection of the fraud has informed the customers that the probability of being defrauded was higher than they had realized. The external benefit is not produced by the fraud itself, but rather, by the information that at least one seller considered fraud to be profitable. In fact, the sooner the information about the fraud is communicated, the shorter the period of time that consumers will be making purchases with less quality assurance then they would have purchased had they had the additional information.[9]

External costs arise when the seller committing the fraud has designed new methods that lower others' costs of committing frauds. The fraud may then motivate increased investment in quality-assurance because it increases the likelihood that other sellers will

[9] Consumers also value learning about potential frauds sooner if it is costly for sellers to quickly change their investments in reputation.

also engage in fraud. The external cost arises because one seller's fraud lowers other sellers' costs of committing fraud.

For consumer fraud, externalities, and thus a role for criminal penalties, arise when the fraud represents an innovation in fraud technology. Even in these cases, however, it is the *innovation* that imposes the external cost, not the fraud itself. External costs of the fraud itself arise when the fraud corresponds with an innovation in fraud technology that changes the costs of other frauds occurring. We do not know the fraction of frauds that also represent innovations in fraud technology. But these cases surely represent a subset of actual frauds. For all other consumer frauds, privately contracted penalties will optimally internalize the expected cost of the fraud.

D. Substitution of Criminal Fines for Private Quality-Assurance

Since private quality-assurance mechanisms typically do not completely eliminate incentives to commit fraud, why not increase criminal penalties to deter fraud further? Can greater reliance on criminal penalties further reduce the incidence of fraud?

The answer depends on the substitutability of criminal penalties and reputation in deterring fraud. If criminal penalties and reputation are perfect substitutes, an increase in penalties will have no effect on the incidence of fraud. Increases in criminal penalties will simply reduce customers' reliance on reputation as a guarantor of quality.

However, criminal penalties typically are not perfect substitutes for reputation. As a result, an increase in the criminal penalty will cause a smaller decrease in reputational investments, causing an overall increase in sellers' expected penalties. This will work to decrease fraud occurrences. But if there are no externalities for the criminal penalty to internalize, the penalty increase will also harm consumers and dissipate wealth.

One reason penalties and reputation are not perfect substitutes is that reputation relies on the threatened loss of supracompetitive prices and their associated (quasi-) rents, while reliance on penalties does not. As Klein and Leffler point out, sellers will compete to obtain those rents by providing additional goods and services (e.g., information, comfort, etc.). A dollar increase in fines will deter fraud as much as a dollar of lost reputation, but customers will prefer reputation because the sunk investments that guarantee quality via reputation also yield other services.[10] As long as customers attach a positive value to the services lost from a reduction in sunk investments, a dollar increase in fines must result in less than a dollar reduction in sunk investments if consumers are to remain indifferent. An increase in criminal penalties therefore will result in smaller than dollar-for-dollar reductions in reputational investments.

Another reason reputation and criminal fines are not perfect substitutes in guaranteeing quality is that some types of fraud are very costly for a third party such as a court to arbitrate, for example, the taste of a hamburger.[11] Customers through the prospect of their repeat purchases can police such frauds more efficiently. Therefore, criminal penalties can protect consumers from only a subset of the frauds from which reputation protects them.

Furthermore, the net costs of criminal penalties increase at an increasing rate because the marginal substitutability of criminal penalties for reputation decreases with higher

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[10] For simplicity, this discussion assumes that the probability of detection and punishment are the same for criminal fines and lost reputation.

[11] For discussions of this see Michael R. Darby and John R. Lott, Jr, "Qualitative Information, Reputation, and Monopolistic Competition," 8 International Review of Law and Economics, (June 1989): 87-103 and Klein and Leffler *supra* note 7.

penalties. Fines and reputation are most similar in their ability to protect customers when the frauds can be demonstrated to third parties. At low fine levels, a relatively large portion of the reputational investment protects consumers from the types of fraud for which fines are also effective; higher fines therefore will cause a relatively large decrease in reputation. As the fine level gets larger, however, reputation and fines become progressively less close substitutes because reputation is increasingly relied on to prevent frauds that are costly to demonstrate to third parties. Further increases in fines therefore cause relatively small reductions in reputation and larger increases in the total penalty for fraud.

To illustrate, assume that expected criminal penalties increase to the point where the fines alone completely internalize those damages from frauds that can be demonstrated to third parties. At that point, further increases in fines are unlikely to reduce reputation to zero because only reputation and not fines would be useful in preventing frauds that cannot be readily proved to third parties. Still further increases in fines would result in little or no reduction in the use of reputation.

Even if reputation and fines were perfect substitutes over a broad range of criminal penalties, there would come a level of fines such that the optimal level of reputational bonding is zero. Further increases in fines will then unambiguously result in higher total penalties. In fact, we show that the more extreme estimates of the U.S. Sentencing Commission's recent penalty increases imply that this increase completely offsets our estimated values of the minimum reputational penalties sellers suffer when they are accused of fraud.

Because reputation and criminal penalties are not perfect substitutes, an increase in penalties increases sellers' total expected penalty of fraud. This works to deter some frauds, but it also increases the expected costs of all sellers, as even innocent sellers may have to defend against fraud charges and will take extra measures to decrease the chance of being accused of fraud.[12] Some such measures will involve investing in production processes that provide a higher level of quality-assurance. That is, sellers will choose a higher level of quality-assurance than consumers would otherwise prefer.

An increase in criminal fines will also decrease sellers' abilities to meet demands for different levels of quality-assurance. Different sellers, or different product lines produced by the same seller, can meet the demands of different consumer clienteles by investing in different amounts of reputation. Criminal penalties that increase the total expected penalty, however, discourage sellers from providing low quality-assurance items. Flea markets may be hotbeds of fraud, but they satisfy a clientele of customers who attach a low value to buying additional quality-assurance. Such consumers undoubtedly value not being cheated, but they are relatively unwilling to pay for quality assurance. For example, they may have alternate means to determine quality or may suffer relatively low costs from fraud. Large criminal penalties can eliminate the flea markets, but at a net cost to customers who prefer the low levels of quality-assurance.

[12] The fact that many business people actively oppose increases in criminal penalties for corporate fraud, as indicated by the intense lobbying by the Business Roundtable on this issue, implies that these people expect their sellers to be guilty of fraud, or they expect their sellers' expected costs of defending against charges of fraud to increase with the criminal penalties even when the sellers are innocent. This latter possibility provides anecdotal evidence that Type II errors (accusing innocent sellers) are important for these sellers. (See Aaron Epstein, "Companies Resist Having Punishment Fit Big-Ticket Crimes," Seattle Times and Seattle Post-Intellegencer, (April 22, 1990): A3.)

Robert Crandall, the Chief Executive Officer of American Airlines, illustrates the effects on consumers of imposing high criminal penalties on sellers in the following comment:[13]

> Suppose [regulators] said, "We don't want you guys to lose our bags anymore. And every time you lose a bag we're going to fine you a million dollars." Well, I can fix that tomorrow morning! We will never lose another bag. But it will be very inconvenient to travel. Today you come into Dallas-Fort Worth from all these different places, and in 45 minutes you make your connection and you go out. But in the world of the future, where bags are never lost, I'm going to keep you there for three hours, because I'm going to make sure I get every bag.

Increased penalties will reduce the number of bags lost, but at a cost most consumers would not pay voluntarily.

These arguments imply that higher criminal penalties can reduce the incidence of fraud, but at a cost. At the very least, higher criminal penalties force some consumers to pay for a higher level of quality-assurance than they would otherwise be willing to pay. It is also likely, however, that higher criminal penalties increase *all* consumers' costs, as *all* sellers' costs rise. This latter conclusion is supported by observation. Criminal penalties could conceivably be lower-cost guarantors of quality. But the fact that we observe very little private arbitration or other third-party enforcement of quality indicates that the additional cost of third-party penalties exceeds the benefit.[14]

These conclusions directly contradict the current conventional wisdom on the topic, as represented by the U.S. Sentencing Commission's guidelines that substantially increase criminal penalties for fraud. To this point, our argument has been based on the

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[13] Quoted in Time, October 28, 1991, p. 18.

[14] One third-party role we do not rule out is the role of a governing body to enforce agreements, as privately arbitrated decisions can be turned over to the public legal system to enforce. But it does not follow that governments have a comparative advantage in determining the penalty level upon conviction (see Lott supra note 5). Individuals are likely to have better information than a government about how much they value higher levels of quality assurance.

premise that private contracting controls and penalizes sellers that commit fraud. In the following sections, we present empirical evidence that supports this premise. The private wealth loss suffered by sellers alleged, indicted, or convicted of fraud is statistically significant and much larger than court-imposed penalties.

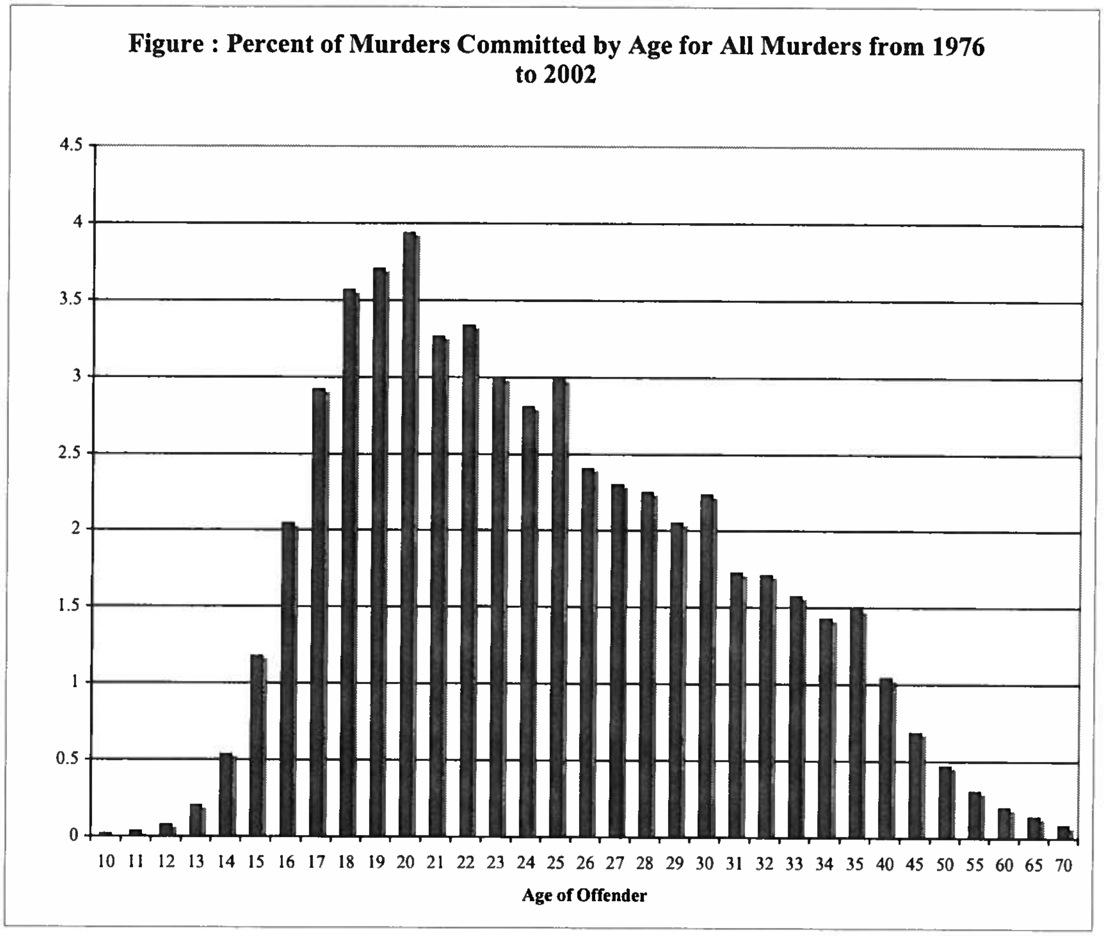
E. The Length of Prison

So how long should prison sentences be? Higher fines, greater reputational losses, larger collateral penalties, and longer prison sentences deter people committing crimes. But when these penalties are imposed can have a big difference on their level of deterrence. Fines, reputation, and collateral penalties can be entirely imposed on the criminal on the day that he is convicted. By contrast, while prison sentences can start right away, the punishment takes place over a number of years. The reason why this is particularly important for criminals is that there is strong empirical evidence that criminals have much higher discount rates than the general population. Compared to other people, criminals are unwilling to wait to have their desires satisfied. Discount rates of 30 percent or more seem quite plausible for criminals.

If a law-abiding citizen had a real discount rate of 4 percent, he would be willing to pay about \$0.68 for a dollar ten years from now. But a criminal with a discount rate of 30 percent would only be willing to pay \$0.07 for that same dollar. The problem is that means longer prison terms represent relatively little additional penalty for criminals. An additional year of prison twenty years from now is valued at less than one percent of the disutility of a year of prison today.

What this says is that the discount rate used to evaluate the cost of prison for society is likely to be radically different from the discount rate used to estimate the increased deterrence from adding an additional year onto a criminal's sentence.

There are also two reasons for prison. The first is deterrence, and the high discount rate for criminals is relevant for that. The second is incapacitation, keeping criminals from committing more crimes. A relatively small percentage of the population commits most of the crimes. Whether it is that certain people are callous to the harm the impose on others or it is simply their high discount rates, certain people are much more prone to committing crime than others. However, crime is a young person's activity. Young males who are 18, 19, and 20 years old commit most murders. By the time a criminal is 45 he is likely to commit crime at about a sixth the rate that he would have done so at age 20 (see attached figure, unfortunately this type of data is only available for murder). This reduced incapacitation effect also reduces the benefit from longer prison sentences.



III. The Importance of Different Law Enforcement Strategies

Arrest rates of criminals is usually the single most important factor in reducing every type of crime. Sensational topics like the death penalty may get the most media attention, but it is everyday police work that really makes a neighborhood safer. Changes in the arrest rate account for around 16 to 18 percent of the drop in the murder rate.[15] Conviction rates explain another 12 percent. Arrest and conviction rates have an even

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[15] David B. Mustard, "Re-examining Criminal Behavior: The Importance of Omitted Variable Bias," Review of Economics and Statistics, Vol. 85 (2003): 205-211.

larger effect on other types of violent crime, while their effect on property crimes is often two or three times larger than for violent crime overall.

While boosting arrest rates indisputably has deterrence, the evidence on longer prison sentences is much less clear. The reason is simple: methodologically, it's surprisingly difficult to measure how long criminals expect to be in prison. The length of a criminal's sentence is often much longer than the actual time served. Furthermore, the time that is served varies widely, even for a single type of crime, depending on a suspect's criminal history and the severity of the offense. Unfortunately, this kind of data is not readily available to researchers.

Arrest and conviction rates and expected prison sentence lengths all deal with deterrence—the cost to the criminal of committing a crime. But some people commit crimes despite those threats. Obviously, locking up the most crime-prone individuals will further decrease crime by keeping habitual criminals off the streets. Indeed, putting more people in prison explains another 10 to 12 percent of the drop in crime rates.[16] Other factors also matter. Overall, the rise in executions during the 1990s accounts for about 12 to 14 percent of the overall drop in murders. Right-to-carry laws explain around another 6 percent.

Simply being arrested or convicted, even without a prison sentence, carries its own substantial penalties. Indeed, as noted earlier, these reputational penalties are the most meaningful penalties that many criminals face.

From a cost-benefit perspective, the ultimate question is: what did it cost for these different policies to produce their reductions in crime? Some rough calculations are

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[16] John R. Lott, Jr., Freedomnomics (Regnery Publishers, 2007); John R. Lott, Jr., More Guns, Less Crime (University of Chicago Press, second edition, 2009), Chapter 9; and Mustard, ibid.

possible. For police, a one percent increase in non-unionized police with arrest powers lowers the murder rate by less than 0.65 percent.[17] With starting police salaries averaging just below $40,000 per year (with benefits costing about $55,000) and a one percent increase in police equaling about 7,000 officers, that comes to about $385 million (not including training costs). Assuming a value of life at $4 million, the value of reduced murders is around $423 million. Other estimates have been made of the cost of crime by looking at jury awards for injuries to victims.[18] Looking at these different types of crime puts the value from additional police at closer to $500 million.

While police are the single most important factor for reducing crime, concealed handgun laws might be the most cost effective. Increasing the percent of the adult population with concealed handgun permits by one percentage point reduces the murder rate by about four percent.[19] Each additional law enforcement officer has a much bigger effect on the amount of crime than each additional citizen with a concealed handgun permit, but the cost of each additional law enforcement officer is also much bigger.

If permit holding policy was a national one, increasing the number of permit holders by about 2.25 million would imply 650 fewer murders in 2008 and the saving from fewer lives lost would equal about $2.6 billion. That comes to a benefit of about $1,156 per permit holder. The costs to state a government from issuing permits is essentially zero as most states actually make money on issuing concealed handgun permits. Given that someplace between 70 and 90 percent of permit holders already own a handgun, the primary cost of having new permit holders involves the cost of training (and about half

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[17] Lott, More Guns, Less Crime (University of Chicago Press, third edition, forthcoming 2010), Chapter 10.
[18] Miller, Ted R., Mark A. Cohen, and Brian Wiersema. *Victim Costs and Consequences: A New Look.* Washington, D.C.: National Institute of Justice, 1996.
[19] Lott, More Guns, Less Crime (University of Chicago Press, second edition, 2009), Chapter 9, table 9.3.

the states don't require formal training, though individuals appear to train even when it isn't required). An eight-hour training course can easily cost two to three hundred dollars. In addition, there are the individual's time costs to go through training.

Externalities from Punishing Criminals

While penalties will deter some criminals from committing crime, penalties can also cause criminals to shift to other types of crimes or to move to other areas to commit them. Ignoring these complications can bias estimated benefits or costs of law enforcement activity.

Suppose the death penalty were imposed on a crime such as robbery. If a robber thought that he was going to get caught by the police, he might find it in his interest to kill all the witnesses to his crime. He can only be executed once and he already faces execution for committing the robbery. In contrast, leaving the witnesses alive means that it might be easier for police to catch and convict him. The only factor that might work in the other direction is that police might spend more resources trying to catch a murderer than a robber and so murdering people could actually still increase the robber's expected penalty.

On the other hand, the death penalty for murder might also work to reduce the rate that other crimes are committed. Because capital punishment can be imposed if a victim dies during the commission of a rape, robbery, or aggravated assault, statistics show the death penalty also acts as a deterrent to these crimes as well.[20] This, however, doesn't mean that the death penalty should be applied directly to these crimes.

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[20] Lott, More Guns, Less Crime (University of Chicago Press, second edition, 2000), Chapter 9.

The point is that externalities mean that one has to think more broadly in evaluating the costs and benefits of criminal penalties. In this case, one can't measure the benefits of the death penalty by simply looking at the impact that this penalty has on robberies. Similar concerns have been pointed out for other penalties, such as three-strike laws, where there is also evidence of small increase in murders when criminals face life sentences.[21]

These types of "spillover" effects can also be seen in private actions to stop crime. Take right-to-carry laws, which allow law-abiding citizens to carry concealed handguns. While violent crimes fall after these laws are adopted and after more people get permits, there is some evidence that property crime rise. Criminals appear to switch out of violent crimes where criminals come into direct contact with victims, crimes that would be affected by the victims being able to defend themselves, and into property crimes where there is no contact between criminals and victims. So criminals may move out of a crime such as robbery and into larceny.

But criminals might also move from one jurisdiction to another. Stephen Bronars and I found significant evidence that criminals move out of areas where concealed handguns are legalized.[22] Our study analyzed counties that border each other on opposite sides of a state line. In such cases, counties in states that adopt right-to-carry laws see a drop in violent crime that is about four times larger than the simultaneous increase in violent crimes in the adjacent counties without such laws. The spillover was greatest when you had two urban counties across the border from each other. These results imply that

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[21] Thomas Marvell and Carlisle Moody. 2001 "The Lethal Effects of Three-Strikes Laws" Journal of Legal Studies 30:89-106.

[22] Stephen Bronars and John R. Lott, Jr., ""Deterrence, Right-to-Carry Concealed Handgun Laws, and the Geographic Displacement of Crime," American Economic Review, May 1998, 475-479.

looking narrowly at the change in crime rates for states that adopt these right-to-carry laws will over estimate the benefit from the law.

Other types of Externalities Regarding Crime

In the early 1980s, James Q. Wilson and George L. Kelling articulated a persuasive new theory about crime.[23] They argued that petty crime such as window breaking creates a vicious cycle whereby law-abiding citizens in a deteriorating neighborhood continually leave, to be replaced by criminals. If crime is rampant as evidenced by broken windows, criminals find it even easier to commit crimes with fewer law-abiding citizens around to witness them. So the key to fighting crime is to begin by cracking down on petty offenses. Some experts credit the huge drop in crime in New York City during the 1990s to a "broken windows" policy that strictly enforced laws against minor crimes like vandalism, public drunkenness, panhandling, and public urination.

How the cost of catching criminals may vary with the size of the crime

Prior to the US Sentencing Commission corporate penalty guidelines in the early 1990s, those who committed major environmental crimes—such as a massive oil spill from a tanker running aground—had to pay fines equivalent to the amount of the damages. In contrast, for minor environmental crimes—for example, dumping a barrelful of waste off the side of a ship—the fines were many times greater than the damage estimates. The commission reversed this relationship so that penalties for the more serious crimes became many times bigger than the damages. Understanding this pattern helps understand how the costs of catching criminals can sometimes vary with the harm done from the crime.

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[23] James Q. Wilson and George L. Kelling, "Broken Windows," The Atlantic Monthly, March 1982.

While the new regulations seem logical, there was a sound reason for the earlier policy. A major oil spill is something that is nearly impossible to hide—we will know with near-certainty that the crime occurred and which ship was responsible. But it is much more difficult to identify the culprit—or even to detect the crime—for a smaller transgression like dumping just a barrelful of waste off the side of a boat. That's why the Sentencing Commission's policy change was actually counter-productive; if we want to create disincentives to environmental crime, we need to ensure that small-time offenders face relatively harsher penalties which act to offset the high probability that they'll get away with their crime.

Conclusion

Penalties, police, and private actions by individuals all impact crime rates. Prison is all too frequently the only focus of legally imposed penalties, though there many other ways that criminals are punished. On the enforcement side, there are different choices there also. In law enforcement there are many areas where it won't be possible to quantify the benefits or costs of different policies, but hopefully those areas where numbers are available can reduce the uncertainty facing decision makers in their final analyses. At the very least, the numbers that are available give decision makers a rough idea of how large other considerations will have to be to offset those factors that can be measured.