Two Types of Risk

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Abstract

When new technologies create risks, government agencies use regulations to control the risks. This paper advances a method of evaluating a democracy’s regulation of risks. It assumes that a regulatory agency should act as the public would act in ideal conditions for negotiation if the public were rational and informed. The method relies on decision theory and game theory to ascertain whether a regulation has the public’s informed support.

The Occupational Safety and Health Administration’s regulation of exposure to carcinogens in the workplace illustrates the account of regulation. The illustration draws attention to a distinction between physical and information-sensitive risks. Regulations guided by the physical sciences alone may overlook the value of reducing information-sensitive risks. These risks exist objectively, and rational people generally have an aversion to them. An information-sensitive risk and an aversion to it may persist after acquisition of all available relevant information. Democratic regulation justifiably aims to reduce such risks.

Two Types of Risk

Advances in science generate new technologies. However, new technologies create new risks. What principles should guide a government’s regulation of risks arising from technology? Appropriate regulation depends on the type of risk. This paper distinguishes two types of risk and explains their significance for regulation.

1. Introduction

Government regulation of risk is a multidisciplinary topic.[[1]](#footnote-1) This paper offers a philosophical assessment of regulatory policy. It presents a framework for a systematic evaluation of regulations and their classification as either reasonable or unreasonable.

The paper’s points about regulation use a normative model for government regulation to reduce risk. The model is an idealized regulatory context with assumptions that permit precise assessments of regulations. The model guides regulation in complex, realistic contexts that do not meet its assumptions, by providing a partial account of reasonable regulation that analyzes the operation of some factors that justify regulations and that controls for other factors.[[2]](#footnote-2)

The model applies decision theory and game theory to government regulation of risk. Decision theory analyzes an individual’s appraisal of a regulation, and game theory aggregates individuals’ appraisals of the regulation into a collective appraisal. A reasonable regulation is a solution to an ideal negotiation problem among informed and rational citizens who personally appraise regulatory options.

A review of the Occupational Safety and Health Administration’s regulation of workplace exposure to the carcinogen benzene illustrates the model’s method of managing risk. A crucial task is objectively establishing the existence of risks and the effectiveness of methods of reducing them.

2. Risk

In an analysis of a person’s stand on a regulatory issue, say, oversight of nuclear power plants, a salient consideration is risk, a probability of an adverse event. This section distinguishes varieties of risk and explains attitudes toward risk and their role in justifications of regulations.

Risks rest on probabilities. Probability theory recognizes (at least) two types of probability, physical probability and evidential probability. Physical probabilities rest on physical facts that may be unknown, whereas evidential probabilities rest on evidence in someone’s possession. In a trial of a person for a crime, the physical probability that the defendant is guilty is either 0% or 100%. It is not sensitive to information. In contrast, the evidential probability that the defendant is guilty varies with information presented during the trial. At an early stage of the trial, the probability may be 10%. At the end of the trial, it may be 90%. A typical evidential probability is personal, because it depends on a person’s evidence, and is accessible, because a person knows the evidence she possesses. When evidence is scanty or mixed, evidential probability may lack a sharp value. Evidential probability becomes impersonal when, instead of being relative to a person’s evidence, it is made relative to a body of evidence, which may be collected from multiple people.

Because a risk is a probability of an unwanted event, corresponding to the two types of probability are two types of risk. One is grounded in physical probabilities and is independent of information; the other is grounded in evidential probabilities and is information-sensitive. A reduction in either type of risk may justify a regulation. Reducing physical risks generally requires new procedures that alter the physical environment, for example, wearing suits to protect against radiation. Methods of reducing information-sensitive risks may collect data that when added to available evidence lowers the evidential probability of harm.[[3]](#footnote-3)

Physical and information-sensitive risks share many features. This section reviews some of their common features and also points out salient differences. It treats especially risks that in a decision problem arise from an option’s adoption.

An option carries a risk if a possible consequence is bad, and the risk’s size is greater the worse the possible consequence and the greater its probability. An option’s risk also depends on the option’s distribution of chances for good and bad consequences. The greater the variance of the utilities of possible consequences, the greater the risk, other things being equal. In the case of information-sensitive risk, an option’s risk depends on the extent of the evidence that generates the distribution and also on the robustness of the probabilities of consequences with respect to changes in information. The more extensive the evidence, and the more robust the probabilities, the less the risk. An option’s physical risk has two components: chances for good or bad consequences and distributional characteristics of these chances. Information-sensitive risk has these two components, involving evidential probabilities instead of physical probabilities, and a third component comprising characteristics of evidence such as its weight.

Most people have an aversion to risk and so are averse to options that bring chances of bad consequences. Of course, benefits sometimes offset risks, so a person’s overall evaluation of an option weighs risks against benefits. The evaluation depends on the option’s expected utility, all things considered, including the risk that the option generates.[[4]](#footnote-4)

Aversion to risk targets both physical and information-sensitive risk. Aversion to physical risks leads people to adopt safety measures such as replacing worn tires with new ones. Aversion to information-sensitive risks leads them to be cautious when confronting the unknown, such as the depth of water flooding across the highway ahead. Not knowing its depth, a driver may be averse to trying to cross, even if in fact the water is shallow and will not make his car stall.

Attitudes toward risk vary, but a typical person has a basic aversion to risk that does not derive from other aversions. Because of its independence from other aversions, a rationally held aversion to risk is relatively insensitive to changes in information. Education and experience do not dramatically change the aversion.

An aversion may target risk in general or a particular risk. An aversion to risk in general is stable, but an aversion to a particular risk is sensitive to information about the risk. If information discredits the risk, then the aversion vanishes. Missing a flight removes the risk of injury during the flight, for example, and the aversion to that risk. Risks have sizes that depend on probabilities and utilities. New information may lower an informative-sensitive risk and so aversion to it. A typical person has a basic aversion to a risk of a certain size, and the aversion is relatively constant with respect to information. However, aversion to a particular information-sensitive risk is not basic, and circumstances and new information affect the aversion as they affect the risk’s size. A physician’s assurance that a treatment is safe lowers the information-sensitive risk of undergoing the treatment and aversion to the risk.

An aversion to risk does not entail an aversion to every particular risk. A person averse to risk may want some particular risks. For instance, a generally cautious person may enjoy the risk of mountain climbing. Aversion to pain similarly fails to extend to all of pain’s instances. A person may welcome the regret he feels after having made a family member suffer. The object of an aversion has a propositional representation. An aversion to risk leaves open ways of making a risk definite. A particular risk’s features affect a person’s attitude toward it.

A theory of rational choice simplifies treatment of good and bad prospects by treating both together and may generalize risk by taking it to arise from chances of desirable events as well as from chances of undesirable events. Generalized, a risk is any chance that a good or bad event occurs. Given this generalization, aversion to risk is aversion to chance. Analogies between aversion to chance and aversion to risk in the narrow sense motivate the generalization of risk. As people prefer certainty that a bad event will not occur to a chance that it will occur, they also prefer certainty that a good event will occur to a chance that it will not occur. Both preferences manifest aversion to chance. By adopting the generalized sense of risk, principles concerning risk may dispense with a benchmark separating the desirable from the undesirable. Gaining $10 and gaining $10 by chance have the same monetary consequences, but gaining the money by chance ran the risk of not gaining it. Not gaining it involves an outcome bad only using gaining $10 as a benchmark. Taking a risk as a chance of a relevant event dispenses with the benchmark. Generalized, a risk can be a chance for a benefit as well as a chance for a loss with respect to a benchmark.

Given an aversion to chance, evaluating a possible world in which good and bad events happen by chance assesses chance’s operation and not just the consequences of its operation. The world’s value depends on the chances that yield good and bad events as well as those events. Gaining $10 by chance and gaining $10 for sure have the same monetary consequences, but a consequence of the chance includes running a risk of not gaining $10. An option’s consequences include the risk the option carries, and the option’s evaluation includes an evaluation of that risk.

The value of the risk of an event’s happening is the product of the probability and the utility of the event’s happening. However, the values of risks are not additive because two chances of harm may produce certainty of harm. Suppose that a harm arrives if a coin toss yields heads, and also if the coin toss yields tails. The values of the two risks are not additive because together the two risks guarantee the harm.

To evaluate an option, this paper follows financial management’s practice of evaluating separately an option’s risk and its other consequences. It adds to the option’s expected utility of consequences besides risk, an evaluation of the part of an option’s risk not evaluated by the option’s expected utility of consequences besides risk. A component of an option’s risk covers interaction of risks the option generates. This component’s evaluation supplements an evaluation of an option that adds the values of chances the option provides for possible consequences besides risk. Adding the values of these chances evaluates the option’s risks except for the interaction factor. Taking account of the interaction factor, that financial management calls risk although it does not comprise all components of an option’s risk, completes the option’s evaluation.

For example, a more extensively tested treatment for an aliment has a lower information-sensitive risk of side effect than has a less extensively tested treatment with the same probability of cure and of side effect. The two treatments have the same expected utility of consequences besides risk, but the more extensively tested treatment is less risky. Given an evidential probability of harm, increasing the extent of the relevant evidence, by, for example, increasing the sample on which the probability rests, reduces information-sensitive risk.

In financial management, the separation of risk and expectation concerning consequences besides risk produces the risk-return method of assessing investments. It divides an investment’s prospects into risk and (expected) return. The method evaluates an investment’s expected return, and then adjusts the result using an evaluation of the part of the investment’s risk not covered by its expected return. It calls the second step the adjustment for risk, although expected return by itself partially appraises the investment’s risk. Consider $10 for sure and a 50% chance of $20. These options have the same expected return, but the chance runs a risk of gaining nothing. The risk decreases the utility of the chance, given a typical aversion to risk. Expected return appraises the chance but not every feature of its risk. Risks are chances, probability-utility products appraise chances, and a risky investment is a collection of chances for possible returns. However, the values of an investment’s chances concerning money do not sum to the investment’s utility. The investment’s utility depends partly on expected return and partly on risk, more precisely, the component of its risk not appraised by its expected return.[[5]](#footnote-5)

The risk-return method of evaluation treats risk as an attribute of an investment and treats aversion to risk as an aversion to that attribute. A financial planner may use a questionnaire to assess an investor’s attitude toward risk and toward return, and may use financial data to obtain an investment’s risk and expected return. Investing in bonds has less risk but a lower expected return than investing in stocks. Because of an investor’s aversion to risk and willingness to reduce returns to reduce risk, a financial planner may recommend investing in bonds rather than in stocks. The reduction in risk compensates for the lower expected return.

To assess an investment’s expected return and risk, a financial planner typically uses data about the investment type’s past returns and their variation. Financial experts debate measures of risk, measures of aversion to risk, and the method of combining aversion to an investment’s risk with attraction to its expected return to obtain an overall evaluation of the investment. A common *mean-risk* formula begins with the investment type’s mean return and subtracts from it a proportion of the standard deviation (the square root of the variance) for returns from the investment type. That is, from expected return it subtracts risk. Raiffa (1968: 55–56) presents and criticizes this mean-risk formula. Despite flaws, the formula may be useful for rough appraisals of investments in a limited range of cases.

Another method of evaluating investments uses the *coefficient of variation*: σ/μ, where σ is the standard deviation for returns from the investment type, and μ is the mean of returns from the investment type, or the investment’s expected return. The smaller the coefficient of variation, the better the investment. A refinement of the coefficient of variation is the *Sharpe ratio*: (*R* – *Rf*)/σ, where *R* is the investment type’s expected return, *Rf* is the risk-free rate of return, and σ is the standard deviation for returns from the investment type. The factor *R* – *Rf* is expected return in excess of return obtainable without risk, or *excess expected return*. The Sharpe ratio, as the previous two formulas, uses standard deviation to measure risk. It uses division to combine assessments of an investment with respect to excess expected return and with respect to risk. The larger the ratio, the better the investment.

The nature of risk and aversion to it is a large topic that this section treats only briefly to set the stage for the paper’s points about regulation of risks. It uses risk-return evaluations of investments only to illustrate risk’s role in evaluation of options, and so does not explore issues concerning limitations and refinements of this method of evaluating investments.[[6]](#footnote-6)

3. Deciding for the Public

In the United States, Congress delegates to regulatory agencies, such as Occupational Safety and Health Administration (OSHA), responsibilities concerning public safety and health. A regulatory agency’s charter issues directives and imposes constraints. Typically, an agency’s charter instructs it to use the best available information to impose regulations that advance the public’s interests, provided that the regulations are economically feasible. OSHA has the job of using technological information to impose standards that reduce work place hazards. It surveys information on hazardous technologies to form an expert assessment of the risks involved and uses this expert assessment and the public’s goals, as articulated by Congress in regulatory directives, to decide on standards for the technologies.

Instead of evaluating regulations that agencies impose, taking conditions to be just as they are, this paper makes some simplifying assumptions. The assumptions create an idealized context of evaluation, or a normative model. Models in a normative field, such as the study of rationality, use idealizations, as do models in science, to make investigations tractable. This paper’s normative model provides a partial account of reasonable regulations that analyzes the operation of some factors that make regulations reasonable and that controls for other factors. Subsequent work may discharge the model’s assumptions to generalize it for realistic cases.

In the model, a democratic government, with legislative, judicial, and executive branches, delegates regulatory authority to federal agencies. Elected legislators create and direct these agencies, and the agencies are subject to executive orders and judicial oversight. The model assumes that the delegation of authority to agencies is reasonable, and that a constitution and agencies’ mandates adequately protect individual rights, so that an agency issuing reasonable regulations acts morally.

Regulatory agencies do not effectively address all public safety issues. For example, a safety measure may benefit only a minority of a country’s population. Perhaps only a minority is at risk from an allergen in food products, but its regulation imposes costs on all. The majority may decline those costs. Addressing the safety issue through the legislative branch of government may not be effective. Protecting the interests of the minority may require putting the issue in the hands of the executive or judicial branch of government. Executive orders tackle some safety issues. Product liability laws give the courts authority to decide additional safety issues. Good governmental design assigns some safety issues to the legislature and others to the administration and to the courts. The model assumes that the legislature assigns appropriate regulatory issues to an agency. Hence in the model an agency’s adoption of policies that represent the people’s will respects people’s rights.

In the paper’s regulatory model, a regulatory agency’s job is to impose regulations that the public would adopt if it were rational, informed, and in ideal conditions for negotiation. This objective takes the agency as a representative of the people acting on behalf of the people. The agency functions democratically when it imposes regulations that rational and informed citizens would achieve on their own in ideal conditions for negotiations that include, as in elections of representatives, equal voices for citizens.

Regulatory agencies fulfilling their charges often make decisions that the public, lacking information, would not reach on its own. For example, an agency may declare a technology safe although the public harbors doubts. An agency’s goal in the model is not to act as the public would act. It has the goal of making decisions that the public would make for itself if everyone had expert information and decision-making tools. A regulatory agency deliberates on behalf of the public. Its institutional objective is to bring to bear available information and principles of rational deliberation to serve the public’s goals. Agencies are trustees acting for the public.[[7]](#footnote-7)

Because in the model regulatory agencies use expert information to serve the public’s goals, they do not evaluate a policy using citizens’ uninformed assessments of the policy. They construct an informed utility assignment for a person that replaces her assessments of risks with expert assessments. Intrinsic utility analysis, as in Weirich (2001), handles this task by dividing an agent’s assessment of an option into parts, and replacing the part assessing an option’s risk with an expert’s assessment of the risk. A regulation’s evaluation uses the theory of cooperative games to aggregate individuals’ assessments of the regulation. In the model, a government regulatory agency aims for the outcome that a democratic public would achieve given informed and unconstrained rational negotiation. The outcome of such ideal negotiation is the solution of a cooperative game, as Section 4 explains. Because the regulation’s evaluation uses individuals’ assessments of the regulation, made using personal probability assignments of the regulation’s possible outcomes, it does not need a collective probability assignment for the possible outcomes. Informed personal opinions suffice for informed personal utility assignments to regulatory options. The game’s solution aggregates those personal utility assignments. The model is parsimonious in its use of collective counterparts of the elements of a person’s evaluation of an option.

Individuals evaluate tradeoffs between conflicting goals concerning safety and prosperity. For example, a person may decide to forgo purchase of a safety device for herself to save money. The model uses a person’s own way of comparing values, that may be incomparable from an impersonal perspective because their comparison varies from person to person, to settle tradeoffs between goods such as safety and productivity. A government justifiably imposes a regulation if equal citizens when rational and informed would agree to the tradeoffs the regulation adopts.

Applications of the paper’s model of regulation confront problems concerning acquisition of data about citizens’ preferences and problems such as the unreliability of market data or information about willingness-to-pay. An agency may lack information about the public’s goals and their importance so that it does not know how to serve them, or it may lack crucial practical information held by private citizens and corporations. The paper’s model assumes the availability of the data required by its decision procedures. Models promote progress despite such idealizations because they set the stage for future research that removes the idealizations. For example, when an agency lacks information, an appropriate subordinate objective is regulation that probably has the public’s informed consent.

An objection to regulations that express the people’s will notices the possibility of conflict between the people’s will and its interest. An agency may know that the public, given its limited information, wants a regulation but may believe that the public’s fears are not grounded in scientific fact. How should the agency handle a conflict between the democratic duty of responsiveness and the fiduciary duty of promoting the public’s interests? If it is responsive to the fully informed will of the people, and the people’s basic goals are rational, its responsiveness promotes the people’s interest. The people’s will and its interest do not conflict if people are rational and fully informed. Suppose, however, that available information is incomplete so that given it a rational public nonetheless does not see its interests. In this case, a regulatory agency, being similarly ignorant of the public’s interests, does not have evidence of a conflict of duties. The conflict does not have a practical bearing on its regulatory actions.

Regulatory agencies such as OSHA may legitimately have objectives besides deciding as the public would decide for itself if it had expert information. An agency’s Congressional mandate, for instance, may give it additional charges. Then it must adjudicate a resolution of its conflicting objectives. In cases of conflict, regulatory agencies may for good reasons fail to realize fully the democratic objective of regulation. That objective, nonetheless, furnishes a valuable guideline for regulatory practice and for improvements in regulatory institutions. Hence explicating the democratic ideal of serving the public’s goals contributes to regulatory theory. The paper’s model explicates the ideal under the assumption that the public’s goals are reasonable and that a regulatory agency has the single primary objective of serving the public’s goals so that trustee decisions serving those goals are reasonable.

Regulatory decisions, taken as trustee decisions, use expert information to reduce risks to which citizens are averse. This form of representation is not paternalistic because it respects the public’s basic goals, assuming that the goals are rational. Representative regulatory agencies take the public’s basic goals for granted and use available information to serve those goals.

Sometimes a person desires a situation but then, when the situation obtains, desires it no longer. Experiencing the situation removes its attractiveness. A person may desire tasting an attractive dessert but may discover, after a bite, that its taste is unappealing. A basic goal is independent of other goals and so independent of information bearing on the realization of other goals. Basic goals, if rational, survive confrontation with all available information. An agency aims to serve citizens’ basic goals because their derived goals may change when they review all available information. Although the citizens’ desire for a derived goal may abate if they were to review rationally all available relevant information, their rational basic goals are constant.

A rational basic aversion to risk does not change with new information. Hence if a rational citizen has a basic aversion to risk, new information will not diminish that aversion. It is robust. Consequently, an agency may focus on assessment of the risk itself, and count on the presence of an aversion to it persisting given all available information. It may conclude that an information-sensitive risk and a basic aversion to it would persist if the public were to rationally assess all available relevant information. Such persistent aversions may justify regulations.

According to this section’s normative model, a regulatory agency’s mandate assigns appropriate regulatory issues, constitutional limits and an agency’s mandate adequately protect individual rights, an agency has the data it needs to decide on behalf of the public, and the public has reasonable basic goals. These assumptions support the model’s main assumption that an agency should impose regulations that represent the people’s will. Under the assumptions, democratic regulations are feasible, do not conflict with other obligations, and so are reasonable.

4. Evaluating Regulations

The Precautionary Principle states that if an action may, but does not demonstrably, cause harm, a reasonable regulation may nonetheless prohibit the action. An action that the principle targets may not generate a physical risk of harm but still creates an information-sensitive risk of harm because the action is not demonstrably safe; with respect to available information, the action has a significant evidential probability of harm. The Precautionary Principle responds to information-sensitive risks, but imprecisely, because it does not state necessary and sufficient conditions for regulatory measures.

Within the paper’s normative model, a reasonable regulation is a solution to a negotiation game among citizens, given that they are rational, informed, and equal. Cooperative games, where joint action is possible, and negotiation games in particular, have controversial solutions, so obtaining necessary and sufficient conditions for reasonable regulations from game theory is a project rather than finished work. However, some features of solutions to ideal games are well established, such as Pareto optimality, or efficiency. Also, some ideal games have restrictions that simplify identification of a solution. The model yields a definite verdict about a regulation in cases where the negotiation game has a clear solution, and in cases where all plausible candidates for a solution support the regulation.

The negotiation game for a regulatory issue specifies the citizens and the regulatory options. The options include imposing a regulation, and not imposing it, and may include a variety of regulations and adjustments to regulations that citizens propose to promote consensus. The game specifies the possible outcomes of negotiations, the citizens’ utility assignments to the possible outcomes, and the citizens’ information about their game and each other. In an ideal game the citizens are fully informed about their game and each other. Their information about each other includes information about their rationality, their game, their information, and other relevant psychological features.

Bargaining over a regulation may modify the regulation to lighten its burden. Workers may accept lower pay to cover the costs of safety regulations, and consumers may accept higher prices to cover the costs of food inspections. Modifications of regulations function as side payments to win support for a regulation. All gain from legislative settling of regulatory issues. Each gains from having a process of reaching resolutions even if not from every particular resolution. All have an incentive to adopt a method of reaching agreements.

In the ideal negotiation game that citizens play about a regulatory issue, only an agreement produces an outcome, either a regulation or the status quo. Thus, the game is a bargaining problem, rather than a coalitional game, although coalitions may lobby for proposals.[[8]](#footnote-8) The participants have informed utility assignments concerning the game’s possible outcomes, and their utility assignments are interpersonally comparable. The participants in a pre-game stage adopt a method of reaching an agreement in the current and future bargaining problems about regulatory issues. They settle a method of reaching agreements in a series of negotiation games. An outcome’s collective utility is the sum of personal utilities the participants assign to the outcome. Maximizing collective utility, that is, realizing an outcome with collective utility at least as great as any other outcome’s collective utility, maximizes each citizen’s prospects in the series of negotiation games, and so the citizens agree to this method of settling a game’s outcome. Maximization of collective utility then yields the solution to their bargaining problem about a regulatory issue. The model adopts collective-utility maximization not as a general method of resolving social issues but just as a method of resolving regulatory issues in a constitutional and legislative context that protects individuals’ rights.

A regulatory agency extends democracy’s goal of equal voice from election of representatives to resolution of regulatory issues. So each citizen’s utility assignment has the same weight in the calculation of collective utility. Cost-benefit analysis sometimes uses dollars to approximate interpersonal utilities but then omits nonmonetary values. Collective utility omits nothing that matters to people. According to collective-utility maximization, a reasonable regulation has benefits that outweigh its costs, given a comprehensive assessment of costs and benefits that includes all factors that matter to citizens. Some theorists call such a comprehensive assessment of a regulation a multiattribute assessment of it.

The paper’s model assumes that maximizing collective utility yields a solution to an ideal negotiation game. Why will those a regulation hinders agree to it if it maximizes collective utility? Bargainers reach an agreement because each wants an agreement. The model assumes that citizens want to resolve a regulatory issue and so have an incentive to reach an agreement even if it only preserves the status quo. In an ideal negotiation game, citizens have to decide on a regulatory issue, and, knowing their disagreement, first decide how to decide. If each possible resolution of a regulatory issue imposes a cost on some people, then a consensus backs only a policy for reaching agreements that offers those who bear the burden of an agreement hope of compensation in future agreements. Not knowing the future, participants agree to a policy for regulatory issues that maximizes collective utility, expecting that they will gain from that policy in the long run. Although not behind Harsanyi’s veil of ignorance, they adopt the policy because, being ignorant of the future, the utilitarian policy offers the best long-term prospects of meeting their personal goals. Majoritarian methods of reaching agreement approximate maximization of collective utility, but maximization of collective utility, in contrast with majoritarian methods, prevents wasteful cyclical resolutions of regulatory issues. So in ideal negotiation games, people settle on maximization of collective utility, reasoning that in the long run they will profit from this method of resolving regulatory issues. Under the law, a citizen sometimes wins and sometimes loses, but overall expects to gain more than lose.

To evaluate a regulation, the paper’s model frames the regulatory issue, specifies the negotiation game concerning the issue, and considers whether the regulation is a solution to the game. The next section uses as an illustration a regulation that OSHA imposed in 1978. The illustration highlights the role of information-sensitive risks in appraisals of a regulation.

5. Safety and Health at Work

The paper’s illustration of its normative model treats OSHA’s regulation of the work place to improve workers’ safety and health. It examines OSHA’s decision in 1978 to reduce workers’ exposure to benzene. The illustration does not yield a practical recommendation because the model has assumptions that the case does not meet. Also, the illustration does not include data fully specifying the negotiation game for this regulatory issue. The game’s specification requires information about citizens’ utility assignments that the illustration omits. The illustration just highlights considerations that reasonable regulation reviews because they affect the utility a rational and informed citizen attaches to a regulation and so affect a solution to the negotiation game for the regulatory issue.

Benzene is a carcinogen that causes leukemia. Refining petroleum produces it. It is present in gasoline and is used as a solvent, for example, in manufacturing automobile tires. According to available information, there is no safe level of exposure to benzene. Any level of exposure may cause cancer. Wearing respirators at petroleum refineries and wearing gloves when using benzene as a solvent reduces exposure to benzene. Hence OSHA imposed a new standard for exposure to benzene that required such procedures in the petroleum industry.

The American Petroleum Institute challenged the new standard, and the issue went to the Supreme Court. Debate in the Supreme Court focused on two regulatory principles appearing in the Occupational Safety and Health Act of 1970. The principles concern conditions for OSHA’s imposition of safety and health standards. Both principles presume that OSHA imposes standards regulating the most serious hazards first so that the resources available for regulating hazards are used optimally.

The first regulatory principle appears in the definition of the occupational safety and health standards that the Act authorizes. It orders work place standards that are economically feasible and will prevent some cases of serious injury or impairment of health in the foreseeable future (*United States Code*, 1995, vol. 16, p. 152). The second principle appears in the Act’s discussion of standards for toxic materials. It orders work place standards that are economically feasible and have a significant chance of preventing some cases of serious injury or impairment of health in the foreseeable future (*United States Code*, 1995, vol. 16, p. 154).

The main difference between the two principles, for carcinogens such as benzene, is that the first orders standards that will prevent some cases of cancer, whereas the second orders standards that have a significant chance of preventing some cases of cancer. For convenience, this section calls the first principle “the principle of guaranteed benefits” because it requires showing that a standard will bring some health benefits, and calls the second principle “the principle of likely benefits” because it requires showing that a standard has a significant chance of bringing some health benefits.

Each party in the Supreme Court debate appealed to one principle and attempted to finesse the other. OSHA invoked the principle of likely benefits. It argued that the standard proposed for benzene has a significant chance of preventing some cases of cancer, because it decreases exposure to benzene, a carcinogen for which no safe level of exposure is known. The petroleum industry invoked the principle of guaranteed benefits. It argued that the evidence that the new standard will prevent some cases of cancer is inconclusive, because as far as anyone knows, the present levels of exposure to benzene are already safe. The Supreme Court did not contest the applications of the principles but gave priority to the principle of guaranteed benefits, and therefore rejected OSHA’s new standard.

Neither the principle of guaranteed benefits nor the principle of likely benefits is a suitable regulatory principle for the case. The problem with the principle of guaranteed benefits is plain. It requires that the imposition of a standard for benzene be supported by evidence that the standard will prevent some cases of cancer. However, typically, as with OSHA’s standard for benzene, it is not clear that a standard will prevent cases of cancer. Rather the evidence only makes it likely that the standard will prevent some cases of cancer. Insisting on practical certainty that the standard will prevent some cases of cancer means waiting for present conditions to cause some people to fall victim to cancer. A regulatory principle should be able to authorize action before that happens.

The principle of likely benefits creates the opposite problem, namely, hasty imposition of regulations. It authorizes the reduction of risks no matter how small and no matter how unlikely to result in harm. It lays itself open to the charge of unrealistically seeking a risk-free work place.

The principles of guaranteed benefits and of likely benefits are both unsatisfactory. Both attend only to physical probabilities and risks resting on them and omit other considerations that regulatory decisions should consider. They should attend to evidential probabilities and information-sensitive risks. An informed and rational citizen balances the utility of a reduction in information-sensitive risk against the chance that the reduction in risk will not actually prevent any cases of cancer. After the utility of the reduction has been suitably discounted, the utility of the reduction may not be positive. The balance depends on the individual citizens and how their assessment of the regulation directs their behavior in the negotiation game that settles the model’s recommendation concerning standards for exposure to benzene.

Information-sensitive risks arise because of uncertainty that physical risks are absent. Information-sensitive risks are greater the less information exists about dose-response curves, other things being equal. Given ignorance of a safe level of exposure, lowering exposure levels reduces information-sensitive risks even if scientific studies do not ensure reduction of physical risks. Available information does not establish a safe level of exposure, and hence any level of exposure runs an information-sensitive risk to which a typical person is averse.

A typical person’s general aversion to information-sensitive risk is basic and therefore persists given acquisition of available scientific information. Her aversion to the information-sensitive risk of cancer from exposure to benzene is also robust with respect to available information about benzene. Given all available scientific information, she finds that exposure to benzene carries an information-sensitive risk of cancer because of the unknown long-term effects of exposure to benzene. The aversion to the risk may change with new information but does not change with acquisition of available information, because available information does not remove uncertainty about dose-response curves. Reasonable regulation attempts to reduce the risk.

Legislation makes reduction of risks of cancer part of OSHA’s mandate. The legislative process furnishes evidence that a majority is against exposure to carcinogens in the work place. A case for regulation therefore demonstrates a positive evidential probability that exposure to benzene causes cancer and demonstrates that lowering levels of exposure reduces that probability. The key point is the reduction in the evidential probability of cancer. Legal proceedings may show that lowering exposure reduces an information-sensitive risk by reducing the evidential probability of cancer. Without showing the precise magnitude of the reduction, it may show that the reduction is significant. A typical informed person may rationally prefer the regulation because of its reduction in the information-sensitive risk of cancer from exposure to benzene.

This section explains how to show in the paper’s model that an information-sensitive risk justifies regulation of exposure to benzene. A justification shows that lowering exposure to benzene lowers an information-sensitive risk by lowering the evidential probability of cancer, and shows that lowering exposure to benzene lowers the evidential probability of cancer by an amount that justifies lowering permissible levels of exposure to benzene. The section does not carry out the justification because that requires collecting data about individuals’ aversions to exposure to benzene and appraisals of steps to reduce exposure. According to the model, lowering permissible levels of exposure is justified if the public agrees on the regulation in an ideal negotiation game. They agree if the regulation maximizes collective utility. However, the section does not argue that OSHA’s standard for exposure to benzene maximizes collective utility. That argument requires more attention than this section provides to the calculation of citizens’ informed assessments of the regulation. The section just shows the possibility of arguing that an information-sensitive risk justifies a regulation to reduce the risk because enough reasonable, informed people want the regulation to reduce the risk.

The model attends to information-sensitive risks that the principle of guaranteed benefits and the principle of likely benefits neglect. Although the illustration does not settle regulation of exposure to benzene, it draws attention to the role of information-sensitive risks in identifying reasonable regulations. The lessons drawn from the model are guides for actual regulatory activities. They suggest revising OSHA’s mandate to accommodate information-sensitive risks, and until such a revision occurs suggest that OSHA attend to these risks when it exercises its discretionary powers.

6. Objectivity

The law makes rulings with momentous consequences, and justice requires accessible and convincing support for its rulings. Support for a risk’s regulation demands the risk’s objective demonstration. Are the existence and reduction of an information-sensitive risk objective matters in an appropriate legal sense?

Testimony concerning regulatory issues comes from experts, and the law adopts standards for the testimony of expert witnesses. Kadane (2008: 42) presents Rule 702 of the Federal Rules of Evidence, which Congress adopted in 1975: “If scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or to determine a fact in issue, a witness qualified as an expert by knowledge, skill, experience, training, or education, may testify thereto in the form of an opinion or otherwise, if (1) the testimony is based upon sufficient facts or data, (2) the testimony is the product of reliable principles and methods, and (3) the witness has applied the principles and methods reliably to the facts of the case.”

Finkelstein and Levin (2008: 44) state that a 1993 decision in *Daubert v. Merrill Dow Pharmaceuticals* takes reliability to require grounding in scientific knowledge. The ruling asks whether prior to an expert witness’s use of a scientific theory, the theory’s reliability had been established. It asks whether “(1) the theory had been tested; (2) the theory had been peer-reviewed and published; (3) application of the theory had a known rate of error; (4) the theory had been generally accepted in the relevant scientific community; and (5) the theory was based on facts or data of a type reasonably relied on by experts in the field.” These indicators are not necessary and sufficient conditions for reliability, so other indicators of reliability may replace them as a particular case warrants.

Bayesian statistics treats evidential probabilities. Kadane and Woodworth (2008) demonstrate and defend, according to the standards of reliability stated, the application of Bayesian statistics in legal proceedings. Bayesian statistics conform with the acknowledged indicators of the reliability of an expert’s testimony in court, including general acceptance of the methods the expert uses to reach conclusions.

In a civil case with a jury, court proceedings pool information from the plaintiff and from the defense. A jury uses the pooled information and inductive reasoning to reach a decision about the preponderance of the evidence. To resolve a regulatory issue, an agency may similarly use the pooled information of experts and inductive reasoning to reach probability assignments for relevant propositions and a regulatory decision that serves the public’s goals as expressed in its mandate.

A Bayesian ideal is to derive evidential probabilities of harm and sizes of information-sensitive risks from the pooled information of experts. This ideal faces several obstacles. The first concerns the pooled information of experts. Combining the beliefs of two experts is likely to produce contradictory beliefs. To overcome this problem, pooling may use only the experts’ relevant data, assuming that they are free of contradictions.

The second obstacle concerns inductive reasoning. Experts disagree about the methods of good inductive reasoning and the probability assignments they yield given a body of evidence. A way of addressing this problem treats experts with pooled data as measuring instruments for evidential probabilities. Although the experts are imperfect instruments, their central tendency is fairly trustworthy in many cases. When their assessments of probabilities are untrustworthy, standard Bayesian constraints on probability assignments still have firm grounding. In this case, after imposing all established constraints on probability assignments, a regulation’s evaluation may use the range of compliant probability assignments to assess risks. Beside the range of reasonable probability assignments, the extent of the evidence affects the size of an information-sensitive risk, and so a regulatory option’s consequences.[[9]](#footnote-9) A derivation of an information-sensitive risk’s size may use the range of probability assignments and a range of estimates of the evidence’s extent. If a regulation is reasonable given all assignments and estimates in their respective ranges, then it is reasonable. Its support is robust relative to reasonable probability assignments and estimates of the evidence’s weight.

Constraints on evidential probabilities besides the standard probability axioms are controversial. The Principal Principle offers a widely accepted constraint: an evidential probability should equal the corresponding physical probability if it is known. However, this constraint does not assist regulatory issues when physical probabilities are unknown. A modest constraint holds that a repeatable event that has happened has a positive evidential probability of happening again. Accordingly, Chernobyl shows that an accident at a nuclear power plant has a positive evidential probability. Establishing that a harmful event has a positive evidential probability has regulatory significance because it establishes an information-sensitive risk. However, the principle’s application faces the problem of assigning an event to a suitable event-type. The disaster at Chernobyl belongs to many event-types, including accidents at nuclear power plants, accidents at Ukrainian nuclear power plants, and fatal accidents at Ukrainian nuclear power plants. It may seem unwarranted to assign a positive probability to another instance of each type of repeatable event to which the accident belongs no matter how narrow the type.

The paper’s model does not use pooled data and canons of inductive reasoning to settle a probability assignment or a range of probability assignments to possible consequences of a regulatory option. It uses the probability assignments of informed rational individuals. These probability assignments meet all constraints that inductive logic imposes. However, the individuals may narrow the range of probability assignments more than the constraints narrow them.

The paper’s model uses a person’s actual attitudes to calculate the person’s informed utility assignment to a regulation. Given all available information, a rational individual updates probability assignments using Bayesian conditionalization. For simplicity, the model assumes that a single probability assignment represents a person’s attitudes toward relevant propositions after acquisition of all available evidence, but the model extends to cases in which a range of probability assignments represents a person’s attitudes toward the propositions. The model uses the person’s probability assignment, and the extent of the evidence on which it rests, to assess a risk’s size. An agency may assess a risk’s magnitude for a person with respect to expert information and assess the person’s aversion to a risk of that size to obtain the person’s informed aversion to the risk. Next, the method uses a person’s aversion to a risk of that size, assuming that the aversion is basic, and the person’s attitudes to an option’s consequences besides risk, to obtain the person’s informed utility for an option that generates the risk.

After obtaining each person’s informed utility assignment to each regulatory option, the model obtains the collective utility of each regulatory option and recommends an option with maximum collective utility. An option that maximizes collective utility is a solution to the citizens’ negotiation game for the regulatory issue. A regulation of a risk emerges only if the regulation significantly reduces the risk, without creating greater problems, so that the risk’s reduction justifies the regulation’s cost.

Using an information-sensitive risk to justify a regulation requires establishing that an aversion to the risk would persist given acquisition of all available relevant information. Information-sensitive risks and aversions to them persist given a rational assessment of all available scientific information, even when the sizes of the risks and the strengths of the aversions change, because they stem from a basic general aversion to information-sensitive risk. That general aversion is robust with respect to new information. Principles of democratic government allow for economically feasible regulations that agencies objectively show will reduce information-sensitive risks.

7. Conclusion

Regulation should acknowledge information-sensitive risks and their objectivity. A reduction of an information-sensitive risk may objectively justify a regulation. As the foregoing shows, an information-sensitive risk is objective, not just perceived. The reduction of an information-sensitive risk is an objective fact, not just a perception. Information-sensitive risks should not be dismissed as baseless fears. Information-sensitive risks, as well as physical risks, may objectively justify reasonable regulations.

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1. Some recent works are Sunstein (2005) and Jasanoff (2005). The former treats regulation from the perspective of jurisprudence and psychology. The latter adopts the perspective of comparative political science. [↑](#footnote-ref-1)
2. Weirich (2011) presents an account of models and explains how they provide partial explanations. [↑](#footnote-ref-2)
3. Sahlin and Persson (2004) use the term epistemic risk for what this paper calls information-sensitive risk. The paper uses the longer term to emphasize a distinctive characteristic of this type of risk. [↑](#footnote-ref-3)
4. The discipline of economics employs a technical sense of aversion to risk defined using the shape of the utility curve for a commodity. This paper treats aversion to risk in its ordinary sense rather than in economics’ technical sense. [↑](#footnote-ref-4)
5. The nonadditivity of the monetary value of chances does not refute the expected utility principle. The principle obtains an option’s expected utility by adding the utilities of the option’s possible consequences, which include all components of an option’s risk. The principle adds the utilities, not the monetary values, of the chances an investment creates for these possible consequences. [↑](#footnote-ref-5)
6. Weirich (1987) reviews some of the issues. Textbooks on financial management, such as Brigham and Houston (2009: Chap. 8), also explore them. [↑](#footnote-ref-6)
7. In a similar vein, Viscusi (1998: 64) states, concerning OSHA’s regulations, “The appropriate basis for protection is to ask what level of risk workers would choose if they were informed of the risks and could make decisions rationally.” [↑](#footnote-ref-7)
8. A bargaining problem is a type of cooperative game in which the characteristic-function yields a value of zero for every coalition except the grand coalition of all players. [↑](#footnote-ref-8)
9. Sahlin and Persson (2004) recommend using a range of probability assignments when evidence is sparse. The extent of evidence may affect the range of reasonable probability assignments so that it expresses the extent of the evidence. [↑](#footnote-ref-9)