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On the Decision-Making Model for Regulatory Defaults Considering Their Conservatism

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1. Introduction

How to choose defaults in risk-informed regulations depends on the conservatism implicated in regulatory defaults. Without a universal agreement on the approaches dealing with the conservatism of defaults, however, the desirability of conservatism in regulatory risk analyses has long been controversial. The opponent views it as needlessly costly and irrational, and the proponent as a form of protection against possible omissions or underestimation of risks. Moreover, the inherent ambiguity of risk makes it difficult to set suitable defaults in terms of risk.

First of all, the question of whether or not regulatory defaults should be set conservatively has long been controversial[1]. The opponent views it as needlessly costly and irrational, and the proponent as a form of protection against possible omissions or underestimation of risks. Currently, agencies differ widely in their approaches to regulatory defaults, and the implications of these differences are not well understood as yet. For example, in the EPA risk assessment guidance for the Superfund program[2], the approved defaults for a variety of quantities are described as "90th-percentile," "reasonable upper-bound," and "reasonable worst case." In the nuclear power industry, by contrast, defaults for their risk analyses have generally been set at or near the mean of the industry to determine the right priorities for the risks. It is because the adoption of conservative defaults can cause irrelevant priorities of the risk-critical components, so-called a shadow effect[3].

So, how should regulatory defaults be set? Bier and Jang[3] insisted that understanding of the effect of defaults should precede all others because stakeholder's interests conflict in this matter. As described by Bier and Jang[3], the regulators and regulated parties have systematically different goals or utility functions. Jang[4] explored four measures, so-called Maximum Gross Effect(MGE), Maximum Gross Effect of Extreme (MGEE), Maximum Pure Effect(MPE) and Maximum Pure Effect of Extreme (MPEE), for evaluating the effect of conservatism in regulatory defaults in terms of risk, according to the postulated behaviors of regulated parties and the diversity of interests of regulators.

This paper focuses simple decision models for setting regulatory defaults, based on the understanding of the effect of conservatism implicated in them. It can help decision makers evaluate the levels of safety likely to result from their regulatory policies.

2. The Method for Setting Regulatory Defaults

From another work[4], first of all, four measures for evaluating effect of conservatism in regulatory default (D) on an risk quantity (X) can be summarized as follows.

$$MGE = \int_0^1 \frac{D}{t} \cdot f_X\left(\frac{D}{t}\right) dt + F_X(D) \tag{1}$$

$$MGEE(T_{(n)}) = n \cdot \int_0^1 \frac{D}{t} \cdot \left[F_x\left(\frac{D}{t}\right)\right]^{n-1} \cdot f_X\left(\frac{D}{t}\right) dt + \left[F_X(D)\right]^n \tag{2}$$

$$MPE = E(T|T<1) = E\left(\frac{D}{X}|X>D\right) = \int_0^1 \frac{D}{t} \cdot f_X\left(\frac{D}{t}\right) dt \tag{3}$$

$$MPEE(T_{(n)}) = n \cdot \int_0^1 \frac{D}{t} \cdot \left[F_x\left(\frac{D}{t}\right)\right]^{n-1} \cdot f_X\left(\frac{D}{t}\right) dt \tag{4}$$

Considering the measure of conservatism above, two decision models regulatory defaults will be suggested in this work: 1) Basic Approach, 2) Decision theoretic approach.

2.1 Basic Approach

The problem of how defaults are chosen in risk-related regulatory matter totally depends on the effects of conservatism implicated in defaults on the estimates of risk. The results presented in another work[4] suggest that systematic and substantial underestimation of the most severe risks may arise when defaults are set near to population means, especially if the population exhibits significant heterogeneity. If more conservative defaults are therefore desirable, simulation analysis of the model described in MGE (and more sophisticated variants, MGEE) can provide guidance on how conservatively the default D ought to be chosen in order to achieve a desired regulatory result. Namely, the question regulators wish to examine is "At what percentile of the distribution $f_X(x)$ should D be set if we wish to ensure that risk is underestimated by no more than $\alpha \times$ 100 % on average, and/or no more than $\beta \times 100\%$ at the worst site?" Then, it can be formulated simply as follows.

$$D^* \equiv Max_D^{-1} F_X(D) \in \Omega \text{, such that } MGE \geq 1-\alpha \text{ and/or } MGEE \geq 1-\beta, \tag{5}$$

where D^* is the decision chosen from space Ω, the domain of X. The notation $D^* \equiv Max_D^{-1} F_X(D) \in \Omega$ means a value of D such that $F_X(D)$ is a maximum. Note in inequality (5) that according to the interests of regulators, they can replace MGE with MPE suggested in the paper. Also, instead of MGEE, regulators can use one of such measures as MPEE, etc.

2.2 Decision Theoretic Approach

In what we called classical decision analysis, the goal is to seek the optimal decision D^* from the quantity of interest X, with our uncertainty expressed as probability distribution $f_X(x)$, the value parameters θ, and the domain parameter Ω. To obtain optimal decisions, a variety of decision criteria can be additionally introduced as an input to the decision analysis. Of them, the use of maximum expected utility (MEU) or minimum expected loss (MEL) is most popular in classical decision analyses. Including MEL as a decision criterion, a conceptual decision model can be formulated as follows [5].

$$Z(X, \theta, \Omega, MEL) \rightarrow D^* \qquad (6)$$

Here, an optimal decision D^* of the model can be affected by uncertainty about the functional relationship Z, where Z incorporates model structure being employed. The methods of operations research can basically provide a wide variety of methods of optimization, which produce an optimal solution D^* given the specified quantities, values of parameters and structure of model.

If the classical decision model of equation (6) is applied to our problem of choosing defaults, a generalized decision model from the structure of equation (5) can be suggested with some constraints (*e.g.*, MGE and MGEE) as follows.

$$D^* \equiv Min_D^{-1} E[L(X, D)], \text{ such that}$$
$$MGE \geq 1 - \alpha \text{ and/or } MGEE \geq 1 - \beta, \qquad (7)$$

where $L(X, D)$ is the loss function of regulators (ultimately, the loss of public), $E[L(X, D)] \equiv \int_X L(x, D) \cdot f_X(x) dx$ denotes the expectation (over X) of the loss function for D, and finally D^* means the optimal decision (default) that minimizes the expected loss function.

First, let us consider loss functions appropriate in the paper. Asymmetric loss functions are required in the proposed decision model, since disclosing default under the situation of $X > D$ (*i.e.*, when the results of the realistic risk analyses are less favorable than the default) brings generally more severe loss than failing to perform realistic risk analyses under the situation of $X \leq D$ (*i.e.*, when the results of the realistic risk analyses would have been more favorable than the default). Therefore, a cubic loss function[5] can be primarily considered as a reasonable approximation for a wide variety of asymmetric and smooth functions in the present problem, which is given by

$$L(X, D) = a(X - D)^3 + b(X - D)^2, \qquad (8)$$

where $a > 0$, $b > 0$, and it is plausible that decision is constrained to be in the range, $(X - D) > EL$ $\left(= -\frac{2b}{3a}\right)$. This cubic loss function is depicted in Fig 1.

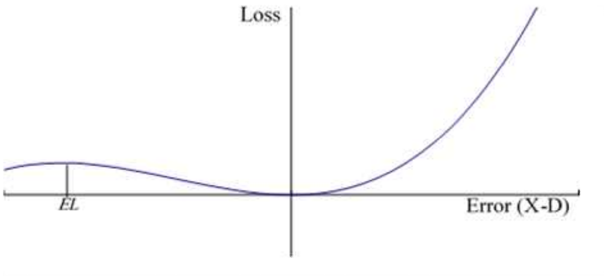

Fig. 1 Cubic loss function

Bilinear loss function[5] is also applicable to the proposed decision model as follows.

$$L(X, D) = a(X - D) \cdot I(X > D) + b(X - D) \cdot I(X \leq D), \qquad (9)$$

where $a > 0$, $b < 0$, and $I(.)$ is index function. This loss function is a simple asymmetric one, and is illustrated in Fig. 2.

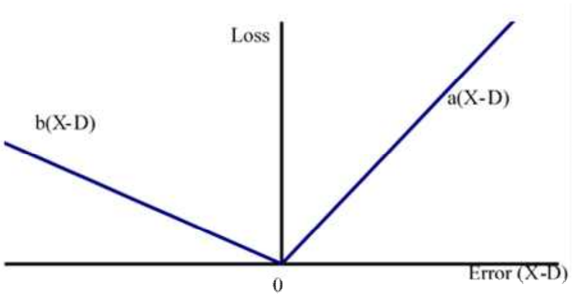

Fig.2. Biliner loss function

The application of loss functions illustrated in equations (8) and (9) can bring us more detailed, concrete formulation of the proposed decision problem. However, the preference and utility functions of both regulators and regulated parties need to be investigated in detail.

3. Conclusions

A topic of how defaults are chosen depends on the effects of conservatism implicated in regulatory defaults on estimating risks, particularly in risk-related regulations. Without any universal agreement on the approaches dealing with the conservatism of defaults, the desirability of conservatism in regulatory risk analyses has long been controversial. The opponent views it as needlessly costly and irrational, and the proponent as a form of protection against possible omissions or underestimation of risks. Moreover, large heterogeneity for the quantity of risk in regulated population makes it difficult to set suitable defaults.

In this work, some decision models to setting defaults in regulatory matters were proposed, based on the suggested measures. The proposed research can help decision makers evaluate the levels of safety likely to result from the current or future regulatory policies.

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