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Preface

This book addresses the complex decision-making issues societies face when considering projects that promise significant benefits, such as nuclear power generation, but also pose risks of severe accidents. It explores the societal dilemma of whether to advance or halt such initiatives. The book is divided into two parts.

The first part discusses the decision-making process for projects like nuclear energy, which can cause severe damage in the event of an accident. Risk assessment must be conducted well in advance. However, the nuclear disaster at TEPCO (Tokyo Electric Power Company)'s Fukushima Daiichi Power Station on March 11, 2011 raises questions about the adequacy of risk-assessment actions. This part investigates the potential factors that lead to insufficient risk assessment in the decision-making process. A model is developed wherein the business entity responsible for operating the project invests in obtaining risk-assessment information, while the decision-making entity makes decisions based on its perceived balance of social costs and benefits. The analysis identifies several factors causing insufficient risk assessment: optimism about the risks involved on the side of the operating business entity, large private benefits associated with the project, a gap between the magnitude of the risks the operating entity perceives and the standards of judgment required by society, and ambiguous liability for compensation. Factors that do not deter the operating entity from effort in risk assessment include the ability to practically make its own decisions by capturing the decision-making entity and the ability to keep risk-related information confidential.

The second part aims to identify the difficulties in decision-making in such situations by creating and analyzing a decision-making model for organizations that advance high-risk projects through trial and error. Even projects with significant risks may need to be considered for implementation given the expected benefits to society. In such examinations, it is crucial to determine whether it is possible to avoid a severe accident (i.e., to assess the extent of the risk). In most cases, it is common to estimate technical risks while trialing the project and make decisions incrementally. However, executing this step-by-step decision-making is challenging. The objective of this part is to analyze the difficulty of incremental decision-making. Recognizing the characteristics of such decision-making challenges is crucial to avoid severe accidents and prevent erroneous decisions.

This study initially embarked on a different trajectory, focusing on empirical industrial organization. My interest was piqued by the peculiar characteristics of industries related to nuclear power generation, such as their multiple subcontracting system. Despite being generally perceived as technologically advanced, these supporting industries appeared inefficient. I was intrigued by the factors impeding their efficiency, which I believed could influence the energy industry's operation. However, the Fukushima Daiichi Nuclear Power Plant disaster prompted a reevaluation of my research direction, leading to a temporary halt. As time passed without a clear research direction, debates on the structural issues behind Japan's nuclear industry following the accident gradually subsided, and nuclear power operations resumed sequentially, with plants reopening one by one. It remains questionable whether policy measures adequately reflect the lessons learned from the major accident and whether the energy structure dependent on nuclear power is being reconsidered.

Motivated by this context, this study was initiated to understand why no efforts have been made to reach a public consensus on the merits and demerits of nuclear power reliance, despite extensive research and debate. The study employs mathematical model analysis, with models constructed to depict the situation leading to the accident at TEPCO's Fukushima Daiichi power station. However, the study does not aim to use the model to identify the institutional factors in the Japanese energy industry that contributed to the accident. Instead, it seeks to answer the following question: Why is nuclear power being promoted without sufficient discussion and research? While I believe further research on this issue is necessary, I present my current analysis here. Numerous research questions remain.

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Contents

Abbreviations

DM	Decision-Maker
HRO	High-Reliability Organization
JAERI	Japan Atomic Energy Research Institute
JPSR	JAERI's Passive Safety Reactor
NAIIC	Fukushima Nuclear Accident Independent Investigation and Verification Commission
PIUS	Process Inherent Ultimate Safety reactor
TEPCO	Tokyo Electric Power Company

Mathematical Notations

$\varnothing$	Empty set
B	Benefit of the project to all members of society
$(\,)^c$	Complementary set
$c(\cdot)$	Cost of effort
$\bar{c}$	Upper bound on $c(\cdot)$
D	Damage caused by an accident
$\bar{D}$	Critical expected accidental damage beyond which the expected project value for society members increases with an observation
D^M	DM's estimate of accident damage
D^A	Agent's estimate of accident damage
D_1^A, D_2^A	Boundaries separating the regions of D^A where the yield from the agent's second trial is positive
D_+^M, D_+^A	Critical expected accidental damage for the DM and the agent, respectively, beyond which the agent's project value increases with the second observation
$\bar{D}^A$	Critical expected accidental damage of the agent beyond which the agent's expected project value increases with the first observation

e	Agent's level of effort in investigation trial
$\bar{e}$	Upper limit of e beyond which no increase of the probability π
e^*	Effort level chosen by the agent
e_i	Agent's effort level chosen for Case i in Chap. 6
$\mathcal{F}$	σ-algebra of all measurable events within the sample space Ω
$F(\cdot)$	Cumulative distribution function of parameter θ
$f(\cdot)$	Probability density function of parameter θ
$H_\sigma(\cdot)$	Indicator function
n	Number of observations
P	Probability measure on $(\omega, \mathcal{F})$
$p(\cdot)$	Probability function
R	Private profit accrued by the agent
$\mathbb{R}$	The set of all real numbers
$\mathbb{R}^+$	The set of all non-negative real numbers
$\mathbb{R}^{++}$	The set of all positive real numbers
$U(\cdot)$	Uniform distribution
V_i^M, V_i^A	Expected project value for the DM and the agent for Case i in Chap. 6
$W(\cdot)$	Project value function
W_0^A	Project value for the agent, based on subjective probability of accident occurrence with a no-information prior distribution
W_0^M	Project value for the DM, based on subjective probability of accident occurrence with a no-information prior distribution
$W_1^a(\cdot)$	Project value for the agent, contingent upon the observation of a precursor
W_1^A	Expected project value for the agent, based on the subjective probability of observing one precursor
W_n	Expected project value for society members when n observation is given
X	Random variable that governs the occurrence of an accident
x_1^A	Optimal critical value of the first observation for the agent beyond which the project should be halted
x_i	Observed random variable representing the outcomes of the i-th trial
$\boldsymbol{x}$	Collective term referring to $\boldsymbol{x}_0$, $\boldsymbol{x}_1$, and $\boldsymbol{x}_2$
$\boldsymbol{x}_0$	Zero-dimensional vector representing the absence of any observation ($\boldsymbol{x}_0 = \varnothing$)
$\boldsymbol{x}_1, \boldsymbol{x}_2$	Vectors representing the specific realizations of the outcomes ω, for one or two observations, respectively
x_n^*	Optimal critical value of the observation for the DM beyond which the project should be halted when n observation(s) are given
$Y(\cdot)$	Payoff for society members
Y_1^a	Agent's expected project value when the second investigation trial is allowed
Y_2^a	Agent's payoff during the second trial
y_n	Highest value of n observation(s)
β_n	Probability of the type II error when n observation(s) is(are) given
γ_n	Probability of the type I error when n observation(s) is(are) given

θ	Parameter of uniform distribution
λ	Constant probability when the effort is no less than $\bar{e}$
$\pi(\cdot)$	Probability a precursor of accident is provided
ρ	Decision where project execution is effectively decided in each case when the observed precursor can be kept concealed
Σ	Collective term referring to Σ^0, Σ^1, and Σ^2
Σ^i	Specialized σ-algebra for scenarios with i observation(s)
σ	Subset of Σ representing the condition under which the DM decides to execute the project
σ^*	Optimal σ for the DM
σ^A	Optimal σ for the agent
σ_i	Subset of Σ^i representing the condition under which the DM decides to execute the project
σ_1^A	Decision that optimizes the project value for the agent point-wisely
τ	Threshold value beyond which an accident occurs
τ^+	Critical threshold of τ beyond which the agent's project value increases with the second observation
$\Phi(\cdot)$	Function used to define the expected project value in Chap. 6
χ_1, χ_2	Boundaries separating the regions of x_1 where the condition the agent exerts effort for the second observation
Ω	Sample space of all possible outcomes of the observations
ω	Individual outcome within the sample space