Advances in Natural and Technological Hazards Research

Aniello Amendola
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Integrated Catastrophe Risk Modeling

Supporting Policy Processes

Springer

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Preface

This book aims to advance risk management policy and its implementation by demonstrating the application of novel techniques, including integrated catastrophe models, to aid policy decisions on contemporary disaster risk issues.

With the dramatic rise in disaster events across an increasingly populous and interdependent world, people and communities are recognizing the importance of reducing their human and economic toll. Efforts are thus being intensified to manage risk and incorporate risk management principles into policymaking.

Science-based risk management policy is not without its challenges. Given the dynamic demographic, economic, and social context in which most hazards are embedded, including the changing climate, it is not only difficult to assess risk, but standard statistical measures are inappropriate for high-impact, low-probability events with probability distributions characterized by fat tails. In addition, data on rare events are, by definition, very limited and fraught with uncertainties. Beyond the assessment of risk itself, identifying robust policy options in a highly uncertain future world poses equally difficult challenges. Finally, experts alone cannot evaluate policy options, as these depend on the values and preferences of those affected. This raises the challenge of designing and assisting stakeholder processes that can inform risk management decisions.

In this book, we address all these challenges by developing and applying modeling techniques for the assessment and management of catastrophe risk through an integrated "systems" approach. We emphasize integration across natural and social systems, applying models that take account of the intensity and frequency of natural phenomena combined with the exposure and vulnerability of social and economic systems. Integration also means gauging the complex interdependencies of risk across different temporal and spatial scales, which often requires estimates to be made into the distant future and at the local, regional, and even global levels. Integration, too, means taking due consideration of the manifold uncertainties and social constructions of disaster risk. Finally, and perhaps most importantly for the risk management policy process, integration means listening and responding to the plural and competing values and worldviews of stakeholders and policymakers.

Catastrophe models are an important part of integrated assessment, as they explore the drivers of disasters (hazard, exposure, and vulnerability), simulate future events based on historical data and expert judgment, apply appropriate statistical distributions, and take account of future drivers, including climate change. As well as providing risk estimates, as this volume shows, models can be embedded in support systems that can account for conflicting values and for the views of multiple stakeholders. In so doing, they provide useful knowledge and support to risk management policies.

The uniqueness of this book lies in its usefulness to real-world policies on catastrophe risk management and in the novelty of the approaches used for this purpose. The three parts of this volume begin with general discussions of catastrophe models for informing risk management policies, and then turn to the implications of disaster risk for economic growth and socioeconomic development along with associated options for managing risk. Finally, we focus on the Tisza River basin in Hungary, describing the implementation of a model-based stakeholder process for managing flood risk in this area.

Specific applications, among others, include designing insurance strategies for seismic risk in Italy; assessing strategies for managing flood risk in Austria and northern Vietnam; evaluating large infrastructure projects throughout the world; examining the development implications of extreme climate events in Nepal; developing catastrophe bonds for public sector risk management in Mexico; informing the development of the Caribbean Catastrophe Risk Insurance Facility; and implementing a model-based participatory process for managing flood risks in Hungary. The applications break new ground by applying advanced modeling techniques to the policy issues at hand. Methodological innovations include novel stochastic optimization approaches and probabilistic risk estimation taking account of indirect losses and climate change. The applications are also innovative in that they are designed for user-friendly policy support. This, as the research shows, can prove to be instrumental in helping stakeholders holding strongly divergent views reach policy consensus and in helping national policymakers, donors, and development bankers devise risk financing strategies for implementation in highly vulnerable developing countries.

The research was carried out by scientists and their collaborators at the International Institute for Applied Systems Analysis (IIASA), which conducts policy-oriented systems research into problems that are too large or too complex to be solved by a single academic discipline. The research is also linked with other international institutions such as the Intergovernmental Panel on Climate Change, UN development agencies, the European Commission, and international finance institutions such as the Asian Development Bank, Inter-American Development Bank and the World Bank. The researchers represent a wide range of physical and social science disciplines, including mathematics, statistics, systems modeling, geology, meteorology, hydrology, physics, engineering, computer sciences, economics, decision analysis, and sociology. The case studies would have not been feasible without the support and availability of data from the national or local institutions involved, as acknowledged in the relevant chapters. In particular, we are

grateful to the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (FORMAS) for providing funding to IIASA for the Hungarian Tisza river project.

It is our hope that this volume will contribute positively to the design and implementation of scientifically grounded and socially acceptable policy options able to reduce the unacceptable human and economic toll of natural hazards, today and in the future.

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Joanne Linnerooth-Bayer
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Part I
Integrated Modeling for Informing Risk Management Policies

Chapter 1
Catastrophe Models for Informing Risk Management Policy: An Introduction

Aniello Amendola, Tatiana Ermolieva, Joanne Linnerooth-Bayer, and Reinhard Mechler

Abstract Catastrophe models that combine data on past occurrences with future simulations of the hazard, exposure and vulnerability, and that take account of the dynamic environment as well as correlated loss distributions, are becoming increasingly important for assessing the risks of extreme events. This volume demonstrates innovative ways for adapting catastrophe models to aid risk management policy processes via a number of wide ranging applications. These are grouped into three parts, according to whether they inform local or regional risk management policy (Part I); the management of country-wide catastrophe risk and its implication on development (Part II); and the participatory design of a national insurance program (Part III). After discussion of the rational for the proposed approaches, which integrate across multiple disciplines and take into account the diverse values and preferences of stakeholders, this chapter introduces Part I of the volume, including cases on the management of flash flood risk in Vienna, Austria, an earthquake insurance program for the Tuscany region in Italy, balancing stakeholder concerns in establishing flood risk management strategies in northern Vietnam, and the choice of appropriate discounting factors in the design of infrastructures under consideration of catastrophe risk.

Keywords Catastrophe models • Integrated risk management • Participative policy process • Catastrophe risk and development • Catastrophe insurance program • Robust decisions • Case studies

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1.1 Scope

Managing the risks of catastrophic events poses difficult challenges to analysts and policy makers. Disasters, whether "natural" or human induced, are embedded in dynamic socio-economic environments characterized by changing demographics, capital movements and social developments. Increasing economic and social interdependencies mean that disastrous events can have long-term and spatially dispersed consequences beyond their immediate or direct impacts. Hazards are also changing, particularly those related to the climate, such as floods, hurricanes, droughts and famine, or those related to technological developments, such as major interventions on rivers. In this dynamic and systemic environment, and because of the nature of the statistical distribution of high-impact and low-probability events, analysts can neither rely solely on historical data and trends nor on standard statistical measures. For these reasons, catastrophe models that combine future simulations of the hazard, exposure and vulnerability, and that take account of the dynamic environment as well as correlated loss distributions, are becoming increasingly important for assessing the risks of extreme events.

This volume demonstrates innovative ways for adapting catastrophe models to aid risk management policy and policy processes. Probability- and model-based policy applications for disaster risk management are relatively new. In the early 1990s insurers developed catastrophe models to take advantage of greatly improved computing capabilities. Only recently, these models have been developed to aid public policy decisions (Grossi and Kunreuther 2005). The applications in this book are wide ranging, including, among many others, the consideration of disaster risk in the public finances of Nepal, the participatory design of a national insurance program in Hungary, the balancing of stakeholder concerns in establishing flood risk management strategies in northern Vietnam, as well as assistance to policy makers in the design of robust investments in dams and other critical infrastructure.

In sum, the models described in this book make use of novel methodologies and tools that aid in the design of robust, efficient and equitable decisions and policy processes for managing disaster risks. Specifically, the authors demonstrate model applications that:

- take account of probabilistic and uncertain evidence on disaster risks (often characterized by fat-tailed distributions) for designing public policy interventions;
- trace the indirect and often hidden effects of disasters on the economic system, particularly in a development context;
- combine simulation models with advanced optimization methods to identify robust policy options;
- apply spatial-temporal approaches for discounting in long- term planning for critical infrastructure under conditions of catastrophe risk;
- include climate change and social-economic dynamics in a systems approach to risk assessment;
- provide interactive and user-friendly decision support for participatory stakeholder processes; and
- evaluate ex ante financial provisions with prevention measures in an overall risk management strategy.

1.2 Risk Management and Systems Analysis

Major natural catastrophes have cost the world's economies close to US$ 800 billion in the first decade of this century (Femke et al. 2010), and alone in 2011 the economic losses from natural disasters amounted to some US$ 380 billion, making it the most expensive natural disaster year to date (Munich Re 2011). Whereas disaster deaths per event are slightly declining, it cannot be ignored that over 95% of fatalities have occurred in low- and middle-income countries (IPCC 2012). Even in developed counties, people and capital continue to locate in high hazard zones, often assuming that they are protected by dams, sea walls or other structures. That these structures also fail catastrophically was demonstrated by the Katrina hurricane in 2005 and the Fukushima tsunami disaster in 2011.

Without improved risk management that takes account of the stochastic and interdependent nature of disaster drivers, the unacceptable human and economic toll of disasters will likely continue (IPCC 2012). The need for risk management as an alternative to a purely post-disaster response is well acknowledged (Mechler et al. 2010). This includes investing in high-return risk reduction projects and regulations, and also in instruments that provide post-disaster capital for the recovery process. Insurance and other financial instruments not only provide needed ex-post resources, but also can contribute to ex ante social protection, to incentives for risk reduction, and to adaptation to climate change (Linnerooth-Bayer et al. 2005).

Providing risk estimates and decision support for investments in risk management, however, is far from straight forward. Analysts must explicitly acknowledge and take account of many complex factors mentioned above: the stochastic and interdependent nature of disaster drivers; the complex risk and policy environment; uncertainties in the magnitude and frequency of current and future hazards; unanticipated interactions between natural events and the response; and conflicting interests and values in allocation of scarce resources. Another complicating feature concerns the nature of the statistical distribution of high-impact, low-probability events, which have a high likelihood of being fat tailed. In the presence of fat tails, it is inappropriate to model the consequences using the normal or lognormal distributions, and techniques based on mean values (for instance, historical averages) are not applicable.

To an important extent, these complicating features can be dealt with by using catastrophe modeling techniques. Catastrophe models explore separately the components of a disaster (hazard, exposure and vulnerability) and simulate future events based on an appropriate statistical distribution. The modeler can also take account of the dynamics of future drivers. Catastrophe models thus are an important form of systems analysis, which can be thought of as the process of investigating the interrelated parts of a system and using the information to assess potential courses of action. Beyond providing risk estimates, as this volume shows, models can be embedded in support systems that take account of conflicting values and views of multiple stakeholders. In this way, they provide useful knowledge and support to risk management policy makers.