

Preface

Real life is full of surprises. Not only do ordinary people in the street face unexpected events, but experts in financial districts and policy-makers in capitals around the globe are often also caught off guard by “once-in-a-century” unanticipated events. One such surprise event was the sudden collapse of European interbank markets on August 9, 2007, which then sparked the global financial crisis. The ramifications of this massive event, largely unexpected, shaped the financial landscape for the entire tenure of one of the coauthors (Nishimura) as Deputy Governor of the Bank of Japan.

Faced with the real possibility of surprise events, human emotions often swing between optimism and pessimism. Just before the global financial crisis, financial markets around the world showed great optimism that “this time” was different and we would see sustained prosperity. Immediately after the crisis was perceived as being real, the same financial markets displayed extreme pessimism leading to failures of financial institutions and even closure of some markets.

As economists, we face two challenges: first, to explain the behavior of people including experts and policy-makers facing such unexpected events according to the first principles of economics; and second, to predict these people’s behaviors when another unexpected event occurs so as to better cope with such an event. The purpose of writing this book is to present the groundwork from which these challenges can be addressed.

A theoretical precursor of our work concerns the so-called Knightian uncertainty. Knight (1921) deliberately distinguished between “measurable uncertainty” or “risk” on one hand, and “unmeasurable uncertainty” that cannot be represented by numerical probabilities on the other, which is now known as “Knightian uncertainty.” Knight also claimed that people face “Knightian uncertainty” in most situations that prevail throughout their lives.

The problem posed by Knight, however, was considered to be at least tentatively resolved by the celebrated theorem of Savage (1954): if the decision-maker’s behavior complies with some axioms that appear plausible, she behaves *as if* she possesses a unique probability with which she computes the expected utility and then chooses an act that maximizes it. If one accepts this concept, “Knightian

uncertainty” is reduced to mere risk. What is important here is that the decision-maker herself need *not* have a clear concept of probability, but rather that we as analysts (not the decision-maker) *can* assume the existence of the probability the decision-maker employs for psychic computations when we construct an analytic framework.

Ellsberg (1961) challenged Savage’s subjective probability theory and argued that the concept of uncertainty advocated by Knight (i.e., “Knightian uncertainty”) still prevails. He presented a famous experiment, known as “Ellsberg’s paradox,” in which the choice patterns of participants can never be explained if they use a probability to evaluate various acts. In particular, he showed that one of the axioms imposed by Savage, known as the “sure-thing principle,” is always violated by the participants’ behavior. Ellsberg’s argument was fairly convincing, and it *is* still convincing today. Nevertheless, Ellsberg’s paradox was regarded as a special case and for a time it was essentially “ignored” in the disciplines of economic science and decision science. This is because Savage’s subjective expected utility (SEU) theory is extremely practical and it makes model building in economics easy in both microeconomics and macroeconomics.

The situation changed in the 1980s. A series of papers by David Schmeidler and Itzhak Gilboa (1982, 1986, 1989) developed operational forms of “Knightian uncertainty,” known as the “Choquet expected utility (CEU)” theory and the “maxmin¹ expected utility (MEU)” theory, with sound axiomatic foundations. The CEU theory assumes that the decision-maker uses a *nonadditive* probability, while the MEU theory assumes that the decision-maker uses a set of probabilities instead of a single probability. Furthermore, both theories do not assume the sure-thing principle and they *can* explain Ellsberg’s paradox.

Since the breakthrough made by Schmeidler and Gilboa, the utility of their theories motivated economists to apply the CEU and MEU theories to model the economic phenomena that we face. As a result, a large literature has been generated in various areas in economics.

Until the global financial crisis, however, these applications of Knightian uncertainty were relatively limited in scope, and were motivated more by theoretical curiosity and the desire to amend the apparent limitations of existing theory in explaining anomalies often found in peripheral phenomena. The situation has changed drastically since the global financial crisis, and there has been a vast expansion of the Knightian uncertainty literature that has been impossible to monitor fully. At the same time, the literature has become methodologically diverse, and in some ways it may be difficult to have a coherent view about Knightian uncertainty.

That said, this book anticipates two types of readers: researchers who have a technical orientation and nontechnical general readers who are interested in the implications of Knightian uncertainty and its relationship with optimism and pessimism.

¹The terms maxmin and maximin are both used in the literature.

For researchers with technical orientation, the objective of this book is to equip the reader with the mathematical and economic methods necessary to understand the contents of this book and to conduct their own research along the lines developed in this book. To this end, the book provides a thorough discussion of mathematics and decision theory in a self-contained manner.

For nontechnical general readers, the book may seem overly formalized or mathematical to understand the real essence of Knightian uncertainty and the characterization of optimism and pessimism. However, the ideas behind the results reported in this book are very intuitive, even though they are (unfortunately) buried in rigorous mathematical detail. To assist nontechnical readers in comprehending the underlying principles, each chapter in the main body of this book provides a detailed “Introduction and Summary” section, in which the essence of the argument developed in the chapter is presented. In some chapters, an “Examples” section is also provided.

Our joint research dates as far back as the very beginning of the twenty-first century, when Ozaki presented a paper at the University of Tokyo. The paper, coauthored with Peter A. Streufert, covered the optimal growth model where the representative agent exhibited uncertainty aversion. Ozaki thought (and still thinks) that the paper was interesting because all the dynamic programming techniques could be invoked even though the agent aggregated uncertainty in a “nonlinear” manner. Furthermore, the paper germinated the ideas of an “ordered set of functions” and the “stochastic nondecrease” when the probability is not additive in the framework of a finite state space. The readers will see that these ideas are thoroughly exploited in both finite and infinite state spaces in this book.

Nishimura, then at the University of Tokyo before joining the Bank of Japan, did not share Ozaki’s enthusiasm. Nishimura thought (and still thinks) that the introduction of a new concept, like a nonadditive probability, must generate new implications that could not be derived from a traditional framework that employed traditional concepts. Then, what might or could be changed by explicitly thinking of a probability that was not necessarily additive? Nishimura’s insight was that an increase in risk represented by an additive probability and an increase in “uncertainty” represented by a nonadditive probability should have opposite effects on the value of waiting for the representative agent. This needed to be proven by solving the agent’s dynamic optimization problem, and this was exactly what Ozaki liked to do by invoking dynamic programming techniques!

Our first joint paper was thus completed in a true collaboration and was published in the *Journal of Economic Theory* in 2004 (Chap. 9 of this book comprises its outgrowth). Since then, the collaboration has continued to this day, often enhanced by the synergy of Nishimura whose interests concern the application of theories to explain real economic phenomena from the policy perspective (especially since the global financial crisis), and that of Ozaki whose interests focus on the beauty of the theory and elaboration of it. These activities culminated in joint articles and discussion papers, and then the concept of this book emerged after Nishimura’s term as Deputy Governor ended and he returned to academia. The actual publication plan started in 2014 with help of Ms. Juno Kawakami (Springer, Japan). We are thankful to Ms. Kawakami on this matter.

It is typical that writing a book owes much to many people. This case is no exception, but we can only name a handful here. We are particularly grateful to Itzhak Gilboa, who, with David Schmeidler, was the intellectual source of our scientific endeavor, and gave us warm encouragement in various stages of our study. Ozaki thanks Peter A. Streufert, who was and has been his only teacher during his career as a professional economist. He learned from Peter that we economists must be extremely prudent and precise in applying mathematics to economics (math is not that superficial tool we can handle easily!) and he also learned from Peter everything about dynamic programming in a verbatim meaning. We hope that Chap. 7 reflects what Ozaki learned from Peter correctly. Chapter 6 is based on a collaborative work of one of us (Ozaki) with Eisei Ohtaki, and we express our deepest thanks to him for allowing us to include it in the book.

Preliminary drafts of the book were used in many graduate classes including those of Hitotsubashi University, the University of Tokyo, and Keio University. We are grateful to the audiences of these lectures. In particular, Daiki Kishishita and Satoshi Nakada proofread the book with great care, which significantly improved the book. Austin Schultz copyedited the draft and helped with both English usage and academic writing. Nevertheless, the book, which is so lengthy, may contain some typographical errors for which we are solely responsible.

Finally, we close the preface with a slight variation of a quote from a French movie²: We hope readers enjoy reading the book as much as we enjoyed writing it!

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²*La Nuit américaine* (1973). English title: *Day for Night*.



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