1 The challenge of understanding choice under risk

Life is uncertain. We hardly know what will happen tomorrow; our best-laid plans go awry with unsettling frequency. Even the recent past is often a matter of conjecture and controversy. Everyday decisions, small and large, are made without certainty as to what will happen next.

It would therefore be comforting to have a well-grounded theory that organizes our observations, guides our decisions, and predicts what others might do in this uncertain world. Since the 1940s most economists have believed they have had such a theory in hand, or nearly so with only a few more tweaks needed to tie up loose ends. That is, most economists have come to accept that Expected Utility Theory (EUT), or one of its many younger cousins such as Cumulative Prospect Theory (CPT), is a useful guide to behavior in a world in which we must often act without being certain of the consequences.

The purpose of this book is to raise doubt, and to create some unease with the current state of knowledge. We do not dispute that the conclusions of EUT follow logically from its premises. Nor do we dispute that, in a sufficiently simple world, EUT would offer good prescriptions on how to make choices in risky situations. Our doubts concern descriptive validity and predictive power. We will argue that EUT (and its cousins) fail to offer useful predictions as to what actual people end up doing.

Under the received theory, it is considered scientifically useful to model choices under risk (or uncertainty) as maximizing the expectation of some curved function of wealth, income, or other outcomes. Indeed, many social scientists have the impression that by applying some elicitation instrument to collect data, a researcher can estimate some permanent aspect of an individual's attitudes or personality (e.g., a coefficient of risk aversion) that governs the individual's choice behavior. This belief is not supported by evidence accumulated over many decades of observations. A careful examination of empirical and theoretical foundations of the theory of choice under uncertainty is therefore overdue.

To begin with the basics: What do we mean by "uncertainty" and "risk"? Economists, starting with, and sometimes following, Frank Knight (1921), have redefined both words away from their original meaning.[1]

In the standard dictionary definition, risk simply refers to the possibility of harm, injury, or loss. This popular concept of risk applies to many specialized domains including medicine, engineering, sports, credit, and insurance. However, in the second half of the twentieth century, a very different definition of risk took hold among economists. This new technical definition refers not to the possibility of harm but rather to the *dispersion* of outcomes inherent in a probability distribution. It is typically measured as variance or a similar statistic. Throughout this book we will be careful to distinguish the possibility-of-harm meaning of risk from the dispersion meaning.

Although the notion of risk as dispersion seems peculiar to laymen, economists acclimated to it easily because it dovetails nicely with EUT. For centuries, economists have used utility theory to represent how individuals construct value. In the 1700s Daniel Bernoulli (1738) first applied the notion to an intriguing gamble, and since the 1940s the uses of expected utility have expanded to applications in a variety of fields, seemingly filling a void.

At the heart of Expected Utility Theory is the proposition that we each, individually or as members of a defined class, have some particular knowable attitudes towards uncertain prospects, and that those attitudes can be captured, at least approximately, in a mathematical function. In various contexts, it has been referred to as a value function (in Prospect Theory), or a utility of income function, or a utility of wealth function. Following the standard textbook (Mas-Colell, Whinston, and Green [1995]) we shall often refer to it as a Bernoulli function. Such a function maps all possible outcomes into a single-dimensional cardinal scale representing their desirability, or "utility." Different individuals may make different choices when facing the same risky prospects (often referred to as "lotteries"), and such differences are attributed to differences in their Bernoulli functions.

In particular, the curvature of an individual's Bernoulli function determines how an individual reacts to the dispersion of outcomes, the second definition of risk. Because the curvature of the Bernoulli function helps govern how much an individual would pay to avoid a given degree of dispersion, economists routinely refer to curvature measures as measures of "risk aversion."

Chapter 2 explains the evolution and current form of EUT, and the Appendix to Chapter 2 lays out the mathematical definitions for the interested reader. Presently, we simply point out that in its first and original meaning, aversion to risk follows logically from the definition. How can one not be averse to the possibility of a loss? If a person somehow prefers the prospect of a loss over that of a gain, or of a greater loss over a smaller loss, in what sense can the worse outcome be labeled a "loss" in the first place? By contrast, under the second definition of risk as dispersion of outcomes, aversion to risk is not inevitable; aversion to, indifference to, and affinity for risk remain open possibilities.

It is a truism that to deserve attention, a scientific theory must be able to predict and explain better than known alternatives. True predictions must, of course, be out-of-sample, because it is always possible to fit a model with enough free parameters to a given finite sample. That exercise is called "overfitting," and it has no scientific value unless the fitted model can predict outside the given sample. Any additional parameters in a theory must pay their way in commensurate extra explanatory power, in order to protect against needless complexity.

We shall see in Chapter 3 that the Expected Utility Theory and its many generalizations have not yet passed this simple test in either controlled laboratory or field settings. These theories arrive endowed with a surfeit of free parameters, and sometimes provide close ex post fits to some specific sample of choice data. The problem is that the estimated parameters, e.g., risk-aversion coefficients, exhibit remarkably little stability outside the context in which they are fitted. Their power to predict out-of-sample is in the poor-to-nonexistent range, and we have seen no convincing victories over naïve alternatives.

Other ways of judging a scientific model include whether it provides new insights or consilience across domains. Chapter 4 presents extensive failures and disappointments on this score. Outside the laboratory, EUT and its generalizations have provided surprisingly little insight into economic phenomena such as securities markets, insurance, gambling, or business cycles.

After almost seven decades of intensive attempts to generate and validate estimates of parameters for standard decision theories, it is perhaps time to ask whether the failure to find stable results *is* the result. Chapter 5 pursues this thought while reconsidering the meaning and measures of risk and of risk aversion.

But does it really matter? What is at stake when empirical support for a theory is much weaker than its users routinely assume? We write this book because the widespread belief in the explanatory usefulness of curved Bernoulli functions has harmful consequences.

1. It can mislead economists, especially graduate students. Excessively literal belief in EUT, or CPT, or some other such model as a robust characterization of decision making can lead to a failed first research program, which could easily end a research career before it gets off the ground. We hope that our book will help current and future graduate students be better informed and avoid this pitfall.
2. It encourages applied researchers to accept a facile explanation for deviations, positive or negative, that they might observe from the default prediction, e.g., of equilibrium with risk-neutral agents. Because preferences are not observable, explaining deviations as arising from risk aversion (or risk seeking) tends to cut off further inquiry that may yield more useful explanations. For example, we will see in Chapter 3 that, besides risk aversion, there are several intriguing explanations for overbidding in first-price sealed-bid auctions.
3. It impedes decision theorists' search for a better descriptive theory of choice. Given the unwarranted belief that there are only a few remaining

> gaps in the empirical support for curved Bernoulli functions, many decision theorists invest their time and talent into tweaking them further, e.g., by including a probability weighting function or making the weighting function cumulative. As we shall argue, these variants add complexity without removing or reducing the defects of the basic EUT, and the new free parameters buy us little additional out-of-sample predictive power.

The question remains, what is to be done? Science shouldn't jettison a bad theory until a better one is at hand. Bernoulli functions and their cousins have dominated the field for decades, but unfortunately we know of no full-fledged alternative theory to replace them.

The best we can do is to offer an interim approach. In Chapter 6 we show how orthodox economics offers some explanatory power that has not yet been exploited. Instead of explaining choice by unobservable preferences (represented, e.g., by estimated Bernoulli functions), we recommend looking for explanatory power in the potentially observable opportunity sets that decision makers face. These often involve indirect consequences (e.g., of frictions, bankruptcy, or higher marginal taxes), and some of them can be analyzed using the theory of real options. Beyond that, we recommend taking a broader view of risk, more sensitive to its first meaning as the possibility of loss or harm.

The interim approach in Chapter 6 has its uses, but we do not believe that it is the final answer. In Chapter 7 we discuss process-based understanding of choice. We speculate on where, eventually, a satisfactory theory might arise. Will neurological data supply an answer? What about heuristics / rule-of-thumb decision making? Can insights from these latter approaches be integrated with the modeling structure outlined in Chapter 6? We are cautiously optimistic that patient work along these lines ultimately will yield genuine advances.

Notes

1 Knight said that a decision maker faced risk when probabilities over all possible future states were truly "known" or "measurable," and faced uncertainty when these probabilities (or some of the possible outcomes) were not known. Knight himself noted that this distinction is different than that of popular discourse.

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