

**2005**

# **Risk and Uncertainty Program**

RSMG Working  
Paper Series

## **TITLE:**

Economists and Uncertainty

**Schools of  
Economics and  
Political Science**

## **AUTHOR:**

John Quiggin

**The University of  
Queensland**

**St Lucia**

**Brisbane**

**Australia 4072**

**Web:**

**[www.uq.edu.au](http://www.uq.edu.au)**

Working Paper: R05\_2

# Economists and uncertainty

John Quiggin,  
Australian Research Council Federation Fellow  
University of Queensland

April 2005

## Abstract

Among economists, discussion of problems involving uncertainty is polarised between advocates of formal decision theories, who claim that uncertainty can be tamed by careful consideration of information and elicitation of preferences, and critics who argue that uncertainty is fundamentally irreducible. Improvements and generalisations of formal decision theory, responding to critical arguments, have generated new counterexamples and anomalies, and new evidence about the limits of our capacity to deal with uncertainty. So, although our understanding of the issues has deepened, the fundamental debate is unresolved.

JEL Code D8

This research was supported by an Australian Research Council Federation Fellowship.

## 1 Introduction

Discussions of uncertainty have always had a bipolar character. On the one hand, humans have always sought to tame, domesticate and, if possible, eliminate uncertainty, using devices ranging from augury to markets in financial derivatives. On the other hand, there has been a continuing insistence on the irreducibility of uncertainty and the importance of this irreducibility for human affairs.

Among social scientists, economists have taken the lead in seeking to tame and domesticate uncertainty. In fields ranging from general equilibrium theory to benefit–cost analysis, economists have sought to show that tools developed for the analysis of problems where outcomes are certain can, with appropriate modifications, be extended and applied to manage problems involving uncertainty. In both normative and positive analysis, the dominant approach has been that of expected utility theory.

On the other hand, economists (along with psychologists) have taken a leading role in developing some of the most significant challenges to expected utility theory. These challenges have been presented at a number of levels. First, the fundamental premises of expected utility, such as the existence of well-defined preferences and subjective probabilities have been questioned. Second, the descriptive accuracy of expected utility theory has been challenged. Finally, the assumption, implicit in much economic discussion, that markets provide an adequate, or near-adequate, set of financial instruments for dealing with economic uncertainty has been questioned.

## 2 The state-contingent approach and expected utility theory

The foundations of the standard economic approach to uncertainty were laid in between 1944 and 1954<sup>1</sup>. The starting point was von Neumann and Morgenstern (1944) who developed the notion of expected utility theory as a tool for the analysis of games involving uncertainty. This idea led in several different directions: to Nash's (1951) non-cooperative equilibrium concept and modern game theory; to Savage's (1954) reformulation of expected utility theory in which the concepts of subjective probability and expected utility are derived jointly from plausible conditions on preferences; and to the derivation, by Arrow and Debreu (1954), of sufficient conditions for the existence of general equilibrium under conditions of uncertainty. The new ideas were also subject to immediate challenge, by Allais (1953), who posed the first in a series of 'paradoxes', that is, choice problems where most people made choices inconsistent with expected utility theory.

All of these were substantial contributions. But the most significant, for economists, was probably the work of Arrow and Debreu (1954). The state-contingent analysis did not require that preferences satisfy the expected-utility hypothesis. The crucial insight of Arrow and Debreu was that, if uncertainty is represented by a set of possible states of nature, and uncertain outputs by vectors of state-contingent commodities, production under uncertainty can be represented as a multi-output technology, formally identical to a non-stochastic technology. Hence, the necessary and sufficient conditions for the existence and optimality of equilibrium are not affected by the introduction of uncertainty. On the other hand, as Arrow (1963) pointed out, the empirical plausibility of the relevant necessary and sufficient conditions is significantly reduced by consideration of uncertainty.

In the absence of uncertainty, the requirement that, for each commodity,

---

<sup>1</sup>There had been important earlier contributions, such as those of De Finetti (1937, 1964), Keynes (1921), Knight (1921) and Ramsey (1931), but they did not amount to a fully-elaborated theory, and their significance was appreciated mainly in retrospect.

there should exist a market seems relatively innocuous. On the other hand, the more general requirement that a market should exist for each commodity in each possible state of nature is clearly not satisfied. Interest is therefore focused on the case when markets are incomplete. The dominant view among economists has been that financial markets are ‘complete enough’ to ensure that the Pareto-optimal general equilibrium characterised by Arrow and Debreu is an appropriate starting point for analysis.

By comparison with general equilibrium theory, game theory and expected-utility analysis of choice under uncertainty were slower to develop. By the 1970s, however, expected-utility theory had displaced the older mean-variance model (Markowitz 1959, Tobin 1958) as the preferred approach to the analysis of problems involving choice under uncertainty. Despite the challenges discussed below, the expected-utility model has remained dominant in mainstream microeconomic analysis of problems involving uncertainty.

### 3 Critiques of expected utility theory

Over the course of the 1970s, the expected-utility hypothesis came under increasing attack. The long-neglected and much-misinterpreted criticisms of Allais (1953) were reinforced by new empirical evidence, which demonstrated the robustness of the ‘Allais paradox’. A number of attempts were made to develop generalisations of expected utility theory that could account for the Allais paradox and related phenomena such as the common ratio effect.

The most influential of these were the contributions of the psychologists Kahneman and Tversky (1979) who proposed ‘prospect theory’ as an alternative to expected utility theory. Among a number of innovations, two became the focus of attention. The first was the idea of making gain (or losses) relative to a starting position, rather than the utility of final outcomes, the carrier of value. The second was the idea of replacing probabilities with weights, allowing for a higher weight on low-probability outcomes. A second major contribution was that of Machina (1982) who showed that many of the features of expected utility theory that were most attractive to economists were not dependent on the linearity and independence properties that appeared inconsistent with the Allais and common ratio effects.

These contributions were part of an explosion of work on the topic, much of it initially undertaken independently. Significant contributions included Chew (1983), Quiggin (1979, 1981, 1982), Loomes and Sugden (1982), Segal (1987, 1989) Schmeidler (1989) and Yaari (1987). Allais (1987) returned to a field that was, to a significant extent, inspired by his own work more than three decades previously. Although a variety of approaches were examined, the most popular, developed independently and with different motivations by several researchers, was the idea of rank-dependent probability weighting.

My own work on this topic (Quiggin 1979, 1981, 1982) was something of a footnote<sup>2</sup> to Kahneman and Tversky (1979), though the main idea had been developed earlier in response to Handa (1977), who also proposed a model based on the idea of probability weighting. The simple model proposed by Handa (1977) and, with modifications, by Kahneman and Tversky (1979), produced violations of first-order stochastic dominance; that is, it predicted that individuals would choose prospects which were worse than available alternative in every state of the world. While there are conceivable conditions under which this might take place, the simple probability weighting model predicted routine violations of stochastic dominance that are not observed in reality.

It turned out that the problem lay in the way in which the idea of probability weighting was formalised. As was observed in Quiggin (1982):

The following example illustrates further the notion that equally probable events should not necessarily receive the same weight. Suppose an individual's normal wage income is uniformly distributed over a range from \$20 000.01 to \$21 000.00. There is also a 1/100 000 chance that the person will win a contest for which the prize is a job paying \$1m a year. The probability of receiving any specified income in the relevant range \$20 000.01 to \$21 000.00 (e.g. \$21 439.72) is also 1/100 000. Nevertheless, it seems reasonable that the extreme outcome will not be weighted in the same way as an intermediate outcome such as \$21 439.72.

The solution was to apply probability weighting to the cumulative probability distribution, so that the weighting attached to a particular outcome depended not only on its probability but also on its rank-order in the distribution. This idea, commonly referred to as rank-dependent expected utility or rank-dependent utility was combined with the original formulation of prospect theory to produce cumulative prospect theory, now the standard form of the model (Tversky & Kahneman 1992). More general sign-dependent and rank-dependent models have been explored by Luce (1991).

### 3.1 The rise of behavioural finance

The critiques of the 1980s focused primarily on the point that the expected utility model does not accurately represent individual choices, and relied primarily on experimental evidence. During the 1990s, this critique was extended to the analysis of market outcomes. A large body of work, much of it presented under the banner of 'behavioural finance', showed that financial markets did not operate in the way predicted by the standard model. Such empirical findings could

---

<sup>2</sup>Literally, in that it was mentioned in a footnote to Kahneman's Nobel prize citation.

be explained in two main ways. First, as noted by Arrow and Debreu, transactions costs may prevent the emergence of some of the markets needed for efficient risk-spreading. Alternatively, as suggested by the behavioral finance school, individuals may not display the strictly rational behaviour required for the efficient markets hypothesis to hold.

Shiller (1989, 2000, 2003) has integrated these arguments to produce a convincing account of the ‘irrational exuberance’ exhibited by stockmarkets in the late 1990s, when companies with no profits, and sometimes even no revenues, were valued by the share market as being worth billions of dollars.<sup>3</sup> Shiller shows how a range of factors combine to produce high levels of stockmarket volatility and periodic bubbles and busts.

More interestingly, by combining analysis of missing markets with observations from behavioral finance, Shiller is able to suggest innovations in government policy and new financial instruments that might improve the spreading of risk and reduce excessive volatility. One example is the creation of securities linked to indexes of real-estate returns in particular markets. This would enable households to hedge the risks associated with home ownership.

## 4 Fundamental critiques of the state-contingent model

Until recently, criticism of the standard economic approach to uncertainty focused on the auxiliary assumptions needed to derive expected-utility preferences from the general state-contingent framework pioneered by Arrow and Debreu (1954). The fundamental assumption that decision-makers can consider all future possibilities, and organise them into an exhaustive and mutually exclusive set of states of nature was not seriously challenged.

The absence of a well-developed critique along these lines was not the result of unthinking acceptance of the state-contingent framework. Informal discussion of ‘unknown unknowns’ reflects the fact that decisionmakers are well aware that their projections may be derailed by unforeseen contingencies. However, formalisation of this awareness has proved to be an exceptionally difficult problem.

One obvious approach is to extend standard state-contingent analyses by adding a residual ‘unforeseen’ event. This approach does not appear to yield any real benefits. Either the residual event is not taken into account in the decision-making model, in which case it is redundant, or it is incorporated in a way that is not significantly different from that adopted in the standard state-contingent framework.

---

<sup>3</sup>Although the focus of this was on ‘dotcom’ companies associated with the burgeoning of the Internet, the speculative frenzy extended more broadly. The Standard & Poors 500 index rose from 400 in the mid-1990s to a peak of 1500 in early 2000, before dropping below 1000 in the subsequent recession. It currently stands at 1200.

Recent work suggests some more promising directions for an attack on this problem. One approach takes as its starting point work by Kreps (1992), who considered problems of static choice over menus of options. This idea has been further developed by Dekel, Lipman and Rusticchini (2001). An alternative approach, developed by Grant and Quiggin (2004), breaks with the traditional approach of decision theory in which problems are considered from the viewpoint of the decisionmaker and adopts the perspective of an outside observer with access to a complete (or at least, expanded) state space to which the decisionmaker has only partial access. It is then possible to represent such occurrences as the discovery of new possibilities, as well as the complementary process of forgetting.

Analysis of unforeseen contingencies is still in its early stages, and it remains to be seen which, if any of the current approaches will prove successful. But it seems clear that this must be a central issue for future work in this field and that, while refractory, it is not insoluble.

## 5 Concluding comments

Discussion of problems involving uncertainty is polarised between advocates of formal decision theories, who claim that uncertainty can be tamed by careful consideration of information and elicitation of preferences, and critics who argue that uncertainty is fundamentally irreducible. Improvements and generalisations of formal decision theory, responding to critical arguments, have generated new counterexamples and anomalies, and new evidence about the limits of our capacity to deal with uncertainty. So, although our understanding of the issues has deepened, the fundamental debate is unresolved.

## 6 References

Allais, M. (1953), 'Le comportement de l'homme rationnel devant le risque: critique des axiomes et postulats de l'école Américaine', *Econometrica*, 21(4), 503–46.

Allais, M. (1987), 'The general theory of random choices in relation to the invariant cardinal utility function and the specific probability function: The (U,  $\theta$ ) model - A general overview,'

Arrow, K. (1963), 'Uncertainty and the welfare economics of medical care', *American Economic Review*, 53(5), 941—73.

Arrow, K. and Debreu, G. (1954), 'Existence of an equilibrium for a competitive economy', *Econometrica*, 22, 265–90.

Bargiacchi, R. (2003), 'Climate change scenarios and the precautionary principle', pp. 113–30 In *Risk and Uncertainty in Environmental and Resource Economics*, (Eds, J.Wesseler, Weikard, H.P. and R.Weaver) Edward Elgar, London.

Chew, S.H. (1983), 'A generalisation of the quasilinear mean with applications

to the measurement of income inequality and decision theory resolving the Allais paradox', *Econometrica*, 51(4), 1065–92.

de Finetti, B.c.V.I., trans. H. E. Kyburg. (1937, 1964), 'Foresight: its Logical Laws, its Subjective Sources', in *Studies in Subjective Probability*, (Eds, . E. Kyburg Jr, Smokler, H.E.), New York: Wiley, 93–158.

Dekel, E., Lipman, B. and Rusticchini, A. (2001), 'A unique subjective state space for unforeseen contingencies', *Econometrica*, 69, 891–934.

Grant, S. and Quiggin, J. (2004), 'Conjectures, refutations and discoveries: incorporating new knowledge in models of belief and decision under uncertainty', Paper presented at the 11th International Conference on the Foundations and Applications of Utility, Risk and Decision Theory (FUR XI–Paris), under the joint auspices of the Ecole Nationale Supérieure d'Arts et Métiers (ENSAM) and the Ecole Spéciale des Travaux Publics (ESTP), Paris, 2 July. Handa, J. (1977), 'Risk, probabilities and a new theory of cardinal utility', *Journal of Political Economy*, 85(1), 97–122.

Kahneman, D. and Tversky, A. (1979), 'Prospect theory: an analysis of decision under risk', *Econometrica*, 47(2), 263–91.

Keynes, J.M. (1921) *A Treatise on Probability*, MacMillan, London.

Kreps, D. (1992), 'Static choice in the presence of unforeseen contingencies', In *Essays in Honour of Frank Hahn*, (Ed, P Dasgupta et al.) MIT Press,

Loomes, G. and Sugden, R. (1982), 'Regret theory: An alternative theory of rational choice under uncertainty', *Economic Journal*, 92(4), 805–24.

Luce, R.D. (1991), 'Rank- and sign-dependent linear utility models for binary gambles', *Journal of Economic Theory*, 53(1), 75–100.

Machina, M. (1982), 'Expected Utility' analysis without the independence axiom', *Econometrica*, 50(2), 277–323.

Markowitz, H. (1959) *Portfolio Selection: the Efficient Diversification of Investments*, Yale University Press, New Haven.

Nash, J. (1951), 'Non-cooperative games', *Annals of Mathematics*, 54, 286–95.

Quiggin, J. (1979) *The theory of the multiproduct firm under uncertainty*. B. Ec. Honors thesis Australian National University 1979 1979 The theory of the multiproduct firm under uncertainty Quiggin, J. The theory of the multiproduct firm under uncertainty

Quiggin, J. (1981), 'Risk perception and risk aversion among Australian farmers', *Australian Journal of Agricultural Economics*, 25(2), 160–69.

Quiggin, J. (1982), 'A theory of anticipated utility', *Journal of Economic Behavior and Organization*, 3(4), 323–43.

Savage, L.J. (1954) *Foundations of Statistics*, Wiley, New York

Schmeidler, D. (1989), 'Subjective probability and expected utility without additivity', *Econometrica*, 57, 571–87.

Segal, U. (1987), 'The Ellsberg paradox and risk aversion: an anticipated utility approach', *International Economic Review*, 28(1), 175–202.



Segal, U. (1989), 'Anticipated utility: a measure representation approach', *Annals of Operations Research*, 19, 359–74.

Shiller, R. (1989) *Market Volatility*, MIT Press, Cambridge, Mass. and London.

Shiller, R. (2000) *Irrational Exuberance*, Princeton University Press, Princeton, New Jersey.

Shiller, R. (2003) *The New Financial Order: Risk in the 21st Century*, Princeton University Press, Princeton.

Tobin, J. (1958), 'Liquidity preference as behavior toward risk', *Review of Economic Studies*, 25(1), 65–86.

Tversky, A. and Kahneman, D. (1992), 'Cumulative prospect theory: an analysis of attitudes towards uncertainty and value', *Journal of Risk and Uncertainty*, 5(3), 297–323.

von Neumann, J. and Morgenstern, O. (1944) *Theory of Games and Economic Behavior*, Princeton University Press, Princeton, NJ.

Yaari, M. (1987), 'The dual theory of choice under risk', *Econometrica*, 55(1), 95–115.