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THEORY DEVELOPMENT PROCESSES IN THE SOCIAL SCIENCES: THE CASE OF STOCHASTIC CHOICE THEORY

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Almost three hundred years ago, Pascal and de Fermat produced a quantitative model for choice under uncertainty, based on expected payoffs. This event triggered a theory development process fueled by contributions like the logarithmic utility model of Bernoulli, the expected utility theorem (EUT) of von Neumann and Morgenstern, the non-expected utility (NEU) theories of Allais, Bell, and Machina, as well as a long series of empirical studies.

This article uses the paradigm-oriented framework of Kuhn and Lakatos to describe and evaluate the history of ideas in stochastic choice theory. Particular attention is paid to the rivalry between the EUT and various NEU models, which has been called one of this century's most important disputes in the social sciences. Specific issues include the quick acceptance of the EUT, the large export of the EUT to several decision-oriented disciplines, and the periods of progress, stagnation and revitalization of NEU research. The article also contrasts the EU and NEU schools by analyzing the remarkable consensus on subject and methodology, the ambiguous use of the rationality concept, the difference in basic implicit assumptions, and the heterogeneous response to given empirical findings.

1. Introduction

The area of choice under uncertainty (stochastic choice) has produced several significant contributions, both in terms of new theories and empirical tests of existing models. A large number of prominent researchers have been involved, particularly during the last 40 years. Most of them have either defended the expected utility (EU) view or adhered to some non-expected utility (NEU) approach. Whereas the EU model was the predominant one from the fifties up to the middle

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seventies, the NEU tradition is presently very active and is gaining ground at the expense of the EU approach.

The existence of two conflicting views may make it difficult to understand what is going on and particularly why the area of stochastic choice develops the way it does. For instance, when commenting on one particular aspect of this history, one observer feels 'it is hard to think of a more notorious, long-standing, and often outright confused controversy in modern decision theory than the continuing debate on the meaning of "rationality"' (Machina 1979: 163).

This article has a dual purpose. First, it evaluates the development of stochastic choice research. Two models of respectively Kuhn (1970, 1976) and Lakatos (1970) will be used to structure and interpret the research history of choice under uncertainty, paying particular attention to the rivalry between the EU and the NEU traditions.

The second purpose of the article is to apply the frameworks of Kuhn and Lakatos to a new case. It examines whether models designed to account for the history of ideas in natural sciences (physics in particular) are useful in the social sciences. In this sense, the spirit of this article resembles that of Gholson and Barker (1985), who relate the models of Kuhn, Lakatos, and Laudan to theory development in the psychology of learning. Recent contributions by Blaug (1980) and Arndt (1985) use a similar approach to economics and marketing, resepectively.

The article is organized as follows. Major events in the history of stochastic choice theory are outlined in the next section. Subsequently, the models of Kuhn and Lakatos are presented and compared in section 3. The fourth section integrates the two former ones by using the Kuhn and Lakatos frameworks to identify seven distinct characteristics of the history of stochastic choice theory. Concluding remarks are given in section 5.

2. The history of stochastic choice theory

A lottery (game) Z is a risky (uncertain) project with payoff (outcome) z_s if and only if state s occurs. The probability that state s will materialize is p_s, and just one of the s mutually exclusive states will occur. Given an option to choose among two such lotteries X and Y, which of the two is the best? This is the classic decision problem studied by stochastic choice researchers for almost 300 years. Table 1 summarizes major events of this period.

2.1. The models

In the beginning of the 18th century, Pascal and de Fermat suggested that X is better than Y if X offers the highest *expected payoff*. A few years later, however, Nicholas Bernoulli presented the St. Petersburg game. This lottery has an infinite expected payoff, but most people would still pay just small amounts to participate. Thus, relative to the expected payoff criterion of Pascal and de Fermat, people's response to this lottery was later called the St. Petersburg Paradox.

Ten years later, both Cramer and Daniel Bernoulli (1738) (a cousin of Nicholas) independently suggested a new criterion which ranked lotteries according to the *expected logarithmic utility* of their potential outcomes. Thus, the implicit assumption of risk neutrality in Pascal and de Fermat's model was replaced by a specific type of risk aversion. Unlike the expected payoff model, this new criterion produced a finite certainty equivalent of the St. Petersburg game.

More than 200 years passed until a new milestone was erected in stochastic choice theory. In 1947, von Neumann and Morgenstern proved the *expected utility theorem* (EUT) in an appendix to the second edition of their book on game theory.

The EUT is outlined in table 2. For expositional purposes, the structure of the axiom set is somewhat altered from that of von Neumann and Morgenstern (1947).

As to the *axioms*, comparability in *A1* assumes that the decision maker can always state indifference or strict preference between two lotteries or lottery outcomes. Moreover, the transitivity part of A1 rules out circular preferences.

Assume outcome z_1 is preferred to z_2 and z_2 to z_3. Game X offers outcomes z_1 and z_3 with probabilities p and $(1-p)$, whereas game Y yields the intermediate payoff z_2 with certainty. Axiom *A2* assumes that there is always some probability p between 0 and 1 which makes the decision maker indifferent between X and Y. The amount z_2 is called the certainty equivalent of lottery X.

A3 assumes that if the outcome is attractive, a high probability is preferred to a low one. This is equivalent to assuming that lotteries can

Table 1
Major events in stochastic choice theory, 1700–1990.

Year	Researcher(s)	Topic
1700	Pascal, de Fermat	Expected payoff model
1728	N. Bernoulli	St. Petersburg Paradox
1738	D. Bernoulli, Cramer	Expected logarithmic utility model
1947	von Neumann and Morgenstern	Expected utility theorem (EUT)
1948	Friedman and Savage	Convex and concave parts of the utility function $U(z)$ explaining simultaneous gambling and insurance by the same person
1952	Allais	Allais Paradox and the first Non-Expected Utility (NEU) model
1952 to present	See table 3	Empirical tests of the EUT axioms and new NEU models
1964 1965	Pratt Arrow	Quantitative measures of risk aversion are related directly to $U(z)$
1978 to present	Karmarkar, Kahneman and Tversky, Bell, others	New NEU models
1979	Allais and Hagen	First joint publication of recent EU and NEU research
1982	Hagen, Leinfellner, and others	First conference on Foundations of Utility and Risk (FUR)
1982	Schoemaker	Survey paper on EU and NEU research in the *Journal of Economic Literature*
1987	Machina	Survey of EU and NEU research in the *Journal of Economic Perspectives* and in *Science*
1988	Allais	Nobel Prize in economics

be ranked according to stochastic dominance of the first order (Hadar and Russel 1969)

The independence axiom $A4$ assumes that the utility of the payoff from X in a particular state is not influenced by what lottery Y would yield in the same state. An important implication of this axiom is that

Table 2
The structure of the expected utility theorem (EUT).

Axioms (assumptions)
A1: Comparability and transitivity
A2: Continuity
A3: Monotonicity
A4: Independence
A5: Substitutability

Theorem (implication)
If A1–A5, then there exists a utility function $U(z)$ such that the lottery X is preferred to the lottery Y if and only if:

$E[U(x)] > E[U(y)]$

the possibility of post-decisional regret is assumed to be disregarded when lotteries are evaluated ex ante.

Finally, *A5* assumes that any composite (multi-stage) lottery X is equivalent to a simple (single-stage) lottery Y, provided the probability distributions involved in X and Y are identical. That is, only payoffs and their probabilities matter, not the way the lottery is organized. Any consumption effect of gambling per se (fun or pain) is ruled out.

Given A1–A5, the *theorem* states that there exists a utility function $U(z)$ with the property that the expected utility index of X exceeds that of Y if and only if X is preferred to Y. Thus, a decision maker whose preferences comply with A1–A5 behaves as if he or she always picks the lottery with the highest expected utility number. This result holds for any positive, linear function of $U(z)$ (i.e., the utility function is unique up to a positive, linear transformation).

It is important to remember that the EUT is a mathematical theorem. Like any such statement, it has *no empirical content* by itself. It is not a behavioral hypothesis about human choice in risky contexts, and the axioms A1–A5 assert nothing about how real-world preferences normally are, what they will gradually transform into, or how they ideally should be. The EUT is no more or less than a mathematical structure saying that *if* certain assumptions are made about a person's basic attitudes to risky prospects, choice behavior by such a hypothetic person can be exactly modeled by the EUT. In this particular sense, axioms are equivalent to assumptions: the axioms A1–A5 are the behavioral assumptions which are necessary and sufficient for the EUT to hold. Whether or not these assumptions are empirically relevant or useful in a descriptive, predictive, or normative sense is not an issue in the theorem. As will be apparent throughout this article, conflicts between EU and NEU researchers can be traced to attempts at using the EUT in empirical contexts.

Although it may look similar, the EUT is fundamentally different from its 18th century ancestors. First, the EUT starts with explicit preference axioms, which were subsequently used to derive an implied decision rule. In that sense, the EUT *axiomized* a proposal made about 200 years earlier. Second, the theorem *generalized* both predecessors in one shot: with a linear utility function $U(z)$, the EUT yields the expected payoff rule of Pascal and de Fermat. A logarithmic $U(z)$ produces the expected ln-criterion of Cramer and Bernoulli.

The first version of an expected utility theorem was in fact developed by Ramsey in 1926 and published posthumously five years later (Ramsey 1931). However, it seems that economists at that time were unaware of Ramsey's work (Borch 1968a: 30). De Finetti presented similar ideas in 1937, but he did not know of Ramsey's paper (de Finetti 1937). Neither did von Neumann and Morgenstern. It was not until 1954, when Savage (1954) published his EU model based on subjective probabilities, that Ramsey's contribution was discovered by the academic community. Savage built his theory on both Ramsey, de Finetti, and von Neumann and Morgenstern.

Shortly after the EUT was published, Friedman and Savage (1948) used an EU approach to rationalize an empirical observation. In particular, they maintained that a $U(z)$ which is concave at low wealth levels and convex at high ones could explain why an individual may both incur risk by playing casino and simultaneously avoid risk by purchasing home insurance. Along the same lines, but 18 years later, Pratt (1964) and Arrow (1965) analytically derived quantitative measures of risk aversion using curvature indexes of $U(z)$. These expressions captured the essential behavioral implications (in terms of risky choice), stated as a function of the decision maker's wealth.

At a conference in Paris in 1952, Allais presented empirical evidence suggesting that people do not behave according to the EUT when choosing between risky projects. In particular, it seemed that the independence axiom A4 was repeatedly violated when lotteries were ranked. This empirical inconsistency with the EUT was later called the Allais Paradox. Technically, it means that whereas the EU index is linear in probabilities, real-world indifference curves are *not* straight-line functions of probabilities. This phenomenon is now called 'fanning-out behavior' (Machina 1987a).

Allais' subsequent paper presented a *non-expected utility* (NEU) theory (Allais 1953). It was not based on the independence axiom A4, and Allais felt his model could account for his empirical evidence against the EUT. This event started the NEU research tradition, which was later called the French School, as opposed to the American EU approach.

At least six new NEU models were developed in the fifties and sixties, like those of Edwards (1955) and Hagen (1969). Still, it was not until about 1980 that a significant and rapidly growing number of people were doing research on NEU models. During the last 10 years, a number of NEU models have been derived, such as those of Karmarkar (1978), Kahneman and Tversky (1979), Machina (1982), Quiggin (1982), Bell (1982, 1985), Chew (1983), Fishburn (1983), Becker and Sarin (1987). All of these models drop the independence axiom A4, and Bell's expected regret model even deletes the transitivity assumption of A1 (Bell 1982).

2.2 *The empirical work*

The 1952 Paris conference started an empirical research tradition of testing the empirical validity of the axioms A1–A5, sometimes also exploring the viability of NEU alternatives. Major contributions are summarized in table 3, which shows that the EUT has been tested rather continuously for almost 40 years. Judging from the table, it seems fair to conclude that by 1980, the cumulative evidence against the EUT as a descriptive or predictive hypothesis was rather heavy: none of the four tested axioms had received substantial empirical support from empirical observations.

In addition to these direct tests of the EU model, three related areas have been subjected to empirical enquiry. First, *context tests* over the last 20 years have shown that when estimating a person's utility function $U(z)$, the estimation procedure has a significant impact on the resulting $U(z)$. This type of research is exemplified by Ronen (1973), Hershey et al. (1981), Slovic et al. (1982), and by Tversky and Kahneman (1981, 1986).

Table 3
Tests of the EU axioms A1–A5.

Comparability and transitivity (A1)	
51	Mosteller and Nogee: Unstable repeated rankings
69	Tversky: Circular preferences
71	Lichtenstein and Slovic: The highest certainty equivalent is not assigned to the preferred lottery
	Similar inconsistencies with A1 found several times later, recently even in experimental market transactions (Knez and Smith 1986)
Continuity (A2)	
75	Coombs: Nearly half the subjects violated the inbetweenness assumption
Monotonicity (A3)	
Not tested	
Independence (A4)	
53	Allais: A4 is frequently violated
68	MacCrimmon: Individuals do want to obey A4. Not confirmed by later studies by Moskowitz (74) and by Slovic and Tversky (74)
79	Kahneman and Tversky: The common consequence effect, where Allais' finding is a special case
85	Battalio et al.: Rats violate A4
86	Chew and Waller: Confirm Kahneman and Tversky (79)
Substitutability (A5)	
61	Ellsberg: Aversion to composite games
73	Bar-Hillel: Probabilities in composite games are miscalculated

The *intellectual capacity* of decision makers has been empirically explored ever since 1947. Among the numerous studies, Reder's data (1947) suggested that alternatives are not compared in a holistic way, but rather in a decomposed, relative fashion. Several studies inspired by Edwards (1953) found that respondents overestimated small probabilities and underestimated high ones (Lee 1971: 61). Later studies uncovered that Bayesian revision of probabilities is not widespread: respondents put too much weight on the sample relative to the prior, as uncovered by Kahneman and Tversky (1973), Bar-Hillel (1974), and Grether (1980). Tversky's (1972) respondents revealed lexicographic preferences, whereas Payne's (1976) data suggested that the more complex the problem, the less holistic and more simplified the evaluation. Tversky and Kahneman (1981) found that their respondents tended to disregard portfolio effects, that is, to neglect a game's net effect on total wealth.

Finally, tests of whether or not people are *risk averse* have been performed over the last 15 years. Both laboratory contexts and field studies have been reported, particularly on the demand for flood and earthquake insurance. Judging from Anderson (1974), Kunreuther (1976), Slovic and Fischhoff (1977), and Schoemaker and Kunreuther (1979), there is a tendency to disregard risk and to stay uninsured in cases of extremely small probabilities of very large losses. This phenomenon occurred even when 90% of the insurance premium was subsidized by the government.

The only field report on insurance behavior which seems consistent with reasonable degrees of risk aversion is Brookshire et al. (1985). Moreover, people reveal risk aversion in real-life decisions, for instance when they diversify their stock portfolios or purchase home and car insurance. In a context resembling that of Friedman and Savage (1948), Laughunn et al. (1980) found that risk aversion among executives was primarily apparent in gambles involving ruinous losses in at least one state. In cases of approximately break-even payoffs, however, risk seeking was the predominant behavior.

2.3. Academic interaction

There was no close contact between the EU and the NEU schools during the first 30 years. The first joint publication of papers from both sides did not appear until 1979 (Allais and Hagen 1979). This was actually the first time that Allais and Morgenstern responded to each other's criticisms. Moreover, 26 years after the publication of Allais' 1953 paper in *Econometrica* (in French), his theory was finally translated into English.

Three years after this attempt at constructive communication, the first FUR conference served a similar purpose of bringing the competing parties together. Moreover, Machina's NEU model was published in *Econometrica* in that year (Machina 1982). At the same time, P.J. Schoemaker from the University of Chicago published an extensive survey of EU and NEU research in the *Journal of Economic Literature* (JEL), concluding: 'at the individual level most of the empirical evidence is difficult to reconcile with the principle of EU maximization' (Schoemaker 1982: 530) and 'Our intellectual indebtedness to the EU model is thus great, although its present paradigmatic status (in certain fields) should be questioned' (Schoemaker 1982: 556).

Five years later, Machina expressed similar views in the *Journal of Economic Perspectives* (JEP): 'Fifteen years ago, the theory of choice under uncertainty could be considered one of the "success stories" of economic analysis' – 'Today (it) is in a field of flux: the standard theory is being challenged on several grounds both within and outside economics' (Machina 1987: 121). A shorter survey in the same spirit recently appeared in *Science* (Machina 1987b).

Any economist or decision theorist considers *Econometrica* a prestigious, norm-setting journal. Moreover, the *JEL* and the *JEP* are both published by the American Economic Association. Another recent sign of the general recognition of NEU research appeared in December 1988, when Allais received the Nobel Prize in economics.

The historic account presented so far only mentions some of the events which I consider important when evaluating this theory development process by the models of Kuhn and Lakatos. When making this appraisal in section 4, I will discuss more details and nuances. Even there, however, many issues must be left out. The interested reader is referred to Fishburn (1987, 1988, 1989a, b), who provides precise, comprehensive, and updated overviews of EU and NEU research.

3. Two models of theory development processes

This section briefly reviews basic components of the Kuhn and Lakatos models. Readers who are familiar with these ideas may proceed directly to section 4.

According to Kuhn's model of the history of ideas, a *paradigm* contains basic beliefs and commitments shared by a particular scientific community. The paradigm broadly defines what phenomena are worth studying (for instance, the pricing of shares) and states the rationale for this preference (for instance, changing share prices which influence social welfare in significant and unpredictable ways). It contains opinions on the appropriate language (medium) for theory construction (for instance, the validity of modeling human choice behavior by mathematical equations). The paradigm states proper ways of collecting and interpreting data (for instance, the relevance of laboratory findings for real-world contexts). Finally, the paradigm includes implicit assumptions which may be difficult to deduce from the specific theories generated within the paradigm (for instance, a belief that human behavior is maximizing in an economic welfare sense, that most observable market prices approach or stay close to those of a competitive equilibrium, or that investors normally prefer more information to less).

In Kuhn's model, the adherents to a paradigm do not question the validity of its components under normal circumstances. The paradigm is considered immune to empirical testing and serves as the general starting point when specific theories and hypotheses are developed and evaluated. For such reasons, paradigms have normative and conserving effects on theory development processes.

The *Scientific Research Programme* (SRP) is the basic concept in a related model of theory development suggested by Lakatos. The SRP is subdivided into two parts; the hard core and the protective belt. The hard core, which resembles Kuhn's paradigm, contains shared commitments which are not subjected to empirical testing.

The protective belt shelters the hard core from being questioned by empirical observations. The content of the protective belt is deliberately altered when new findings challenge the hard core. The major objects of change in the protective belt are new specific hypotheses and modified explicit assumptions. For instance, if optimizing choice behavior is in the hard core of the SRP, seemingly inconsistent empirical evidence (like limited search for alternatives by most economic agents) may be reconciled with the basic beliefs by explicitly introducing information costs and transaction costs into models of human decision making. Simon's ideas of bounded rationality (Simon 1955) may be interpreted along these lines: taking costs of search and information processing into account, people are indeed doing their best in net economic terms. Thus, the protective belt (markets with friction) prevents the hard core (optimizing behavior) from being attacked.

The purpose of the Kuhn and Lakatos frameworks is to model the development over time of paradigms and SRPs, respectively. According to Kuhn, only one single paradigm can be dominant at one particular point in time. During the initial, revolutionary phase of a new paradigm's life cycle, the old paradigm is replaced by the new one. The number of adherents to the new paradigm as well as their productivity is sharply increasing, gradually reaching a more mature and less innovative phase. Kuhn uses the term normal science to characterize the research carried out in this mature period, as opposed to revolutionary science in the initial phase. Finally, the paradigm is attacked and replaced by a new one. During this period, an increasing number of researchers question the basic beliefs of the old paradigm, ultimately rejecting it and simultaneously converting to the challenger, which in turn enters its revolutionary phase. Thus, the new paradigm kills the old one once and for all.

At this point, Lakatos disagrees with Kuhn on two fundamental issues. First, he thinks more than one SRP can exist at one given point in time. Moreover, even if a particular SRP is degenerating for some time, it may have strong phases later on. Thus, several SRPs may *coexist*, and one particular SRP may *revitalize* after periods of stagnation.

The two models also differ on the *comparability* of old and new basic beliefs. According to Kuhn, successive paradigms are incommensurable. This occurs because rival paradigms tend to focus on different phenomena, to define their own concepts, and to apply different methodological standards to their own research as well as to that of others. Consequently, the relative performance of two paradigms is hard to evaluate, and empirical work in one of them has limited relevance to the other. Due to this missing standard of comparison, Kuhn deliberately uses the term revolution to characterize the succession of one paradigm by the next. He does not believe in an evolutionary process of theory development, where knowledge accumulates along smooth lines with a high degree of continuity.

Although Lakatos admits that competing paradigms may be difficult to compare, his model still contains a yardstick for choosing between them. This criterion is the heuristic of the SRP, that is, the program's potential for generating better theories in the future. According to Lakatos, most researchers feel that progressive (successful) SRPs can accommodate the findings which put the hard core of its rival into miscredit; that is, it deletes the *anomalies*. Moreover, Lakatos thinks specific theories of such progressive SRPs typically include its rival as a special case. Finally, they make new predictions that are not as easily falsified by empirical observations.

In either model, the anomalies are essential, as such evidence will always challenge paradigms or the hard core. Still, Lakatos disagrees with Kuhn on what mechanism is the crucial one for a paradigm to be defeated. In Lakatos' model, conversion from one SRP to another is determined by most researchers' genuine concern for *progress* in their field. In such a perspective, the driving force is the cumulative weight of the anomalies which put pressure on every adherent to the common beliefs.

Evolution, not revolution, characterizes the process as seen by Lakatos, who feels that Kuhn's theory of conversion processes is too much of an appeal to metaphysics and mob psychology. Kuhn seems to think that for a significant conversion to occur, a sufficient number of influential researchers must reject the old paradigm and accept a new one. Then, but only then, will the risk of choosing the wrong side seem sufficiently small to their hesitant colleagues. Lakatos feels that this bandwagon effect reduces the philosophy of science to an unrealistic social psychology of science, where imitation of the leading scientists becomes a driving force.

Nevertheless, this part of Kuhn's model, which rests on the incommensurability hypothesis, seems to have been well received by the academic community. Admittedly not by philosophers of science (such as Lakatos), but rather by social scientists who have used Kuhn's ideas to characterize theory development processes in their own fields (Gholson and Barker 1985).

This outline of the two models is sketchy and incomplete. Except for some finer points, this account still includes most of what I shall now use to evaluate the development of stochastic choice theory.

4. Characteristics of the stochastic choice theory development process

This section integrates the two preceding ones by using the models of Kuhn and Lakatos to structure and evaluate the history of stochastic choice theory. The discussion is organized around seven distinct characteristics.

4.1. Consensus on subject and methodology

According to Kuhn, one reason why successive paradigms are hard to compare is that they focus on different phenomena and use non-overlapping methodological standards. If this conjecture is correct, there is definitely no sign of even a minor revolution in stochastic choice theory.

During its almost 300 years of existence, exactly *the same phenomenon* has been studied: individual choice between mutually exclusive lotteries, quantified in terms of probabilities and state-dependent payoffs. Moreover, *mathematics* has been the language for theory construction throughout the entire period. The only significant shift in *methodology* seems to be the 'axiom-theorem-proof' structure introduced by von Neumann and Morgenstern in 1947. This event brought an ultimate end to the Pascal/de Fermat/Cramer/Bernoulli tradition of just suggesting apparently reasonable decision rules. Although section 4.6 will show that there is no unified view on the proper procedure for empirically testing EU and NEU theories, this is due to different objectives of theory construction rather than different methodological standards.

Judging from these characteristics of the process, no Kuhnian fight between paradigms is visible at any point in time. According to Lakatos' model, this aspect of the history signals a smooth evolution along the same SRP, where the 'axiom-theorem-proof' structure served as a progressive factor.

4.2. *Quick initial acceptance of the EUT*

The EUT seems to have been very well received by the stochastic choice research community. This response is easily explained within a paradigm/SRP framework.

In a Kuhnian context, there was *no competing paradigm* which had to be defeated. In fact, Cramer and Bernoulli had prepared the ground 200 years earlier by introducing the expected logarithmic utility criterion. The problem with this model, however, was not what it did contain, but rather what it lacked. There were no explicit behavioral assumptions, and consequently no way of knowing exactly what kind of basic preferences were reflected in the proposed decision rule. The EUT solved these problems by proving mathematically that the preferences reflected in A1–A5 implied the EU criterion. Thus, unlike its predecessors, the EUT offered its user full control in the sense that the criterion was correctly derived from explicit behavioral assumptions.

Given the *quantitative tradition* of stochastic choice research, the formal structure of the EUT was ideal: five seemingly non-restrictive axioms produced a mathematical model of human behavior under uncertainty with an amazingly neat and simple structure. Thus, in terms of clarity, parsimony, and elegance, the high score of the EUT in 1947 set a demanding, positivistic standard for any subsequent competitor. In fact, almost 40 years later, Simon (who has never been enthusiastic about using the EUT in his own research) states: 'Conceptually, the (EU) model is a beautiful object deserving a prominent place in Plato's heaven of ideas' (Simon 1983: 13).

At its introduction in 1947, the EUT was also successful in the Lakatos sense: it *generalized* its predecessors and *explained* people's response to St. Petersburg games. Moreover, at first sight, *A1–A5 looked innocent* in terms of permissible behavior. One may easily get the misleading impression that A1–A5 are just the uncertainty analogues of (by then) well-known axioms in the micro-economic theory of deterministic consumer choice. Thus, jumping on the bandwagon and accepting A1–A5 may not have looked like taking a brave chance. Kuhn's social psychology factor may also have worked via an intellectual elite: the EUT was developed by two prominent researchers, and the model was soon backed by respected economists like Arrow (1953), Friedman (Friedman and Savage 1948), Marschak (1950), Markowitz (1952, 1959: 209), Samuelson (1952, 1983: 510), Savage (Friedman and Savage 1948; Savage 1954), and Tobin (1958).

Based on the pathbreaking content of the EUT and its subsequent impact on research, one may be tempted to think of 1947 as a revolutionary year in stochastic choice theory. Still, however, the event would not qualify as a revolution according to Kuhn's glossary. Neither a discontinuity in subject nor a serious fight with an existing, competing paradigm was present at that time. It seems more appropriate to use Lakatos' terms by stating that the EUT entered the protective belt of the stochastic choice research community.

4.3. *Large export of the EUT*

The EUT is a general model which may be relevant to any decision in uncertain environments. During the fifties and sixties, the theorem was widely adopted by several disciplines, such as finance, accounting, information economics, and economics.

Markowitz (1959: chs. 10–13) built a normative *financial model* for optimal portfolio selection, using the EUT and hence A1–A5 as an explicit investor assumption. Some years later, Sharpe (1964), Lintner (1965), and Mossin (1966, 1973: ch. 3) derived a competitive equilibrium model of capital asset prices (CAPM), assuming every market participant to choose among securities according to the diversification principle of Markowitz.

The CAPM, with its explicit formula for the equilibrium present value of future stochastic cashflows, was a significant breakthrough for the financial SRP. This valuation model has been extensively used ever since to explain observed security prices, to predict future returns, and to derive value-maximizing decision rules for investments in financial and real assets (Brealey and Myers 1988).

Two basic problems in *financial accounting* are to estimate the current value of non-traded assets and to determine the impact of accounting information releases. The CAPM is directly aimed at solving the first problem. The model can also operationalize the null hypothesis of no abnormal security return when testing the impact of accounting information releases. Not surprisingly, the CAPM has been important to empirical accounting research for almost 20 years (American Accounting Association 1977; Beaver 1981).

Information value is also a critical concept in *management accounting*. Typically, the demand for information is determined from its ability to change optimal actions as specified by standard managerial decision theories, such as cost-volume-profit models and rules for inventory management. Obviously, uncertainty is a necessary condition for new information to have positive value. As is evident from Demski (1972, 1980) and Demski and Feltham (1976), the EUT is the standard assumption about managerial behavior in information value contexts. A characteristic statement is the following: 'Analysis of information systems follows quite directly from the dual assumptions of a completely identified choice problem and choice behavior described by expected utility maximization' (Demski 1980: 37).

The early attempts at treating accounting information analytically was nurtured by a separate, more general research tradition in *information economics*. This field is concerned with issues like rational expectations (Muth 1961), market viability under asymmetric information (Akerlof 1970), the value of information systems (Marschak 1971), and principal–agent relationships under information asymmetry (Jensen and Meckling 1976). Again, the EUT is routinely used as a behavioral assumption at the individual level. In fact, in a survey of advances in information economics research, the EUT and the contingent claims approach were called the two main foundation stones that 'have brought about this intellectual revolution' (Hirshleifer and Riley 1979: 1376).

The EUT also found its way into the SRPs of *economics*. At the micro level, an illustrating case is Sandmo's (1971) extension of deterministic comparative-statics results to uncertain environments. The focus here is whether a firm's production will increase or decrease when deterministic prices are replaced by stochastic ones. Individual behavior is specified in terms of the EUT, like in the general equilibrium models of Arrow (1953) and Debreu (1959).

Before the EUT, all these disciplines modeled choice behavior by either disregarding uncertainty or by introducing it in ad hoc ways. At the same time, there was an increasing demand for mathematical modeling in general. Thus, the EUT was exported from stochastic choice theory to several decision-oriented disciplines which all lacked a well-founded, mathematically tractable model of individual choice under uncertainty. In fact, the exporter's theorem *became the importer's axiom*, serving as an assumption behind new theorems that were subsequently developed by the importers. In this way, the EUT entered the SRPs of the importing disciplines. As will be discussed in section 4.6, it may even be argued that the theorem entered the hard core in some of the importing disciplines, obtaining the status of an unquestionable premise.

4.4. Ambiguous use of the rationality concept

In Kuhn's model, communication across paradigms is difficult because the same term is given different meaning by the competing parties. After 1947, and particularly after Allais' findings in 1952, ambiguous use of the rationality term is an illustrating example of this phenomenon. According to Allais (1983: 4), '.. the heated, and sometimes sharp and polemical, discussions to which the Theory of Decision has given rise over the last thirty years appear mostly to be the result of semantic confusion between entirely different concepts'. In fact, the dispute caused by this phenomenon would suggest a real conflict between two paradigms in a Kuhnian sense.

As demonstrated by Sen (1986), rationality is a concept with inherent ambiguities. In stochastic choice theory, the term seems to have been used in at least two very different ways; sometimes explicitly, too often implicitly. One use of rationality is just *consistency* between preferences and behavior: if you do prefer apples to oranges, you should not rank them the opposite way. If you don't act according to your objectives (whatever they are), that would be foolish behavior. Both SRPs seem to agree that if rationality means consistency, any viable decision model should have this property (Allais 1979a: 10). In axiom-based models, this requirement simply means that the theorem must be provable from the axioms.

The second use of the term is problematic. Here, being rational means *having particular preferences*. Hence, it might be termed rational to prefer apples to oranges, and irrational to favor oranges. In an axiom-based model, this is equivalent to relating rationality to a particular axiom set.

To most people, defining rationality in terms of axioms is not just semantics, but a clear value judgement. Unfortunately, this was exactly what Marschak (1950) did when he used A1–A5 as a definition of rationality, implicitly saying that any model which was not based on A1–A5 mirrors irrational behavior. Similar positions were taken by Borch (1968b), Arrow (1972: 21–24) and Pratt (1974: 91–92). Given the negative signal of the irrationality term, it is not surprising that this axiom-based use of rationality has been a matter of conflict between the EU and NEU ever since. The articles by Amihud (1979: 181–188), Allais (1979b: 543–546), and Sugden (1986a) are illustrative and clarifying examples.

4.5. Different implicit assumptions

The ambiguous use of the rationality concept has caused much confusion when comparing the merits of EU and NEU models. Underneath this semantic problem, however, is a deeper, more general conflict on the objective of applying quantitative models to human decision making. An event at the 1952 Paris conference is an illustrating case. Savage, who was enthusiastic about the EUT, was asked by Allais to choose between some lotteries. It turned out that Savage initially ranked them according to the Allais Paradox, that is, in a way which could not be modeled by the EUT. When Allais made him aware that he had violated axiom A4, however, Savage structured the decisions in terms of payoff matrixes and subsequently switched to a EUT-consistent ranking in this second round.

This peculiar event may serve to illustrate the distinction between *three different objectives* of model construction in stochastic choice theory. First, a model may be normative, that is, a prescription of how Savage should have behaved in the first round. Second, it may have a positive objective, that is, describe or forecast how Savage (and most other people) actually choose when left alone with lotteries. Third, the model may be selectively positive, that is, aimed at describing or predicting risky choices made by a limited number of trained or guided persons, like Savage after correction and reflection in the second round.

The EUT-proponents have primarily justified the EUT by the normative purpose. Because they think A1–A5 characterize a large class of reasonable, attractive preferences, building on this axiom structure is different from requiring everybody to prefer apples to oranges (Marschak 1950; Harsanyi 1983: 298 and 307; Pratt 1986). For the same reason, EUT-proponents tend to consider the competing group of NEU models normatively unattractive, as they allow for reactions like regret and sometimes even circularity. Moreover, NEU models have been repeatedly criticized for being ad-hoc, non-falsifiable, and just able to explain everything ex post, but unable to predict anything ex ante (Amihud 1979: 186; Morgenstern 1979: 179–180).

According to Chicago economist Melvin Reder (1982: 11), the Chicago tradition of economic research goes further by also using the EUT as a positive hypothesis. In the Chicago view, EU maximization is part of the hard core conjecture that observed, real-world allocations are well approximated by a Pareto optimum. The related survivor principle of this tradition maintains that inefficient market traders (that is, those who don't behave according to the EUT) consistently lose wealth to EU-maximizers and are eliminated by competition (Reder 1982: 24). How such a view can be maintained despite the cumulative evidence on EUT violations will be dicussed in the next section.

Those who are *sceptical to the EUT* argue that a long series of empirical research has repeatedly falsified the theorem as a positive hypothesis. Moreover, it is argued, its merit as a purely normative model has also been questioned by observation. Many people do not change their decisions after having been faced with their A1–A5 violations. For instance, they do want to take the potential discomfort of post-decisional regret into account ex ante, that is, when making the choice between risky actions. Due to this low general validity in practice, the EUT has normative and positive power only for the limited number of Savage-like cases. On the other hand, because NEU axioms reflect actual and legitimate preferences, NEU-proponents consider NEU models more generally useful both in the normative and the positive sense. Slovic and Tversky (1974) and Loomes and Sugden (1984) seem to be examples of this view. Allais, in his Nobel lecture, takes a very clear position as to whether a theory can serve normative purposes only: 'Any theory whatever, if it is not verified by empirical evidence, has no scientific value and it should be rejected' (Allais 1988: 20). Fishburn (1988: 267 and 280) implicitly argues along similar lines, maintaining that normative alternatives to the EUT must stand up against the empirical violations of A1–A5.

Thus, the two groups in fact represent three different objectives of theory construction. The EUT proponents defend their model on normative grounds, and the Chicago tradition within this group uses a positive rationale as well. Those favoring NEU approaches tend to stress the superiority of their models on a positive standard. Despite these fundamental differences, there are still *several common elements* in the hard core of the two SRPs. Mathematical modeling and the 'axiom theorem proof' structure has already been mentioned as a methodological norm. In addition, shared implicit assumptions about the decision maker include:

- The relevant aspects of choice can be captured by and decomposed into a set of actions, states, probabilities, outcomes, and preferences;
- Given the preferences, the decision maker is doing her or his best in terms of maximizing the level of satisfaction;
- The decision maker is consistent, has a complete ordering, and appreciates high probabilities of attractive outcomes;
- The decision maker has unlimited intellectual capacity in the sense that every relevant aspect of the decision problem is clearly perceived.

4.6. The paradigm determines the response to empirical evidence

According to Bayes rule for revision of beliefs, a given sample evidence has a smaller impact on the posterior probability the stronger the prior belief. Correspondingly, as argued by both Kuhn and Lakatos, a researcher's response to empirical observations depends on the paradigm or SRP which he or she favors. In particular, a given finding may be considered an anomaly by one group of researchers, but not at all by others. Given the empirical work summarized in section 2, the struggle between EU and NEU is well described by this response pattern.

Several groups have held or still hold tight priors on the qualities of the EUT. The *positivistic* research tradition appreciates mathematical models, stresses the positive objective of a theory, and favors Friedman's methodological norm of empirically testing a theory's *predictions* rather than the descriptive validity of its assumptions. It may hence be argued that no empirical test of A1–A5 alone would ever qualify as a valid anomaly. Such findings do not necessarily invalidate the EUT, only its assumptions (Schoemaker 1982: 538).

This latter view is problematic, as there is formal equivalence between A1–A5 and the EUT: A1–A5 are both necessary and sufficient conditions for the EUT to hold. Moreover, several studies have directly tested the predictive power of the EUT. For instance, Allais' empirical test in 1952 revealed the opposite behavior of what was predicted by the EUT. This is (Popperian) falsifying evidence according to positivistic norms. Moreover, Allais showed that this low predictive power of the EUT was caused by widespread violation of A4. Allais' experiment was actually a joint test of the descriptive validity of A4 and the predictive power of the EUT.

The *Chicago view* is sceptical to any test of A1–A5 within a laboratory (synthetic) setting, which is used in most of the empirical work listed in table 3. This paradigm contains a positivistic methodology and uses the EUT as a positive hypothesis in competitive markets. Accordingly, most testing contexts in table 3 are considered artificial and irrelevant, as a finding would only qualify as anomalous if it falsifies the EUT in *real-world, competitive contexts*.

This position clearly reduces the amount of empirical findings which may challenge the hard core, as only field studies would qualify as potentially relevant. Moreover, as noted by Schoemaker (1982: 539), this definition of proper empirical settings makes it questionable whether hypotheses like the EUT are scientific in Popper's sense, as they may end up being non-falsifiable. It can always be argued that the competitive markets assumption is not really met in real-world contexts. This case may be an example of a massive protective belt which makes the hard core almost immune to any challenge.

Within stochastic choice theory, *decision analysis* was established by contributions from Raiffa (1968), Schlaifer (1969), and Keeney and Raiffa (1976). This tradition is definitely normative, aimed at assisting real-world decision makers in complex, ill-structured contexts (Keeney and Raiffa 1976: ch. 1). The EUT is still used as a stepping stone of this approach, and the empirical violations of its axioms may in fact be used as an argument *for* assisting people with normative decision-analytic tools (Marschak 1979: 170; Morgenstern 1979: 180). The idea here is that if left alone in complex environments, decision makers do not always act according to their best interests. Moreover, considering the large number of approximations and shortcuts that must be made in practical applications of stochastic choice theory, the questionable descriptive power of A1–A5 may not be among the most critical factors. Instructive discussions of these points are given by Keeney (1983) and Bouyssou (1984).

I showed in section 4.3 that the EUT *importers* have been using it as an axiom in their own theorems for at least 20 years. However, separate empirical tests of the EUT have rarely been made within these fields. Judging from the present use of the EUT by the importers, the gradual accumulation of empirical evidence questioning the descriptive and predictive validity of A1–A5 seems to have passed the importers rather unnoticed. For instance, when commenting on progress in economic research, Blinder states: 'The von Neumann-Morgenstern axioms are routinely violated. It is remarkable how little impact this evidence has had on modern economics. Is that scientific detachment or religious zealotry?' (Blinder 1987: 135). One may hypothesize that the EUT is in the hard core of these fields, sheltered by a strong protective belt.

The importers, who use the EUT as an axiom in their own theories, face a *joint hypothesis problem* in empirical tests. Still, nobody seems to question the validity of the underlying EUT when their theories are falsified empirically. For instance, capital market studies have repeatedly cast doubt on the CAPM as a positive theory. This evidence includes too high an intercept and too low a slope of the security market line and the impact on realized returns from factors like firm size, month of the year, and day of the week (Brealey and Myers 1988). Nevertheless, the typical response to such findings is not to question the individual investor behavior implied by the inherent EUT. Rather, the problem is blamed on factors like non-observable returns on the true market portfolio, non-existence of a genuinely riskless asset, large information asymmetries for small firms, and tax-loss selling at year-end.

This reluctance by the importers to question the EUT may not be too hard to explain within the models of Kuhn and Lakatos. So far, no NEU alternative has been shown to have a similar simplicity and analytic tractability, in particular when aggregating from individual behavior to market characteristics under uncertainty. Thus, although the importers may have noticed the descriptive and predictive weakness of the EUT, its qualities as a *non-substitutable building block* in the importers' theories necessitates a protective belt which makes the EUT robust to attacks. Too much may seem to be at stake if the EUT is just flatly rejected. For instance, Schmidt (1982) maintains that the prominent role of equilibrium relationships is the most important reason for the remarkable success of finance as an academic discipline.

Allais' findings in 1952 questioned the positive power of the EUT. As I have just discussed and also pointed out in section 4.2, several other qualities of the EUT still gave it a strong standing after the Paris conference. The typical response was therefore not to consider Allais' findings a damaging, crisis-inducing anomaly in the Kuhn/Lakatos sense. Rather, the violation of A4 was and is often still called a *paradox*. This term normally means a statement which is contrary to received opinion or an observed choice which is inconsistent with generally accepted axioms (MacCrimmon and Larsson 1979). In the terminology of Kuhn and Lakatos, the Allais Paradox was the first *anomaly* relative to the EUT as a positive hypothesis. Correspondingly, the small certainty equivalent revealed in St. Petersburg games was also termed a paradox, but it was really an anomaly relative to the expected payoff criterion as a positive theory. The St. Petersburg anomaly seems to have been sufficient to clear the ground for the new theory of Cramer and D. Bernoulli. The EUT anomaly implied by the Allais Paradox did not have a comparable impact.

Among the groups who are sceptical to the EUT, *the NEU tradition* initiated by Allais has always stressed the positive objective of stochastic choice theory. The large number of EU test results is perceived anomalous evidence against the EUT and a stimulus for more research on NEU models. There is, however, a tendency to kick the EUT too hard. Some of the results listed in table 3 are *irrelevant evidence against the EUT* and cannot be counted as anomalies. This is not always clearly visible in papers criticizing the EUT, like in Schoemaker (1982) and Machina (1987a).

First, tests of *risk aversion* do not count, as such behavior is not contained in or implied by A1–A5. Second, the EUT does not model the impact of new information on probability beliefs. Therefore, it does not assume *Bayesian updating*. Strictly speaking, the theorem does not even presuppose that the decision maker can *compute correct probabilities* of multi-stage lotteries from several single-stage ones. It only assumes that *if* the fully specified multi-stage lottery X and the fully specified single-stage lottery Y involve the same overall distribution, they are considered equally attractive.

Third, the fact that *rats* or possibly other non-humans seem to violate A4 is no argument against the EUT. Of course, neither EU nor NEU research has any objective of modeling animal behavior.

Finally, some empirical irregularities found in EU tests will hit almost any choice model, including the competing NEU approach. The *context effect* applies here, as the research design may influence the measured response in any interview-based study. Hence, it is not surprising that the shape of the utility function depends on the particular reference lottery which is used. Moreover, *transitivity* (non-circularity) is a standard assumption in almost any existing choice theory, even under certainty. If intransitivity prevails in practice, this finding is a general choice-theoretic problem which cannot be used selectively against the EUT. It is only relevant as a comparative advantage for the very few choice theories which are not based on transitivity. Bell's NEU model is one such notable exception (Bell 1982).

Some of this irrelevant critique may of course be due to ignorance about the EU axioms. A more plausible explanation stems from the idea of two competing paradigms. The EUT proponents either normatively define rationality in terms of A1–A5 or use the EUT as a positive hypothesis. In either case, it may be tempting to (implicitly) argue from the attacking NEU side that whenever A1–A5 is assumed, it is just a rather innocent *extension* to also assume Bayesian updating, correct probability calculations and no context effect. That is, such behavior should also be expected from someone who does satisfy or at least wants to obey A1–A5. Such an argument may be understandable, given the differing objectives of theory construction in the two research traditions.

4.7. Co-existence and revitalization

The two SRPs of EU and NEU have existed *side by side* for thirty-seven years. The EU model was quickly accepted, was not subsequently altered in any way, and remained dominant in stochastic choice theory until the late seventies.

The activity of NEU research has been varying over time. Despite its rather flying start in Paris in 1952, the program was no real threat to the EUT during the sixties and early seventies. In this period, the major achievement of the NEU program was to uncover defects in the EU model as a positive behavioral hypothesis. In Kuhnian terms, this was a period of puzzle-solving and normal science.

Towards the end of the seventies, the NEU program was *revitalized*. The major drive was the cumulative weight of many EU tests and several new NEU models aimed at accounting for the findings which challenged the EUT. The number of researchers within the field and the richness of the theories produced now seems to be growing rapidly. Presently, visible signs of widespread recognition in the general academic community are Allais' Nobel Prize and three recent papers in prestigious journals containing extensive, critical surveys of the EUT and comparisons to NEU approaches. This may also signal an increased recognition of the positive objective of theory construction, which is in the hard core of the NEU program.

This time pattern conforms well with Lakatos' hypotheses about rival theory development processes from section 3. It does not comply with Kuhn's notion of a single ruling paradigm which never returns after weaker periods. Moreover, Lakatos' idea that progressive SRPs are characterized by increasingly general theories is also present in this story. This so-called heuristic of a program is illustrated by Bell's expected regret approach, which is a NEU model containing the EUT as a special case (Bell 1982). Moreover, Machina (1982, 1983) recently showed that as long as indifference curves are smooth (but not necessarily linear) in the probability range covered by lottery Z, choice between other lotteries located in the neighborhood of Z will be made as though the individual maximizes EU.

According to Lakatos, such cases of increasing generality and the ability to account for anomalous evidence (relative to the old SRP) are essential criteria in most researchers' decision to convert to the rival SRP.

5. Concluding remarks

This paper has used the models of Kuhn and Lakatos to structure and interpret the history of ideas in stochastic choice theory. Judged as a case study aimed at testing two general approaches from the philosophy of science, the paper illustrates that both models offer insights into this specific theory development process. Moreover, it does not seem difficult to apply frameworks from the natural sciences to a history of ideas in the social sciences.

Nevertheless, one may wonder why the SRP approach of Lakatos seems to perform better than Kuhn's paradigm-based model. It seems that in this case, the high generality and the correspondingly low precision in Kuhn's model causes ambiguity right at the conceptual level. This is a well-known problem with Kuhn's approach. For instance, Masterman (1970) noticed that Kuhn initially used the term paradigm in at least twenty-one different ways. Because of this vagueness in what is probably the model's most important concept, it is for instance hard to determine if the history of stochastic choice theory really involves several simultaneous paradigms (Lakatos' hypothesis) or if there is just a single, dominating one at any point in time (Kuhn's hypothesis). Correspondingly, the issue of conversion from one paradigm to another becomes elusive because of this conceptual ambiguity. Lakatos' model is less problematic in this respect, as SRP, hard core, and protective belt are more precise concepts and thus more applicable to specific cases.

Partly for the same reason, Kuhn's framework may be more powerful at a very aggregate level, like structuring the history of heliocentric versus geocentric theories of the universe. As to detailed historical developments within a much more narrow discipline, Lakatos' approach may be more powerful, simply because the components of his SRP are more specific. In fact, one may think of different SRPs (like the EU and NEU traditions) as subgroups within one single paradigm (stochastic choice theory). Although these groups disagree on important points, they still share several overall commitments (see section 4.5). Thus, a paradigm may be considered a broader and more general concept than an SRP. If so, Kuhn versus Lakatos is not primarily a question of which model is the better. Rather, the point is that the power of the two models may not be visible within the same empirical context.

Besides testing basic ideas of Kuhn and Lakatos through a case study, the paper has evaluated the development of stochastic choice theory. That history clearly illustrates how competing ideas and extensive empirical testing over a long period of time have worked as permanent, strong engines pushing research into particular directions. In such a perspective, the EUT has been extremely productive. First, it still serves as a building block for a vast body of research in several decision-oriented disciplines within the social sciences (the EUT importers). Second, the EUT triggered the NEU tradition and still shapes its research program.

Among stochastic choice researchers, NEU approaches are presently gaining ground at the expense of the EUT. In fact, it was recently asserted from the NEU side that 'what was a blasphemy thirty years ago (that is, to question the EUT) is now a respectable academic item' (Bernard 1984: 135). Judging from several events in the eighties, it seems that the EUT has entered a crisis and that a slow, disciplined, non-Kuhnian conversion is taking place. In this sense, Fishburn (1988: 267) is right when he asserts that '... a revolution in the foundations of decision has been in progress for several years'.

Due to a lack of viable alternatives, the EUT still has no serious challenger in the importing disciplines, and no sign of a conversion is visible. Because the theorem is so basic in the importers' theory construction efforts, too much may seem to be at stake if the theorem were just dropped. This point illustrates Kuhn's idea that before rejecting an existing paradigm, there must be a serious alternative to fill the gap. That is, the decision to leave one paradigm also involves a decision to embrace another (Kuhn 1970: 77).

In this case, an acceptable alternative must accommodate the analytical success of its predecessor. Moreover, it should also account for the empirical findings which have questioned the EUT. The latter task is now completed beyond any reasonable doubt by various NEU models. The former criterion, however, is not met. Thus, as to a future conversion to NEU models in the importing disciplines, a crucial area of future research is to reveal how critical the EUT really is in these fields. That is, what survives if the EUT falls, and what type of NEU model could possibly serve similar analytical purposes?

Several existing lines of research apply to this point. First, stochastic dominance of the first order (Hadar and Russel 1969) is a well-known choice criterion which presupposes non-satiation of preferences, but assumes nothing about risk attitudes (see axiom A3 of table 2). Second, Machina (1982) and others are using NEU models to account for non-linearity in probabilities (fanning out behavior), while simultaneously trying to preserve the results of the EU approach. Third, thirty years ago Debreu (1959) showed that general equilibrium results can in fact be derived without assuming EU-maximizing individuals. Similarly, the option pricing model (OPM) of Black and Scholes (1973) assumes non-satiation, but puts no restriction on risk attitudes.

Although these fields are promising areas of research, the results obtained so far do not solve the current problems faced by the EUT or the difficulties that emerge if the importers reject the EUT. For instance, first-order stochastic dominance is a rather weak criterion, as this method cannot rank most lotteries met in practice. Moreover, even if fanning out behavior may be captured by new NEU theories, empirical problems like context effects and limited intellectual capacity apply to any such model as well. Finally, even though models like the OPM offer an exact, closed-form and empirically successful option pricing equation, the value of the underlying asset (for instance, the stock on which the option is written) is an exogeneous input. To specify such a value, an EU-based model like the CAPM is required.

Present importers of the EUT will be reluctant to reject it until some alternative combines EUT-like analytical tractability with high empirical power. In this perspective, it is interesting to notice that some EUT-importers are now addressing this issue. A recent example is an equilibrium pricing model which does not lean on the EUT (Shefrin and Statman 1989). Here, a CAPM is developed for the case where some investors behave according to the EU axioms, whereas another group exhibits prospect theory preferences of Kahneman and Tversky (1979).

To tell the history of stochastic choice research is to subjectively select and evaluate contributions from a large number of people over almost three hundred years. Therefore, it seems fair to conclude this survey by citing the current view of an active member of this research community: 'Experiments show that human beings, choosing under uncertainty, behave in systematic and predictable ways. It would be extremely satisfying to discover a simple theory that was compatible with all of this evidence – only a fraction of which I have discussed in this paper. No such theory has yet been found. Perhaps one is waiting to be discovered by an Isaac Newton of economics; perhaps not. I suggest that it is worth carrying on the search,...'(Sugden 1986a: 21).

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