Advanced information on the Prize in Economic Sciences 2002, 17 December 2002

KUNGL.
VETENSKAPSAKADEMIEN
THE ROYAL SWEDISH ACADEMY OF SCIENCES

Information Department, P.O. Box 50005, SE-104 05 Stockholm, Sweden
Phone: +46 8 673 95 00, Fax: +46 8 15 56 70, E-mail: info@kva.se, Website: www.kva.se

Foundations of Behavioral and Experimental Economics: Daniel Kahneman and Vernon Smith

Until recently, economics was widely regarded as a non-experimental science that had to rely on observation of real-world economies rather than controlled laboratory experiments. Many commentators also found restrictive the common assumption of a *homo oeconomicus* motivated by self-interest and capable of making rational decisions. But research in economics has taken off in new directions. A large and growing body of scientific work is now devoted to the empirical testing and modification of traditional postulates in economics, in particular those of unbounded rationality, pure self-interest, and complete self-control. Moreover, today's research increasingly relies on new data from laboratory experiments rather than on more traditional field data, that is, data obtained from observations of real economies. This recent research has its roots in two distinct, but converging, traditions: theoretical and empirical studies of human decision-making in cognitive psychology, and tests of predictions from economic theory by way of laboratory experiments. Today, behavioral economics and experimental economics are among the most active fields in economics, as measured by publications in major journals, new doctoral dissertations, seminars, workshops and conferences. This year's laureates are pioneers of these two fields of research.

Human decision-making deviates in one way or another from the standard assumptions of the rationalistic paradigm in economics. If such deviations from rationality and self-interest were small and purely idiosyncratic, they would on average cancel out, and economic theory would not be too wide off the mark when predicting outcomes for large aggregates of agents. Following the lead of Vernon Smith, early studies of alternative market mechanisms by experimental economists can be viewed as tests of the hypothesis of idiosyncratic deviations from standard economic theory. If deviations from rationality and self-interest were systematic, however, this would call for a revision of economic theory itself. Following the lead of Daniel Kahneman and the late Amos Tversky, early studies of human decision-making by cognitive psychologists can be seen as testing hypotheses of systematic deviations from rationality.

This text begins by addressing Vernon Smith's contributions to the field of experimental economics. It then considers Daniel Kahneman's findings in the field now known as behavioral economics. The final sections summarize these contributions and their importance, and offer some suggestions for further reading.

1. Foundations of experimental economics

Traditionally, economics has been viewed as a non-experimental science that had to rely exclusively on field data:

> "Economics … cannot perform the controlled experiments of chemists or biologists because [it] cannot easily control other important factors. Like astronomers or meteorologists, [it] generally must be content largely to observe." (Samuelson and Nordhaus, 1985, p. 8)

Many perceived this as an obstacle to the continued development of economics as a science. Unless controlled experiments could be carried out, tests of economic theory would remain restricted. Solely on the basis of field data, it is difficult to decide whether and when a theory fails, and to pinpoint the aspects responsible for this failure. The feedback channel between theory and observation under controlled circumstances – where new experimental findings suggest new theories and new theories suggest new experiments – seemed to be largely unavailable to economics.

The establishment of a growing research field called experimental economics has radically challenged this view.[1] Under controlled laboratory conditions, experimentalists study human behavior in situations that, in simplified and pure forms, mimic those encountered in markets and other forms of economic interaction. The extent to which the results of such experiments can be generalized to market situations is still under debate. But the notion that laboratory results concerning microeconomic behavior can crucially inform the development of economic theory is basically the same as the notion that laboratory results concerning small-scale phenomena in physics (such as those pertaining to elementary particles and thermodynamics) can crucially inform the development of theoretical physics (with regard to the universe or the weather).[2]

Experimental research in economics has early predecessors. More than fifty years ago, Chamberlin (1948) attempted to test the neoclassical theory of perfect competition by way of experiments, and 1994 economics laureate Reinhard Selten conducted early experimental studies of price formation in oligopoly markets, the first paper being Sauerman and Selten (1959). There are also early studies on the predictive power of game theory in an experimental setting, by John Nash – also a 1994 economics laureate – with colleagues (Kalish, Milnor, Nash and Nehrig, 1954) and by Flood (1959). Furthermore Siegel and Fouraker (1960) and Fouraker and Siegel (1963) reported experimental results on bargaining.

Without any doubt, however, the main researcher in the experimental tradition is Vernon Smith. Smith not only made the most important early contributions, but has also remained a key figure in the field to date. He has educated and collaborated with a large number of younger researchers in experimental economics. The most prominent of these is Charles Plott, who has also made important contributions to the field.

[1] New panel data sets and advancements in econometrics, such as those recognized in the awards to Heckman and Mc Fadden in 2000, have also substantially improved the potential for convincing causal inference from observational data.

[2] External validity requires that the results uncovered in the laboratory be valid across time and space. This may be a stronger assumption in economics than in meteorology or astrophysics, but theories about the atmosphere or the big bang that build on experimental results also have to resort to the same kind of assumption.

1.1. Market mechanisms

Vernon Smith's most significant work concerns market mechanisms. He laid the groundwork for this research area in innovative experiments with competitive markets (Smith, 1962), in tests of different auction forms (Smith, 1965, 1976b, Coppinger, Smith and Titus, 1980), and in the design of the so-called induced-value method (Smith, 1976a).

Smith's first experimental article (Smith, 1962) was inspired by Chamberlin's (1948) classroom experiments. Chamberlin, who was Smith's teacher at Harvard at the time, had let participants engage in pairwise bargaining, acting as buyers and sellers of a fictitious good. Chamberlin regarded his experimental results as a falsification of the standard neoclassical model of a market under perfect competition (that is, with price-taking and rational agents).

Smith realized that Chamberlin's results would be more compelling if the participants were placed in a setting more similar to a real market. He thus set up an experiment where subjects were divided into groups of potential sellers and buyers in a so-called *double oral auction*, a market mechanism used in many financial and commodity markets. Subjects were randomly assigned the roles of seller and buyer, and each seller was given one unit of the good to be sold, and a reservation price for this unit. If the reservation price was v for the unit, the seller was not allowed to sell below that price, while she would earn $p–v$ dollars by selling at a price $p>v$. A seller's reservation price v was her own private information. Similarly, each buyer was assigned a private reservation price w, the highest price at which he was allowed to buy a unit. Purchases at a price $p<w$ resulted in earnings of $w-p$ dollars. Based on the distribution of reservation prices which he had chosen, Smith could draw a supply and a demand schedule and locate the competitive equilibrium price as their intersection. The subjects, by contrast, did not have this information and were thus not able to compute the theoretical equilibrium price. Much to his surprise, Smith found that the actual trading prices came close to the theoretical equilibrium price, hence supporting the theory that the experiments were initially supposed to reject.

The result from one of his experiments is illustrated in *Figure* 1 (Smith, 1962, Chart 1, p. 113). The left-hand panel shows the demand and supply schedules induced by the given distribution of reservation prices. The schedules intersect at $p = 2.00$, which is thus the competitive equilibrium price. The right-hand panel shows the trading prices in five successive trading periods, as well as the standard deviation of the price distribution in each period, expressed as a percentage of the theoretical equilibrium price (the number α in the diagram). As is seen in this diagram, most trading prices were close to the theoretical prediction, and the standard deviation fell over time as the prices converged towards the theoretical prediction.

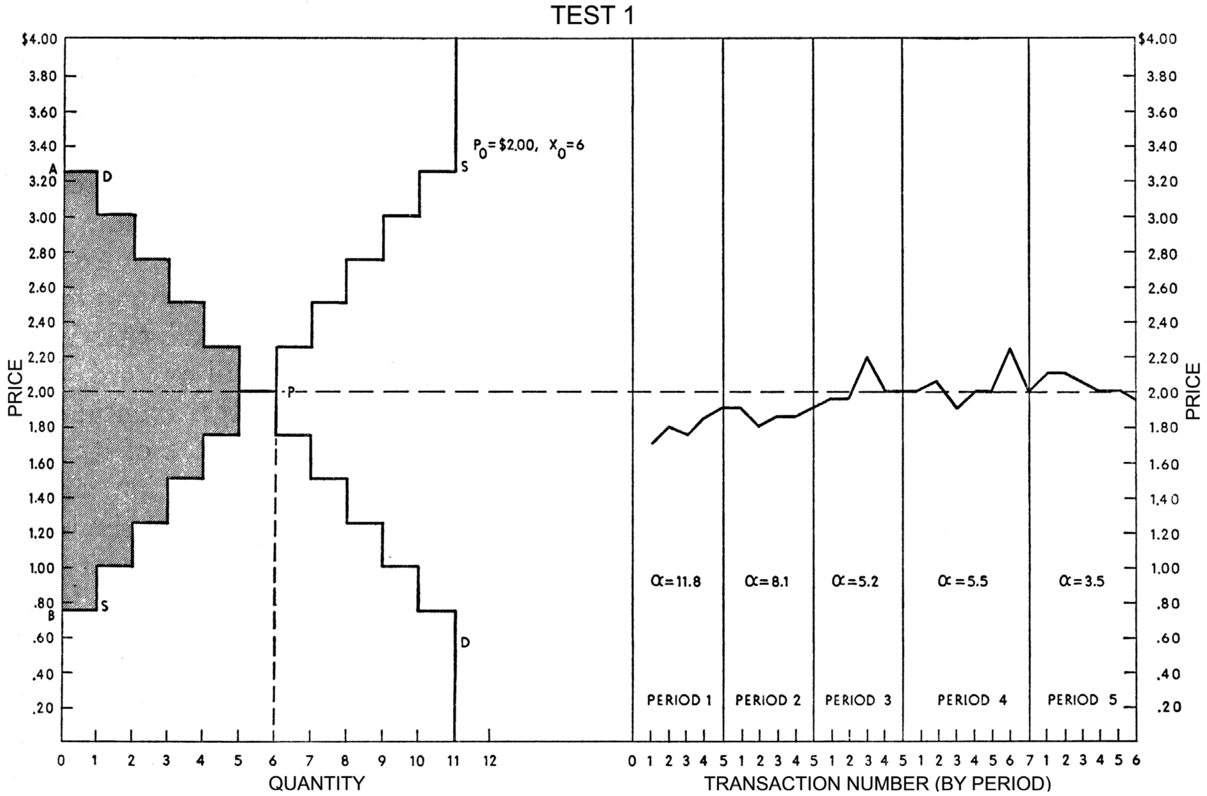

Figure 1

Smith concluded that

> "…there are strong tendencies for a … competitive equilibrium to be attained as long as one is able to prohibit collusion and to maintain absolute publicity of all bids, offers, and transactions. … Changes in the conditions of supply and demand cause changes in the volume of transaction per period and the general level of contract prices. These latter correspond reasonably well with the predictions of competitive price theory." (Smith, 1962, p. 134).

Smith and other researchers subsequently carried out a series of similar experiments to check whether this agreement with theory was a mere coincidence. Later experiments continued to confirm Smith's original result. In joint work, Plott and Smith (1978) obtained the same general result, but added an important twist: market institutions do "matter." Specifically, they compared the outcomes when sellers and buyers were allowed to change prices continuously during a trading period (Smith's original design) with the outcomes when they had to post a price for an entire trading period. The latter design turned out to result in a slower convergence towards the theoretical equilibrium price. The experimental approach, as opposed to collecting field data, was essential in driving home this result; it made it possible to hold constant the "market environment" (in this case the distribution of reservation prices) while varying the "market institution" (in this case the rules for price adjustment) in a controlled fashion.

In almost any market experiment, a clear test of the hypothesis in question requires controlling for the subjects' preferences. This is a major difficulty, as selling and buying will generally be influenced by the subjects' idiosyncratic evaluations of gains and losses, evaluations that are not directly observable to the researcher. This problem was first addressed by Chamberlin (1948), who suggested a method for resolving it, essentially by providing the subjects with the "right" monetary incentives. This so-called *induced-value method* was developed further by Smith (1976a) [3], and has now become a standard tool in experimental economics.

In order to illustrate this method, consider a subject assigned the role of buyer in a market for a homogeneous good (where all units are identical). Suppose that the experimentalist wants this subject to express a certain demand function D. That is, at any price p, the subject should be willing to buy precisely $q = D(p)$ units. But the experimentalist does not know the subject's utility of wealth, $u(w)$. Smith's method induces the desired demand function by rewarding the subject with $R(q) - pq$ dollars for any quantity q bought at price p, where R is a suitably chosen reward function. According to economic theory, the subject will choose the quantity q such that her marginal benefit from increasing q equals her marginal cost of doing so, that is, such that $R'(q) = p$.[4] As long as the unknown utility function u is increasing and concave, her demand will coincide with the desired demand function if, for any relevant price, the inverse derivative of the reward function R is set equal to the desired demand function, that is, if $(R')^{-1}(p) = D(p)$ for all relevant prices p. Similar methods have been applied ever since in the experimental literature.

[3] Smith had sketched this method in an earlier working paper (Smith, 1973).
[4] If the quantity q maximizes the subject's utility of wealth, $u(R(q)-pq)$, then the first-order condition

1.2. Tests of auction theory

Auction theory has emerged as one of the most successful developments in microeconomic theory and game theory since the early 1960s. A number of precise theoretical results for a variety of auction forms were developed by the late economics laureate William Vickrey, followed by a number of younger researchers (see Krishna, 2002, for an overview). Smith initiated the experimental testing of many of these propositions, and has published extensively on the subject (see, for example, Smith, 1976b, Coppinger, Smith and Titus, 1980, and Cox, Robertson and Smith, 1982). Moreover, he pioneered the use of controlled laboratory experiments as "wind tunnel" tests of new auction designs – for which precise theoretical predictions are hard to obtain – before they are used in practice (see section 1.3).

As the term is commonly understood, auctions may seem of little importance for real-world economies. However, by proceeding from simpler to more complex auction forms, theory has deepened our understanding of the functioning of many real-world markets. Even some of the simpler auction forms studied in theory are widely used in practice, particularly in the context of deregulation and privatization of natural monopolies, public procurement, the sale of government bonds, etc.

Central to Smith's experimental work on auctions are the established theoretical predictions for certain auction forms used in the sale of a single object. Such auctions are traditionally classified into four types. In an *English* or ascending auction, buyers announce their bids sequentially and in an increasing order, until no higher bid is submitted. In a *Dutch* or descending auction, a high initial bid by the seller is gradually lowered in fixed steps at fixed times regulated by a clock, until some buyer shouts "buy," whereupon the clock stops. Both of these auctions are usually oral, and the trading price is the last (first) bidder's bid. In the other two auction forms, all bidders instead simultaneously submit their bids in sealed envelopes and the unit for sale is allocated to the highest bidder. In the *first-price sealed-bid* auction, this bidder pays his or her bid to the seller; while in the *second-price sealed-bid* auction, this bidder pays only the second highest bid.

Microeconomic theory also distinguishes between auctions with private and common values. In both cases, the value to each buyer is treated as a random variable. In the case of private

---

$u'(w)(R'(q)-p)=0$ has to be met, granted u is differentiable.

values, these valuations are statistically independent across the population of potential bidders – the value to a buyer is his or her purely idiosyncratic valuation of the object. In common-value auctions, by contrast, the value to the buyers also has a common component, such as a resale market value or the conditions in some related market (examples include spectrum auctions and telecommunication markets).

Economic theory makes the following three predictions in the case of private values: (1) English and second-price auctions are equivalent, in terms of who will (probabilistically) obtain the item and the expected revenue to the seller. This result follows from individual rationality (more precisely, from assuming that bidders do not use weakly dominated strategies). (2) Dutch and first-price auctions are equivalent, a result which follows from the more restrictive assumption of Nash equilibrium behavior, that is, individual rationality combined with interpersonally consistent expectations. (3) All four auction forms are equivalent if all buyers are risk neutral (that is, if they are indifferent between participating in an actuarially fair lottery and obtaining the expected lottery prize for sure; see also section 2).

Smith carried out many experiments – once more, controlling for demand and supply conditions, while varying the market institution – in order to empirically test these and other theoretical predictions.[5] In order to generate private values, each bidder was given a randomly and independently drawn number, v, which was kept private to the bidder. If the bidder won the auction and paid the price p, this subject would earn the monetary amount $p–v$. In regard to prediction (1) above, Smith discovered that English and sealed-bid second-price auctions indeed produce similar experimental outcomes, just as theory says. As for (2), Dutch and sealed-price first-price auctions did not give rise to equivalent outcomes, in contrast with theory. In the case of (3), he found that models which presume that buyers have identical attitudes toward risk could be rejected. Furthermore, he found that the average sale price was higher in English and sealed-bid second-price auctions than in sealed-bid first-price auctions, and that the latter yielded higher average selling prices than Dutch auctions.

Of these results, one of the most unexpected was that Dutch and sealed-bid first-price auctions turned out to be unequivalent. Two theoretical explanations have been suggested. One is that utility depends not only on the monetary outcome but also on the "suspense of waiting" in the

Dutch auction, the other that bidders underestimate the increased risk associated with waiting in the Dutch auction. These and other possible reasons for the observed non-equivalence between the two auctions are explored in Smith (1991b).

1.3. The laboratory as a "wind tunnel"

Smith, as well as Plott, initiated the use of the laboratory as a "wind tunnel" (a laboratory setup used to test prototypes for aircraft) in order to study the performance of proposed institutional mechanisms for deregulation, privatization, and the provision of public goods. These mechanisms are usually so complex that existing theory does not provide precise predictions, which makes the experimental method particularly useful. In a series of studies (Smith, 1979a-c, 1980, and Coursey and Smith, 1984) he studied the design of incentive-compatible mechanisms for the provision of public goods. In these experiments, Smith tested the effectiveness of mechanisms proposed by economic theorists, as well as some of his own variants. Smith has also done experimental work on mechanisms to allocate airport time slots by means of computer-assisted markets (Bulfin, Rasenti and Smith, 1982, and McCabe, Rasenti and Smith, 1989) and on alternative organizations of energy markets (Rasenti, Smith and Wilson, 2001).

1.4. Experimental methodology

Apart from substantive results on markets and auctions, Smith's work has had an enormous methodological impact. His seminal *American Economic Review* article "Experimental economics: Induced-value theory"(Smith, 1976a), provided a practical and detailed guide to the design of economic experiments in the laboratory and a motivation for these guidelines (see also Smith, 1982). In recent years, this paper has served as a paradigm for experimental scholars in economics.

The experimental method developed by Smith deviates from the experimental approach used in psychology (cf. section 2). It emphasizes the importance of providing subjects with sufficient monetary incentives, in order to outweigh the distorting effects of decision costs.

[5] Smith (1976b) is a seminal paper on this topic. See also Coppinger, Smith and Titus (1980), who seem to have been the first to test these propositions in a comparison of all four types of auction, and Cox, Roberson and Smith (1982).

Smith's method also emphasizes the importance of designing experiments as repeated trials, so that the subjects can become familiar with and understand the experimental situation.

In many respects, the differences vis-à-vis psychologically oriented methods are a matter of focus. Whereas psychologists have been predominantly interested in individual behavior, Smith designed his original experiments mainly to analyze market outcomes. Genuine differences of opinion about the appropriate methodology have not subsided, however. To some extent, they reflect two different approaches to understanding human behavior, as further discussed in section 2 (see Smith, 1991a, and Loewenstein, 1999, for different sides of the debate).[6]

Be that as it may, Smith's approach to experimentation constitutes a vital contribution, of relevance not only for economists but also for other social scientists. For instance, Plott's experiments on decision-making in committees (Fiorina and Plott, 1978) followed much the same approach and generated an extensive experimental literature in political science.

2. Foundations of behavioral economics

Nearly half a century ago, Edwards (1954) introduced decision-making as a research topic for psychologists, outlining an agenda for future research. Allais (1953a,b) outlined a psychology-based positive theory of choice under uncertainty, while Simon (1956) proposed an approach to information processing and decision-making based on bounded rationality. But research in cognitive psychology did not come into its own until Daniel Kahneman and Amos Tversky (deceased in 1996) published their findings on judgment and decision-making. Although adhering to the tradition of cognitive psychology, Kahneman's research has equally well been directed towards economists. Many of his articles have been published in economics journals; one article, Kahneman and Tversky (1979), even has the highest citation count of all articles published in *Econometrica,* by many considered the most prestigious journal in economics. Given the barriers to communicating across traditional disciplines, considerable effort has gone into building a bridge between research in economics and psychology. Nowadays, there are in fact two bridges between these disciplines – one built

[6] The importance of monetary incentives or repetition obviously depends on the hypothesis that the experiment is supposed to test. Incentives may also affect different cognitive functions in distinct ways (Nilsson, 1987).

around experimental methods and the other around theoretical modeling. Both serve as the basis for the current wave of work in behavioral economics. Before discussing Kahneman's specific contributions, the next section outlines some differences between conceptions of decision-making in economics and psychology.

2.1. Decision-making in economics and psychology

Economists typically assume that market behavior is motivated primarily by material incentives, and that economic decisions are governed mainly by self-interest and rationality. In this context, rationality means that decision-makers use available information in a logical and systematic way, so as to make optimal choices given the alternatives at hand and the objective to be reached. It also implies that decisions are made in a forward-looking way, by fully taking into account future consequences of current decisions. In other words, so-called extrinsic incentives are assumed to shape economic behavior.

In psychology, especially cognitive psychology, a human being is commonly regarded as a system, which codes and interprets available information in a conscious and rational way. But other, less conscious, factors are also assumed to govern human behavior in a systematic way. It is this more complex view – where intrinsic incentives help shape human behavior – that has come to penetrate recent developments in economic theory.

Economists have traditionally treated a decision-maker's *preferences* over available alternatives as fixed and given. The decision-maker is assumed to form *probabilistic beliefs* or *expectations* about the state of nature and the effects of her actions, and to process available information according to statistical principles. More precisely, standard economic theory relies on the *expected-utility maximization* approach founded by von Neumann and Morgenstern (1944) and extended by Savage (1953). Here, it is presumed that for every decision-maker there exists some real-valued function u, defined on the relevant set X of outcomes $x_1, x_2, \ldots x_{\mathrm{I}}$, such that if one available action a results in probabilities p_i over the outcomes x_i (for $i=1,\ldots,\mathrm{I}$) and another available action b results in probabilities q_i over the same outcomes, then the decision-maker (strictly) prefers action a to action b if and only if the statistically expected value of this "utility function" u is greater under a than under b.[7] Formally, the criterion for choosing a is thus

$$\sum_i p_i u(x_i) > \sum_i q_i u(x_i) \quad . \tag{1}$$

Hence, given existing market conditions, which define the choice set available to the decision-maker, the cognitive process is reduced to a problem of expectation formation and maximization. The decision-maker is thus assumed to behave as if she correctly assigned probabilities to relevant random events and chose an action that maximized the expected value of her resulting utility.

By contrast, cognitive psychologists consider an interactive process where several factors may influence a decision in a non-trivial way. These components include *perception,* which follows its own laws, as well as beliefs or *mental models* for interpreting situations as they arise. Intrinsic motives, such as *emotions* – the state of mind of the decision-maker – and *attitudes* – stable psychological tendencies to relate to a given phenomenon in one's environment – may influence a decision. Moreover, the *memory* of previous decisions and their consequences serves as a critical cognitive function that also has a strong influence on current decision-making. Given this complex view, human behavior is regarded as locally conditioned to a given situation. Typically, behavior is adaptive; it is dependent on the context and transitory perceptual conditions.

These differences between psychology and traditional economics also show up in research methodology. While experiments in economics often emphasize the generality of a situation and comprise monetary rewards and repeated trials, psychologists try to capture intrinsic motivations and the mental processes at work in a particular decision situation, what has been termed the *framing* of a decision problem.

Extensive behavioral evidence, collected by Kahneman and others through surveys and experiments, calls the assumption of economic rationality into question, at least in complex decision situations. A number of studies have uncovered a non-trivial amount of deviations from the traditional model of rational economic behavior. For example, real-world decision-makers do not always evaluate uncertain prospects according to the laws of probability, and

[7] To be exact, the function u is not a utility function: such functions map decision alternatives (here actions) into

sometimes make decisions that violate the principles of expected-utility maximization outlined above. Kahneman's major contributions concerning judgment and decisions under uncertainty are discussed in the following.

2.2. Judgment under uncertainty: heuristics and biases

Kahneman and Tversky discovered how judgment under uncertainty systematically departs from the kind of rationality postulated in traditional economic theory (Kahneman and Tversky, 1972, 1973, Tversky and Kahneman, 1971, 1973, 1974, 1982). A basic notion underlying much of Kahneman and Tversky's early research is that people in general are frequently unable to fully analyze situations that involve economic and probabilistic judgments. In such situations, human judgment relies on certain shortcuts or heuristics, which are sometimes systematically biased.

One fundamental bias is that individuals appear to use a *law of small numbers*, attributing the same probability distribution to the empirical mean value from small and large samples, thereby violating the law of *large* numbers in probability theory (Tversky and Kahneman, 1971). For example, in a well-known experiment it was found that subjects thought it equally likely that more than 60 percent of births on a given day would be boys in a small hospital as in a large hospital. In general, people do not appear to realize how fast the variance of the sample mean of a random variable decreases with sample size.

More precisely, according to the statistical laws of large numbers, the probability distribution of the mean from a large sample of independent observations of a random variable is concentrated at the expected value of the random variable, and the variance of the sample mean goes to zero as the sample size increases.[8] According to the psychological law of small numbers, by contrast, people believe that the mean value from a small sample also has a distribution concentrated at the expected value of the random variable. This leads to "over-inference" from short sequences of independent observations.

---

the real numbers.

[8] According to the most basic version of the law of large numbers, the following claim is essentially true for all $\varepsilon>0$ and for any infinite sequence of independent and identically distributed random variables with mean μ: the probability that the sample mean will deviate more than ε from μ goes to zero as the sample size goes to infinity.

An example of the law of small numbers is when an investor observes a fund manager performing above average two years in a row and concludes that the fund manager is much better than average, while the true statistical implication is very weak. A related example is the so-called gambler's fallacy: many individuals expect the second draw of a random mechanism to be negatively correlated with the first, even if the draws are statistically independent. If a few early tosses of a fair coin give disproportionately many heads, many individuals believe that the next flip is more likely to be tails. Recent work, such as Rabin (2002), describes the importance of the law of small numbers for economic decisions.

The law of small numbers is related to *representativeness,* a heuristic which Kahneman and Tversky discovered to be an important ingredient in human judgment. Tversky and Kahneman (1973, 1974, 1982) illustrated the function of this heuristic in several elegant experiments. Subjects were asked to categorize persons, e.g., as a "salesman" or a "member of parliament," on the basis of given descriptions. Confronted with a description of an individual – randomly drawn from a given population – as "interested in politics, likes to participate in debates, and is eager to appear in the media," most subjects would say that the person is a member of parliament, even though the higher proportion of salespersons in the population makes it more likely that the person is a salesman. This observed heuristic way of thinking was examined further by Tversky and Kahneman (1973), who report an experiment where some subjects received explicit information about the true proportions in the population. One design stated that the person to be categorized was drawn from a pool of 30 percent engineers and 70 percent lawyers, while another design reversed these proportions. The results revealed that this difference had virtually no effect on subjects' judgment.

The same heuristic can also prompt people to believe that the joint probability of two events is larger than the probability of one of the constituent events, in contradiction to a fundamental principle of probability (the so-called conjunction rule). For instance, some subjects in an experiment thought that if Björn Borg reached the Wimbledon final, he would be less likely to lose the first set than to lose the first set and win the match.

In an overview of behavioral finance, Shleifer (2000) argues that the law of small numbers and representativeness may explain certain anomalies in financial markets. For example, the excess sensitivity of stock prices (Shiller, 1981) may be a result of investors' overreacting to short strings of good news.

Another bias common in probabilistic judgment is *availability*, whereby people judge probabilities by the ease of conjuring up examples. The result is that disproportionately high weight is assigned to salient or easily remembered information (Tversky and Kahneman, 1973). People thus overstate, say, the probability of violent crimes in a city if they personally know someone who has been assaulted, even if they have access to more relevant aggregate statistics. A general finding in cognitive psychology is that, compared to unfamiliar information, familiar information is more easily accessible from memory and is believed to be more real or relevant. Familiarity and availability may thus serve as *cues* for accuracy and relevance. Therefore, mere repetition of certain information in the media, regardless of its accuracy, makes it more easily available and therefore falsely perceived as more accurate.

Such evidence on human judgment demonstrates that people's reasoning violates basic laws of probability in a systematic way. By demonstrating this, Kahneman's research has seriously questioned the empirical validity of one of the fundamentals of traditional economic theory.

2.3. Decision-making under uncertainty: prospect theory

Available evidence indicates that not only judgment, but also decision-making under uncertainty departs in a systematic way from traditional economic theory. In particular, many decisions under uncertainty diverge from the predictions of expected-utility theory.

Departures from the von Neumann-Morgenstern-Savage expected-utility theories of decisions under uncertainty were first pointed out by the 1988 economics laureate Maurice Allais (1953a), who established the so-called Allais paradox (see also Ellsberg, 1961, for a related paradox). For example, many individuals prefer a certain gain of 3,000 dollars to a lottery giving 4,000 dollars with 80% probability and 0 otherwise. However, some of these same individuals also prefer winning 4,000 dollars with 20% probability to winning 3,000 dollars with 25% probability, even though the probabilities for the gains were scaled down by the same factor, 0.25, in both alternatives (from 80% to 20%, and from 100% to 25%). Such preferences violate the so-called substitution axiom of expected-utility theory.[9] Kahneman has provided extensive evidence of departures from the predictions of expected utility (see

[9] By this axiom, if a decision-maker prefers lottery A to B, he should also prefer a probability mixture $pA + (1-p)C$ to the probability mixture $pB + (1-p)C$, for all lotteries C.

Kahneman and Tversky, 1979, Tversky and Kahneman, 1991, 1992, Kahneman and Lovallo, 1993, and Kahneman, Knetsch and Thaler, 1990).

One striking finding is that people are often much more sensitive to the way an outcome differs from some non-constant *reference level* (such as the *status quo*) than to the outcome measured in absolute terms. This focus on changes rather than levels may be related to well-established psychophysical laws of cognition, whereby humans are more sensitive to changes than to levels of outside conditions, such as temperature or light.

Moreover, people appear to be more adverse to losses, relative to their reference level, than attracted by gains of the same size. Tversky and Kahneman (1992) estimated that the value attached to a moderate loss is about twice the value attached to an equally large gain. That is, people's preferences seem to be characterized by (local) *loss aversion*. With small stakes, they generally prefer the *status quo* to a fifty-fifty chance of winning, say, 12 dollars or losing 10 dollars. This renders counterfactual the implied preferences over large gains and losses, according to conventional economic analysis; see Rabin (2000). The common finding of apparently *risk-loving behavior* with respect to large losses is inconsistent with the traditional assumption of risk aversion.[10] For example, Kahneman and Tversky (1979) found that seven out of ten people prefer a 25% probability of losing 6,000 dollars, to a 50% probability of losing either 4,000 or 2,000 dollars, with equal probability (25%) for each. Since the expected monetary value of the two lotteries is the same, the first lottery is a mean-preserving spread of the second, and should thus not be preferred under conventional risk aversion.

Kahneman and Tversky moved beyond criticism, however, and suggested an alternative modeling framework in their seminal article, "Prospect Theory: An Analysis of Decisions under Risk" (1979). While expected-utility theory is axiomatic, their *prospect theory* is descriptive. It was thus developed in an inductive way from empirical observations, rather than deductively from a set of logically appealing axioms. Later, Tversky and Kahneman (1986) argued that two theories are in fact required: expected-utility theory to characterize rational behavior and something like prospect theory to describe actual behavior. Although expected-utility theory provides an accurate representation of actual choices in some

[10] As explained in Section 1, a decision-maker is called *risk neutral* if she is indifferent between participating in any actuarially fair lottery and obtaining the expected prize for sure. A decision-maker who prefers the expected prize for sure is called *risk averse*, while she is called *risk loving* if she prefers the lottery.

transparent and simple decision problems, most real-life decision problems are complex and call for behaviorally richer models.

What, then, are the differences between the two theories? In the case of monetary gains and losses, the decision criterion in expected-utility theory, equation (1) above, presumes the existence of a real-valued function u of wealth w, for the decision-maker in the current situation. If action a induces probabilities p_i over the different levels w_i of wealth, and action b induces probabilities q_i, then the decision-maker (strictly) prefers a to b if and only if

$$\sum_i p_i u(w_i) > \sum_i q_i u(w_i) \ . \qquad (2)$$

By contrast, prospect theory postulates the existence of two functions, v and π, such that the decision-maker (strictly) prefers action a over action b if and only if

$$\sum_i \pi(p_i)v(\Delta w_i) > \sum_i \pi(q_i)v(\Delta w_i) \ , \qquad (3)$$

where $\Delta w_i = w_i - w_o$ is the deviation in wealth from some reference level w_o (which may be initial or aspired wealth, see below).

There are three differences between the two models. First, in prospect theory, the decision-maker is not concerned with final values of wealth *per se*, but with changes in wealth, Δw, relative to some reference point. This reference point is often the decision-maker's current level of wealth, so that gains and losses are defined relative to the *status quo*. But the reference level can also be some aspiration level: a wealth level the subject strives to acquire, given his or her current wealth and expectations. Kahneman and Tversky argued that a decision problem has two stages. It is "edited", so as to establish an appropriate reference point for the decision at hand. The outcome of such a choice is then "coded" as a gain when it exceeds this point and as a loss when the outcome falls short of it. This editing stage is followed by an evaluation stage, which is based on the criterion in (3).

The second difference relative to expected-utility theory concerns the value function v . In addition to being defined over changes in wealth, this function is S-shaped. Thus it is concave for gains and convex for losses, displaying diminishing sensitivity to change in both directions. Furthermore, it has a kink at zero, being steeper for small losses than for small gains. The function u in expected-utility theory, by contrast, is usually taken to be smooth and concave everywhere. The form of the value function is illustrated in *Figure 2* (Figure 3 in Kahneman and Tversky, 1979).

Third, the decision-weight function π is a transformation of the objective probabilities p and q. This function is monotonically increasing, with discontinuities at 0 and 1, such that it systematically gives overweight to small probabilities and underweight to large probabilities. Its typical shape is illustrated in *Figure 3* (Figure 4 in Kahneman and Tversky, 1979).

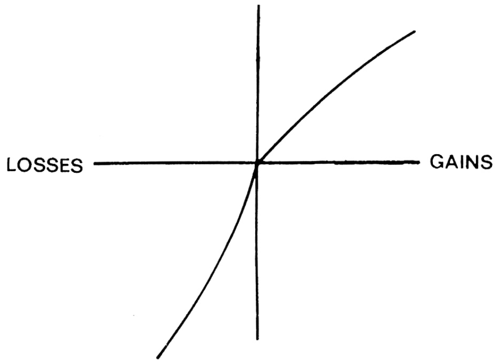

Figure 2

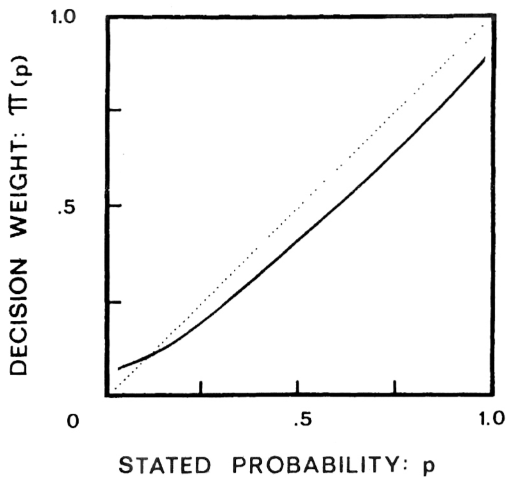

Figure 3

These differences make prospect theory consistent with the experimental evidence mentioned earlier in thissection. Since people evaluate risky prospects on the basis of changes in wealth relative to some reference level, appropriate assumptions about the editing stage would make the model consistent with the common observation that people choose differently depending on how a problem is framed. The kink on the value function at the reference point – making the function much steeper for small losses than for small gains – implies that choices are consistent with loss aversion. As a consequence of the diminishing marginal sensitivity to change in the v function, decision-makers become risk averse towards gains (they value large gains less than proportionally) and risk loving towards losses (they value large losses less than proportionally), in line with the evidence. Moreover, the fact that the decision-weight function overweighs small probabilities and underweighs large probabilities can explain the Allais paradox.

Already Allais (1953 a,b) outlined foundations for a psychologically based theory of preferences over uncertain prospects with monetary outcomes. Unlike prospect theory, Allais attached (cardinal) utilities to final wealth levels, but like prospect theory, he made a distinction between objective probabilities and the decision-maker's perception of these. Allais suggested that objective probabilities be transformed differently for gains and losses, in such a way that the perceived probabilities sum to one.

Prospect theory may also capture several regularities that appear as anomalies from the perspective of traditional economic theory: the propensity for people to take out expensive small-scale insurance when buying appliances; their willingness to drive to a distant store to save a few dollars on a small purchase, but reluctance to make the same trip for an equally large discount on an expensive item; or their resistance to lowering consumption in response to bad news about lifetime income.

In sum, the empirical work conducted by Kahneman and others indicates several regularities in choice under uncertainty, and the ideas incorporated in prospect theory go a long way towards explaining these regularities. Kahneman's results have provided researchers in economics with new insights and have been instrumental in subsequent model building by alerting decision analysts to the errors commonly committed by real-life decision-makers. A further extension of prospect theory, known as cumulative prospect theory (Tversky and Kahneman, 1992) addresses some weaknesses of the original version. In particular, cumulative prospect theory allows for prospects with a large number of outcomes, and it is consistent with stochastic dominance.[11]

Prospect theory and its extensions have taken important steps towards a more accurate description of individual behavior under risk than expected-utility theory. It now forms the basis for much of the applied empirical work in this field.

[11] Cumulative prospect theory combines prospect theory with a cumulative approach developed by Quiggin (1982), Schmeidler (1989) and Luce and Fishburn (1991).

3. Summary

Daniel Kahneman has used insights from cognitive psychology regarding the mental processes of answering questions, forming judgments, and making choices, to help us better understand how people make economic decisions. Other psychologists have also made important contributions along the same lines. But Kahneman's work with Tversky on decision-making under uncertainty clearly stands out as the most influential. Kahneman also made early contributions to other areas of behavioral economics. One example is his joint work with Knetsch and Thaler (Kahneman, Knetsch and Thaler, 1986) on the importance of fairness considerations. This has become a lively field of research, and many experimental studies have subsequently been carried out by other researchers, showing that a variety of market behaviors can be derived from considerations of fairness and reciprocity (see e.g. Fehr and Falk, 2002 for a recent review). Through this and other work, Kahneman has been a major source of inspiration behind the recent boom of research in behavioral economics and finance. His research has also had a substantial impact in other fields. It is widely quoted in other social sciences as well as within the natural sciences, the humanities and medicine.

Vernon Smith is the most influential figure in launching experiments as an empirical methodology in economics. Unlike Kahneman, he did not start out by challenging the traditional economic theory of rational decision-making. Rather, he tested alternative hypotheses regarding market performance, in particular the importance of different market institutions. While Kahneman's surveys and experiments have mainly focused on decisions by individual agents, Smith has focused his experiments on the interaction between agents in specific market environments. He has also emphasized methodological issues, developing practical experimental methods and establishing standards for what constitutes a good experiment.[12] Other researchers have furthered this tradition. Charles Plott, in particular, has written several important papers, further developed the experimental methodology and spear-headed experimental research in new areas. But it is largely through Smith's achievement that many economists have come to view laboratory experiments as an essential tool.

[12] Since experimentation with human subjects had been a well-established method in psychology for almost a century, it was more important for Smith than for Kahneman to develop experimental methodology.

A current wave of research draws on the combined traditions of psychology and experimental economics. This new research is potentially significant for all areas of economics and finance. Experimental evidence indicates that certain psychological phenomena – such as bounded rationality, limited self-interest, and imperfect self-control – are important factors behind a range of market outcomes. To the extent parsimonious behavioral theories, consistent with this evidence, can be developed, they may eventually replace elements of traditional economic theory. A challenging task in financial economics is to consider the extent to which the effects of systematic irrationality on asset prices will be weeded out by market arbitrage.

Although Kahneman's and Smith's research agendas differ in many respects, their combined scientific contributions have already changed the direction of economic science. Economics used to be limited to theorizing by way of a relatively simple rationalistic model of human decision-making, *homo oeconomicus*, and to empirical work on field data. When they appeared, Kahneman's and Smith's initial works were received with skepticism by the scientific community in economics. It took considerable time and much further research before their main ideas seriously began to penetrate the profession. It is their achievement that many – perhaps most – economists today view psychological insights and experimental methods as essential ingredients in modern economics.

4. Suggestions for further reading

Smith (1962) and Kahneman and Tversky (1979) are two classical articles by this year's laureates. For collections of papers we refer to Smith (2000) and Kahneman and Tversky, eds. (2000). Overviews of the fields are given in Kagel and Roth, eds. (1995), and in Rabin (1998).

References

Allais M. (1953a), “Le comportement de l’homme rationnel devant le risque: Critique des postulats et axiomes de l’école americaine”, *Econometrica* 21, 503-546.

Allais M. (1953b), “Fondements d'une Théorie Positive des Choix Comportant un Risque et Critique des Postulats et Axiomes de l’Ecole Americaine”, in *Econometrie, Colloques Internationaux du Centre de la Recherche Scientifique*, Volume XL, 257-332, Paris. (Translated into English in M. Allais and O. Hagen (eds.): *Expected Utility Hypotheses and the Allais Paradox*, D. Reidel Publishing Company, Dortrecht, Holland, 1979.)

Bulfin R.L., S.J. Rasenti, and V.L. Smith (1982), “A combinatorial auction mechanism for airport time slot allocation”, *Bell Journal of Economics* 13, 402-417.

Chamberlin E.H. (1948), “An experimental imperfect market”, *Journal of Political Economy* 56, 95-108.

Coppinger V.M., V.L Smith, and J.A. Titus (1980), “Incentives and behavior in English, Dutch, and sealed-bid auctions”, *Economic Inquiry* 18, 1-22.

Coursey D.L. and V.L. Smith (1984), “Experimental tests of an allocation method for public, private, or externality goods”, *Scandinavian Journal of Economics* 86, 468-484.

Cox J.L., B. Roberson, and V.L Smith (1982), “Theory and behavior of single object auctions”, in V.L. Smith (ed.) *Research in Experimental Economics*, JAI Press, Greenwich CT.

Edwards W. (1954), “Behavioral decision theory”, *Annual Review of Psychology* 12, 473-98.

Ellsberg D. (1961), “Risk, ambiguity, and the Savage axioms”, *Quarterly Journal of Economics* 75, 643-669.

Fehr E. and A. Falk (2002), “Psychological foundations of incentives. 2001 Schumpeter Lecture”, *European Economic Review* 46, 687-724.

Fiorina M. and C. Plott (1978), “Committee decisions under majority rule: An experimental study”, *American Political Science Review* 72, 575-98.

Flood M. (1959), “Some experimental games”, *Management Scienc*e 5, 5-26.

Fouraker L.E. and S.Siegel (1963), *Bargaining Behavior*, McGraw Hill, New York.

Kagel, J. H. and A. E. Roth, eds. (1995), *Handbook of experimental economics*, Princeton University Press, Princeton.

Kahneman D., J. Knetsch, and R. Thaler (1986), “Fairness and the assumptions of economics”, *Journal of Business* 59, S285-S300.

Kahneman D., J. Knetsch, and R. Thaler (1990), “Experimental tests of the endowment effect and the Coase theorem”, *Journal of Political Economy* 98, 1325-1348.

Kahneman D. and D. Lovallo (1993), “Timid choices and bold forecasts: A cognitive perspective on risk taking”, *Management Science* 39, 17-31.

Kahneman D. and A. Tversky (1972), “Subjective probability: A judgment of representativeness”, *Cognitive Psychology* 3, 430-454.

Kahneman D. and A. Tversky (1973), “On the psychology of prediction”, *Psychological Review* 80, 237-251.

Kahneman D. and A. Tversky (1979), ”Prospect theory: An analysis of decision under risk”, *Econometrica* 47, 263-291.

Kahneman, D, and A. Tversky, eds. (2000), *Choices, values and frames,* Cambridge University Press, Cambridge.

Kalish G.K., J.W. Milnor, J. Nash, and E.D. Nehrig (1954), “Some experimental n-person games”, in R.M. Thrall, C.H. Coombs, and R.L. Davis (eds.), *Decision Processes*, Wiley, New York.

Krishna, V. (2002), *Auction Theory*, Academic Press.

Loewenstein G. (1999), “Experimental economics from the vantage-point of behavioral economics”, *Economic Journal* 109, S25-S34.

Luce, R. D. and P. C. Fishburn (1991), "Rank-and sign-dependent linear utility models for finite first-order gambles", *Journal of Risk and Uncertainty* 4, 29-59.

McCabe K.A., S.J. Rasenti, and V.L. Smith (1989), “Designing 'smart' computer-assisted markets”, *European Journal of Political Economy* 5, 259-283.

von Neumann J. and O. Morgenstern (1944), *Theory of Games and Economic Behavior* (3rd ed.), Princeton University Press, Princeton.

Nilsson L-G. (1987), “Motivated memory: Dissociations between performance data and subjective reports”, *Psychological Research* 46, 183-188.

Plott C. and V.L. Smith (1978), “An experimental examination of two exchange institutions”, *Review of Economic Studies* 45, 133-153.

Quiggin, J. (1982), "A theory of anticipated utility", *Journal of Economic Behavior and Organization* 3, 323-343.

Rabin, M. (1998), “Psychology and Economics," *Journal of Economic Literature* 35, 11-46.

Rabin, M. (2000), “Risk aversion and expected-utility theory: A calibration theorem”, *Econometrica* 68, 1281-92.

Rabin M. (2002), “Inference by believers in the law of small numbers”, *Quarterly Journal of Economics* 117, 775-816.

Rasenti S.J., V.L. Smith, and B.J. Wilson (2001), “Controlling market power and price spikes in electricity networks: Demand-side bidding”, mimeo, George Mason University.

Samuelson, P. and W. Nordhaus (1985), *Economics*, McGraw-Hill.

Sauerman, H., and R. Selten (1959), “Ein Oligopolexperiment”, *Zeitschrift für die gesamte Staatswissenschaft* 115, 427-471.

Savage L. (1953), *The Foundations of Statistics*, John Wiley and Sons, New York.

Schmeidler, D. (1989), "Subjective probability and expected utility without additivity", *Econometrica* 57, 571-587.

Shiller R. (1981), “Do stock prices move too much to be justified by subsequent changes in dividends?”, *American Economic Review* 71, 421-436.

Shleifer A. (2000), *Inefficient Markets – An Introduction to Behavioral Finance*. Clarendon Lectures in Economics, Oxford University Press, Oxford.

Siegel S. and L.E. Fouraker (1960), *Bargaining and Group Decision Making*, McGraw Hill, New York.

Simon H.A. (1956), “Rational choice and the structure of the environment”, *Psychological Review* 63, 129-138.

Smith V.L. (1962), “An experimental study of competitive market behavior”, *Journal of Political Economy* 70, 111-137.

Smith V.L. (1965), “Experimental auction markets and the Walrasian hypothesis”, *Journal of Political Economy* 73, 387-393.

Smith V.L. (1973), “Notes on some literature in experimental economics”, Social Sciences working paper No. 21, California Institute of Technology.

Smith V.L. (1976a), “Experimental economics: Induced value theory”, *American Economic Review*, Papers and Proceedings, 274-279.

Smith V.L. (1976b), “Bidding and auctioning institutions: Experimental results”, in Y. Amihud (ed.), *Bidding and Auctioning for Procurement and Allocation*, New York University Press, New York.

Smith V.L. (1979a), “An experimental comparison of three public good decision mechanisms”, *Scandinavian Journal of Economics* 81, 198-215.

Smith V.L. (1979b), “Incentive compatible experimental processes for the provision of public goods”, in V.L. Smith (ed.), *Research in Experimental Economics*, JAI Press. Greenwich, CT.

Smith V.L. (1979c), “Indirect revelation of the demand for public goods: An overview and critique”, *Scottish Journal of Political Economy* 26, 183-189.

Smith V.L. (1980), “Experiments with a decentralized mechanism for public good decisions”, *American Economic Review* 70, 584-599.

Smith V.L. (1982), “Microeconomic systems as an experimental science”, *American Economic Review* 72, 923-955.

Smith V.L. (1991a), “Rational choice – the contrast between economics and psychology”, *Journal of Political Economy* 99, 877-897.

Smith V.L. (1991b), *Papers in Experimental Economics*, Cambridge University Press, Cambridge.

Smith, V.L. (2000), *Bargaining and Market Behavior : Essays in Experimental Economics*, Cambridge University Press, Cambridge.

Tversky A. and D. Kahneman (1971), “Belief in the law of small numbers”, *Psychological Bulletin* 76, 105-110.

Tversky A. and D. Kahneman (1973), “Availability: A heursistic for judging frequency and probability”, *Cognitive Psychology* 5, 207-232.

Tversky, A. and D. Kahneman (1974), “Judgment under uncertainty: Heuristics and biases”, *Science* 185, 1124-1131.

Tversky, A. and D. Kahneman (1982), “Judgment of and by representativeness”, in Kahneman, D., P. Slovic, and A. Tversky (eds.). *Judgment Under Uncertainty: Heuristics and Biases*, Cambridge University Press, Cambridge.

Tversky A. and D. Kahneman (1986), “Rational choice and framing of decisions”, *Journal of Business* 59, S252-278.

Tversky A. and D. Kahneman (1991), “Loss aversion in riskless choice: A reference-dependent model”, *Quarterly Journal of Economics* 106, 1039-1061.

Tversky A. and D. Kahneman (1992),”Advances in prospect theory: Cumulative representation under uncertainty”, *Journal of Risk and Uncertainty* 5, 297-323.