Mind & Society, 1, 2000, Vol. 1, pp. 25-39

Bounded Rationality in Social Science: Today and Tomorrow

Herbert A. Simon

Department of Psychology, Carnegie Mellon University, Pittsburg, PA 15213-3890, e-mail: Herb_Simon@v.gp.cs.cmu.edu

(Received March 1999, accepted May 1999)

Abstract *With the discovery of voluminous discordant empirical evidence, maximizing expected utility is rapidly disappearing as the core of the theory of human rationality, and a theory of bounded rationality, embracing both the processes and products of choice, is replacing it. There remains a large task of organizing our picture of economic and social processes and adding the new facts needed to shape the theory in an empirically sound way. It is also urgent that new tools now available for conducting empirical inquiry and constructing models be incorporated in social science graduate education.*

Keywords *rationality, economic; rationality, psychological; rationality, bounded; rationality under uncertainty; utility theory; decision theory; scientific discovery; game theory*

Bounded rationality is simply the idea that the choices people make are determined not only by some consistent overall goal and the properties of the external world, but also by the knowledge that decision makers do and don't have of the world, their ability or inability to evoke that knowledge when it is relevant, to work out the consequences of their actions, to conjure up possible courses of action, to cope with uncertainty (including uncertainty deriving from the possible responses of other actors), and to adjudicate among their many competing wants. Rationality is bounded because these abilities are severely limited. Consequently, rational behavior in the real world is as much determined by the "inner environment" of people's minds, both their memory contents and their processes, as by the "outer environment" of the world on which they act, and which acts on them.

A theory of bounded rationality, then, will be as much concerned with procedural rationality, the quality of the processes of decision, as with substantive rationality, the quality of the outcome. To understand the former, one must have a theory of the psychology of the decision maker; to understand the latter, one needs have only a theory of the goal (the utility function) and the external environment.

We can call bounded rationality a theory, although it is hard to say just what empirical predictions it makes. Alternatively, we can call it a representation: a

suitable framework for economic theories, where the product of decision cannot be predicted without knowledge of the processes. Choosing bounded rationality for our representation of economic phenomena has substantial consequences for theory and for the ways of discovering and testing it.

This paper sketches some long-term historical trends in the social sciences, focusing on the theory of rationality. We must look briefly at past events, at least back to Adam Smith and John Locke, in order to understand the principal paradigm shifts that have taken place in the treatment of rationality in economics and the other social sciences. This will lead us to current paradigms and the changes they are undergoing at present; and finally, to some simple projections of the current trends over the next several decades. Of course we cannot insure the reader against new paradigm shifts that are still invisible over the horizon; we only wish that we knew what they might be.

1. The Substitution of "Perfect" Rationality for Bounded Rationality in Economics

That human rationality is bounded is not a recent idea. Rationality has been an important topic of study and discussion at least since classical times, and whether in logic or elsewhere in the works of the Greek philosophers, rationality was viewed as an aspect of the processes of reasoning. One constructed a proof by reasoning from premises, formally, as in Aristotle's Prior and Posterior Analytics, dialectically, as in the Socratic dialogues, pragmatically, as in most classical rhetoric. When rationality is associated with reasoning *processes,* and not just with its *products,* limits on the abilities of Homo sapiens to reason cannot be ignored. So the reasoning we find in the classics sounds very different from the calculus of maximization of expected utility in modern neoclassical economics. Taking account of process as well as product is compatible, as neoclassical thinking is not, with the idea that, while human beings usually have reasons for what they do, these are seldom the best reasons, and are seldom consistent over the whole range of their choices.

Attention to the limitations of human rationality persisted from classical up to quite modern times. Voltaire, in the *Dictionaire Philosophique* (1746), was so bold as to proclaim that "the best is the enemy of the good," that if you are too preoccupied with attaining the optimum, you won't get even an acceptable result. In modern translation: "optimizing is the enemy of satisficing."

A generation after Voltaire, Adam Smith's, *The Wealth of Nations* (1776), does not include the term "rationality" in the index, and all of Smith's examples of economic actors advancing their selfish interests are qualified: "the superior value of their produce *may frequently be no more* than a *reasonable* compensation for the time and labour which must be spent in acquiring them," or "wherever *a great deal*

can be made by the use of money, *a great deal will commonly* be given for the use of it." This sounds very much like the practical behavior of reasonable persons, but hardly like the precise behavior of utility maximizers. Human beings use their wits to gain what they want, but Adam Smith makes no claims that they optimize or maximize, and he recognizes the variety of human desires without crowding all of these desires into a common utility function.

The term "utility," in its modern sense (far more abstract than the "happiness" sense of Bentham) appears to have been introduced by Mill about 1848, and the Oxford English Dictionary supplies no examples of the use of "maximum" or "maximization" in their modern senses before the last quarter of the 19th Century. So the novelty in social science as it moved into the 20th Century was not bounded rationality but maximization of expected utility. By the middle of the century, if not before, utility theory had swept the field as the proper description of economic rationality, and it had become difficult to publish papers in economics journals that did not assume it (and began to be increasingly difficult to publish papers that did not treat it mathematically).

The substitution of utility maximization for a "reasonable person" principle as the central rule of economic decision making focused attention upon substantive rationality: the quality of the adaptation to the external environment in the light of the decision maker's utility function. At the same time, it justified ignoring procedural rationality - the processes of decision. The new principle was: "To predict the shape of jello, don't look at the jello; look at the mold in which it is jelling". Assuming utility maximization, behavior could be predicted without concern for the decision processes of the economic actor, a wholly malleable gel before the onset of jelling.

2. The Introduction of Uncertainty

The economics of this period was primarily the economics of static equilibrium, or at most, of steady-state equilibrium and stability of stochastic dynamic systems. As a climax to this movement, major successes were ultimately achieved in formalizing general equilibrium theory at a high level of mathematical sophistication (e.g., Arrow, Debreux). Even those economists who made little use of mathematics generally employed, in verbal form, the theories that it expressed.

These developments left macroeconomics, the study of business cycles and long-term economic development, in an unsatisfactory state, mostly unconnected in any strict way with the new rigorous theories. Until the end of World War II theory of rational decision making under dynamic uncertainty was terra incognita, which had been the site of only a few tentative explorations: by such economists as Frank Knight, Albert Hart, and G.L.S. Shackle. Any serious treatment of dynamics had to take account of human uncertainty about the present and future state of the world.

Probability Theory

Three intellectual events changed this situation drastically. The earliest was the incorporation of probability theory into utility theory, a move that allowed maximization of *expected* utility under uncertainty. "In principle", this solved at least the problem of extending statics into an uncertain world, but only in conditions of equilibrium. Alas, it brought along its own deep problems. The first was the question of where the decision maker's probabilities originated. (The theorists avoided this question by focusing on "subjective" expectations.) If humans had uncertainty about their world, one might expect that they would have even greater uncertainty about the frequency distribution of future events than about the first moment - the average - of this distribution.

A second difficulty was that the introduction of probabilities made the computational problems of decision making orders of magnitude more difficult than before. Nevertheless, it provided a field day for theorists, who were not immediately concerned with numerical estimation, in stochasticizing their mathematical models.

The Theory of Games

The second event affecting the theory of decision making under uncertainty was the appearance of von Neumann and Morgenstern's *Theory of Games* (1944), which seemed to promise a definition of rationality in those situations where the problem was not uncertainty in the probabilistic sense of the term but the uncertainty arising from mutual attempts of decision makers to outguess the persons with whom they were competing. This problem can be traced at least back to Cournot, and gave rise to imperfect competition and oligopoly theory, but it had not found any solutions that could withstand stern scrutiny.

A great body of careful theoretical research on game theory showed, first, that the original, von Neumann-Morgenstern, definition of "solution" for n-person games, again conceived in terms of equilibrium, was unconvincing and deeply flawed, and second, that attempts to mend the flaws only led to new difficulties. After a half century of extremely sophisticated mathematical work on this problem, we can say that the chief contribution of formal game theory to our understanding of rationality has been to demonstrate rather convincingly (if not mathematically) that there is no satisfactory definition of "optimal" rationality in the presence of opportunities for outguessing and outwitting.

The conflicting definitions of rational action in many kinds of games ultimately stimulated some exceedingly important empirical research. Anatol Rappaport and Robert Axelrod each conducted experiments in which they invited game theorists (and other interested researchers) to enter computer programs capable of playing the Prisoners' Dilemma game in a contest to determine what strategies would be

most successful against an array of competing strategies. It was a great surprise for most game theorists that the so-called "tit-for-tat" strategy turned in a performance that was usually distinctly superior to that of any of the other strategies that were entered. Although theorists were subsequently able to find reformulations of the rules of the game (e.g., of the rules for continuation or termination of play) and the definition of rationality that would make "tit-for-tat" substantively rational for a player, the reformulations were entirely ad hoc responses to the empirical findings. (I would except here the recent reformulation by Bendor & Swistak, 1997, that introduces bounded rationality ideas as well as social motivations.) Here was an impressive demonstration of the need for factual information about the process of decision in order to predict rational response to a game situation.

A second conclusion could also have been drawn from the experiments, but generally wasn't: that the wide range of different strategies entered by the competitors showed that the choice of a rational strategy was not at all obvious even to aficionados of game theory, much less to non-experts. To predict the behavior of this jello it was not enough to look at the shape of the mold. This demonstration of bounded rationality and the relevance of procedure to choice has strongly pushed the game theory community toward complementing its theorizing with experimenting, and there now exists a vigorous activity in experimental games, especially in Europe.

Rational Expectations

The third event that changed the treatment of uncertainty in economics was the invention of "rational expectations" by Muth (1961), and its further development by Lucas and Sargent a decade later. This notion was another tour-de-force that "solved" a major component of the uncertainty problem (uncertainty about the behavior of others) by assuming that all economic actors had the same economic model in mind when making their decisions, and all agreed on where its equilibrium lay and carried out their calculations as though it would be reached immediately. In the world of economics, where optimization of utility was already largely taken for granted, this assumption was not, somehow, viewed as making preposterous demands on the decision makers. However, this new expansion of the rationality principle was sufficiently startling that it did not immediately command universal assent, especially outside the United States, and was soon also confronted with various conflicting empirical phenomena.

3. Experimental Economics

Another important development that is attributable to the concern with uncertainty is the rapid growth of experimental economics, which, in addition to experimenting with games, as already mentioned, has experimented extensively with markets. Ironically, experimental economics had its origins in classroom experiments, using the students as subjects trading under specified market rules to demonstrate that the

laws of markets set forth in economics textbooks actually predict behavior (V. Smith, 1962). In many cases the experiments did support the textbook predictions, but increasingly, phenomena not predicted by the theory of substantive rationality began to appear. For example, in some experiments involving trading over a week's time in commodities that had a known fixed value at the end of the week, typical boom-and-bust phenomena occurred. The commodities were bid up by the middle of the week to large multiples of their week-end values, then crashed in a day or two. Clearly, some traders were not exhibiting rational expectations.

Some experimenters have taken the next step, of writing computer programs that can participate in markets as traders. Gode & Sunder (1997) have shown that even markets staffed with "zero intelligence" trading programs (sellers that will make any trade that meets a reservation price, and buyers that will make any trade below a ceiling price) usually converge to the competitive equilibrium price, although perhaps a little more slowly than markets where the participants are more sophisticated. Again, the phenomena observed in experimental markets have turned the attention of economists to the processes of decision, and thereby to the limits of the rationality of market traders.

4. The Revival of Bounded Rationality

I have now mentioned several examples of the revival of bounded rationality in economics, which in the past several years has become positively a fad in discussions of economic theory. As various bounds on rationality begin to replace the utility-maximizing rationality of neoclassical economics with the practical reasoning that Adam Smith and his contemporaries observed in economic actors, there appears to be less a revolution in economic theory than a counter-revolution that seeks to restore the old regime. This is true as far as it goes, but it is not the whole story. The economics of Adam Smith, while it left a great deal of room for human limitations, and while its conclusions did not rest on assumptions of optimization, did not provide, or even aspire to provide, a systematic theory of the limitations of rationality or their implications for economic decision making and the operation of the economy.

What is new in the counter-revolution is a shift of attention from the rational aspects of decision to the phenomena that arise from, or are substantially modified by, the limits on rationality. This shift is essential for building a theory of human decision making that is consistent with what we know, from empirical study in all of the social and behavioral sciences, about both facets of human thinking: the substantively and the procedurally rational. It combines these facets into the boundedly rational, as they actually are combined in the human head. The social sciences require theories built around realistic models of human actors; that capture that realism only approximately, but avoid over-simplification where it makes a consequential difference.

With these new goals, the counter-revolution requires new methods of research: formal methods for building theories, and empirical methods for testing them, and - perhaps most important - empirical methods for discovering the important phenomena of thinking and decision making. Much of our discussion of the future must deal with this methodology of theory building and fact finding. But, before discussing what the counter-revolution implies for the social sciences generally, we need to look at the social sciences that lie outside economics.

5. Rationality in Social Science outside Economics and Psychology

Simply put, the revolution represented by modern utility theory in neoclassical economics never spread, in more than small degree, to the other social sciences. The predominant approach to rationality of those disciplines continued to be the "reasonable person" approach that we have found in Adam Smith's works and most other economics almost up to the beginning of our century. As a counterpart in political science to *The Wealth of Nations,* we can take *The Federalist Papers* (Locke's *Of Civil Government* or Machiavelli's *The Prince* will do as well, or perhaps even Plato's *Republic*). In none of these works do we find a formal characterization of rationality, certainly not one that at all resembles utility maximization; but in all of them we find many statements about how reasonable people usually behave in matters that concern them.

Not long before World War II, when economics had already gone far towards taking its final neoclassical shape, political science also underwent a major shift, usually called the behavioral revolution. But instead of moving to a vision of perfect rationality sheathed in a formal mathematical structure, as economics did, political science joined with sociology, psychology and anthropology to build a more general empirical theory of human behavior, including decision making and social behavior.

To pursue the empirical side of the venture, traditional methods, drawn from the disciplines of history, anthropology and sociology, including field study of phenomena and interview methods, were supplemented by relatively new and untried techniques, including sample polls (Merriam & Gosnell, 1924), field and laboratory experiments, and intensive observation of ongoing operations in organizations. Intercultural studies (e.g., Merriam, 1931; Murdock, 1949) used the data from more or less comparable case studies in individual cultures to test hypotheses about relations among cultural variables. Although this work used largely qualitative data, some made substantial use of quantitative data (if sometimes no more sophisticated than numerical tallies). Instruments devised by psychologists for assessing various aspects of intelligence, personality or other traits were adapted to political and sociological inquiries.

The behavioral revolution also brought about major innovations on the theoretical side. Political scientists acquired the standard statistical tools of hypothesis testing,

factor analysis, and regression analysis. In fact, causal analysis, based upon regression analysis and employing either the path analysis ideas developed by Sewall Wright or the structural equations methods of the Cowles Commission, probably was used more extensively, in the decades after 1960, by political scientists and sociologists than by economists. Thus multivariate theories increasingly took the form of causal models composed of structural equations.

The increased mathematical sophistication of a significant number of political scientists and sociologists now began to permit more communication between them and the highly mathematized economists. The communication was, however, largely one way: a missionary (or, some would say, imperialistic) effort by economists and their converts in the other social sciences to introduce the utility maximizing concept of rationality at the core of all political and social phenomena. In political science, this formulation was known as "public choice theory"; in sociology, it is typified by Gary Becker's book on *The Family* (1981). Its impact has not been insignificant, but it has fallen far short of achieving majority support in any of the social sciences outside economics. Perhaps its greatest failing was in not producing major insights into political and social processes that were not already well known, if in somewhat more qualitative and less formalized statements.

This economic imperialism has had even less impact up to the present time upon psychology, but even here, we find the Act-R (the "R" stands for "rational") computer simulation language of John R. Anderson seeking to model rational procedures that have become embodied in the nervous system through evolutionary selection. In fact, evolutionary considerations become a principal vector through which substantive rationality is transferred into theories of organismic behavior.

In political science applications, for example, of the utility maximizing framework, voters are usually interpreted as income or wealth maximizers, politicians as power maximizers. However, it is difficult to determine which electoral or legislative choices would in fact be regarded as income maximizing or power maximizing, respectively, for there are large uncertainties in voters' minds as to which policies would improve their economic conditions, and in politicians' minds as to which policies would increase their electoral support.

Consequently, formalization of the theory contributes little to its predictive power, and adds little to the less formal empirical analysis of politics in terms of economics and power that was already well established in political science. Beard (1913 and 1922), for example, had already argued cogently for a central role for economic motives in voting behavior from the earliest days of American history. And the idea that both parties in a two-party system would be driven toward moderate positions near the center was well understood long before the economist Hotelling formalized this idea in his famous theorem.

6. Rationality in Cognitive Psychology

From the beginning of this century until well after the end of World War II, American cognitive psychology was experimental at its core, with theory generally playing a subordinate role. At the level of relatively simple processes there were very qualitative and general learning theories, which involved conditioned reflexes and associations brought about by reinforcement. These were supplemented by equally qualitative, but very specific mechanisms like retroactive and proactive inhibition, the "mechanisms" being scarcely more than names for the phenomena. European process theories of such complex phenomena as problem solving were more sophisticated - for example the theory of Selz, based on directed associations and goal-directed search, and the Gestalt theories of Durkheim and Wertheimer, which elaborated on these processes. But these theories were also purely verbal, making them difficult to operationalize, or to test in more than very simple experimental situations.

In the late 1950s, the introduction into psychology of computer programs that modeled relatively complex psychological phenomena at the level of symbolic processes helped bring about a vigorous revitalization of cognitive theory and experimentation. Increasingly, experiments looked at the processes, and not just the products, of thought. New or improved experimental methods, like the analysis of thinking-aloud protocols and of eye movements, produced new kinds of empirical data for testing the validity of these models as explanations of behavior. Study of these data created a considerable body of theory that made detailed quantitative predictions about the behavior of people in a considerable range of complex problem solving tasks, of which chessplaying and the Tower of Hanoi puzzle are well-known examples.

There have as yet been few systematic attempts to use this body of theory, the new symbolic modeling methods, or the new experimental methods to reconstruct the core of economic theory. The general framework of a theory of rational decision, involving satisficing instead of optimizing criteria, borrowing the aspiration level and attention mechanisms from psychology, and using heuristic search as the principal problem solving method has been sketched (Simon, 1955 and 1956), but has never been applied systematically to reconstructing the theory of markets. Numerous experiments on behavior under uncertainty have revealed large deviations between actual human behavior and the prediction that expected utility would be maximized (Tversky & Kahneman, 1981), and some partially successful attempts have been made to create and test a replacement for that hypothesis (Kahneman & Tversky, 1985). I have already discussed the psychologically motivated experiments with the Prisoners' Dilemma Game, which revealed an unanticipated robustness of the tit-for-tat strategy. Bounded rationality was introduced within an evolutionary framework in the dynamic theory of the firm of Nelson & Winter (1982).

The verdict stands: In spite of these and other efforts, anyone who undertook today to prepare an elementary or intermediate level economics textbook would not find a ready-made bounded rationality theory that could frame formally the discussion of such central topics as markets, the firm, or uncertainty, although he or she would find (and textbook authors like Peter Earl and Robert Frank have found) a large body of empirical material that provides a rich qualitative description of the phenomena.

7. Overview

The status of the concept of rationality in the social sciences, excluding psychology, at the end of the 20th Century can be summarized with three major generalizations:

1. The fascination with maximization of expected utility as the core of the theory of economic (and other) rationality has waned rapidly in recent years with the discovery of a large body of empirical evidence of human behavior that diverges widely from this theory. Dissatisfaction has led to the introduction of ad hoc patches to the theory in the form of specific, but seldom empirically-grounded, assumptions of limits upon rationality. Economists have become increasingly cynical about the neoclassical formalism, and increasingly interested in alternative theories and new empirical approaches, like experimental markets, to obtaining a better formalism, both macro and micro (Selten, 1994; V. Smith, 1989). Very visible members of the "formal" majority - such figures as Kenneth Arrow and Tom Sargent - have expressed major doubts publicly about neoclassical theory, especially as it applies to uncertainty, and have turned their attention to possible new ways to formalize theory.

The number of defectors has clearly not yet reached a majority of the profession, but if we add serious doubters to defectors the numbers increase greatly. Every development, theoretical or empirical, that gives the alternatives to classical theory a clearer and more definite shape hastens the abandonment of the theory for one or another of those others.

2. The older approach to rationality - what might be called pragmatic rationality - remains the predominate view in all of the social sciences except economics, and the inroads of formal economic reasoning into these other disciplines has peaked and begun to wane. Moreover, great strides have been made in the past forty years, largely within cognitive psychology, to formulate an empirically grounded theory of decision making and problem solving processes.

The new theory does not exhibit the very high levels of abstraction and generalization that characterized neoclassical theory in the last half of our century,

but it does lend itself very well to formal simulation with computer models - that is to say, with symbolic difference equations instead of the more familiar arithmetic differential equations borrowed from physics. The theory includes not only the processes of choosing among alternatives, but also the processes for generating new alternatives, hence meets a basic requirement for any satisfactory theory of long-term economic phenomena.

3. There remains a large task of organizing and systematizing the empirical picture of economic processes that has already been assembled, and of continuing to provide the body of facts that are necessary to guide an empirically sound reformulation of the theory.

In the final part of this paper, I will look at the future of the concept of rationality in the social sciences in the light of thes developments and needs, and the methodological and substantive changes that will help shape future research.

8. Systematizing the Theory of Bounded Rationality

The picture of the future can be organized conveniently under four headings:

1. Tools for finding the empirical phenomena
2. Tools for building theories
3. Tools for testing theories
4. Dealing with uncertainty
    - About the future environment
    - About the reactions of other actors
    - About changes in one's own tastes and values

The treatment of these topics can be concise, because our best guides to the future (however inadequate these may be) are the developments of the recent past, already discussed, and what we have learned from them. Because the timing of history is even more difficult to predict than the directions it will take, it is safest to think in terms of some not-too-distant terminus, like the year 2025, without taking the last two digits seriously.

9. Tools for Finding the Phenomena

The traditional empirical tool of economics, collection of aggregated data and their analysis by statistical regression, can only provide one weapon in the armory, and that not the most important. One key requirement for forward movement is broadening the training of economists in methods of gathering data. Especially, they need to understand how to carry out field studies on decision making (and field experiments), especially within the walls of business firms.

This means that economists must be trained in methods of observing and interviewing, of taking and analysing verbal think-aloud protocols, of extracting information about decision processes from written records, and of drawing conclusions reliably from multiple studies of these kinds, not all of which will obtain exactly the same data, and none of which will obtain more than a sample of the data that would be relevant. It is especially important that they learn how to use non-numerical data (e.g., verbal and written information expressed in natural language). Movement toward including this kind of training regularly in the economics doctoral curriculum is hardly visible at present, but it can be expected to begin and accelerate with the rapid advance of the theory of bounded rationality and the accumulation of related data from economics experiments.

A second development, already under way, is training research economists in the design and conduct of laboratory experiments, and in the use of experimental data to discover and test economic theories. There is every reason to expect the number of economics departments offering this kind of training to continue to expand rapidly, so that in a decade, say, it will be a standard part of virtually every doctoral program. Because they have been receptive to a wider range of research methods and kinds of data, business schools are apt to make this transition more rapidly the departments of economics.

Clearly, reaching these goals will require major changes in the doctoral curricula in both economics departments and business schools. All of the techniques mentioned are now well developed and widely practiced, but mainly by psychologists and others trained in disciplines outside economics. The methodological know-how of these other disciplines will have to be imported into economics and adapted to the specific needs of economic analysis.

10. Tools for Building Theories

I have already discussed why symbolic theories in the form of computer programs will become increasingly important in economics. So long as the theory is only concerned with quantities of goods and prices, more traditional mathematics can be used, but more general theories of economic decision making will require theories that can handle nature language as well as numbers.

The use of computer simulations will also enable economics to build a realistic theory of the firm that will go far beyond the traditional production function and short- and long-run cost curves into characteristics of organization structure and human motivation, and their consequences for the decision-making process.

Most of the cognitive research has been concerned with individual problem solvers and decision makers. Research has begun only recently to build formal

theories of the decision process in organizations (Carley & Prietula, 1994; Prietula, Carley & Gasser, 1998).

11. Tools for testing theories

The recent progress in experimental economics and experimental game theory has already begun to show the power of these tools for providing the data that can be used to test theory and also to enrich our knowledge of economic phenomena in markets and in business firms. Experimental work needs to be complemented by field studies in business firms of the actual decision processes employed for various kinds of decisions (for example, capital investment, discovery and development of new products, reorganization).

An important and powerful component of theories in the natural sciences and psychology are parameters for important observables and theoretical terms that maintain their values over wide ranges of situations, thereby reducing the number of degrees of freedom in theories that are to hold over different situations. Economics has no "speed of light" or "quantum" or "short-term-memory capacity," or "time required for recognition," whose values estimated from one experiment or set of observations allows prediction to other situations.

12. Dealing with Uncertainty

Dealing with uncertainty, and especially with uncertainty about the reactions of others to ones actions, will continue to be one of the leading edges of economic research. One very important direction of research, now scarcely developed, will be the study of the processes for generating alternatives for choice. Here, the research that has already been done in cognitive psychology on topics like scientific discovery, will provide a very useful starting point.

Another issue that economics has rarely dealt with is the dynamic character of the utility function. In fact, Stigler & Becker (1977), in a valiant and widely noticed effort to stabilize it (without providing empirical evidence to support their undertaking), once argued that the utility function was stable, but that learning experiences could change the utility extractable from any particular consumption of a commodity. Their chief example was the increase in musical enjoyment (per hour of listening, presumably) one could obtain by studying music or listening to it.

It is not at all certain that this is the best way, or even a feasible way, to theorize about changing tastes. As all of the available evidence seems to suggest that people do not have consistent utility functions, even at a single point of time, over all conceivable baskets of goods, it may well prove to be more fruitful to introduce changes in taste directly in to the theory as both exogenous and endogenous variables.

As this is about as far as my crystal ball allows me to peer into the future, I will bring my analysis to an end at this point, hoping that I have at least sketched some of the exciting challenges that lie before economists at this moment in the ongoing rapidly accelerating shift from neoclassicism to a theory of bounded rationality that accounts for the processes as well as the products of decision. The next quarter century shows every sign of being as productive of fundamental progress in economics as were the years around the middle of the 20th Century that saw the mathematization of neoclassical theory.

References

Beard, C.A. (1913) *An economic interpretation of the constitution of the United States* (New York, Macmillan).

Beard, C.A. (1922) *The economic basis of politics* (New York, A.A. Knopf).

Becker, G. (1981) *A treatise on the family* (Cambridge, Harvard University Press).

Bendor, J. & Swistak, P. (1997) The evolutionary stability of cooperation, *American Political Science Review*, 91, pp. 290-306.

Carley, K.M. & Prietula, M.J. (1994) *Computational organization theory* (Hillsdale, Erlbaum).

Gode, D.K. & Sunder, S. (1997) What makes markets allocationally efficient?, *Quarterly Jounal of Economics*, 111, pp. 604-629.

Hamilton, A., Madison, J. & Jay, J. (1787) *The Federalist Papers* (Richmond, Westvaco, 1995).

Kahneman, D. & Tversky, A. (1985) Prospect theory: An analysis of decision-making under risk, *Econometrica*, 47, pp. 263-291.

Locke, J. (1690) *On civil government* (London, J. M. Dent, 1924).

Machiavelli, N. (1513) *The Prince* (London, Oxford University Press, 1935).

Merriam, C.E. (1931) *The making of citizens* (Chicago, University of Chicago Press).

Merriam, C.E. & Gosnell H.F. (1924) *Non-voting* (Chicago, University of Chicago Press).

Mill, J.S. (1848) *Principles of political economy* (New York, Longmans, 1920).

Murdock, G.P. (1949) *Social structure* (New York, The Free Press).

Muth, J.F. (1961) Rational expectations and the theory of price movements, *Econometrica*, 29, pp.315-335.

Nelson, R.R. & Winter, S.G. (1982) *An evolutionary theory of economic change* (Cambridge, Harvard University Press).

von Neumann, J. & Morgenstern, O. (1944) *The theory of games and economic behavior* (Princeton, Princeton University Press).

Plato (1997 edition) *The Republic* (Ware, Wordsworth Editions).

Prietula, M.J., Carley, K.M. & Gasser, L. (Eds.) (1998) *Simulating organizations* (Cambridge, AAAI Press - The MIT Press).

Selten, R. (1994) In search of better understanding of economic behavior, in A. Heertje (Ed.), *The makers of modern economics* (New York, Harvester Wheatsheaf).

Simon, H.A. (1955) A behavioral model of rational choice, *Quarterly Journal of Economics*, 69, pp 99-118.

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

Smith, A. (1776) *The wealth of nations* (New York, The Modern Library, 1937). (Text based on 5th edition).

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

Smith, V. (1989) Theory, experiment and economics, *The Journal of Economic Perspectives*, 3(1), pp. 151-169.

Stigler, G.J. & Becker, G.S. (1977) De gustibus non est disputandum, *American Economic Review*, 67, pp. 76-90.
Tversky, A. & Kahneman, D. (1981) The framing of decisions and the psychology of choice, *Science*, 211 (Jan. 30), pp. 435-58.
Voltaire, F. M. A. (1746) *Dictionnaire philosophique* (Paris, Garnier, 1973).