JOHN CHARLES HARSANYI

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Working Paper No. 06-W07

March 2006

DEPARTMENT OF ECONOMICS
VANDERBILT UNIVERSITY
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March 2006

Abstract. This article provides an overview of the main events in the life of John Harsanyi and a summary of his research on decision-theoretic foundations for utilitarianism, cooperative bargaining theory, games of incomplete information, and equilibrium selection in noncooperative games.

Journal of Economic Literature classification number: B31.

Keywords and phrases: John Harsanyi, utilitarianism, bargaining theory, games of incomplete information, equilibrium selection.

The definitive published version of this article is forthcoming in Noretta Koertge, ed., *New Dictionary of Scientific Biography*, Charles Scribner's Sons (an imprint of Thomson Gale), New York. This version of the manuscript has not been reviewed or edited. It is being made available in this form with the permission of the publisher.

HARSANYI, JOHN CHARLES (*b.* Budapest, Hungary, 29 May 1920; *d.* Berkeley, California, 9 August 2000), *economics, game theory*

Harsanyi is best known for providing a decision-theoretic foundation for utilitarianism, for his work on equilibrium selection in noncooperative games, and for developing the conceptual foundations for analyzing games of incomplete information. For the latter research, Harsanyi was awarded the 1994 Nobel Memorial Prize in Economic Sciences jointly with John Nash and Reinhard Selten.

Harsanyi (born Harsányi János Károly) was the only child of Charles and Alice Gombos Harsanyi. His father, a pharmacist by profession, and mother both converted to Catholicism from Judaism. Harsanyi attended the Lutheran Gymnasium in Budapest, whose alumni include one of the founding fathers of game theory, John von Neumann. In the year of his graduation, 1937, Harsanyi won First Prize in the national competition for high school students in mathematics. The next two years were spent working in his father's pharmacy.

Although Harsanyi's own inclination was to study mathematics and philosophy, at his father's urging, he went to France in 1939 with the intention of enrolling in chemical engineering at the University of Lyons. However, having completed a summer course to improve his French in Grenoble, with the outbreak of World War II, his parents summoned Harsanyi back to Budapest, where he studied pharmacology, receiving the Diploma in pharmacology from the University of Budapest in 1944. By studying pharmacology, Harsanyi received a military deferment which, because of his Jewish background, would have required that he serve in a forced labor unit. With the Nazi occupation of Hungary, Harsanyi lost this exemption and spent seven months doing forced labor in 1944. When his unit was being deported to work in a mine in Yugoslavia, Harsanyi managed to escape at the Budapest railway station. He found sanctuary in a Jesuit monastery until the end of the Nazi occupation. Harsanyi was the only member of his labor unit to survive the war. His mother, an asthmatic whose health deteriorated because of the privations of the war, died later that year.

Following World War II, Harsanyi, then a devout Catholic, studied theology (in Latin) in a Dominican seminary, later joining their lay order. However, he lost his faith in his late twenties and was anti-religious for the rest of his life. While at the seminary, Harsanyi simultaneously pursued graduate studies at the University of Budapest. In 1947, after completing a dissertation on "The Logical Structure of Errors in Philosophical Arguments," he was awarded a Dr.Phil. in philosophy, with minors in sociology and psychology.

Harsanyi spent the academic year 1947–48 as a faculty member of the University's Institute of Sociology, where he met his future wife, Anne Klauber, who was a student in one of his classes. Forced to resign this position because of his anti-Marxist views, Harsanyi spent the next two years running the family pharmacy, which he now co-owned. In April of 1950, when confiscation of the pharmacy by the communist government was imminent, Harsanyi, his future wife, and her parents escaped to Vienna. At the end of that year, they all immigrated to Sydney, Australia, where Anne and John Harsanyi were married in January, 1951, a few days after their arrival. Harsanyi became an Australian citizen in 1956. His father was kept on as a poorly paid state employee after his pharmacy was confiscated and subsequently died of kidney failure in 1954.

In 1951, Harsanyi enrolled as an evening student in economics at the University of Sydney while spending his days working in a series of factory and clerical jobs. He completed his M.A. in economics in late 1953 with a dissertation on "Invention and Economic Growth" and then spent two and a half years as a Lecturer at the University of Queensland. While still a student in Sydney, Harsanyi had articles on welfare economics accepted in two of the most pre-eminent economics journals, the *Journal of Political Economy* and the *Review of Economic Studies*.

Harsanyi then went to Stanford University on a one-year Rockefeller Fellowship in 1956, where he wrote a game theory dissertation, "A Bargaining Model for the Cooperative n-person Game," supervised by future Nobel Laureate, Kenneth Arrow. Harsanyi's visa permitted him to spend one more year in the United Sates, which he did, first spending a semester visiting the Cowles Foundation for Research in Economics at Yale University before returning to Stanford as a Visiting Assistant Professor of Economics. In 1958, Harsanyi took up a position as a Research Fellow at the Australian National University a few months before receiving his Ph.D. in economics from Stanford in 1959.

Feeling isolated because of the lack of interest in game theory by his colleagues, Harsanyi returned to the United States where, except for visiting positions, he spent the rest of his career, becoming a United States citizen in 1990. From 1961 to 1963, he was a Professor of Economics at Wayne State University. Following a year as a Visiting Professor, Harsanyi became a Professor of Business Administration at the University of California at Berkeley in 1965 with a secondary appointment as a Professor of Economics from 1966. From 1966 to 1968, Harsanyi, together with other prominent game theorists, served as consultants to the United States Arms Control and Disarmament Agency under contract to Mathematica, the Princeton-based consulting group that included the game theorists, Harold Kuhn and Oskar Morgenstern, as principals. Harsanyi retired from Berkeley in 1990.

In addition to his Nobel Prize, Harsanyi's many honors included Fellowships in the Econometic Society (1968), the American Academy of Arts and Science (1984), and the European Academy of Arts, Sciences and Humanities (1996), as well as a number of honorary doctorates. He was made a Distinguished Fellow of the American Economic Association in 1994 and an Honorary Member of the Hungarian Academy of Sciences in 1995. Harsanyi was President of the Society for Social Choice and Welfare in 1996–97. Harsányi János College in Budapest is named after him.

The Harsanyis had one child, a son Tom, born in 1964 shortly after their arrival in Berkeley. For some time prior to his death in 2000 from a heart attack, Harsanyi had been in poor health, suffering from Alzheimer's Disease.

For utilitarianism to be a well-defined doctrine, individual well-being must be measurable by a cardinal utility function that permits interpersonal comparisons of utility gains and losses. Following the ordinalist revolution of the 1930s, it was thought that no such function exists. In *Theory of Games and Economic Behavior* (Princeton, 1944), John von Neumann and Oskar Morgenstern argued that the preferences of a rational individual evaluating risky alternatives should conform to a set of properties (axioms) that result in these alternatives being ranked by the expected value of a cardinal utility function, what Harsanyi called "Bayesian rationality." However, subequent commentators denied that this utility function had any significance for social welfare analysis. In his first publication in 1953, Harsanyi set out to refute this claim. For Harsanyi, welfare judgments are the impersonal preferences expressed by an impartial observer who orders social alternatives based on a sympathetic but impartial concern for the interests of everyone in society. Specifically, the impartial observer engages in a thought experiment in which he imagines having an equal chance of being anyone in society, complete with that person's preferences and objective circumstances. Thus, ranking social alternatives is reduced to a problem in individual decision-making under risk and therefore, by applying the von Neumann–Morgenstern expected utility theory, Harsanyi argued that different social states should be ranked by the average of the utilities of all the individuals in society, thereby providing a Bayesian decision-theoretic foundation for average utilitarianism.

The hypothetic choice situation utilized in Harsanyi's impartial observer theorem is a example of what the philosopher, John Rawls, in his 1971 monograph, *A Theory of*

Justice, has called an original position. The idea of deriving substantive principles of morality based on rational individual decision-making behind a veil of ignorance (to use another Rawlsian expression) in which morally irrelevant information has been withheld is arguably Harsanyi's most important contribution to ethics. (Although this thought experiment had been briefly mentioned by future Nobel Laureate, William Vickrey, in a 1945 *Econometrica* article, this was not known by Harsanyi until a few years after his own article was published.) In Rawls' formulation of this idea, less information is permitted behind the veil, with the consequence, or so Rawls argued, that social institutions should be designed so as to maximize the prospects of the worst-off individuals (once priority has been given to ensuring that everyone enjoys equal liberties and fair equality of opportunity). In his 1975 commentary on Rawls, Harsanyi defended his Bayesian use of expected utility theory and argued that Rawls' maximin reasoning leads to unsatisfactory outcomes.

Harsanyi's impartial observer must be able to make interpersonal comparisons of utility gains and losses in order to rank the social lotteries he is faced with. In a 1955 article, Harsanyi investigated the logical basis for these comparisons. For Harsanyi, interpersonal utility comparisons are made by empathetic identification; the observer evaluates how well off someone else is in a particular situation by asking how well off he would be if he were put in the place of that individual complete with that individual's tastes and values. In effect, all interpersonal utility comparisons are reduced to intrapersonal comparisons. Furthermore, these comparisons are empirical statements made on the basis of an *a priori* principle, Harsanyi's similarity principle, that says that the utility obtained from an alternative by any individual is determined by a function (common to everyone) of the biological and cultural variables that determine tastes and values.

In his 1955 article, Harsanyi also provided an alternative justification for a weighted form of utilitarianism, his social aggregation theorem. In this theorem, alternatives are risky alternatives and all preferences, both individual and social, are assumed to satisfy the von Neumann–Morgenstern expected utility axioms. The individual and social preferences are related to each other by the requirement that if everyone is indifferent between two alternatives, society should be as well. With these assumptions, Harsanyi showed that if von Neumann–Morgenstern utility functions are used to represent the preferences, then alternatives are socially ranked according to a weighted sum of the individual utilities asociated with them.

The interpretation of Harsanyi's impartial observer and social aggregation theorems as being theorems about utilitarianism has been controversial. In a 1976 article, Amartya Sen (a future Nobel Laureate) argued that, contrary to what many believe, von Neumann–Morgenstern utility functions are not cardinal and, hence, cannot serve as a basis for a defense of utilitarianism. In a 1991 article, while endorsing Sen's critique, I showed how Harsanyi's utilitarian conclusions could be supported by incorporating ideas from Harsanyi's writings that are not stated explicitly in his theorems.

Harsanyi wrote extensively about the philosophical issues related to his version of utilitarianism. For example, in a 1977 article, Harsanyi presented his case for rule utilitarianism, the doctrine that utilitarian principles should be applied to rules for behavior, not individual acts.

Game theory is concerned with the analysis of rational decision-making by players (individuals or groups) when the outcome obtained by any player depends not only on the choices he makes, but also on the choices of the other players. In cooperative game theory, binding agreements are possible, whereas in noncooperative game theory, they are not.

In the 1950s, cooperative games dominated the research agenda of game theorists. In John Nash's formulation of the two-player bargaining problem (*Econometrica*, 1950), a bargaining problem is described by the set of utility payoffs that are achievable for the players if they can reach an agreement and the payoffs that result if no agreement is reached (the threat point). A solution specifies the payoffs of the players in each bargaining problem. Proceeding axiomatically, Nash identified a unique solution to all such problems. Earlier, Frederik Zeuthen, in his *Problems of Monopoly and Economic Warfare* (London, 1930), had considered a dynamic approach to two-player bargaining in which, at each stage of the bargaining, the player who is less willing to risk a conflict makes the next concession. In a 1956 article, Harsanyi showed that Bayesian decision-makers would behave as Zeuthen suggested and that the final outcome of Zeuthen's bargaining process is the Nash solution.

In his 1953 *Annals of Mathematics Studies* article, Lloyd Shapley axiomatically characterized a unique solution—the Shapley value—for any n-person transferable utility (TU) cooperative game. In a TU game, actions are available that permit the transfer of a unit of utility between any two players. In his Stanford Ph.D. thesis, published in abridged form in 1959, and, more generally, in a 1963 article, Harsanyi showed how to extend Shapley's solution to n-player cooperative games in which utility is not transferable. Furthermore, his general solution for cooperative games has Nash's bargaining solution for two-player games with variable threat points as a special case. Harsanyi's general solution for cooperative games is supported by a noncooperative threat game in which each coalition of individuals guarantees its members certain payoff levels by announcing a threat strategy that the coalition would implement if it cannot reach agreement with the coalition consisting of the rest of the players.

By the early 1960s, Harsanyi had started shifting the focus of his research to noncooperative games. The extensive form of a noncooperative game specifies the order in which the players make decisions (simultaneous moves are not precluded), what actions are available and what information is known to a player about past choices each time he gets to make a decision, and the expected payoffs to each player at the end of the game as a function of the history of these decisions. Exogenous random events are modelled as decisions made by nature. In a game of complete information, the structure of the game is common knowledge, although at any point in time, players need not know the complete past history of play (in which case, the game is one of imperfect knowledge). A strategy for a player is a contingent plan of action that specifies what choice is to be made each time this player gets to make a decision. A mixed strategy includes nondeterministic choices, whereas a pure strategy does not. In the normal form of a game, the players are regarded as independently and simultaneously choosing these strategies once and for all at the beginning of the game. The decisions specified by these strategies are then implemented as the game unfolds. These strategies are a Nash equilibrium if no individual could change his strategy so as to achieve a higher payoff given the strategy choices of the other players.

The assumption that the payoffs obtained from each history of play is common knowledge in a game of complete information limits the applicability of this theory. In a game of incomplete information, players need not have full knowledge of the extensive form. In particular, a player need not know anyone else's payoff from a given history of play. However, prior to Harsanyi's pathbreaking three-part article in the 1967–68 volume of *Management Science*, little progress had been made in analyzing games of incomplete information. Harsanyi's conceptual breakthrough was to recognize that it is possible to embed a game of incomplete information in a larger game of complete information and use it to determine equilibrium behavior in the original game. He did this by thinking of each player as potentially being one of a number of possible types, with each type corresponding to a different specification of a player's private information about the structure of the game, including this player's beliefs about the other players' types. The augmented game begins with a chance move by nature, made in accordance with a common prior probability distribution on the players' possible types, that determines the types that are to play the rest of the game. Following this chance move, each player learns his own type and updates his beliefs about the other players' types using Bayes' rule. At this point, the original incomplete information game begins. In this way, incomplete information about the other players' types in the original game is transformed into imperfect information about nature's initial decision in the augmented game, which is something that games of complete information were already equipped to handle.

A strategy for a player in the augmented game can be thought of as specifying a conditional plan of action for each possible type of this player. Viewed from this perspective, a Nash equilibrium can be equivalently described using Harsanyi's concept of a Bayesian–Nash equilibrium, which requires each type to choose a strategy so as to maximize its expected payoff given the beliefs it has about the other players' types and given the strategies of the possible types of the other players. As Harsanyi recognized, this equilibrium concept is well-defined even if the type-conditional beliefs are not derivable from a common prior. However, in a way reminiscent of his similarity principle, Harsanyi argued that differences in players' types can be accounted for by differences in their information and that prior to nature's initial move, everyone has the same information, so there should be a common prior. This argument is known as the Harsanyi doctrine.

From the time Harsanyi presented his research on games of incomplete information to the Jerusalem Game Theory workshop in 1965, it has had a major impact. Together with the theory of repeated games, which has its origins in a 1959 article (which appeared in the same volume as the published version of Harsanyi's Stanford thesis) by Robert Aumann (another future Nobel Laureate), Harsanyi's games of incomplete information provided the theoretical basis for the Mathematica arms control project. Harsanyi's formalization of a game of incomplete information and his concept of a Bayesian–Nash equilibrium has become the standard way in which games of incomplete information are modelled and analyzed. His insights provided the foundation for much of the subsequent research on problems in which individuals are asymmetrically informed about economically-relevant information.

In the traditional interpretation of a mixed strategy in a game of complete information, a player chooses the probability that he wishes to assign to each of his pure strategies and then he employs a random device to determine which of his pure strategies to implement. In a mixed-strategy Nash equilibrium, a player is indifferent between all of the pure strategies that he assigns positive probability to, but he randomizes so as to hide his intentions from the other players. However, the other players only observe the pure strategy that is actually implemented, which leads one to ask: why randomize? In 1973, Harsanyi used his games of incomplete information to provide a reinterpretation of the meaning of a mixed strategy that resolves this paradox. Harsanyi supposed that a player's payoffs are subject to small random perturbations due to factors whose realization is only known to himself. The resulting game of incomplete information has a unique Bayesian–Nash equilibrium in which each type chooses a pure strategy. However, because a player only has probabilistic information about the types of the other players, it actually appears from the perspective of the first player that they are using mixed strategies even though they are behaving deterministically. By letting the size of the payoff perturbations go to zero, a mixed strategy equilbrium of the original game of complete information is obtained.

John Nash had suggested in a 1953 *Econometrica* article that the binding agreements that are assumed to be possible in a cooperative game need to be justified by showing that they can arise as equilibrium outcomes in some noncooperative game. The search for noncooperative foundations for cooperative games is known as the Nash program. The noncooperative elements of Harsanyi's general solution for cooperative games can now be seen to be a step towards Harsanyi's full-fledged support of the Nash program. He made a major contribution to this program in 1974 by providing a noncooperative foundation for the solution for cooperative games proposed by John von Neumann and Oskar Morgenstern in their 1944 monograph.

A major theme of Harsanyi's work on game theory is that the goal of game theory should be to use Bayesian principles of rationality to determine a unique solution to any game. Games often have multiple equilibria, so, in order to achieve this goal, some procedure must be used to select among the equilibria. This research agenda reached its apogee in Harsanyi's 1988 monograph with Reinhard Selten, in which the selection is accomplished using a procedure in which the tracing procedure introduced by Harsanyi in 1975 plays a major role.

The tracing procedure identifies a unique equilibrium in a noncooperative game by analyzing equilibrium behavior in a continuum of auxiliary games that only differ from the original game in the payoffs players receive from the possible strategy combinations. This procedure begins with an auxiliary game in which a probability distribution over a player's pure strategies is given *a priori*. This distribution represents the initial conjecture on the part of the other players about this player's mixed strategy choice. The payoff to any player from a strategy choice in this auxiliary game is the payoff that would be obtained in the original game if the other players played according the initially conjectured strategies. In this game, each player has a unique best response to the conjectured strategy choices of the other players, but these best responses are typically not a Nash equilibrium in the original game. Next, for each number t between 0 and 1, a t-auxiliary game is defined in which the payoffs to players are weighted combinations of the payoffs they would obtain in the original game and the initial auxiliary game, with weights t and $1 - t$ respectively, plus a small additional payoff that ensures that the equilibrium in each of the t-auxiliary games is unique. The value $1 - t$ represents the degree of confidence placed in the initial conjecture. The equilibria defined by this procedure converge to a unique equilibrium in the 1-auxiliary game, which is a unique equilibrium in the original game when the values of the small added payoffs go to zero. Harsanyi interpreted the tracing procedure as being a mathematical formalization of the process by which rational players coordinate their choices of stategies.

Harsanyi continued to work on equilibrium selection until his final illness ended his research career. In his 1995 articles on this topic, Harsanyi's tracing procedure, which for two decades had been an important component of the Harsanyi–Selten theory of equilibrium selection, only plays a minor role.

There is a unity in Harsanyi's research that is quite remarkable when one considers the range of problems that he considered over his lifetime. In his 1977 monograph, Harsanyi announced that his goal was to provide a systematic account of rational behavior based on Bayesian principles that yields determinate solutions in individual decision-making, in games, and in moral decision-making. In retrospect, one can see that most of what Harsanyi wrote contributed to the achievement of this objective.

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