

The Prize in Economic Sciences 2005

ROBERT AUMANN and **THOMAS SCHELLING** have contributed to enhancing our understanding of conflict and cooperation. They have achieved this by extending and applying game theory – a method used to analyze strategic interaction among different agents. Their work has transformed the social sciences far beyond the boundaries of economics. Aumann's and Schelling's research continues to shape the debate on the formation of social institutions.

Conflict and cooperation through the lens of game theory

In human interaction, a single individual can seldom determine what will happen; everyone can to some extent affect the outcome. For example, if someone in a two-party relation can choose between two alternative courses of action and the other party has three options, there are a total of $2 \times 3 = 6$ possible outcomes. The two parties usually have different evaluations of these outcomes and act on the basis of which alternative they think the other party will choose. Many interactions involve several steps over time and it is not unusual for them to be associated with asymmetric information, i.e., some parties know something which others do not. The analysis of strategic interaction – of all kinds – is the essence of game theory. The term itself brings to mind games in everyday life. But, as this year's Laureates have shown, the most important applications of game theory are to be found in such vital issues as security and disarmament policies, price formation on markets, as well as economic and political negotiations.

Negotiations in the Shadow of the Cold War

In the mid-1950s, **Thomas Schelling** began to apply game-theory methods to one of the era's most vital issues – global security and the arms race. As Schelling himself noted, considerable progress can be achieved simply by drawing a diagram which describes the alternatives available to the opponent and to one's own country, followed by systematic consideration of the outcome in the different cases. Such a process also serves as a reminder that the other party in a conflict faces a similar decision-making problem.

Schelling was particularly intrigued by the ways in which the parties' negotiating strength could be affected by different factors, such as the initial alternatives at their disposal and their potential to influence their own and each others' alternatives during the process. He clarified why it could be advantageous to limit one's own alternatives or worsen one's own options – literally to burn one's bridges. He was also interested in the process of establishing a climate of confidence, whereby long-term cooperation could be built up over a period of time, and in the long-run gains a party could achieve by making short-run concessions. The results of Schelling's work were published in his book, *The Strategy of Conflict* (1960), which became a classic and has influenced generations of strategic thinkers.

Other researchers have extended several of the concepts in Schelling's book. His ideas regarding credible threats and limitations on one's own alternatives were later formalized by Reinhard Selten, an Economics Laureate in 1994. Schelling's formulation of the prerequisites for cooperation has elicited extensive research on the origins and development of cooperation over time between parties who initially lacked confidence in one another.

Schelling was also concerned with the ability of individuals to coordinate their behavior in

situations without any strong conflict of interest, but where unsuccessful coordination would give rise to high costs for all parties. In his research, including classroom experiments with his students, Schelling found that coordinative solutions – which he called focal points – could be arrived at more often than predicted by theory. The ability to coordinate appears to be related to the parties' common frames of reference. Social conventions and norms are integral parts of this common ground. Schelling's work in this area inspired the philosopher David Lewis to specify the idea that language originated as a means of coordination.

Why Does Segregation Arise?

A recurring theme in Thomas Schelling's research is: what happens when individual plans and patterns of behavior are confronted in the social arena? The title of one of his most widely read books, *Micromotives and Macrobehavior* (1978), reveals the overall theme. The book addresses different everyday phenomena such as professional ice-hockey players' use of helmets, audiences' choice of seats in an auditorium, and racial and sexual discrimination.

Segregation is usually associated with oppression. Historically, this has been an important part of the explanation, but segregation is also a stable phenomenon in developed societies, where considerable effort is devoted to counteracting it. Schelling formulated a simple model where he assumed that all individuals are tolerant in the sense that they willingly live in the proximity of people with a different culture, religion or skin color, but that they want to have at least a few neighbors that share their own characteristics. If not, then they move to a neighborhood where they can find more people like themselves. Schelling showed that even rather weak preferences regarding the share of like persons in a neighborhood can result in strongly segregated living patterns. In other words, no extreme preferences on the part of individuals are required in order for a social problem to arise.

Long-run Cooperation

While Tomas Schelling's strength lies largely in his ability to introduce original ideas and concepts with a minimum of mathematical technique, **Robert Aumann's** primary contributions consist of using the tools of mathematical analysis to develop concepts and hypotheses, provide them with concise formulations and draw precise conclusions. He once likened his research to artistic creativity – as “expressing through a difficult or resistive medium”

Aumann shared Schelling's early interest in interaction where the parties interact many times over a long period, so-called repeated games. He showed that peaceful cooperation is often an equilibrium solution in a repeated game, even between parties with strong short-run conflicts of interest. Aumann and other researchers have extended and generalized his results in different directions, for example regarding credibility in “threats of punishment” for deviating from cooperation. Aumann, in joint work with Michael Maschler, also established the theory of repeated games with asymmetric (or, more generally, incomplete) information, i.e., situations where one party knows more than another about certain aspects of the repeated game, for example concerning the real costs of a competitor or the military strength of another country.

The theory of repeated games is now the common framework for analysis of long-run cooperation in the social sciences. Applications extend from competing firms which collude to maintain a high price level, and farmers who share pastures or irrigation systems, to countries which enter into environmental agreements or are involved in territorial disputes.

Common Knowledge and Correlated Equilibria

Another of Aumann's fundamental contributions concerns the cognitive foundations of game theory, i.e., the implications of the parties' knowledge about the various aspects of the game, including "knowledge about each others' knowledge". In the early days of game theory, analysis was often simplified by assuming that the parties know everything about all aspects of the game, in analogy, e.g., to physics, where friction or air resistance are sometimes disregarded. Knowledge that another party is rational can affect one's own behavior, as will knowledge about someone else's knowledge about one's own rationality, and so on. Aumann's formalization of the concept of common knowledge allowed for systematic analysis of the relation between the knowledge of the parties and the outcome of the game.

Aumann also introduced a new equilibrium concept, correlated equilibrium, which is weaker than Nash equilibrium, the solution concept developed by John Nash, an economics laureate in 1994. Correlated equilibrium can explain why it may be advantageous for negotiating parties to allow an impartial mediator to speak to the parties either jointly or separately, and in some instances give them different information.

The Limits of Rationality

As scholars, Robert Aumann and Thomas Schelling have distinctive profiles, but throughout their research they have shared a common trait: an interest in considering aspects neglected by established theory and in developing new concepts and analytical tools, thereby extending the scope of analysis. A consequence of these endeavors is that the concept of rationality now has a wider interpretation; behavior which used to be classified as irrational has become understandable and rational. Their work has contributed significantly to bridging the gap between economics and other behavioral and social sciences.

FURTHER READING

A great deal of Schelling's work is accessible to non-specialists and many of Aumann's publications contain non-technical discussions of his mathematical results. Dixit and Nalebuff (1991) offer a highly readable introduction to game theory with a focus on applications. Dixit and Skeath (2004) provide an introductory textbook, whereas Fudenberg and Tirole (1991) and Myerson (1991) give more advanced and technical expositions. Biographical and personal details about the laureates may be found in Zeckhauser's (1989) portrait of Schelling and in Hart's (2005) interview with Aumann.

Literature

- Aumann, R. (1985): "What is Game Theory Trying to Accomplish?", in K. Arrow and S. Honkapohja (eds.), *Frontiers of Economics*, Basil Blackwell
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- Hart S. (2005): "An interview with Robert Aumann," *Macroeconomic Dynamics*, forthcoming
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Links

At the official Nobel website, <http://nobelprize.org>, one can find , e.g. the press conference as web-TV. There is also a scientific article, for the more advanced reader.

Links and Further Reading: www.kva.se/swe/awards/nobel/economy/press/ecoreado5.asp

Game Theory: www.gametheory.net

THE LAUREATES

ROBERT J. AUMANN

Center for Rationality
Hebrew University of Jerusalem
91904 Jerusalem
Israel

www.ma.huji.ac.il/~raumann

Israeli and US citizen. Born 1930 (75 years) in Frankfurt, Germany. PhD in mathematics in 1955 from Massachusetts Institute of Technology (MIT), Cambridge, MA, USA. Professor at the Center of Rationality, Hebrew University of Jerusalem, Israel.

THOMAS C. SCHELLING,

Maryland School of Public Policy
University of Maryland
College Park, MD 20742
USA

www.puaf.umd.edu/facstaff/faculty/schelling.html

US citizen. Born 1921 (84 years) in Oakland, CA, USA. PhD in economics in 1951 from Harvard University, Cambridge, MA, USA. Distinguished University Professor at the Department of Economics and School of Public Policy, Emeritus, at University of Maryland, College Park, MD, USA and Lucius N. Littauer Professor of Political Economy, Emeritus, at Harvard University.