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CONFLICT AND COOPERATION
IN TERMS OF GAME THEORY
– THOMAS SCHELLING'S RESEARCH

Abstract. The Nobel Prize in Economic Sciences 2005 became to Robert Aumann[1] and Thomas Schelling[2] "for having enhanced our understanding of conflict and cooperation through game-theory analysis"[3].

Their work was essential in developing non-cooperative game theory further and bringing it to bear on major questions in the social sciences. Approaching the subject from different angles – Aumann from mathematics and Schelling from economics – they both perceived that the perspective of game theory had the potential to reshape the analysis of human interaction. Schelling showed that many social interactions could be viewed as non-cooperative games that involve both common and conflicting interests. Aumann demonstrated that long-run social interaction could be comprehensively analyzed using formal non-cooperative game theory.

This paper presents a report from Schelling's research.

Introduction

Thomas Schelling began applying game theory methods to one of the era's most important matters – global security and the arms race. He was particularly interested by the ways in which the players negotiating strength could be touched by different factors, such as the initial alternatives at their disposal and their potential to influence their own and each others alterna-

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[1] born 1930 in Frankfurt, Germany. PhD in mathematics in 1955 from Massachusetts Institute of Technology (MIT), Cambridge, MA, USA. Professor at the Center for Rationality, Hebrew University of Jerusalem, Israel

[2] born 1921 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

[3] *Press Release*, The Royal Swedish Academy of Sciences, 10/10/2005

tives during the process. He explained why it could be profitable to limit one's own alternatives or worsen one's own options. 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 his work were published in 1960 in book *The Strategy of Conflict*[4], which became a classic and has influenced generations of strategic thinkers.

Credible deterrence

Schelling's earliest main contribution is his analysis of behavior in bilateral situations of trade negotiations. Trade negotiations be interpreted fundamentally: except clear negotiations – on example between two countries or seller and buyer – trade negotiations are also "when two trucks loaded with dynamite meet on a road wide enough for one"[5]. Trade negotiations always cause some conflict of interest, in that every party usually looks for an agreement which is as favourable as possible. Yet, any agreement is better for both party than no agreement at all. Every player has to ballance search for large the "part of cake" against interest for agreement.

Schelling examines tactician trade negotiations, which player can use in order to, to bend down in him result or her service. He underlines particularly, that this can be profitable, to worsen one's own options in order to to obtain from opponent concession. For example, it can be beneficial for general, to burn bridges for his squads as credible commitment to enemy to does not resign. A politician can gain from announcing promises which they would be to embarrass, to to break. Such tactics work, if the commitment is irreversible or it can to be unfastened in great cost only, while commitments that are cheap to reverse will turn away not obtain large concessions. Yet, if both parties do irreversible and discordant commitment, harmful disagreement may follow.

Let us consider a simple example. Suppose, that two countries do not agree by right to patch of territory. Every country can choose to mobilize military strength or hold back from doing so. If both mobilize there is a high probability of war. The payoff to each country be 0 if both mobilize. If they

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[4] T. C. Schelling: *The Strategy of Conflict*, Harvard University Press, Cambridge MA, 1960

[5] T. C. Schelling: "An essay on bargaining", *American Economic Review* 46 (1956), p. 281–306

instead both refrain from mobilization, a peaceful agreement about division of territory has a high probability. In this case, each country receives a payoff b. If only one country mobilizes, then it can take the complete control of the territory without war, and other can't force a military retreat by the occupant. Aggressor receives payoff a, and the loser's payoff is c, where $a > b > c > 0$ (Table 1).

	mobilize	refrain
mobilize	$0, 0$	a, c
refrain	c, a	b, b

Table 1. Payoff matrix

Such games have three Nash equilibria[6]: two pure and one mixed. The pure equilibria cause to exactly mobilization one country; if one country waits the other to mobilize, then it is optimal to hold back from mobilization. The mixed equilibrium causes assured chance variation mobilization by each country and in this way positive probability of war.

The game's mixed equilibrium appears more plausible than the pure equilibria. Each country is then insecure about the other's movement, marking some probability p to event that the other country will mobilize. The Nash equilibrium probability of mobilization is:

$$p = \frac{(a - b)}{(a - b + c)}.$$

It's result from equating expected payoff of mobilize: $(1-p)a$ and payoff of refrain: $pc + (1 - p)b$. Notice, the probability of war is decreasing in the loser's payoff c. The key to minimizing the risk of war is not only to contain the winner's profit, but also to improve the loser's payoff.

Mobilizing and threatening to mobilize are not equivalent. Suppose that first Country 1 chooses whether to hold back from mobilization completely or to commit to mobilize if and only if Country 2 mobilizes. Thereafter, Country 2 observes 1's movement and decides whether or not to mobilize. If payoffs are as described in Table 1, the equilibrium result will be that

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[6] Nash equilibrium – a set of strategies, one for each player, such that no player has incentive to unilaterally change her action. Players are in equilibrium if a change in strategies by any one of them would lead that player to earn less than if she remained with her current strategy. For games in which players randomize (mixed strategies), the expected or average payoff must be at least as large as that obtainable by any other strategy.

Country 1 makes the mobilization commitment, and both countries refrain from mobilization. Such scaring away in this way guarantees a peaceful outcome.

Judge, moreover, that it Country 1 is uncertain, or Country 2 prefers war to the negotiated result. The question is: should Country 1 still commit to mobilize if country Country 2 mobilizes? Schelling's analysis reveals that the optimal commitment strategy is then often to choose a probability of mobilization that is less than one. Therefore, in the face of an enemy's military escalation, a country should threaten rather than commit to certain retaliation; in Schelling's words, make "threats that leave some things to chance", because a modest probability of war can suffice to hold back enemy's mobilization.

The above analysis suggests, that countries should keep conjecturing enemy about their answer on aggression, simultaneously assuring that strong vengeance is concerned as true option. It's necessary to remember that instability is dangerous. The balance of terror is maintained only if vengeance is sufficiently probable and heavy compared to the profits from occupation. War can be ignited by changes in preferences, in technology and successful attempts at disarmament have to be balanced throughout. Schelling's analysis of credible commitments demonstrated that some Nash equilibria are more plausible than others. His study of credible deterrence takes up a major part of *The Strategy of Conflict*.

Sometimes conflicts of interest may appear so strong as to be insoluble. The best strategy for person can call out bad result for group. The shortrun gains from cheating on an agreement might by far outweigh the short-run losses. Schelling wrote that "What makes many agreements enforceable is only the recognition of future opportunities for agreement that will be eliminated if mutual trust is not created and maintained, and whose value outweighs the momentary gain from cheating in the present instance"[7]. In this way, if parties take long perspective and affect mutually many times in fact, them common interests can be suffciently strong to support cooperation. People can structure their relationships, by extending interaction over time, in such a way as to reduce the incentive to behave opportunistically at each point in time.

The next part of Schelling's work is studying a class of social interactions that involve little or no conflict of interest (pure coordination games). These are games where all players prefer coordination on some common course

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[7] T. C. Schelling: "An essay on bargaining", *American Economic Review* 46(1956), p. 301

of action and no player cares about which coordinated course of action is taken. In this case, coordination may be easy, if players can communicate with each other but difficult without communication. By experimenting with his students and colleagues, Schelling discovered that they were often able to coordinate rather well without communicating even in unknown games, which had host Nash equilibria. As an example, consider the game, where two peole would be asked to choose total positive integer each. They both gen an award, if choose the same number, differently no award is given. The majority was inclines to choose the number 1. This number is outstanding distinctive, this is the smallest positive integer. It seems probable that many social conventions and organizational preparation appeared because they facilitate coordination.

Mutual distrust

A final interesting class of social decision problems are interactions in which participants are mutually distrustful. For example, two generals may both agree that war is undesirable, and will hence prepare for peace as long as they both think that the other will do likewise. Yet, if one general suspects that the other is preparing for war, then his best response may be to prepare for war as well – when war is less undesirable than being occupied. This idea had already been clearly formulated by Xenophon (in the fourth century B.C.)[8]. Schelling expressed it in game-theoretic terms and considered explicitly the role of uncertainty in triggering aggression[9]. To illustrate the possibility that war is caused solely by mutual distrust, consider the payoff matrix:

	war	peace
war	2, 2	3, 0
peace	0, 3	4, 4

Table 2. Payoff matrix

[8] T. C. Schelling: *Arms and Influence*, Yale University Press, New Haven, 1966, p. 261

[9] T. C. Schelling: *The Strategy of Conflict*, Harvard University Press, Cambridge MA, 1960, p. 207–229

Each player has the choice between going to war and keeping peacefully. The two pure strategy Nash equilibria are (War, War) and (Peace, Peace). If players are rational, conduct their plans perfectly and have not no uncertainty about opponent payoff. Schelling thought that peace would be the most credible result of such a game[10]. However, Schelling also fought, that the small quantity of nervousness about opponent's intentions would can be infectious sufficiently, to make peaceful equilibrium crush. He describe this situation as an attack dilemma: "If I go downstairs to investigate a noise at night, with a gun in my hand, and find myself face to face with a burglar who has a gun in his hand, there is a danger of an outcome that neither of us desires. Even if he prefers just to leave quietly, and I wish him to, there is danger that he may think I want to shoot, and shoot first. Worse, there is danger that he may think that I think he wants to shoot"[11].

The Strategy of Conflict has had a durable influence on the economics profession as well as on other social sciences. It has inspired, the detailed analysis of negotiating in historical crisis situations. The book and its draughts *Strategy and Arms Control*, (coauthored with Morton Halperin) and *Arms and Influence*, also had a profound impact on military theorists and practitioners in the cold war era, played a major role in establishing strategic studies as an academic field of study, and may well have contributed significantly to deterrence and disarmament among the superpowers.

Segregation

Schelling also consider what it happens when individual plans and forehead the examples of behaviour are confronted in social arena. His book *Micromotives and Macrobehavior*[12] total discloses this subject. Schelling formulated a simple model where he put, that all individuals are tolerant in the sense, that they live on place of work willingly the men's closeness with different culture, the religion or the colour of skin, but that they want to have at least several neighbour neighbors this part their own features. If not, they move to neighbourhood then they can find more people as them. Schelling

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[10] T. C. Schelling: *The Strategy of Conflict*, Harvard University Press, Cambridge MA, 1960, p. 210

[11] T. C. Schelling: *The Strategy of Conflict*, Harvard University Press, Cambridge MA, 1960, p. 207

[12] T. C. Schelling: *Micromotives and Macrobehavior*, Harvard University Press, Cambridge MA, 1978

was visible, that even rather weak preferences regarding part person's like in neighbourhood can result in strongly he sorted the life of examples. Differently saying, no extreme preferences on the part of individuals are required in order to for a social problem to arrise.

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