LECTIO PRAECURSORIA **18.8.2016**

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Doctor Custos, Doctor Opponent, ladies and gentlemen.

Economic actors often make decisions that do not only benefit themselves but also others. Sometimes this behavior is other-regarding without any obvious motives. For example, the internet giant Google has stated that they are a company that is “not evil” and does “good things for the world” even at the cost of forgoing short term profits.

What are the motivations for such behavior? This question has interested researchers in the social and life sciences for centuries. Game theorists argue that decision makers forgo cooperation and defect if they have the incentives to do so. That is, if the payoff from unilateral defection exceeds the payoff from cooperation, all players are better off by defecting than by cooperating. However, in this *social dilemma* everyone defects and all are worse off than if all were to cooperate.

Social dilemmas have of course been present since the dawn of the civilization. However, it was in the 19^{th} century France where social dilemmas were studied for the first time using mathematical formalism. Antoine Augustin Cournot, a mathematician, first took up the task of analyzing producer competition and formalized the model that would become a cornerstone of modern microeconomics.

In the Cournot oligopoly model, published in 1838, there are a limited number of firms making decisions about production quantities. They sell what they have produced to a common market, thus their decisions affect each others’ profits. Cournot’s far-reaching insight was the derivation of a set of quantities which would satisfy the following requirement: when *these* quantities are produced in the market, each firm gets their maximal profits and does not have the incentive to unilaterally increase nor decrease their quantity. The firms are in *equilibrium* with respect to their decisions.

Largely as the output of massive investments in science and technology when preparing for the Second World War, a new branch of mathematics was born. Game theorists, led by John von Neumann and Oskar Morgenstern, began studying multiplayer decision making problems. Game theory was particularly intensive at Princeton University, where John F. Nash wrote an important paper that proved the existence and uniqueness of an equilibrium in games. Coincidentally the equilibrium formulated previously by Cournot was a special case of the Nash equilibrium. By the 1980s game theory had become an indispensable tool used to analyze strategic behavior in economics, political science, and theoretical biology. The Nash equilibrium was game theory's most celebrated concept.

Science evolves gradually, and the works of Cournot and Nash were just the initial steps towards understanding strategic behavior. The Nash equilibrium has since undergone multiple *refinements*. The problem with the Nash equilibrium as such is that if the rules of the game are loosened, the Nash equilibrium might lose its predictive power due to non-uniqueness.

One such situation is sequential decision making: if one producer can serve the market first, then another producer is left only with the option of calculating the optimal reaction to the first-mover's quantity. In this two-player sequential move duopoly game there can actually be several Nash equilibria, production quantity pairs from which neither wants to deviate. But if the first-moving producer is smart enough to notice that it has *commitment power*, there is only one Nash equilibrium that will be played.

H.F. von Stackelberg was the first to study sequential duopoly problems in the 1940s. The Stackelberg duopoly model was an important source of insight for the subgame-perfect Nash equilibrium – a Nash equilibrium refinement developed by Reinhard Selten in the 1970s – that can be applied to all sequential games.

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Important for scientific theories is empirical regularity, a theory's capability to predict what happens in the actual world. Evidence of empirical regularity can be sought from real world interactions. But for simple games this kind of data is often noisy and has many variables that are out of the influence of the scientist. As in the physical sciences, control in the empirical studies in game theory can be established by using laboratory experiments. These are controlled decision situations where subjects are incentivized by using money.

In the first paper of my Dissertation we wanted to study how varying the level of commitment affects behavior in the Stackelberg duopoly. We arranged a laboratory experiment where subjects repeatedly played this game. In some treatments the first movers could change their decisions after the second-mover. This option effectively yielded their first decision as mere cheap talk communication. In other treatments only the first movers knew the payoffs of both, while the second movers knew only their own payoffs.

The purpose of this experiment was to test how altering commitment and information affect behavior. From previous literature we assumed that these two alterations would pull the results into opposite directions: cheap talk should increase cooperation, while private information should decrease cooperation.

The players did cooperate, except in one treatment, when information was private but the cheap talk option was not present. In that treatment the most common outcome was the Nash equilibrium that has inferior payoffs to the joint-optimum, which was the most common outcome in the other treatments. This suggests that the cheap talk mechanism can substitute private information in generating cooperation.

Decision situations suffer from the regrettable feature that it is hard to avoid meeting the other players again in the future. Producers usually live longer than just one production period. The fact that the producers can meet again in the market in the next week raises a concern for the equilibrium concept. Are there production quantities that are subgame perfect Nash equilibria in the repeated game that would not be Nash equilibria in the one-shot game?

In our Stackelberg experiment the producers colluded to lower their production quantities, bringing them towards the cooperative outcome. According to the *Folk Theorem* of game theory, this requires that the situation is repeated to the foreseeable future and that the producers are patient enough to value the long-term gains from cooperating more than the short term gains from defecting and sticking to the one-shot Nash quantities. Collusion by cooperation is beneficial for the producers but harmful to the society, thus receiving considerable interest from lawmakers and industrial economists.

The preceding discussion outlines one possible reason why economic actors might display other-regarding behavior. Game theory explains this in terms of self-regarding incentives, and this can be called an *instrumental* motivation for other regarding behavior. You cooperate, but only because cooperation is an instrument that brings you the optimal payoffs.

Laboratory experiments have for long been carried out to test game theoretic predictions. Initially, in the 1960s and 1970s, experimental results largely agreed to theoretical predictions, and if not, they were used to formulate new Nash equilibrium refinements.

One important class of games that is intensively studied using experiments is bargaining games. In the most rudimentary asymmetric bargaining game one player is given the full stake and the task of offering the other player a share of this stake. The other player is just left with the option of accepting or rejecting the offer. This game is called the Ultimatum Game and it is simple to solve using the subgame perfect Nash equilibrium. The other player is offered the smallest amount possible and this is accepted.

The Nash equilibrium and its refinements require certain skills from the decision makers. The subgame perfect Nash equilibrium relies on the ability to use backwards induction. This means the ability to picture the situation from the end to the beginning. In the humble Ultimatum Game this is not a very stringent requirement, and laboratory evidence points out that subjects are able to backwards induce in simple games.

In 1982 Professor Werner Güth published the results of Ultimatum Game experiments that he ran at the University of Cologne that confused many game theorists who so far had believed in the Nash equilibrium refinements. In those experiments the small offers were rejected and modal offers were close to the half division of the stake rather than the extreme outcome predicted by the subgame perfect Nash equilibrium. In the decades that followed the Ultimatum Game was repeated thousands of times in different laboratories. But the unexpected result of other-regarding behavior sustained.

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We should now note that in the basic Ultimatum Game each player decides only once and thus the instrumental motivation for cooperation is not present. Therefore the current understanding of other-regarding behavior in the Ultimatum Game and other one-shot games relies on *intrinsic* motivations. The players offer close to equal stakes because they are altruistic, because they value fair outcomes, or because they are reciprocal. The players have intrinsic other regarding *preferences*.

What about repeated games? The intrinsic motivation is a tempting explanation for cooperation but is problematic in repeated games. Because the instrumental motivation is always present, one cannot explain the other away just by observing the decisions that the players make. Therefore the study of other-regarding preferences must be restricted to one-shot games. Alternatively, other methods than behavioral observations must be used.

In the second paper of my Dissertation we applied the latter option. In addition to studying the decisions that the laboratory subjects make, we studied their psychophysiological correlates as they played in pairs the repeated Cournot duopoly game.

Emotions are a difficult subject to study. Self-reports of emotional activity are prone to biases. That is why many researchers have turned to neuroscience methods in measuring emotional correlates. These methods give objective information about the cognitive and affective processes that occur when we make decisions.

In earlier experiments it has been found for example that the brain's reward processing parts activate when subjects cooperate in social dilemmas. One study that especially motivated us was by a group in the US that studied the disgust emotion in the Ultimatum Game. They found that disgust was pronounced when receiving unfair offers in the game but not when receiving fair offers. We thought that maybe this mechanism of moral disgust would show up in the duopoly games as well.

The psychophysiological correlates that we studied included activity in the autonomous nervous system and activity in the facial musculature. ANS activity was studied by measuring electrodermal changes in the fingers. Facial emotions were studied by recording small electric potential changes in the face muscles. The emotional expressions that we coded from the face were anger, disgust, and positive affect.

We found that emotions were indeed correlated with the outcomes during the game. Arousal was activated when both players lost in payoffs relative to the previous round, and the positive affect expression was displayed when both gained. The disgust expression was displayed when the player himself had gained but the other had lost, possibly relating to aversion of advantageous inequality.

We also studied the ANS correlates when the players made decisions. We found that the production quantity was adjusted upwards from a cooperative level, as a punishment, when the other had defected from cooperation. However, this upwards adjustment was modulated by the level of arousal: the higher the arousal, the higher the adjustment.

We think our results in this paper challenge recent behavioral experiments that argue that cooperation in repeated games is instrumental and not intrinsically other-regarding. If emotions are present, as we have shown, then cooperation must be at least partly intrinsic.

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The Nash equilibrium concept includes the assumption that the players believe that others hold their decisions constant at the equilibrium. This assumption is contested by some researchers who argue that a player should not believe that the other is unreactive to changes of own decisions. The so-called conjectural variations models assume that the players believe the others do not hold their decisions constant at the equilibrium. An especially appealing concept is the *consistent conjecture* in which the players correctly anticipate each others' rational reaction functions at the equilibrium.

Conjectural variations received much criticism in the 1980s when the Nash equilibrium became to dominate game theory. It is difficult to defend conjectural variations on epistemic grounds, as we essentially have to force a dynamic interaction into a static game. Nevertheless, conjectural variations can be used as shortcuts to modeling dynamic interactions in one-shot games, and empirical analysis often relies on this concept.

If holding a conjecture is irrational, as some argue, we can turn the question the other way around and ask: what is the conjecture that the players are likely to hold if they can choose one freely? To analyze this question we must first have a way to model the conjecture-formation process of the players.

Evolutionary game theory assumes that players maximize a fitness function that determines their reproductive success. A player with a higher fitness is more likely to pass its characteristics onwards than a player with a lower fitness. Eventually, as a result of selection pressure, this leads to stable characteristics that stay successful even if other firms come up with other characteristics that compete with the most successful ones. Here we can also talk about an equilibrium concept, an evolutionarily stable strategy, pioneered by evolutionary biologist John Maynard Smith. In the 1990s this concept was used in economics by Professor Güth with his colleague Helmut Bester to explain the evolutionary stability of altruism.

In principle these characteristics can be anything. We can think of a firm having managers with a specific kind of a decision making style. If this decision making style leads the firm to success in some markets, then other firms are likely to imitate.

In the third paper of my Dissertation we show that if selection favors a nonzero conjecture, then there is a previously unknown way in which beliefs interact with other-regarding preferences. The evolutionarily stable conjecture has explicit dependence on the other-regarding preference, something that the consistent conjecture does not have.

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If strategic behavior is partly other-regarding, as I earlier argued, where does this behavior come from? This question is again naturally answered by evolutionary arguments. In the fourth paper of my Dissertation we derive the evolutionarily stable other-regarding preference in a model where the players have either the consistent conjectures or the zero conjectures of the Nash equilibrium model.

We already know that altruism can be evolutionarily stable in a conventional Nash equilibrium model that does not use the conjectural variations concept. Research has also shown that spiteful preferences can be stable, depending on whether the strategies in the game are complements or substitutes.

So what happens if the players have consistent conjectures? In this case we show that only self-regarding behavior is evolutionarily stable. This suggests a sort of a duality between the concepts of consistent conjectures and evolutionarily stable other-regarding preferences.

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Let us now go back to the question about commitments that was introduced at the beginning of this Lectio. While commitments are often thought only as either perfect or nonexistent, we should also consider the intermediate cases.

Think of firms that use advertising to announce prices or opening dates. Are they absolutely committed to such announcements? If a firm backs away from its commitment, it may incur a short-term reputational damage or may even have to pay a fine, but in the long term it may be beneficial to break commitments. In this case we can talk about *partial commitments*.

In the fifth and final paper of my Dissertation we studied partial commitments in a class of duopoly games that have one very annoying feature. Games have often several Nash equilibria and it is impossible to predict which of those equilibria will actually occur. This coordination problem is characteristic to sequential duopoly games with price competition in which the timing of moves is determined endogenously, by the firms themselves.

In endogenous timing games the players announce when they are going to decide upon their strategies. If a firm is the second to announce, then it enjoys the advantage of observing the other's price before having to decide its own price. However, you can see that this is a coordination dilemma because then both firms want to be followers, giving suboptimal profits to both.

Our analysis of this situation reveals that if one of the firms has a higher marginal cost, then this coordination problem can be solved if there is a possibility to commit partially to the timing announcement. The crucial condition for this solution is that the ensuing cost of backing away from the announcement is expensive enough for the low cost firm but cheap enough for the high cost firm. What happens then is that the high cost firm becomes the follower and the low cost firm the leader. If we additionally consider the conditions for sharing the private cost information, we can conclude that neither firm wants to share information at the equilibrium.

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As a summary, my Dissertation shows by using experimental and analytical methods the ways in which economic actors cooperate and commit in two-player games. Imperfect commitments are valuable but their effects depend on the availability of information. Cooperative behavior has an emotional foundation even in repeated games. Beliefs regarding the other's reactions interact in previously unknown ways and complement the picture drawn by evolutionary models of other-regarding behavior.

This concludes my Lectio Praecursoria, which I hope makes it easier for the audience to follow the examination of my Dissertation.

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I ask you, Professor Doctor Werner Güth, as the opponent appointed by the Aalto University School of Science to make any observations on the Dissertation that you consider appropriate.