Mechanisms for the evolution of prosociality

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Mechanisms for the Evolution of Prosociality

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ACADEMISCH PROEFSCHRIFT

ter verkrijging van de graad van doctor
aan de Universiteit van Amsterdam
op gezag van de Rector Magnificus
prof. dr. ir. P.P.C.C. Verbeek
ten overstaan van een door het College voor Promoties ingestelde commissie,
in het openbaar te verdedigen in de Agnietenkapel
op woensdag 24 april 2024, te 13.00 uur

door Christopher Julian Graser
geboren te München

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Faculteit Economie en Bedrijfskunde

With lots of love, I dedicate this dissertation to my grandmother Monique Weiss, who turns 83 on the day that I am defending this dissertation.

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The biggest Thank You, of course, goes out to Matthijs, who has done all three of those. When I came to the Tinbergen Institute, evolutionary game theory was not remotely on my radar for things to do in my PhD. But meeting you, Matthijs, and taking your course promptly got me set in this direction, and I am very grateful for that. Moreover, your extreme casualness in this too often overly pretentious world of academia, coupled with your sturdy commitment to scientific rigor ("the math, the whole math, and nothing but the math"), and your distaste for results that sell well but cut corners, all are a constant inspiration to me. I have had a great time working with you, and hope that we continue to do so in the future. Thank you for all your support during this time, and thank you for tolerating my (maybe at times somewhat excessive) adventures into rather unrelated fields.

The next Thank You goes out to Asli, with whom I worked on the first chapter of this thesis, and who, more importantly, was an incredible academic *older* sister. Thank you for teaching me the essentials of Turkish game theory slang, for tolerating my non-stop distractions at the office to discuss odd animal trivia and other highly scientific matters, and for everything else.

I also want to extend a big Thank You to my matcha suppliers and alternative offices, Rumbaba Café (the one on Pretoriusstraat), and Flour Bakery (the one on Erie Street), where I have spent most of my working hours. You were my key to productivity and focus.

Like in football, the key to a happy PhD experience lies in the "Umschaltspiel" – the quick transitions between mindsets. Cheering up, when you spend weeks trying to prove a theorem that turns out not to be true; getting into a non-work mode, when you are fixated on some puzzle that you cannot let go of before you solve it. All of that can be challenging, but I am very lucky to have spent my PhD years with lots of people who have made it easy.

The MVP, of course, is Isi. To stay with the Umschaltspiel metaphor, she is like a mixture of Di Maria and Kanté. Like a good-looking version of Luka Modric. From my caffeine-crashes, my stressedness and absent-mindedness, to my being 5,556 kilometers away from you, you have endured me and always cheered me up. “Ballon D’Or”-worthy.

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Contributions

Chapter 1 of this thesis is based on two working papers written in collaboration with Aslıhan Akdeniz, and Matthijs van Veelen (Akdeniz et al. (2020, 2023)). The other Chapters were all written in collaboration with Matthijs van Veelen.

Contents

Overview

The question of how prosocial behaviours, which increase the fitness of others, can evolve, when these behaviours come at a fitness cost to oneself, is at the core of evolutionary game theory. There is a large body of literature which deals with this question, and which has identified and categorised mechanisms and conditions under which prosocial outcomes can evolve. In very broad terms, this thesis contributes to this literature, by looking at different mechanisms – or features of evolutionary processes – , and by investigating how these features shape the evolution of prosocial behaviours.

More concretely, the features considered in Chapter 1 of this thesis are *assortment* and *incomplete information* about others' preferences. The term assortment here refers to the tendency of individuals in a population to preferentially find themselves interacting with *genotypically* similar other individuals. In a model of preference evolution, where this *genotype* encodes a utility function, Alger and Weibull (2013) suggested that if (1) individuals do not observe others' utility functions, and if (2) there is assortment, then a particular utility function fares especially well in evolution. Alger and Weibull (2013) call this particular utility function Homo Hamiltonensis.

Chapter 1 challenges this suggestion. In games in which Homo Hamlitonensis preferences prescribe a well-defined behaviour, this behaviour is also consistent with a regular altruistic utility function – a linear combination of one's own payoffs and the payoffs of one's opponent. However, there are games in which the set of strategies that maximises Homo Hamiltonensis' utility is empty. Chapter 1 shows that natural ways of extending the definition of Homo Hamiltonensis to cover these games either, again, lead to behaviour that is also consistent with regular altruism, or, they lead to behaviour that makes Homo Hamiltonensis lose out in direct competition against regular altruists.

In Chapter 2 and 3 this thesis moves away from preference evolution and looks at evolution for prosociality in specific games. Both Chapter 2 and Chapter 3 look at versions of the repeated prisoner's dilemma. In the version in Chapter 2, the added feature is that players have the option to leave the player with whom they are currently matched, and to re-match with a randomly drawn new player. In Chapter 3 the added feature is that players' actions are subject to errors.

Both of these features – errors, and the option to leave – change the sets of strategies that constitute different types of equilibria in the repeated prisoner's dilemma, and Chapters 2 and 3 focus extensively on characterising these changes analytically. However, with either feature, the set of strategies that satisfy at least some stability criteria is large, and ranges from very cooperative strategies, to very uncooperative strategies. Moreover, none of these equilibria are particularly robust. Cooperative equilibria tend to be invadable by (at least arbitrarily close to) neutral mutants.

To quantify the effect of errors, and of the option to leave, on how well different strategies fare in evolution, Chapters 2 and 3 therefore look at stochastic population dynamics over long time horizons, in which the population transitions many times between different equilibria. In simulations of these population dynamics, errors (at moderate rates), and the option to leave, both lead to increased long run average levels of cooperation. Notably, Chapter 2 also computes the percentage increase in the level of cooperation with the option to leave compared to without. Here, the answer is 42. This is, of course, consistent with previous literature (see Adams (1979)).

In analyzing such simulations, a key challenge is to identify whether the strategies that become and remain prevalent in a population constitute equilibria, or to see how much of a selective advantage potential invading mutants can have for non-equilibrium resident strategies. Doing this in a time-efficient manner for a large number of resident strategies across many simulation runs requires efficient algorithmic approaches. Chapter 4 presents such an algorithm for the extensions to the repeated prisoners dilemma from Chapters 2 and 3.