

Exploring Group Behavior through Evolutionary Game Theory: Disease Dynamics, Cooperation, and Reputation

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Abstract

Cooperation is fundamental in the natural world and crucial to modern society, particularly in managing public health crises such as infectious diseases. This thesis investigates the evolutionary dynamics of cooperation, focusing on its role in combating infectious diseases, exemplified by the recent COVID-19 pandemic. We first examine the social dilemma posed by non-pharmaceutical interventions, such as social distancing and face covering. We integrate these interventions into models of disease dynamics, revealing an oscillatory tragedy of the commons: as infection rates fall, public adherence to social distancing wanes, leading to subsequent infection surges. Expanding the model to include less effective and more cost-efficient social distancing measures demonstrates that these imperfect strategies must achieve a certain level of effectiveness to gain acceptance by the public. Furthermore, the findings indicate that once people adopt milder measures, they are unlikely to revert to more stringent ones. Further, we analyze the implications of varying levels of vaccination compliance. Our findings suggest that heterogeneity in vaccine uptake, compounded by social homophily, can lead to more complex and challenging epidemic control scenarios. In particular, we show that these factors can exacerbate phenomena like backward bifurcations. Additionally, we explore public health strategies as public goods games, focusing on the impact of incentives on maintaining cooperation. Using adaptive dynamics, we demonstrate that rewarding consistent cooperation can result in the evolutionary branching into distinct groups of volunteers and free-riders. Lastly, we study the role of reputation in fostering cooperation, introducing a model that differentiates the speed of reputation updates based on individual actions versus those of co-players. This differentiation reveals a critical balance between fostering cooperation and preventing the invasion of defectors. Each section of this thesis contributes to a more nuanced understanding of how evolutionary principles can inform and improve public health strategies against infectious diseases.