

## **sDiv working group meeting report**

### **“UNICOP - Unification of modern Coexistence theory and Price equation”**

The UNICOP project focuses on conceptual and mathematical synthesis between the Price equation and modern coexistence theory (MCT). In previous online meetings, individual team members introduced themselves and presented their work and knowledge of relevant subjects (e.g., invasion analysis models, eco-evolutionary models). At the first group meeting at sDiv, the UNICOP team investigated the shared assumptions of the Price equation and MCT, reviewed and discussed the current state of the literature and potential avenues into a formal bridge between the two frameworks, and began developing an eco-evolutionary framework. The UNICOP group is relatively small, including six researchers who overlap in focus to varying degrees between ecology, evolution, philosophy, and mathematics. Consequently, break out groups were not required, but group discussions and problem-solving were punctuated by independent periods of review and reflection before reconvening. Four members of the group met face-to-face, and two joined remotely.

An initial challenge for this project is finding the best starting point for making progress in conceptual synthesis between the Price equation and MCT. We discussed ways to do this, including recent advances in applying the Price equation to eco-evolutionary dynamics, and ecosystem function. On the first day, we discussed the scope of the problem and the shared assumptions underlying the Price equation and MCT. We then aggregated existing literature relevant to the problem, including recent papers written by UNICOP researchers. By the end of the first day, two potential paths towards an interesting theoretical synthesis began to emerge.

A first path focused on an integration of eco-evolutionary models primarily developed by UNICOP members Lion and Patel, which would reformulate a coexistence model in terms of the Price equation. Specific assumptions of the two models were discussed (e.g., heritability and within-species genetic variation), followed by attempts to apply existing equations from eco-evolutionary dynamics to coexistence. The general starting point is an existing model from Patel, to which some initial work led by Lion can be used to derive ecological dynamics and trait mean dynamics. This initial work has led to some promising insights into incorporating intraspecific trait variation into eco-evolutionary models, which could be applied to more fully understanding the role of evolution in MCT. A next step might be to apply this developing framework toward a community context (e.g., competition). The link to MCT was explored in terms of applying invasion criteria given trait-dependent competition coefficients. The next step will be to connect these different lines of mathematical modelling, which we will do in future meetings, with a plan toward drafting a manuscript demonstrating an initial conceptual link between eco-evolutionary modelling (and therefore the Price equation) and invasion analysis in MCT.

A second path was a bit more speculative, attempting to more directly integrate the Price equation with a generalized Lotka-Volterra model in a way that would produce novel, foundational, theoretical insights. This approach is a bit riskier, and involved a considerable amount of open-ended work over a whiteboard in attempt to find creative ways to achieve synthesis. We left off this approach with a potential equation for synthesis, but now need time to review if it is accurate and what, if any, theoretical insight it can provide. A spin-off idea of this second path was briefly investigated concerning the recursive property of the second term of the Price equation and base levels of covariance in biological organization. A second, more philosophically driven manuscript might be planned to communicate these ideas and their implications for evolution and ecology.

Overall, this first meeting opened up several interesting avenues of modelling and theory, and consolidating these ideas into a formal framework that links the Price equation and MCT will be the primary goal of future meetings.

In this first workshop, the UNICOP team received excellent support from the sDiv staff. Meeting rooms had all the necessary tools for lively discussions and for exploring ideas on whiteboards. Technical and organizational support was provided, with the meeting room well-equipped for hybrid meetings (cameras, microphones, and a large screen), which was necessary given two remote participants. Help with accommodations (e.g., hotel and travel) was also excellent, and the team is especially grateful to Luise Dietel for all of the support. Despite being a smaller group, the team was well taken care of and the meeting was ultimately a success.

The UNICOP project is jointly funded by the sDiv synthesis centre and Centre for the synthesis and analysis of biodiversity (CESAB). The next UNICOP meeting will be held in Montpellier, France during the week of 19 June. A third meeting hosted by sDiv will then take place in the autumn of 2023.