Disrespect Others, Respect the Climate? Applying Coupled Social-Climate Dynamics With Inequality to Forests

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Abstract

Understanding anthropogenic climate impacts is key to averting the climate crisis. Many pre-existing models have been built to parse out important relationships such as those between vegetation and mitigative action (Shu and Fu, 2023)[3], temperature and income inequality (Menard et al., 2021)[2], perceived environmental risk and mitigative action (Liu et al., 2023)[1], and others. Given the plethora of parameters and assumptions baked into each of these models, applicability to the real world climate system is always considered one of the primary benchmarks. Creating a simplified model which synthesizes many of the important components of previous theoretical models, I hope to examine key social dynamics influencing society's response to a worsening climate. While Menard et al. (2021) conclude that homophily prompts greater warming unconditionally, this study finds that in the context of a forest model (i.e. modelling growth/destruction of the Amazon rainforest), homophily can prevent catastrophic effects given a poor initial environmental state. Assuming that poor countries have the resources to do so, a consensus in that class group to defect from the strategy of the rich group (who are more frequently incentivized to continue "business as usual") can frequently prevent the vegetation proportion from converging to 0. This offers important insights into the impacts less endowed groups can have, as well as a better understanding of the place which rich groups find themselves in, and how they can conduct themselves to minimize climate harm.

Project Background

Using a forest dieback model coupled to a homogeneous population, Shu and Fu (2023)[3] find a limited number of stable fixed-points (varying depending on the initial temperature conditions), signifying a limited number of potential vegetative outcomes in equilibrium. This simplified model already limits the number of potential climate futures, but does not account for heterogeneous population dynamics. Menard et al. (2021)[2] account for population differences and dynamics. Modeling populations as divided into rich and poor groups (with interactions in between), they find through an earth systems model that increasing homophily (how much individuals want to only interact within their own group) increases peak temperature anomaly, regardless of initial environmental conditions. Hence, this project combines the simplicity of the forest dieback model with the more realistic heterogeneous population dynamics.

Methods and Equations

Methods: We first allow vegetation to grow/decay for 10 years without human interference (using a standard forest dieback model). Then, we solve for the following system of delay differential equations for years 10-200. We repeat these simulations allowing values of our parameters to vary.

Vegetation Dynamics [3]: $\dot{v} = 2[1 - 0.01(T_v - 23 - 5v)^2](0.2 + 0.4x)v(1 - v) - 0.2v$

Homogeneous Population Dynamics [3]: $\dot{x} = x(1 - x)[E(M) - E(N)]$

Heterogeneous Population Dynamics [2]: Proportion ρ of the population are in the "rich" class (denoted with subscript R), $1 - \rho$ of the population are in the "poor" class (subscript P).
$x = s * \rho x_R + (1 - \rho)x_P$

In short:
Heterogeneous Dynamics = Homogeneous Dynamics + Homophily $*$ (Your Payoff − Other's Payoff)

Key Parameters

v: Vegetation level/Forest coverage (proportion between 0 and 1)
T_v: Ambient Temperature (temperature of the environment with full forest coverage)
T_c: Critical temperature
x: Total proportion of mitigators in the population
x_i: Proportion of players in class group i who are mitigators
$E_i(M)$: Payoff for a player in class group i choosing to mitigate
$E_i(N)$: Payoff for a player in class group i choosing to not mitigate
h: Prevalence of homophily in the population. When $h = 0$, players communicate equally within and between class groups. When $h = 1$, players only communicate within their class group

Homophily Restricts Vegetation in Favorable Regimes

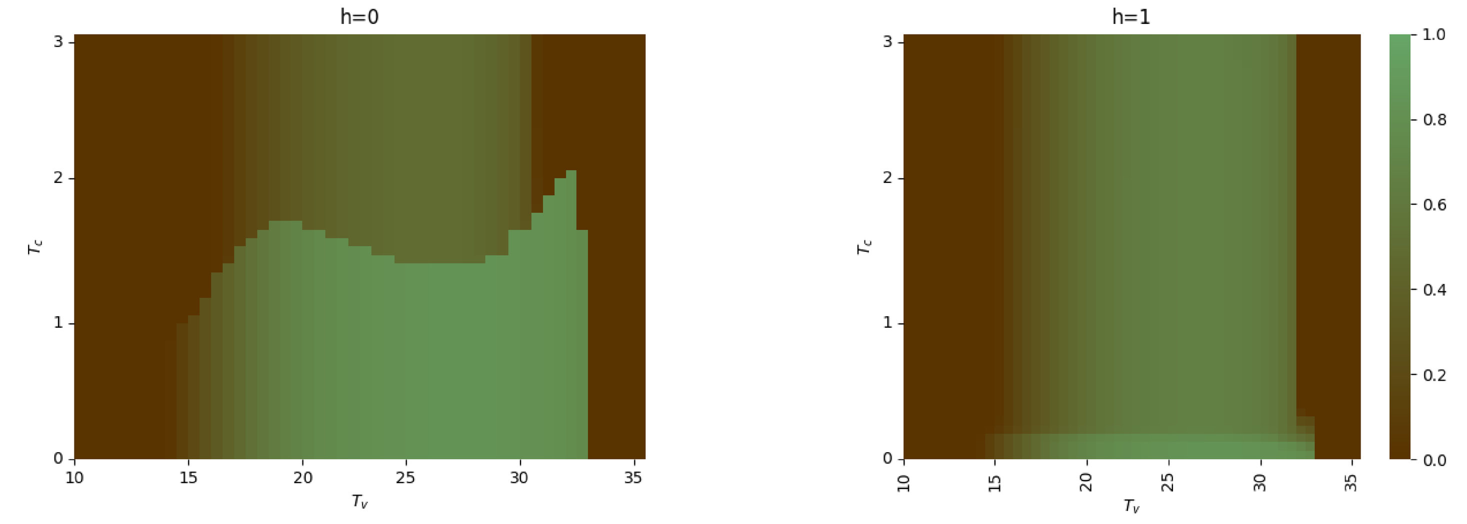

Figure 1: Perceived Cost of Climate Change ($f_{\max}$) = 6, Cost of Expressing Climate Dissatisfaction (d) = 1

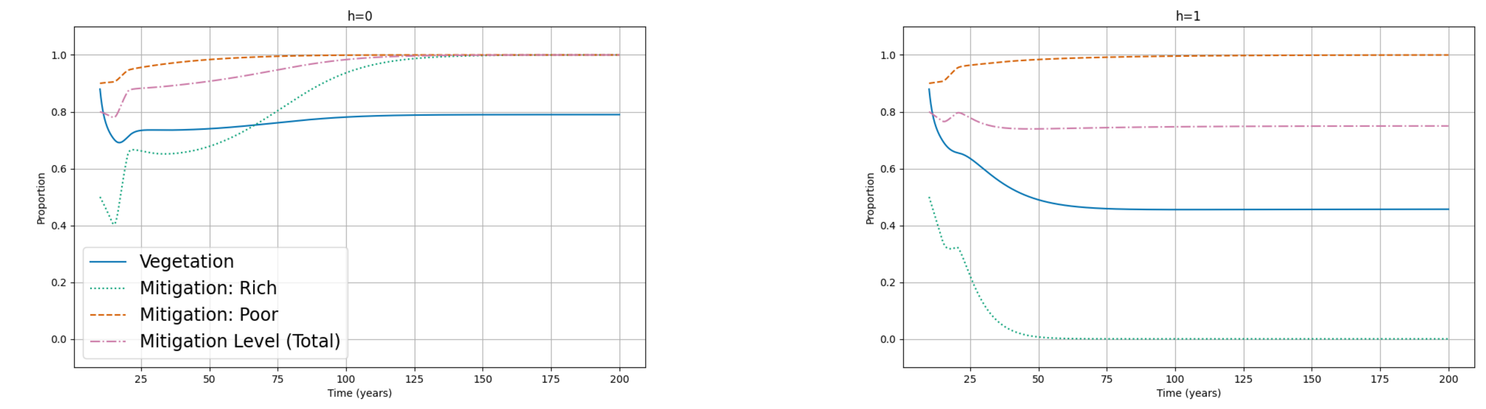

Figure 2: $v_0 = 0.5, x_{R_0} = 0.5, x_{P_0} = 0.9$, Cost of Expressing Climate Dissatisfaction (d) = 1.5

Homophily Improves Sensitivity to Warming Costs

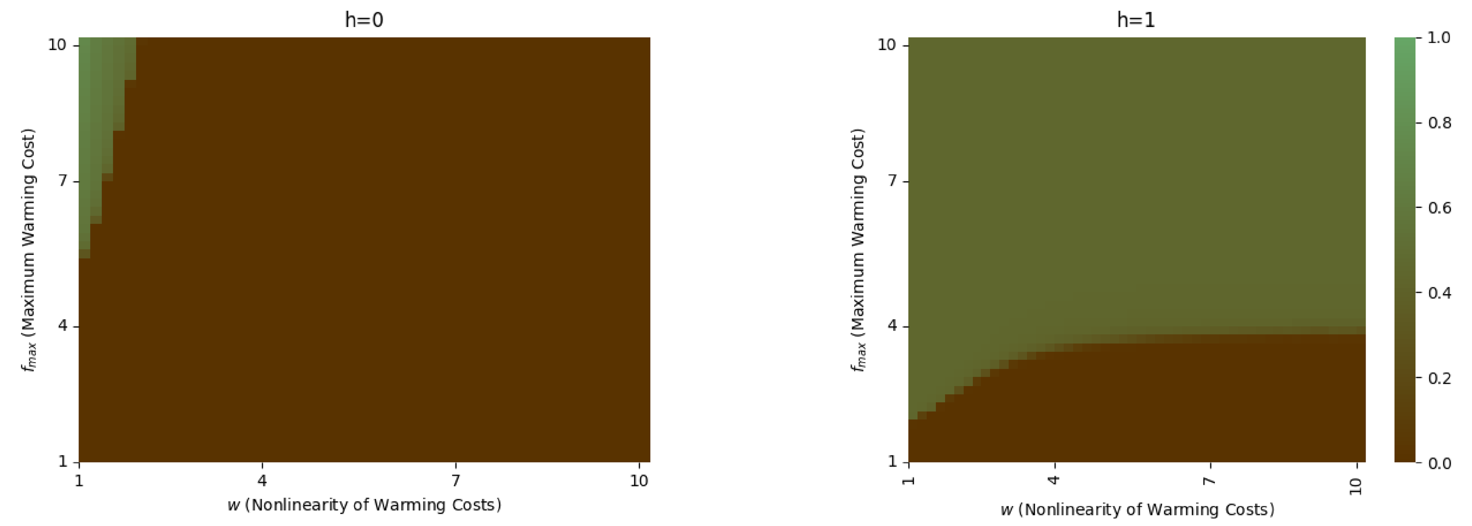

Figure 3: $T_v = 31.5, T_c = 1.5, v_0 = 0.1, x_{R_0} = 0.5, x_{P_0} = 0.5$

Analyzing Wealth Inequality Under Fixed Homophily

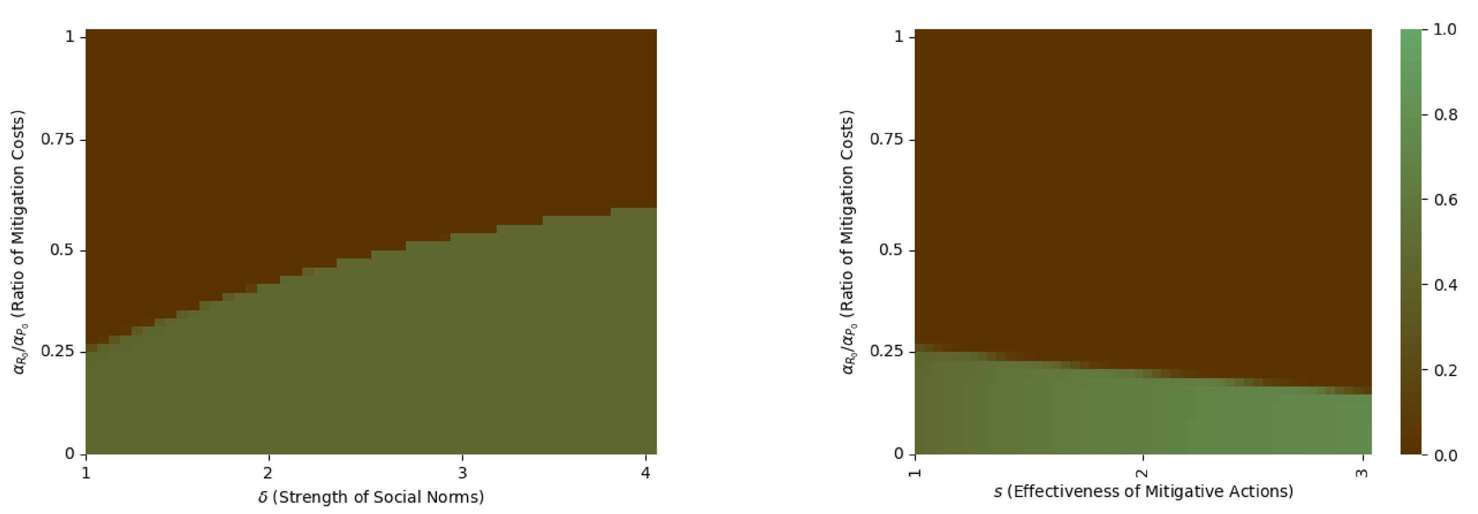

Figure 4: y-axis: Ratio of mitigation costs between rich and poor groups. Left: Strength of Social Norms (δ). Right: Effectiveness of mitigative action for rich group relative to poor group (s)

Homophily Prevents Destruction in Unfavorable Regimes

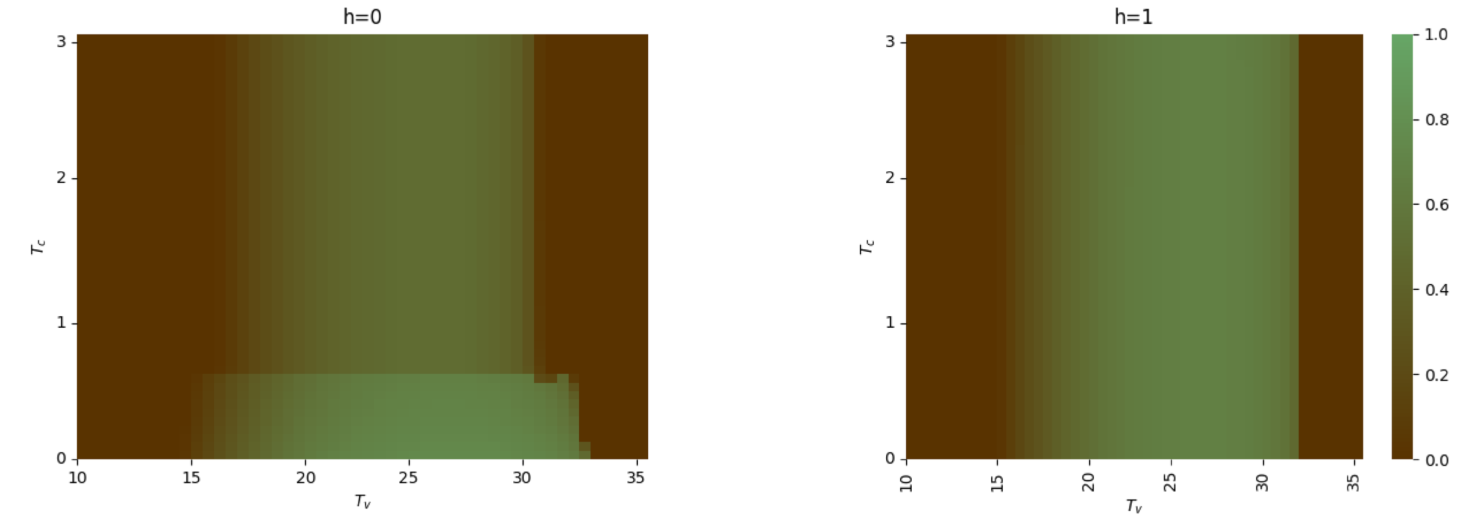

Figure 5: Perceived Cost of Climate Change ($f_{\max}$) = 4, Cost of Expressing Climate Dissatisfaction (d) = 10

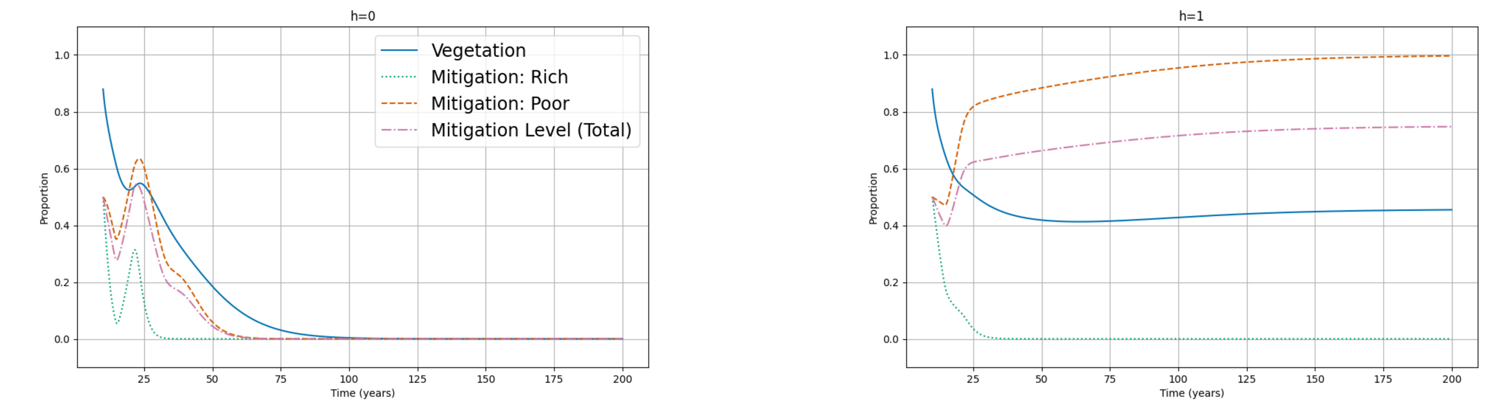

Figure 6: $v_0 = 0.1, x_{R_0} = 0.5, x_{P_0} = 0.5$, Cost of Expressing Climate Dissatisfaction (d) = 5

Color bars on heatmaps represent vegetative proportion after simulating for 200 years.

Conclusions and Future Directions

Collective action is critical to minimizing climate damages. While natural inclination leads us to assume that promoting maximum dialogue is the way to get us there, this study shows that this is not always the case. When a group has little to no incentive to mitigate (as is the case with the rich group, who bears little of the costs of climate inaction), dialogue may be futile. Coupling a forest dieback model [3] with more robust population dynamics [2], we see that the rich group's inaction drags down the poor group's mitigation proportion when communication is open between the two groups ($h = 0$). However, because the poor group bears more of the costs of mitigation, it is commonly in their best interests to mitigate. In this case, creating an "echo chamber" through high homophily ($h = 1$) promotes collective climate action among the poor group, which results in more vegetative states.
Additionally, improving a sense of social responsibility for all players unsurprisingly increases the range of climate scenarios preserving some level of vegetation. Furthermore, technological improvements actually reduce the range of non-barren climate scenarios, casting doubt on technological improvements being able on their own to lead to lasting warming mitigation (because they fail to address underlying motivations to mitigate).
While this model currently assumes that players accurately understand climate dangers and impacts, a further investigation of individual perception of risk, and how that changes in relation to a changing climate, would make this model more robust to changing sentiments as well as a changing climate. Additionally, further analysis of tipping points and overshooting climate targets is another related detail which should be investigated further in this context.

References and Acknowledgements

[1] Linjie Liu, Xiaojie Chen, and Attila Szolnoki, *Coevolutionary dynamics via adaptive feedback in collective-risk social dilemma game*, eLife **12** (2023), e82954.

[2] Jyler Menard, Thomas M. Bury, Chris T. Bauch, and Madhur Anand, *When conflicts get heated, so does the planet: coupled social-climate dynamics under inequality*, Proceedings of the Royal Society B **288** (2021), no. 1959.

[3] Longmei Shu and Feng Fu, *Determinants of successful mitigation in coupled social-climate dynamics*, Proceedings of the Royal Society A **479** (2023), no. 2280.

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