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Game Theoretical Aspects Towards a Sustainable Path to Fight Climate Change

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CEFAGE center for advanced studies in management and economics

Game Theoretical Aspects Towards a Sustainable Path to Fight Climate Change by *Sousa*

- **Abstract**
- We provide a new form of re-globalization tackling the aspects of climate change by addressing it through a theoretical approach rooted in game theory. A first holistic game of Berlin—between the individual and the group—is presented, grounded in Isaiah Berlin's (Berlin (1961)) concepts of negative and positive liberty. Next, we generalize a non-cooperative game of climate change. Building on an evolutionary game theory approach (Caleiro et al., 2019), we propose a novel framework. We then explore cooperative games and introduce the notion of Kantian equilibriumas developed by Roemer (2019). Finally, we discuss the intertemporal political-economic approach to climate change in the context of an overlapping generations (OLG) model, as in Rocha de Sousa and Pica (2023). We conclude with conjectures on global climate governance, drawing from simulations of global ecological footprints (Araujo et al., 2025).

- **Keywords:** Game Theory, Climate Change, Re-globalization, Kantian Equilibrium,
- OLG Model, Global Governance.

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- 4.2. *An OLG model*
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- 4.4. *Putting it all together: going Kantian*
- 4.5. Definition of KE vs NE
- 5 Conclusion
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- **1 Introduction**

Roots/classics

- *Von Neumann's 1921*
- *Von Neumann's and Morgenstern 1944*
- *Nash (1950 a,b)*

Our approach

- Caleiro et al. (2019)-evol GT
- GG- Positive versus negative liberty (Berlin, 1961)
- KE (Roemer, 2019) vs NE (Nash, 1950, a,b)

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- **2 Theoretical framework**
- **Positive (+) versus Negative (-) liberty- Berlin (1961)**
- **Freedom and neoclassicals (Smith, 1776; von Hayek, 1960, Von Mises, 1949; Rothbard, 2009)- utmost free individual and mkts**
- **In contrast Socialists tended to curtail individual for the state**
- **Recently Joseph Stiglitz (2024) wrote "*The road to freedom*" a reply to von Hayek's "*The road to serfdom*" (1944).**

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- **2 Theoretical framework**
- **Positive (+) versus Negative (-) liberty- Berlin (1961)**

Table 1: Alleged Theoretical Superiority of Global Capitalism Under Global Order

Individual \ Group	Positive Liberty	Negative Liberty
Positive Liberty	(10, 10)	(0, -5)
Negative Liberty	(-5, 0)	(-10, -10)

Source: Authors' creation (Rocha de Sousa et al. (2025)) based on interpretation of Stiglitz (2024).

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- **2 Theoretical framework**
- **Positive (+) GROUP versus Negative (-) individual liberty- Berlin (1961)**

Table 2: A New Vision of Global Capitalism Under Global Order — A Solution to Global Crises?

Individual \ Group	Positive Liberty	Negative Liberty
Positive Liberty	(-5, 0)	(0, -5)
Negative Liberty	(10, 10)	(-10, -10)

Source: Authors' creation (Rocha de Sousa et al. (2025)) based on interpretation of Stiglitz (2024).

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- **2 Theoretical framework : GG- Global Governance**

Table 3: Comparative Capacity of International Organizations for Global Governance (Scale: -1(negative), 0 (neutral) to 1 (positive))

Dimension	UNFCCC	IMF	WTO	WB	UNDP	G20	OECD
Democracy / Transparency	1	-1	-1	0	1	-1	0
Accountability	0	-1	0	0	0	-1	1
Effectiveness	0	1	1	1	0	1	1
Enforcement	-1	1	1	1	-1	0	0
Legitimacy	1	0	-1	0	1	-1	0
Inclusiveness	1	-1	0	0	1	-1	-1
Total Score	**2**	**-1**	**0**	**2**	**2**	**-3**	**1**
Ranking	#1	#5	#4	#1	#1	#7	#3

Source: Authors' creation based on interpretation of Zweifel (2006) and updated Rocha de Sousa (2013).

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- **3 Methodology**

- In this section, we expand our approach by analyzing three key dimensions related to global climate governance:

- i) Evolutionary game theory
- ii) Overlapping Generations (OLG) models
- iii) World eco-footprint forecasting

- **Crossing these three approaches is new in this paper ant trying to find a global roadmoap for climate change mitigation and adaptation.**

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- **4.1. *Evolutionary Game Theo*ry: Fig.1**

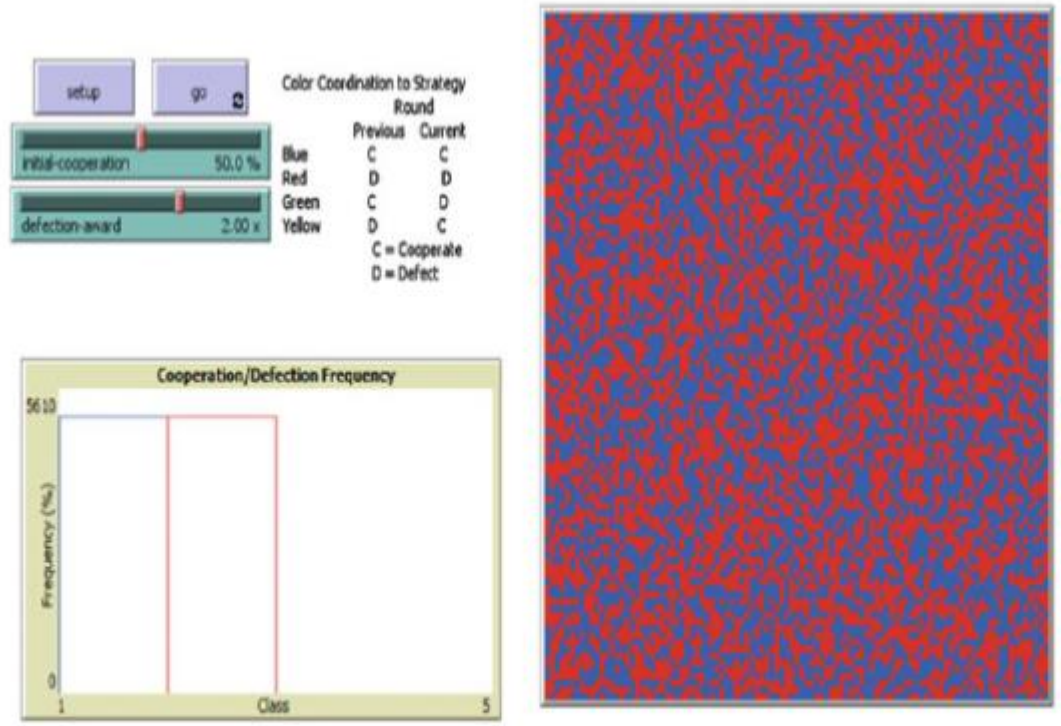

Fig. 1 The initial situation

Figure 1: The initial situation with 50% cooperatives and 50% non-cooperatives agents. Source: Caleiro et al. (2019)

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- **4.1. *Evolutionary Game Theo*ory- fig.2**

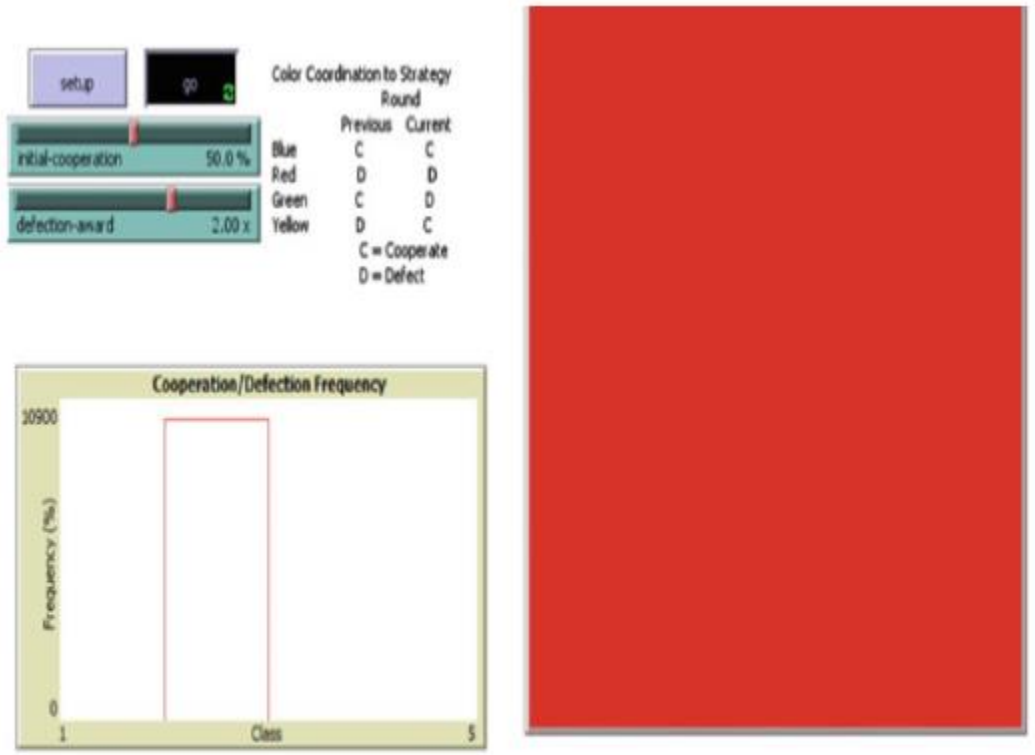

Fig. 2 The disastrous situation

Figure 2: The disastrous situation with 100% non-cooperatives agents. Source: Caleiro et al. (2019)

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- **4.1. *Evolutionary Game Theo*ry- Fig.3**

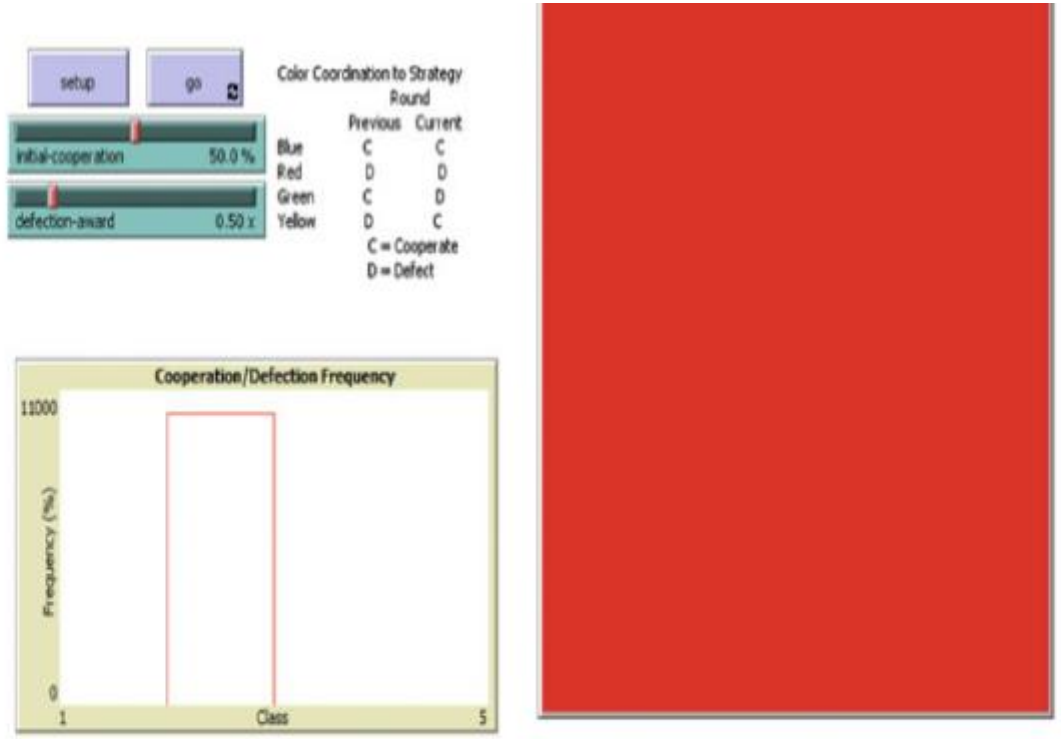

Fig. 3 The reduced defection-award situation

Figure 3: The reduced defection award situation with 100% non-cooperatives agents as a start. Source:Caleiro et al. (2019)

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- **4.1. *Evolutionary Game Theo*ory- Fig. 4**

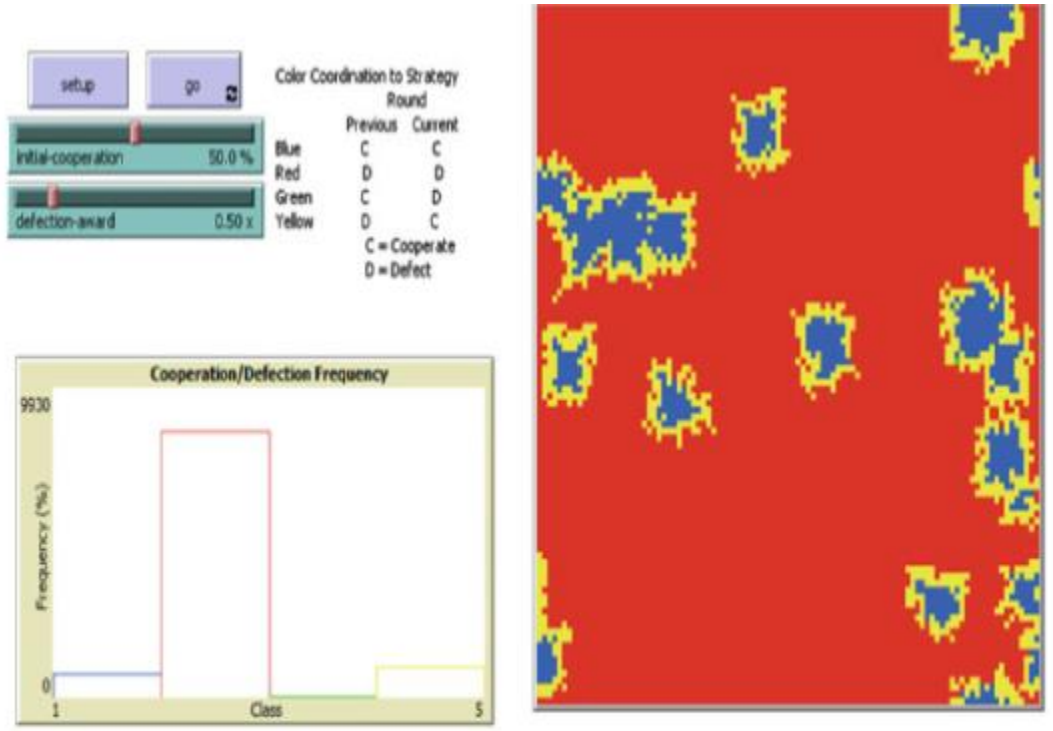

Fig. 4 A first intermediate situation

Figure 4: A first intermedite situation with islands of hope. Source:Caleiro et al. (2019)

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- **4.1. *Evolutionary Game Theo*ry- Fig. 5**

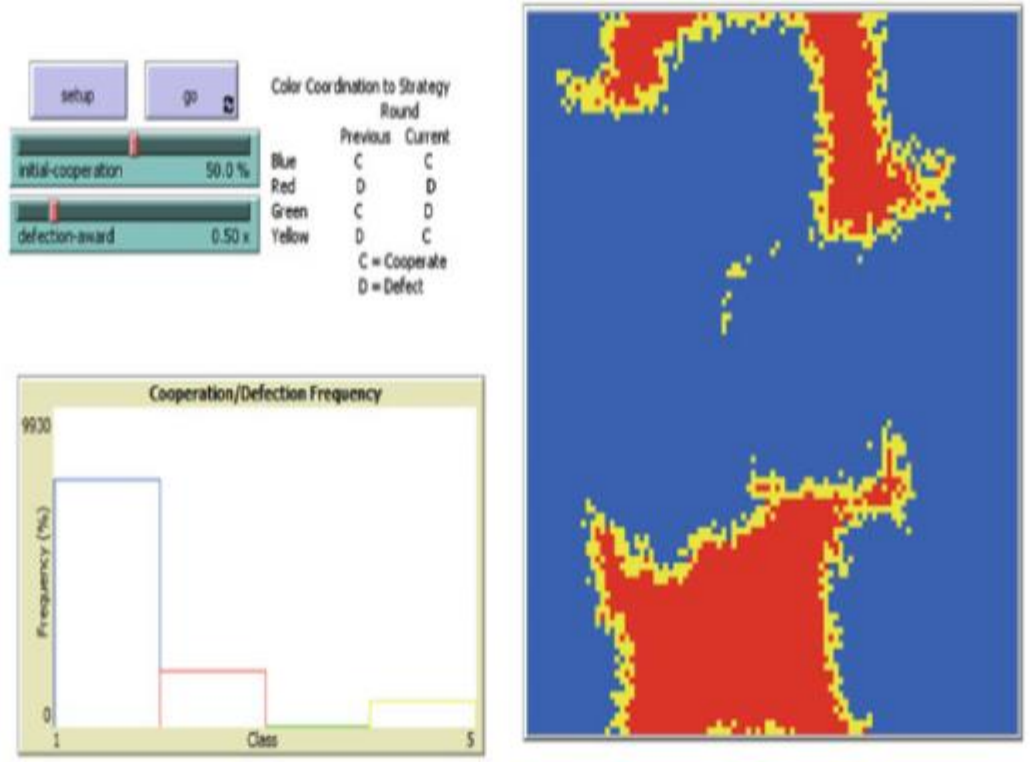

Fig. 5 A second intermediate situation

Figure 5: A second intermedite situation going well. Source: Caleiro et al. (2019)

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- **4.1. *Evolutionary Game Theo*ry- Fig. 6**

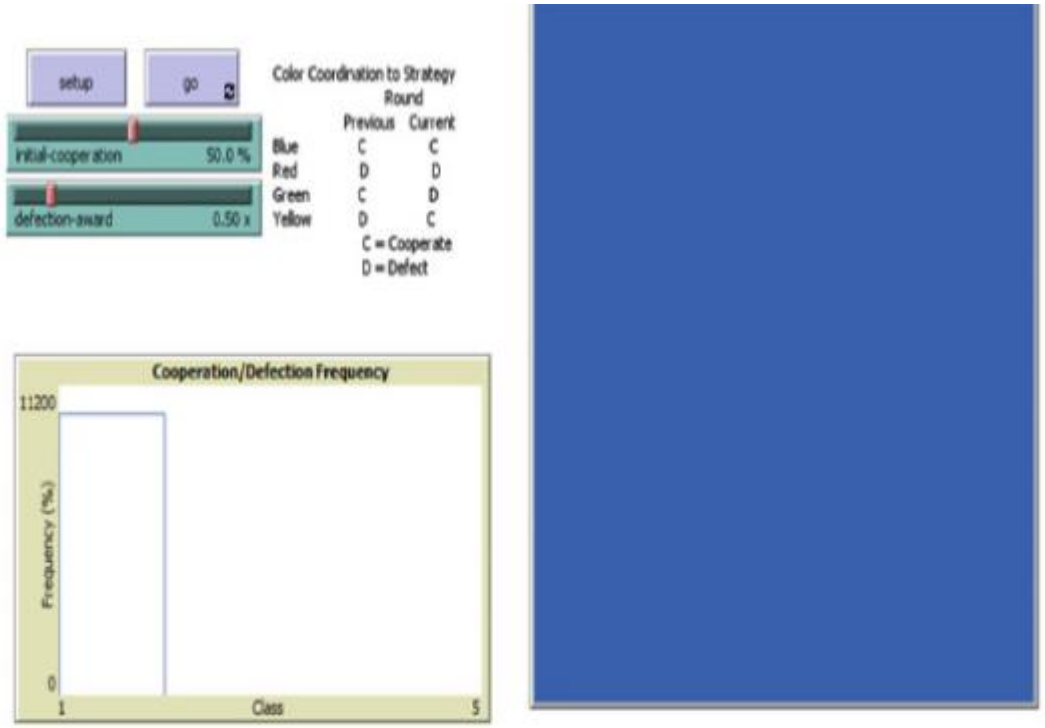

Fig. 6 The final situation

Figure 6: An ideal solution in the long run. Source: Caleiro et al. (2019)

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- **4.2. *An OLG model***

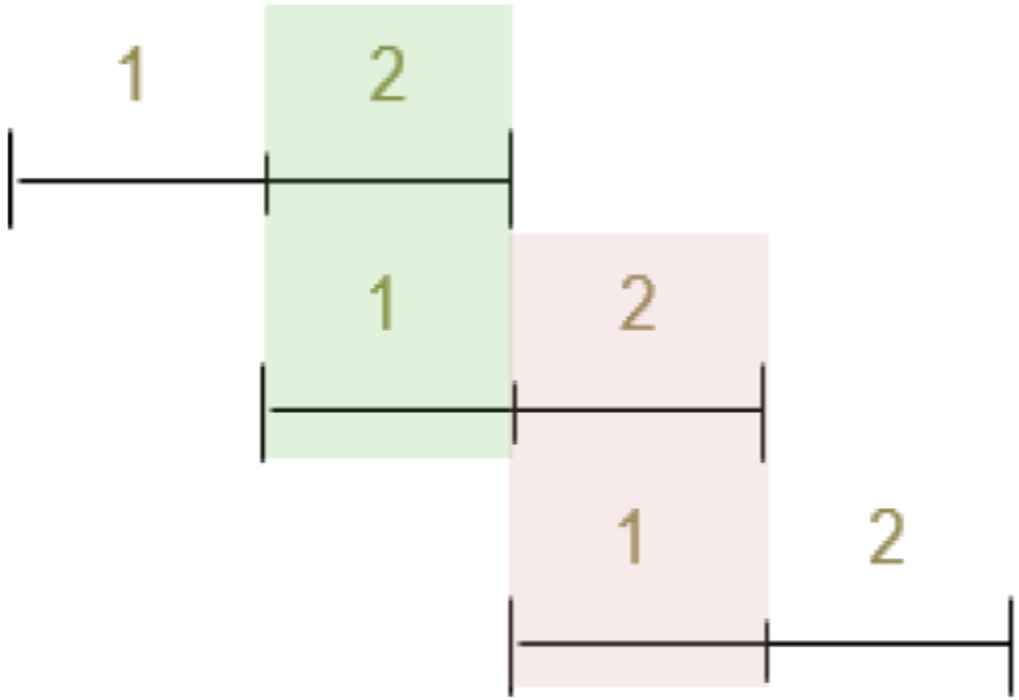

Figure 7: The two cohorts in an OLG model. Source: Rocha de Sousa and Pica (2023)

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- **4.2. *An OLG model- Nordaus results***

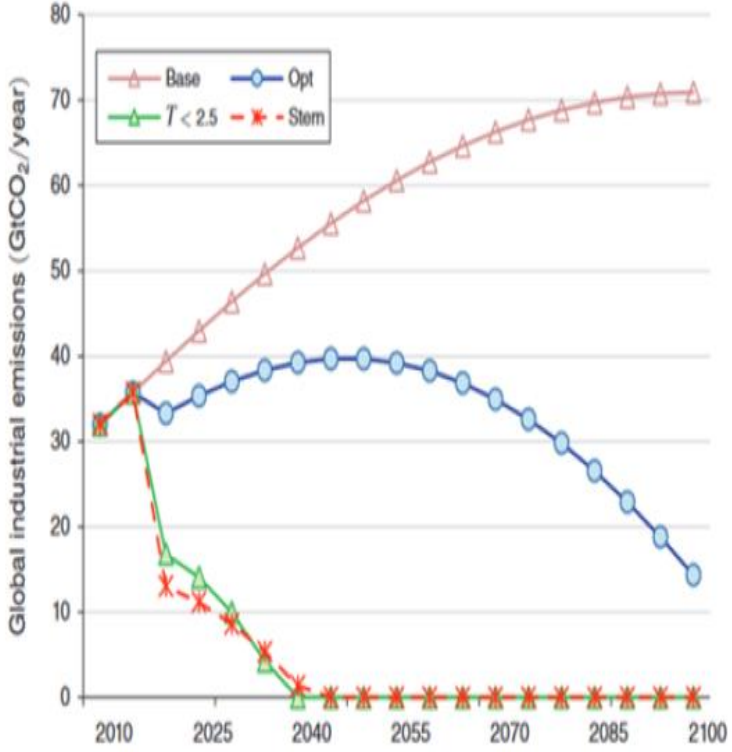

Figure 8: The trajectory accordingly to Nordhaus(2019). Source:Rocha de Sousa and Pica (2023)

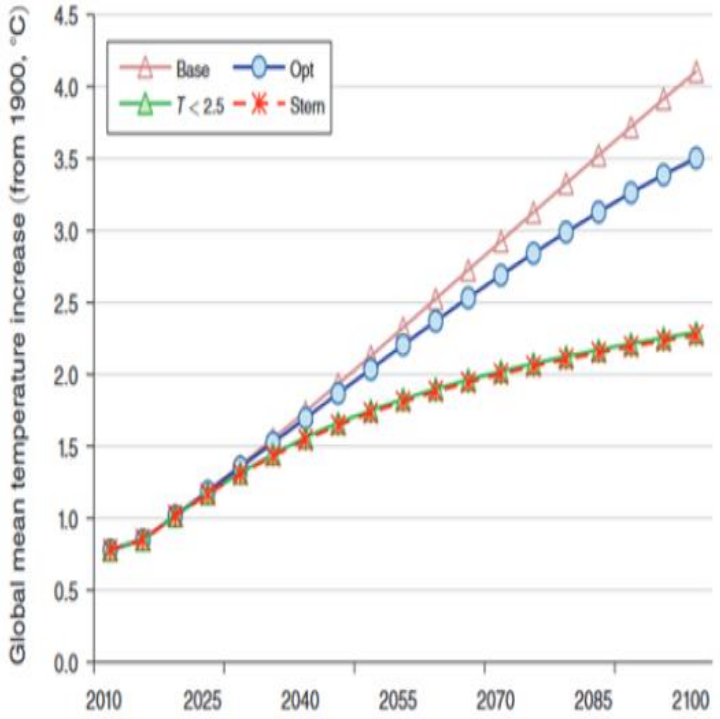

Figure 9: The trajectory of global mean temperature accordingly to Nordhaus(2019). Source:Rocha de Sousa and Pica (2023)

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- **4.2. *An OLG model***
- ***My results***
- ***Youngsters***
- ***NO interaction***

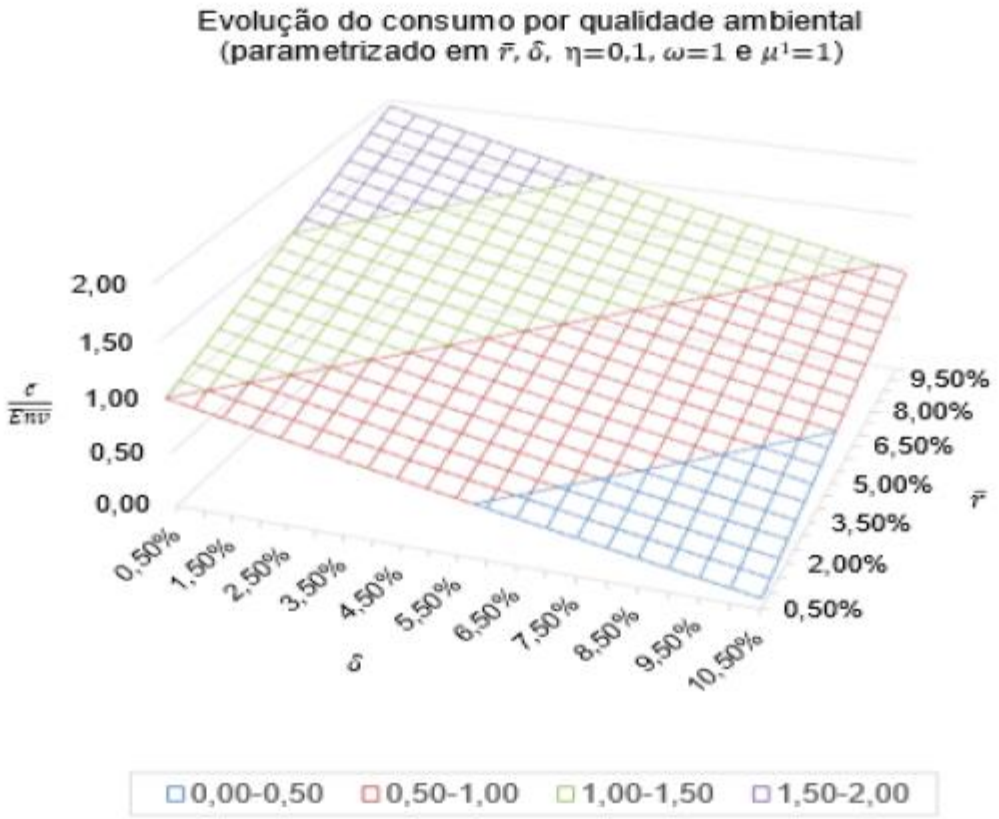

Figure 10: Consumption evolution by environmental quality as a function of δ intertemporal concern, and r interest rate, by youngsters on extended OLG model. Source: Rocha de Sousa and Pica (2023)

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- ***4.2. An OLG model***
- ***My results***
- ***Elderly***
- ***No interaction***

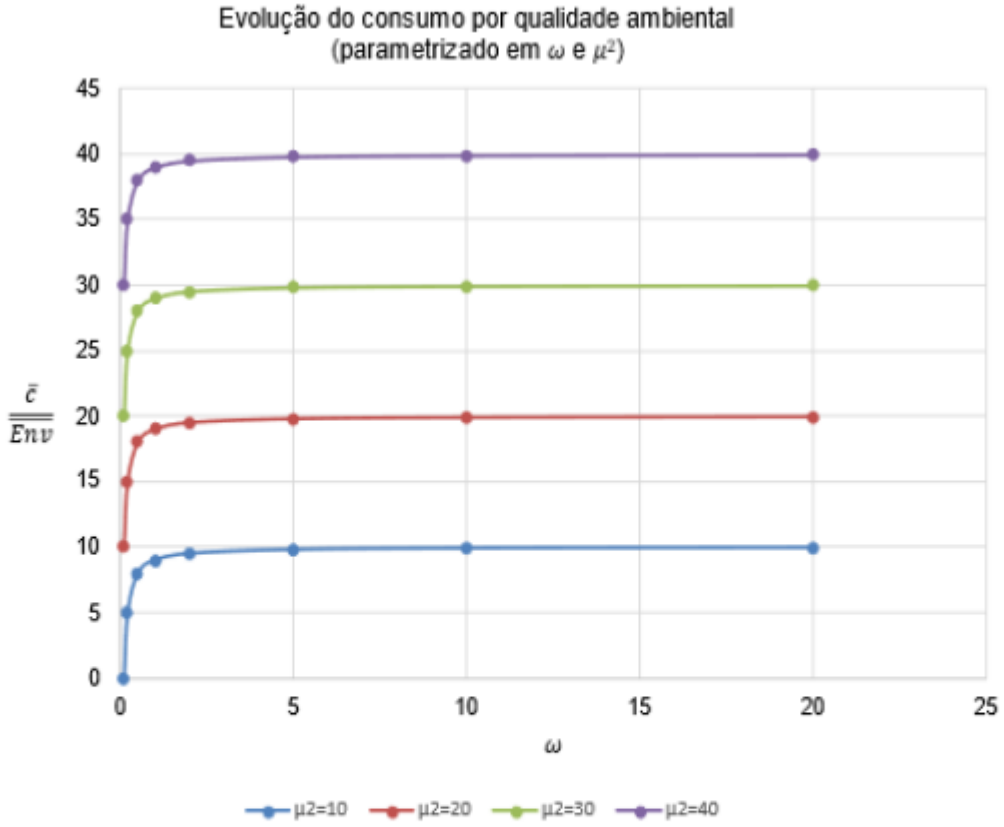

Figure 11: Consumption evolution by environmental quality as a function of δ intertemporal concern, and r interest rate, by elderly on extended OLG model. Source: Rocha de Sousa and Pica (2023)

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- ***4.2. An OLG model***
- ***My results***
- ***Youngsters=Elderly***
- ***NE correspondences***

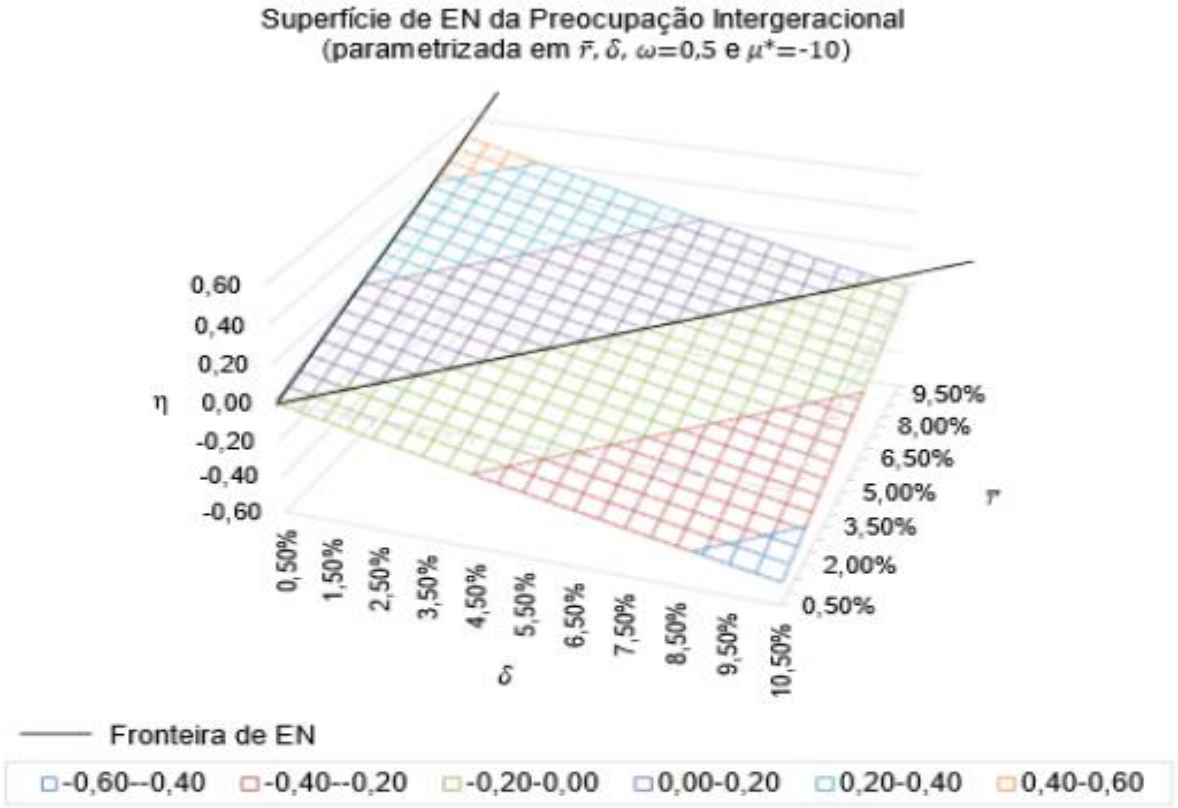

Figure 12: Nash equilibria surface (NE) of intergenerational concern η by elderly and youngsters on extended OLG model as a function of δ intertemporal concern, and r interest rate, on extended OLG model. Source: Rocha de Sousa and Pica (2023)

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- **4.3. World *Ecofootprint 2050-2100*: Fig.13**

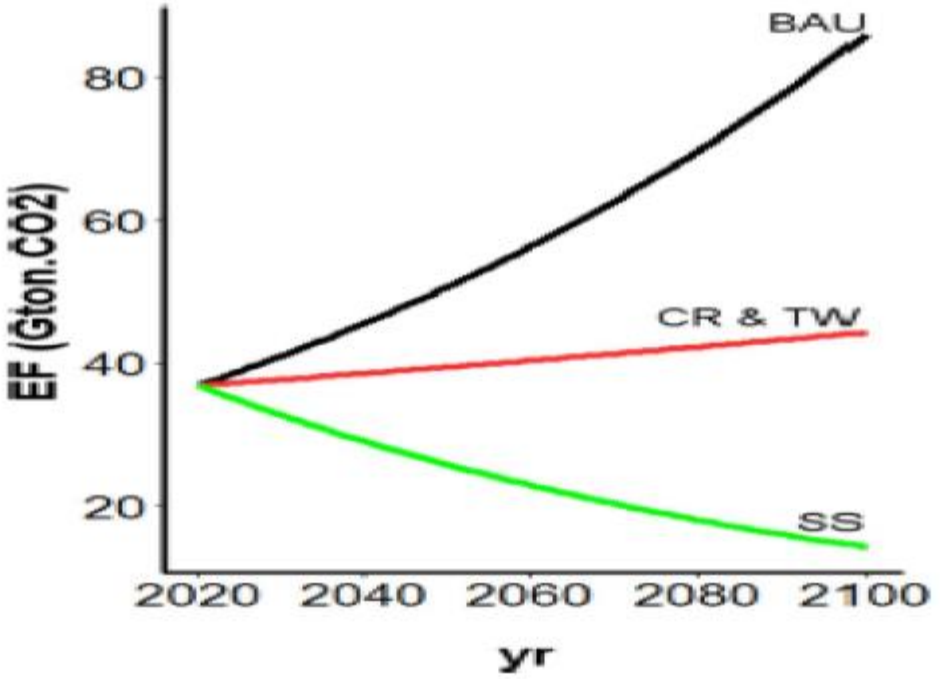

Fig. 1 Simulated human ecological footprint throughout the twenty-first century. The ecological footprint varies in response to four UN scenarios: BAU "Business-as-Usual"; TW "Tech World"; CR "Consumption Reduction"; and SS "Smart Sustainability". See supplementary materials for details on the underlying data, methods, and assumptions

Figure 13: Ecofootprint accordingly to different UN scenarios 2050 to 2100 Source: Araújo et al. (2025)

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- **4.3. World *Ecofootprint 2050-2100*: Fig.14**

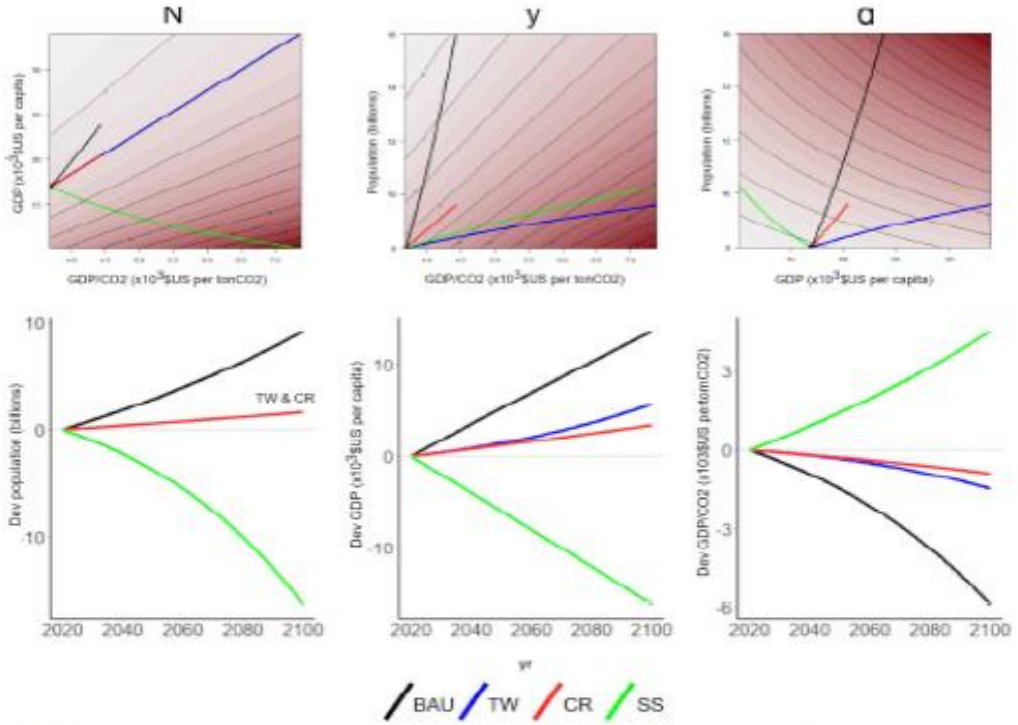

Fig. 2 Pathways to stabilize the human ecological footprint. The upper charts depict future development trajectories with two parameters held constant, and showing the required values for the third parameter to maintain the ecological impact at 2020 levels by 2100: EF(2100)= EF(2020) (represented by the isolines). The lower charts reveal the absolute deviations of each parameter within each development scenario from its "stability value," as shown in the respective upper chart. "*N*" denotes human population, "y" consumption level, and "*a*" efficiency in resource use. BAU indicates the "Business-As-Usual" scenario, TW stands for "Tech World," CR for "Consumption Reduction," and SS signifies "Smart Sustainability"

Figure 14: Ecofootprint accordingly to different UN scenarios 2050 to 2100: sensitivity analysis Source: Araújo et al. (2025)

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- **4.4. Putting it all toghether: Going Kantian- 6B and 7B**

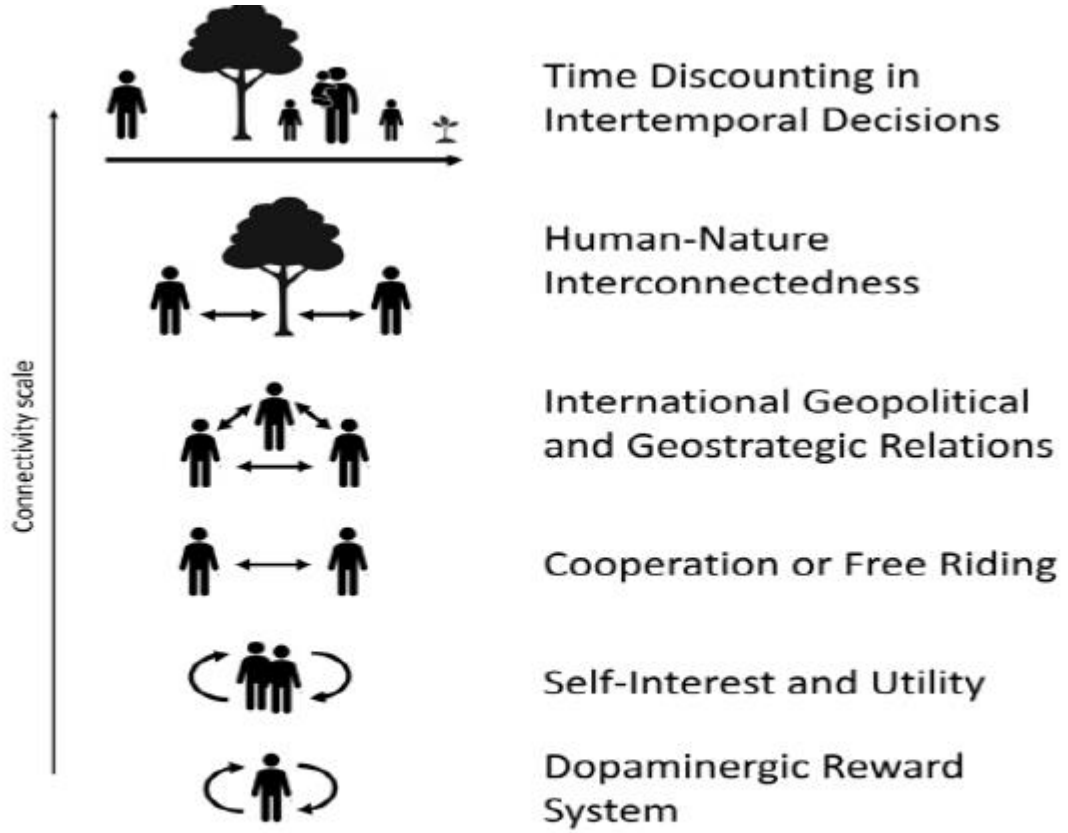

Figure 15: Six sustainability Boundaries. Source:Santos et al. (2024b,a) adapted by Avelar

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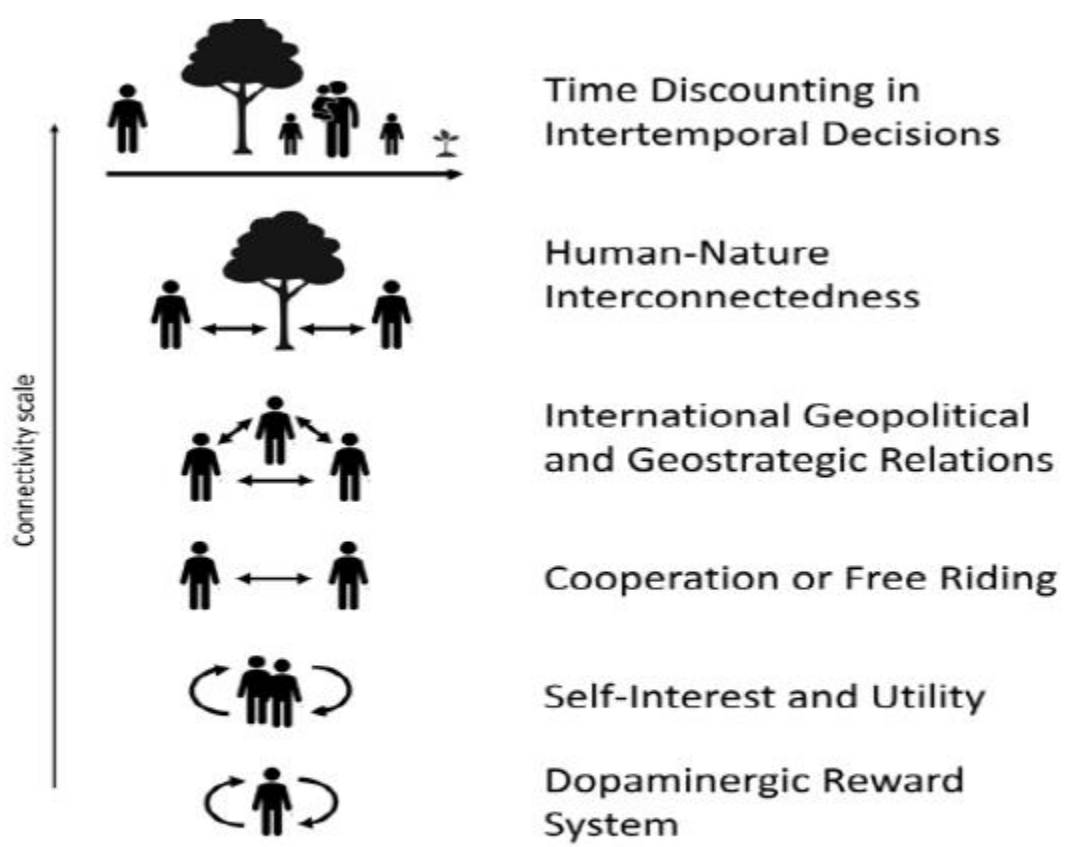
- **4.4. Putting it all toghether: Going Kantian- 6B → 7B**



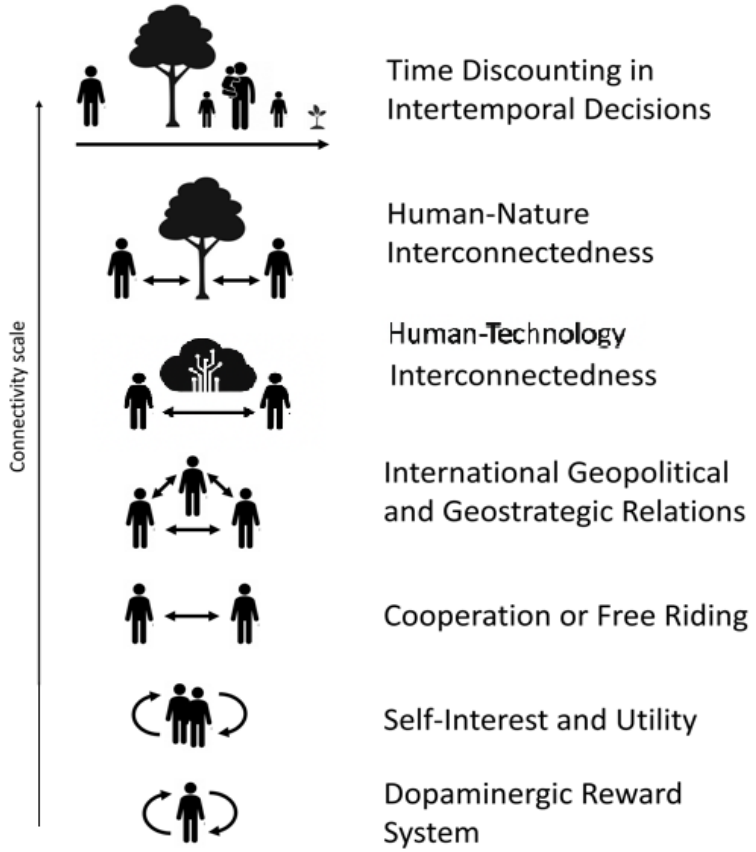


Figure 15: Six sustainability Boundaries. Source:Santos et al. (2024b,a) adapted by Avelar

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- **4.4. Putting it all toghether: Going Kantian- 6B Hardness**

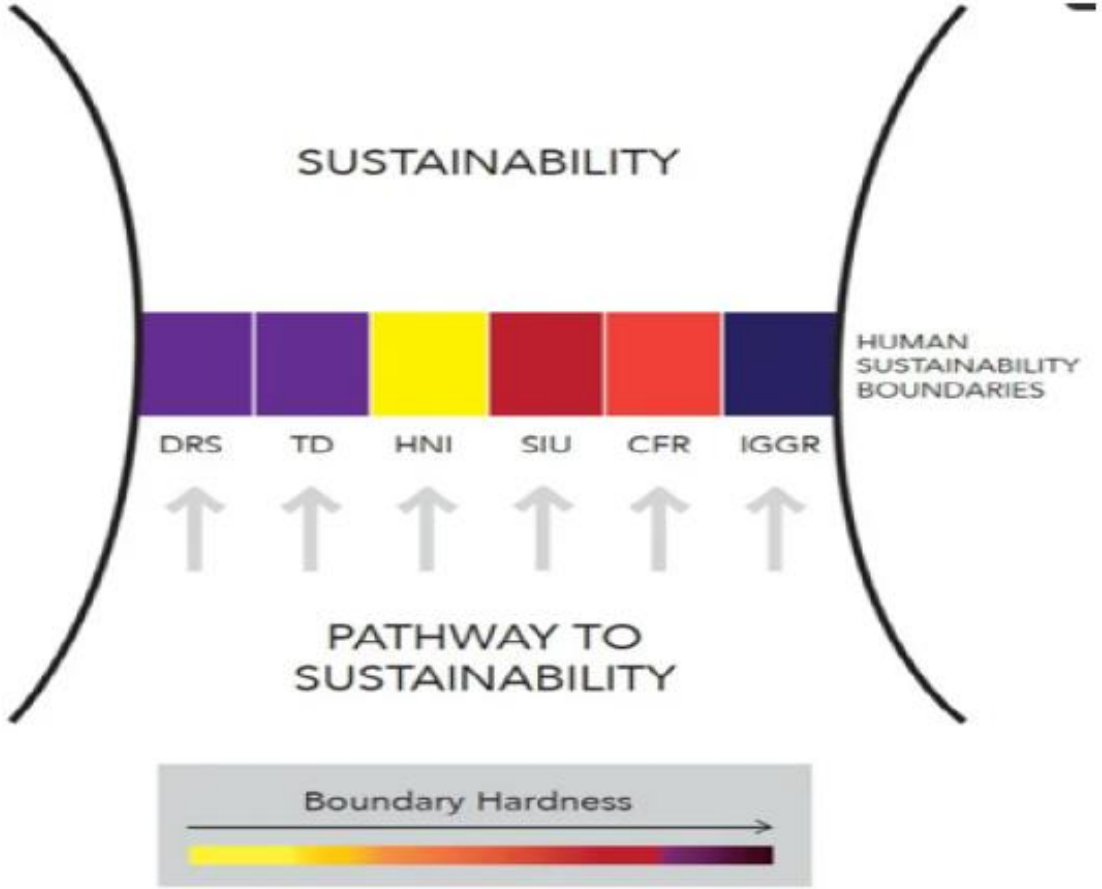

Figure 16: Six sustainability Boundaries Hardness. Source:Santos et al. (2024b,a)

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- **4.5. Def. NE vs KE**

We first depart from Nash equilibrium concept (Nash (1950b,a)):

Nash Equilibrium. *Let S be the set of possible strategies for a given climate policy (e.g., emission reductions, climate finance contributions).*
A Nash equilibrium satisfies:

$$U_i(s_i^*, s_{-i}^*) \geq U_i(s_i, s_{-i}^*) \quad \forall s_i \in S.$$

However, as discussed throughout other papers, Nash equilibrium might not be efficient under public goods provision.

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- **4.5. Def. NE vs KE**

So, presenting Kantian equilibria, based upon Roemer (2019):

Kantian Equilibrium. *A strategy profile s^* is Kantian if:*

$$u_i(\lambda s_i^*, \lambda s_{-i}^*) \leq u_i(s^*) \quad \forall \lambda > 0.$$

Unlike Nash equilibrium, where players unilaterally optimize given others' fixed choices, Kantian equilibrium assumes proportional adjustments, leading to more cooperative behavior.

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- **4.5. Def. NE vs KE - Graph**

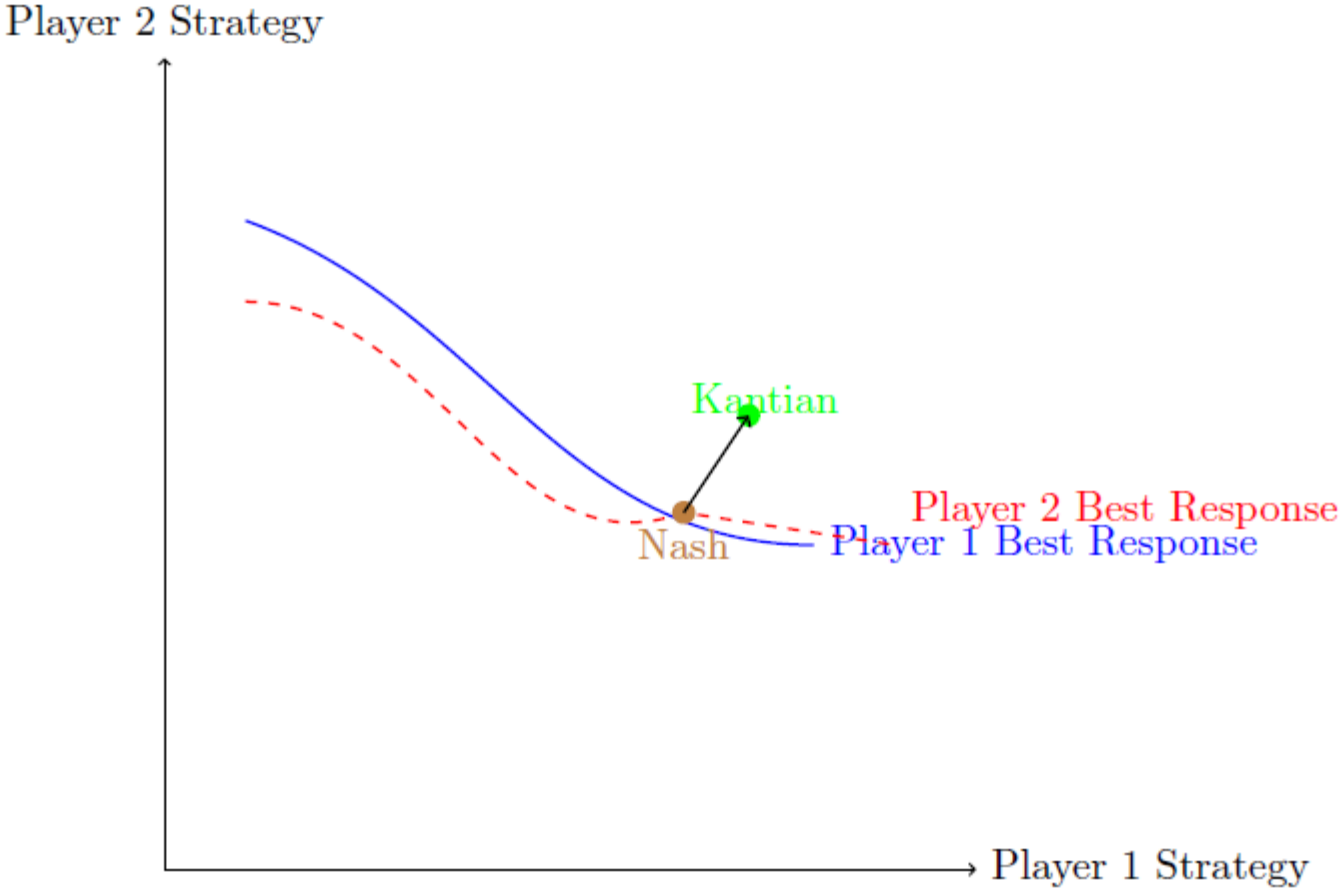

Figure 17: Comparison of Nash and Kantian Equilibria. The Nash equilibrium (brown) occurs at the exact intersection of Player 1's and Player 2's best response functions. The Kantian equilibrium (green) is a proportional shift towards greater cooperation and efficiency. Source:Rocha de Sousa (2025)

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- **5 Conclusion**

- Several aspects of global governance have been scrutinized throughout this paper: the need for a reordering of the global order and the importance of rethinking the world system through new conceptual lenses. One such concept is ”reglobalization,” which involves examining both positive and negative liberty/freedom in the sense articulated by Isaiah Berlin (Berlin (1961)). We have shown that, to optimize incentive schemes within the global capitalist system, a slight restriction on individual liberty may be necessary, while full positive liberty should be granted to groups or associations.

- In Table 3, we demonstrate that establishing a global governance ranking can serve as a useful diagnostic tool for evaluating global climate challenges.

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- **5 Conclusion**
- We then examined three complementary approaches.
- First, we discussed evolutionary game theory (as in Caleiro et al. (2019)), which illustrates how incentives can be designed by considering tipping points and dynamic shifts in agent behavior—from cooperation to non-cooperation and vice versa.
- Second, we analyzed an overlapping generations (OLG) model (as in Rocha de Sousa and Pica (2023)), which introduces intergenerational concerns across time. However, this model is not immune to criticism, particularly regarding the fact that unborn generations cannot advocate for present-day action. How, then, can we address this issue? One way forward is to incorporate a moral framework based on caring for others even after one's death—a concept aligned with Tomasello's or Gilligan's ethics of care, or even a Christian stewardship ethic. Such an approach may help prevent ecological collapse.
- The third approach examines the consequences of inaction—the "business-as-usual" (BAU) scenario—which presents a grim and catastrophic outlook for the planet (as in Araújo et al. (2025)).
- Finally, we revisited the foundational work of Santos et al. (2024b,a, 2025), which originally identified six critical boundaries to sustainability (6B). We have since added a seventh (7B) : the human–technology interconnectedness barrier, particularly relevant to the discussions of RC35 on technology and development.

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- **5 Conclusion**
- These studies offer a clear and urgent warning about the need to craft a holistic, coherent, and sustainable future.
- The Hobbesian view of humanity—as ”man is a wolf to man”—has underpinned much of neoclassical economics, from Smith to Malthus to Ricardo. Yet, if we turn to Smith’s Theory of Moral Sentiments, we may find a path toward a more sustainable world. In this framework, the decision-making agent acts as an impartial spectator of their own actions, guided by values such as tolerance, virtue, and empathy.
- Building on this moral foundation, we returned to incentive theory and argued that the market failure represented by climate change can only be addressed through Kantian cooperation—as opposed to the egocentric individualism inherent in Nashian strategies.
- Thus, we must transition from a Nashian world to a Kantian one. This involves negotiations between agents—bilateral or multilateral—leading to a common equilibrium grounded in proportional effort and shared goals.
- Such cooperation points the way toward a collective solution to the climate crisis. As Belbute and Pereira (2022) has shown, if the world’s most polluting countries were to agree on a common policy framework, over 75% of global CO2 emissions could be effectively addressed.

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- **Comments**

- **Thk u for your time**

- **Acknowledgements for FCT and**

- **Miguel Rocha de Sousa**
- **mrsousa@uevora.pt**

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- **Ackowledgements**
- The usual caveat applies. I am solely responsible for any remaining errors or omissions. This study was conducted at the ***Research Center in Political Science (UIDB/CPO/00758/2024), University of ´Evora, and supported by the Portuguese Foundation for Science and Technology (FCT) and the Portuguese Ministry of Education and Science through national funds***;

- It also benefited from research support at CEFAGE. Previous studies on this topic were presented at SASE (Rio, July 2023), IPSA (Buenos Aires, July 2023), and as a keynote speaker at UNICAMP (Campinas, Brazil, July 2023).

- This paper was prepared for IPSA's Seoul World Congress at RC35 Technology and Development Panel, July 2025.