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Conditional rehabilitation of cooperation under strategic uncertainty. (English)

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Summary: In order to address the topic of the tragedy of the commons, more specifically that of tropical forest ecosystems explored as common-pool resources endowed with public-good features and exposed to deforestation risks, we consider game-theoretic population dynamics contingent on various differential equations. We propose an evolutionary model handed down to the Price theorem of selection. In a set of model-players evolving in strategic uncertainty and subject to certain mutation toward cooperation, the Price equation evens out unstructured and structured population replicator dynamics. According to the model outputs, avoiding the tragedy of the commons can be achieved on condition that half of the population temporarily exhibits a cooperative behavior. Furthermore, cooperative model-players ought to be rewarded at a level equivalent to the joint selection of cooperators and competitors issued from the unifying Price identity.

MSC:

[91A22](#) Evolutionary games

[91B76](#) Environmental economics (natural resource models, harvesting, pollution, etc.)

[92D25](#) Population dynamics (general)

Keywords:

bioeconomics; evolutionary game theory; price equation; strategic uncertainty; tragedy of the commons; tropical forest management

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References:

- [1] Allen, B.; Rosenbloom, D., Mutation rate evolution in replicator dynamics, Bull Math Biol, 74, 2650-2675, (2012) · [Zbl 1362.92047](#)
- [2] Bach, L.; Helvik, T.; Christiansen, F., The evolution of N-player cooperation: threshold games and ESS bifurcations, J Theor Biol, 238, 426-434, (2006)
- [3] Barton, N.; Polechová, J., The limitations of adaptive dynamics as a model of evolution, J Evolut Biol, 18, 1186-1190, (2005)
- [4] Bovolo, C.; Wagner, T.; Parkin, G.; Hein-Griggs, D.; Pereira, R.; Jones, R., The Guiana Shield rainforests: overlooked guardians of South American climate, Environ Res Lett, 13, 074029-1-074029-12, (2018)
- [5] Bürger, R., Mathematical principles of mutation-selection models, Genetica, 102-103, 279-298, (1998)
- [6] Capraro V, Perc M (2018) Grand challenges in social physics. Pursuit of moral behavior. Front Phys 6:107-1-107-6
- [7] Chatterjee, K.; Zufferey, D.; Nowak, M., Evolutionary game dynamics in populations with different learners, J Theor Biol, 301, 161-173, (2012) · [Zbl 1397.91062](#)
- [8] Collins, S.; Gardner, A., Integrating physiological, ecological and evolutionary change: a price equation approach, Ecol Lett, 12, 744-757, (2009)
- [9] Combes, J-L; Combes-Motel, P.; Schwartz, S., A review of the economic theory of the commons, Revue d'Économie du Développement, 24, 55-83, (2016)
- [10] Cressman, R.; Tao, Y., The replicator equation and other game dynamics, Proc Natl Acad Sci, 111, 10810-10817, (2014) · [Zbl 1355.91011](#)
- [11] Deke, O., Preserving biodiversity as a global public good: protected areas and international transfers, No. 339, 185-342, (2008), Berlin
- [12] Dercole F, Rinaldi S (2008) Analysis of evolutionary processes: the adaptive dynamics approach and its applications. Princeton series in theoretical and computational biology. Princeton University Press, Princeton · [Zbl 1305.92001](#)
- [13] De Roos A, Persson L (2005) Unstructured population models: do population-level assumptions yield general theory? Ecological paradigms lost: routes of theory change. Academic Press, Cambridge
- [14] Dragicevic, A., From robustness to resilience: a network price identity approach, Ecol Complex, 28, 47-53, (2016)
- [15] Dragicevic, A., Option fund market dynamics for threshold public goods, Dyn Games Appl, 7, 21-33, (2017) · [Zbl 1391.91090](#)

- [16] Dragicevic, A., Reflective evolution under strategic uncertainty, *Int J Bifurc Chaos*, 29, 1950018, (2019) · [Zbl 1411.91085](#)
- [17] Dragicevic, A., Comparing forest governance models against invasive biological threats, *J Theor Biol*, 462, 270-282, (2019) · [Zbl 1406.92657](#)
- [18] Elqayam S, Over D (2016) From is to ought: the place of normative models in the study of human thought. *Frontiers Media, Lausanne*
- [19] Fleischman, F.; Loken, B.; Garcia-Lopez, G.; Villamayor-Tomas, S., Evaluating the utility of common-pool resource theory for understanding forest governance and outcomes in Indonesia between 1965 and 2012, *Int J Commons*, 8, 304-336, (2014)
- [20] Fox, J., Using the price equation to partition the effects of biodiversity loss on ecosystem function, *Ecology*, 87, 2687-2696, (2006)
- [21] Frank, S., George price's contributions to evolutionary genetics, *J Theor Biol*, 175, 373-388, (1995)
- [22] García, Julián; Traulsen, Arne, The Structure of Mutations and the Evolution of Cooperation, *PLoS ONE*, 7, e35287, (2012) · [Zbl 1337.91020](#)
- [23] Gillen B, Markowitz H (2010) *A taxonomy of utility functions, variations in economic analysis: essays in honor of Eli Schwartz.* Springer, New York
- [24] GSF (2018) *Guyana New Institutional Host Of Guiana Shield Facility and Fund*, Guiana Shield Facility. <http://www.guianashield.org>. Accessed 11 Apr 2019
- [25] Hammond D (2005) *Tropical forests of the Guiana Shield: ancient forests in a modern world.* CABI, Wallingford
- [26] Haden P (1999) *Forestry issues in the Guiana Shield region: a perspective on Guyana and Suriname.* European Unions Tropical Forestry Paper, Overseas Development Institute
- [27] Hardin, G., The tragedy of the commons, *Science*, 162, 1243-1248, (1968)
- [28] Hasson, R.; Löfgren, A.; Visser, M., Climate change in a public goods game, investment decision in mitigation versus adaptation, *Ecol Econom*, 70, 331-338, (2010)
- [29] Hauert, C.; Monte, S.; Hofbauer, J.; Sigmund, K., Volunteering as red queen mechanism for cooperation in public goods games, *Science*, 296, 1129-1132, (2002)
- [30] Hauert, C.; Holmes, M.; Doebeli, M., Evolutionary games and population dynamics: maintenance of cooperation in public goods games, *Proc R Soc B*, 273, 2565-2570, (2006)
- [31] Helanterä, H.; Uller, T., The price equation and extended inheritance, *Philos Theory Biol*, 2, 1-17, (2010)
- [32] Hilbe, C., Local replicator dynamics: a simple link between deterministic and stochastic models of evolutionary game theory, *Bull Math Biol*, 73, 2068-2087, (2011) · [Zbl 1225.92043](#)
- [33] Hilbert, M., Complementary variety: when can cooperation in uncertain environments outperform competitive selection?, *Complexity*, 5052071, 1-15, (2017) · [Zbl 1373.92090](#)
- [34] Hofbauer J, Sigmund K (1998) *Evolutionary games and population dynamics.* Cambridge University Press, Cambridge · [Zbl 0914.90287](#)
- [35] IUFRO (2010) *Making forests work for people and nature: responding to global drivers of change, Policy Brief of the International Union of Forest Research Organizations' Special Project on World Forest, Society and Environment*
- [36] Kalamandeen, M.; Gloor, E.; Mitchard, E.; Quincey, D.; Ziv, G.; Spracklen, D.; Spracklen, B.; Adami, M.; Aragão, L.; Galbraith, D., Pervasive rise of small-scale deforestation in Amazonia, *Sci Rep*, 8, 1-10, (2018)
- [37] Kaul I, Conceição P, Le Goulven K, Mendoza R (2003) *Providing Global Public Goods: Managing Globalization.* Oxford University Press, Oxford
- [38] Keohane R, Ostrom E (1995) *Local commons and global interdependence: heterogeneity and cooperation in two domains.* Sage Publications, Thousand Oaks
- [39] Kerr, B.; Godfrey-Smith, P., Generalization of the price equation for evolutionary change, *Evolution*, 63, 531-536, (2008)
- [40] Knudsen, T., General selection theory and economic evolution: the price equation and the replicator/interactor distinction, *J Econ Methodol*, 11, 147-173, (2004)
- [41] Levin, S., Complex adaptive systems: exploring the known, the unknown and the unknowable, *Bull Am Math Soc*, 40, 3-19, (2002)
- [42] Laurence, W.; Albernaz, A.; Fearnside, P.; Vasconcelos, H.; Ferreira, L., Deforestation in Amazonia, *Science*, 304, 1109, (2004)
- [43] Maynard, SJ; Price, G., The logic of animal conflicts, *Nature*, 246, 15-18, (1973) · [Zbl 1369.92134](#)
- [44] Melbinger, A.; Vergassola, M., The impact of environmental fluctuations on evolutionary fitness functions, *Sci Rep*, 5, 15211-1-11, (2015)
- [45] Nolte D (2015) *Introduction to modern dynamics, chaos, networks, space and time.* Oxford University Press, Oxford · [Zbl 1357.70018](#)
- [46] Nowak, M.; May, R., Evolutionary games and spatial chaos, *Nature*, 359, 826-829, (1992)
- [47] Nowak, M.; Sigmund, K., Evolution of indirect reciprocity by image scoring, *Nature*, 393, 573-577, (1998)
- [48] Odenbaugh J (2005) *The structure of population ecology: philosophical reflections on unstructured and structured models, paradigm's lost—theory change in ecology.* Academic Press, Cambridge
- [49] ONF (2014) *REDD+ for the Guiana Shield, technical and regional development of REDD+ in the Guiana Shield.* <https://reddguianashield.com>. Accessed 11 Apr 2019

- [50] ONF International (2015) Regional interactions of deforestation inside the Guiana Shield. <https://reddguianashield.com>. Accessed 11 Apr 2019
- [51] Ostrom, E.; Burger, J.; Field, C.; Norgaard, R.; Policansky, D., Revisiting the commons: local lessons, global challenges, *Science*, 284, 278-282, (1999)
- [52] Page K (2003) Unifying evolutionary dynamics. *Mathematical modelling and computing in biology and medicine*, Società Editrice Esculapio, Bologna
- [53] Page, K.; Nowak, M., Unifying evolutionary dynamics, *J Theor Biol*, 219, 93-98, (2002)
- [54] Perc M (2006) Coherence resonance in a spatial prisoner's dilemma game. *New J Phys* 8:22-1-22-8
- [55] Perc, M., Phase transitions in models of human cooperation, *Phys Lett A*, 380, 2803-2808, (2016)
- [56] Perc, M.; Szolnoki, A., Coevolutionary games: a mini review, *Biosystems*, 99, 109-125, (2010)
- [57] Perc, M.; Gómez-Gardeñes, J.; Szolnoki, A.; Flora, L.; Moreno, Y., Evolutionary dynamics of group interactions on structured populations: a review, *J R Soc Interface*, 10, 20120997-1-20120997-17, (2013)
- [58] Perc, M.; Jordan, J.; Rand, D.; Wang, Z.; Boccaletti, S.; Szolnoki, A., Statistical physics of human cooperation, *Phys Rep*, 687, 1-51, (2017) · [Zbl 1366.80006](#)
- [59] Price, G., Selection and covariance, *Nature*, 227, 520-521, (1970)
- [60] Rahm M, Thibault P, Shapiro A, Smartt T, Paloeng C, Crabbe S, Farias P, Carvalho R, Joubert P (2017) Monitoring the impact of gold mining on the forest cover and freshwater in the Guiana Shield. ONF International and World Wide Fund for Nature France
- [61] RAISG (2012) Amazonian network of georeferenced socio-environmental information: Amazonia under pressure. www.raisg.socioambiental.org. Accessed 11 Apr 2019
- [62] Ramamohan Rao T (2016) Risk sharing, risk spreading and efficient regulation. Springer, New Delhi
- [63] Santos, F.; Santos, M.; Pacheco, J., Social diversity promotes the emergence of cooperation in public goods games, *Nature*, 454, 213-216, (2008)
- [64] Sato, Y.; Crutchfield, J., Coupled replicator equations for the dynamics of learning in multiagent systems, *Phys Rev E*, 67, 015206-1-015206-4, (2003)
- [65] Shyu, E.; Caswell, H., Calculating second derivatives of population growth rates for ecology and evolution, *Methods Ecol Evolut*, 5, 473-482, (2014)
- [66] Szolnoki, A.; Perc, M., Conditional strategies and the evolution of cooperation in spatial public goods games, *Phys Rev E*, 85, 026104-1-026104-7, (2012)
- [67] Szolnoki, A.; Perc, M., Correlation of positive and negative reciprocity fails to confer an evolutionary advantage: phase transitions to elementary strategies, *Phys Rev X*, 3, 041021-1-041021-11, (2013)
- [68] Szolnoki, A.; Perc, M.; Szabo, G., Defense mechanisms of empathetic players in the spatial ultimatum game, *Phys Rev Lett*, 109, 078701-1-078701-4, (2012)
- [69] Tenreiro Machado J (2018) Dynamical systems. MDPI Books, Basel · [Zbl 1392.49033](#)
- [70] Traulsen, A.; Röhl, T.; Schuster, H., Stochastic gain in population dynamics, *Phys Rev Lett*, 93, 028701-1-028701-4, (2004)
- [71] Tucker, C., Learning on governance in forest ecosystems: lessons from recent research, *Int J Commons*, 4, 687-706, (2010)
- [72] UNFCCC (2019) United Nations Framework Convention on Climate Change. <https://redd.unfccc.int>. Accessed 11 Apr 2019
- [73] Wang J, Fu F, Wu T, Wang L (2009) Emergence of social cooperation in threshold public goods games with collective risk. *Phys Rev E* 80:016101.1-016101.11
- [74] Yoshimura, J.; Jansen, V., Evolution and population dynamics in stochastic environments, *Res Popul Ecol*, 38, 165-182, (1996)
- [75] Zhang, H.; Perc, M., Evolution of conditional cooperation under multilevel selection, *Sci Rep*, 6, 23006-1-13, (2016)

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