Exploiting resources: evolutionarily stable strategy with no conflicts and emergence of property rights

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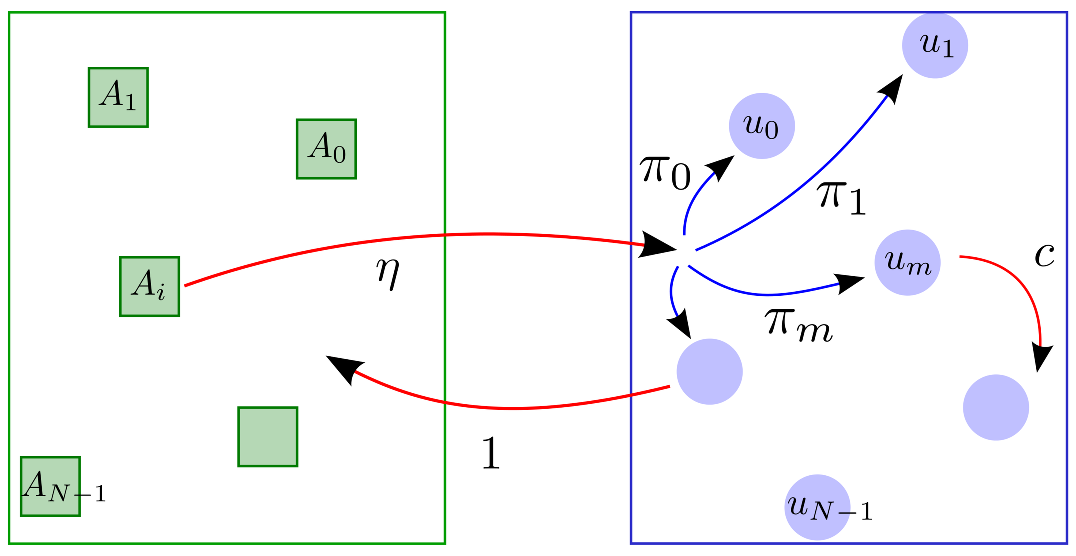
Introduction and multi-agent model

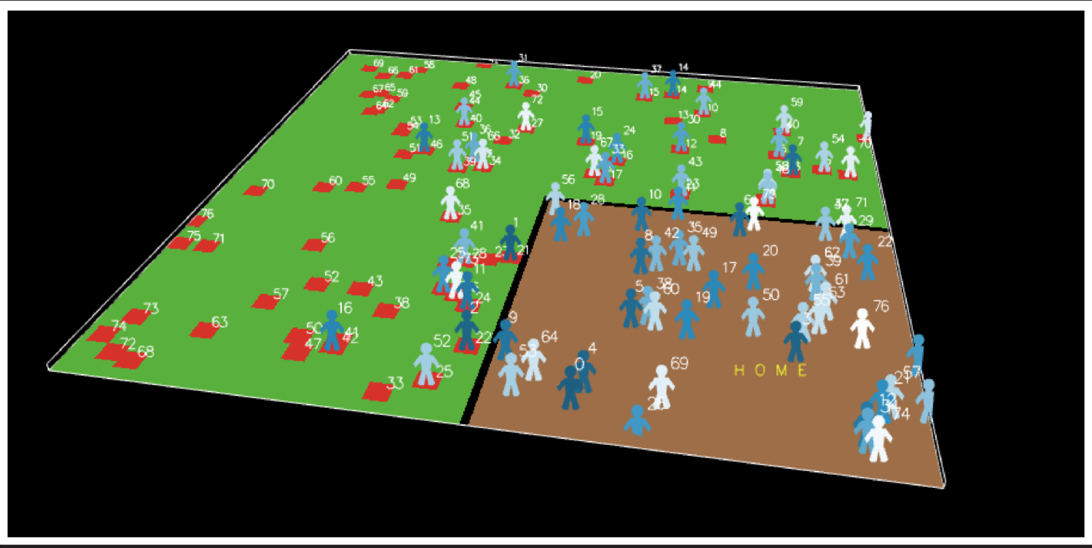
In a game theoretic approach to the study of the evolution of animal conflicts, it has been shown that choosing an initial asymmetric feature (such as first arrived to the good) to settle a contest is evolutionarily stable, and that in such circumstances animal fights are generally avoided.

In this context, we concider a system of N agents A_i (the animals) competing for N ressources F_m with different payoff $\{u_m\}_{0\leq m<N}$.

Each resource can be exploited only by one agent at a time; if an agent finds a resource already occupied, it looks for another resource which cost it c.



NetLogo



Optimal Mean-field Strategy, $\{\pi_m\}_{0\leq m<N}$

Mean-Field Strategy, for which every agent uses the same strategy $\{\pi_m\}_{0\leq m<N}$.

The optimal mean-field strategy is the one that maximises the average payoff of the agents

$$E[\pi] = \sum_m \pi_m \left[e_m u_m + (1-e_m)(-c+E[\pi])\right] \qquad (1)$$

with respect of the constraint $\sum_m \pi_m = 1$.

Definitions

* e_m is the probability that the site m is free;
* $\bar{e} = \sum_m \pi_m e_m$;
* $H = N/(1+\eta)$ is the mean number of agents at home.

Solution

For m such that

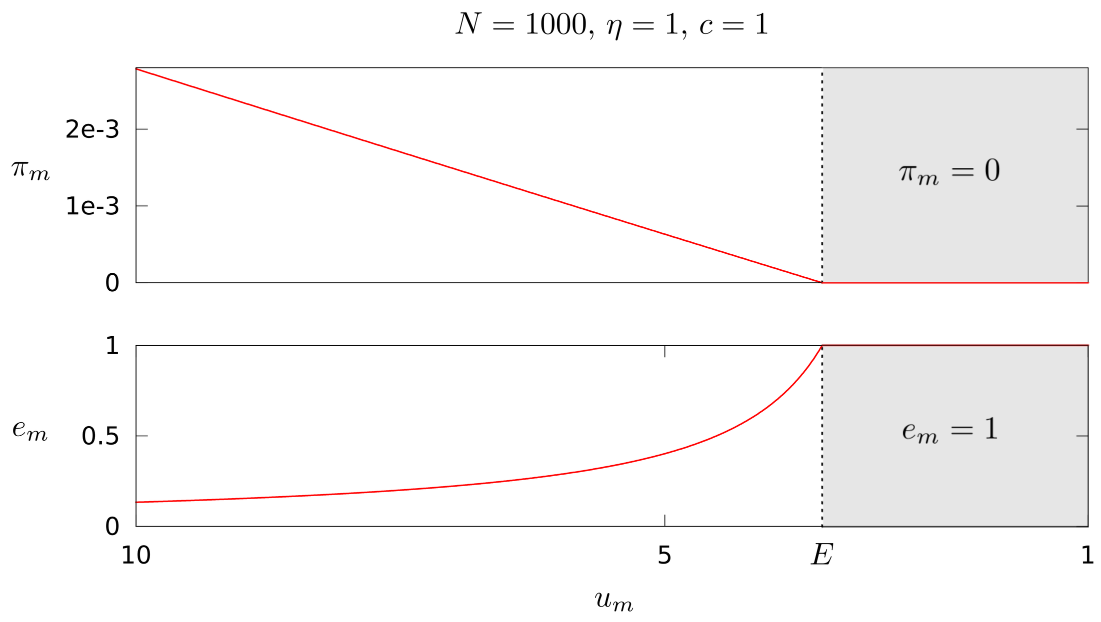
* $u_m \leq E$, $\quad \pi_m = 0$ and $e_m = 1$;
* $u_m > E$,

$$\pi_m = \frac{\phi_m(1+\phi_m)\,\bar{e}}{H\eta(1+\phi_m)-\phi_m^2} \quad \text{and} \quad e_m = \frac{1}{1+\phi_m}, \qquad (2)$$

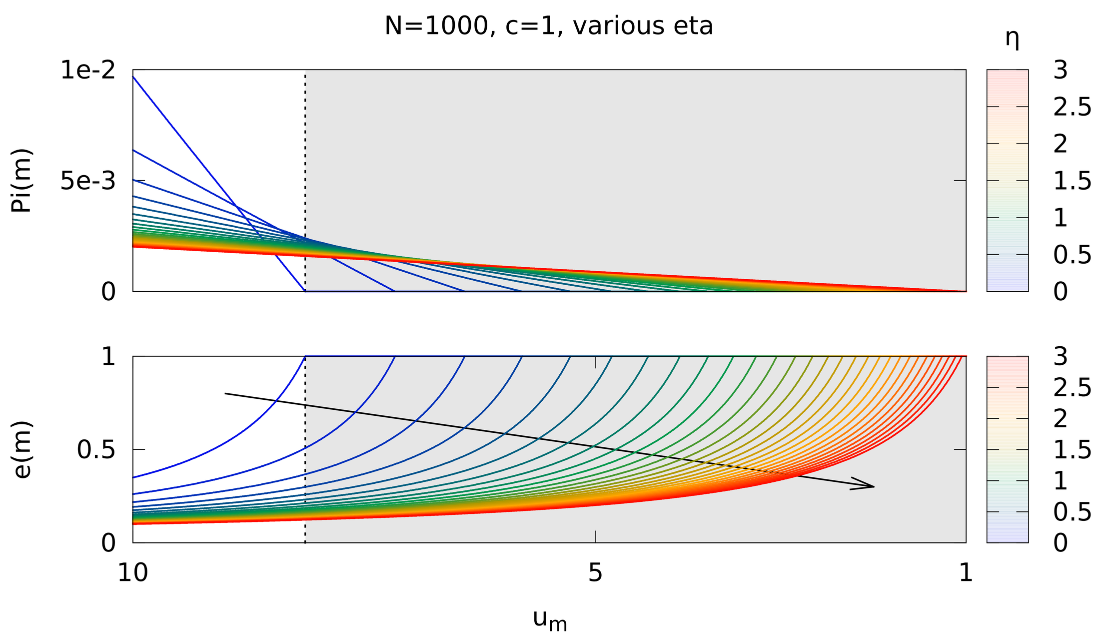
where $\phi_m = (u_m - E)/c > 0$ satisfies

$$\sum_{\phi_m>0} = \frac{\phi_m(1+\phi_m)}{H\eta(1+\phi_m)-\phi_m^2} = 1. \qquad (3)$$

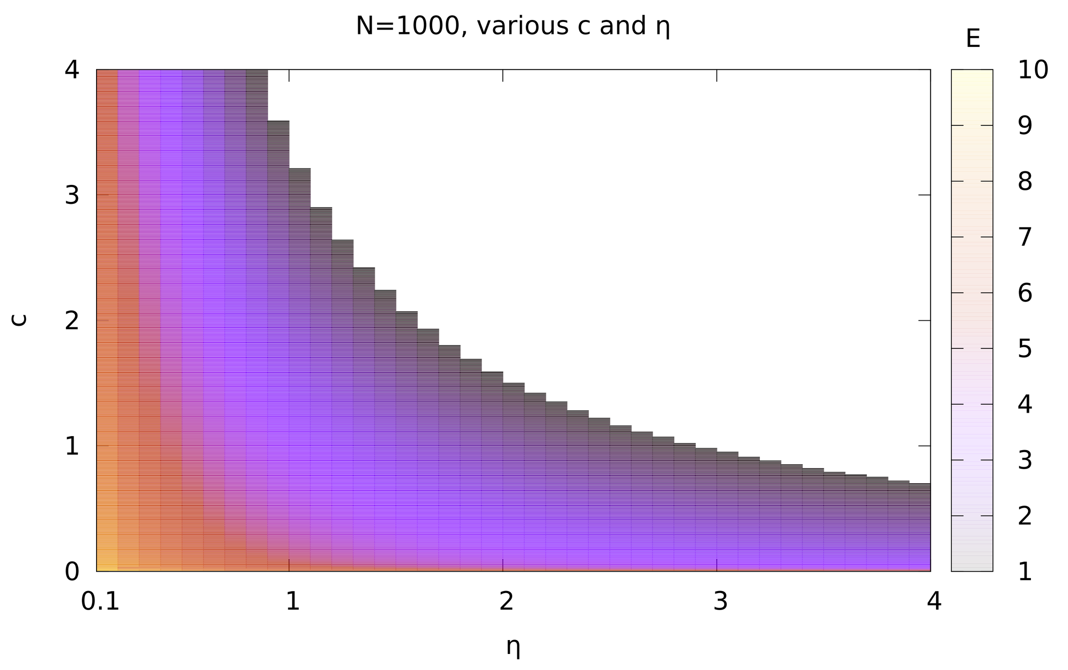
Numerical solution for a linear payoff between 0 and 10



Varying η



Existence of a solution, varying η and c



Monte Carlo with learning

Initially

⟶ Each agent knows the payoff u_m of every spot.
⟶ They start exploring believing that all places are free with the same probability e_m.

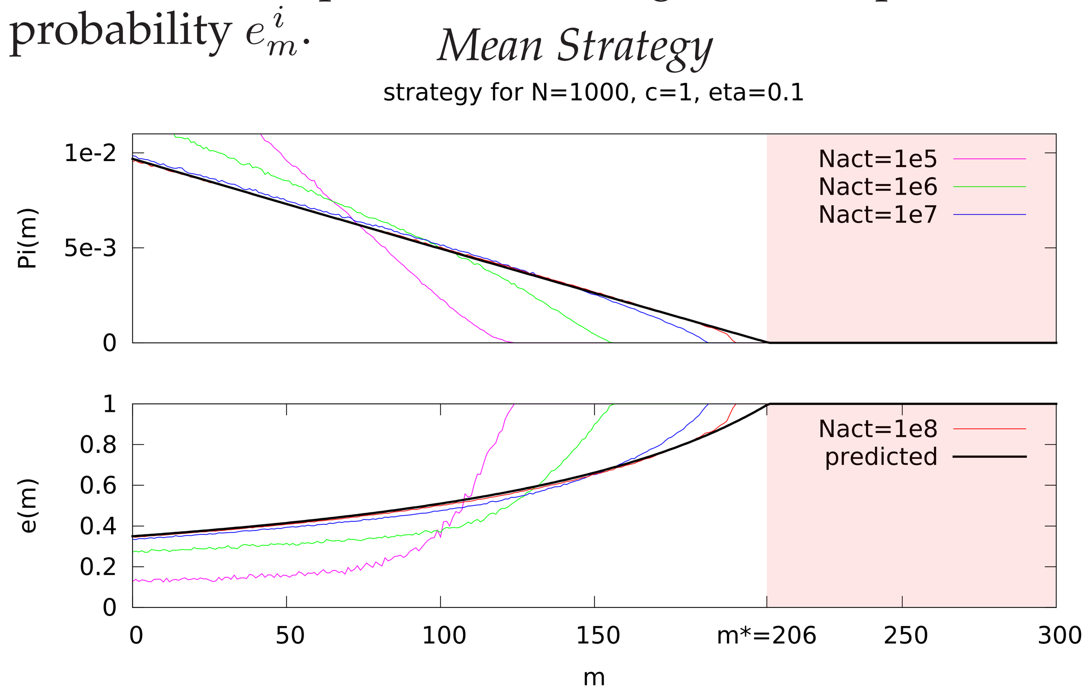
MC and Learning

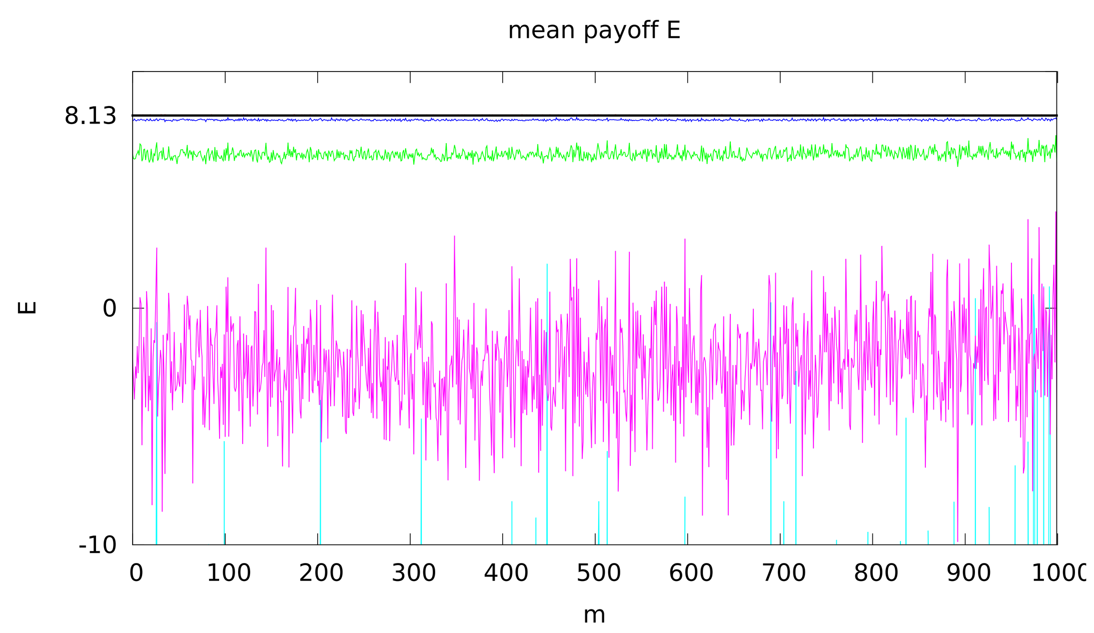
⟶ Agent A_i chooses where to go depending on its own knowledge of the system, $\{e^i_m\}$. It then prefers a spot m to a spot n if its expected payoff of trying m first and then n (in case m is occupied) is larger than doing the opposite, $E_i[m\to n] > E_i[n\to m]$, which can be reformulated as

$$u_m - \frac{c}{e^i_m} > u_n - \frac{c}{e^i_n}. \qquad (4)$$

⟶ For each spot m visited, agent A_i implements the probability e^i_m.

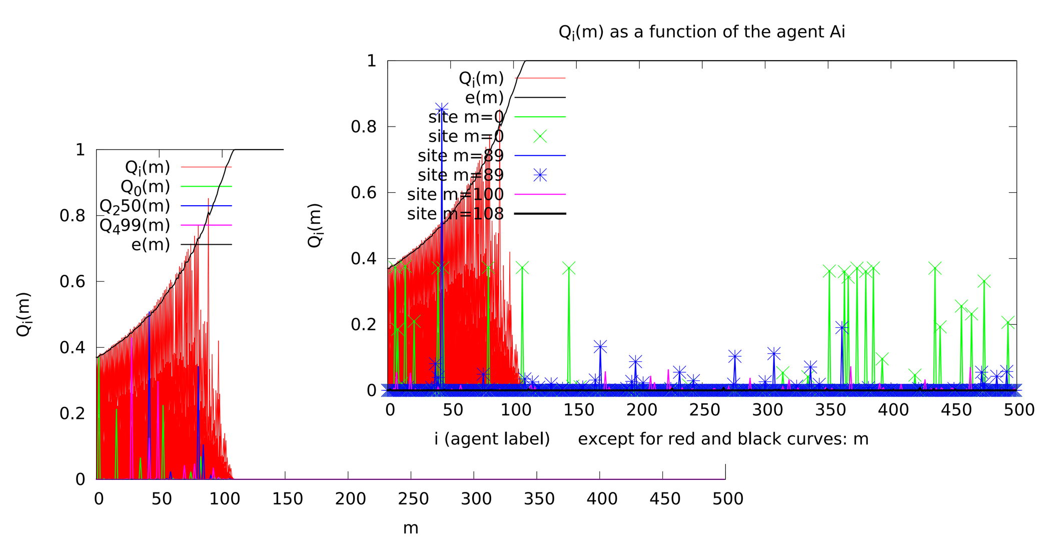
Mean Strategy



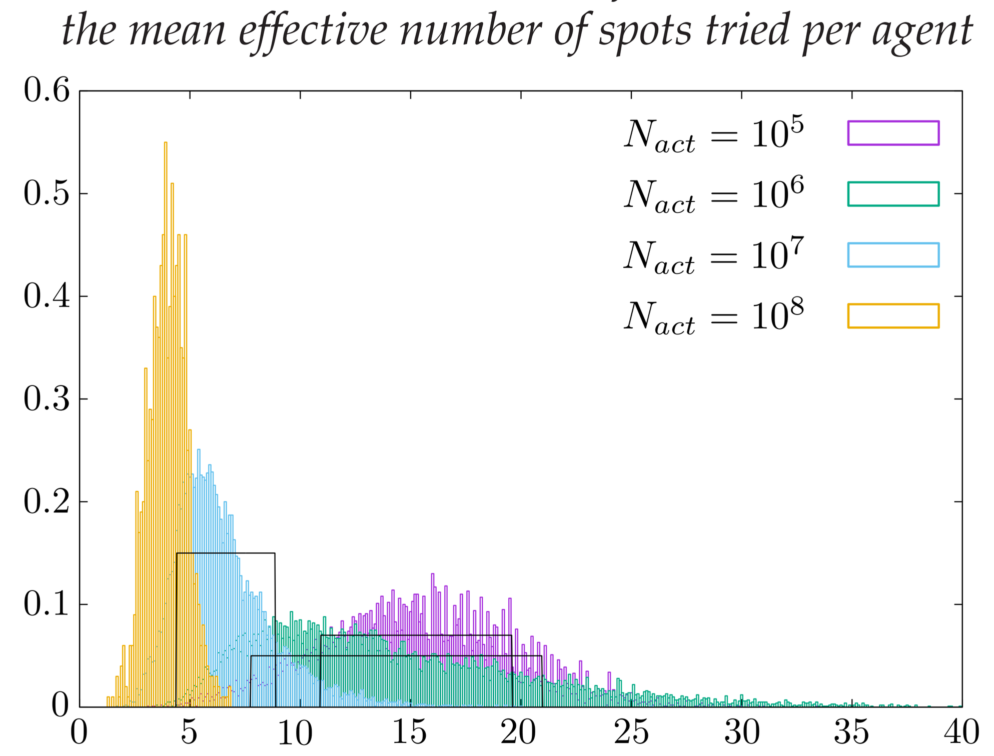


Personal strategy

Strategy of each agent



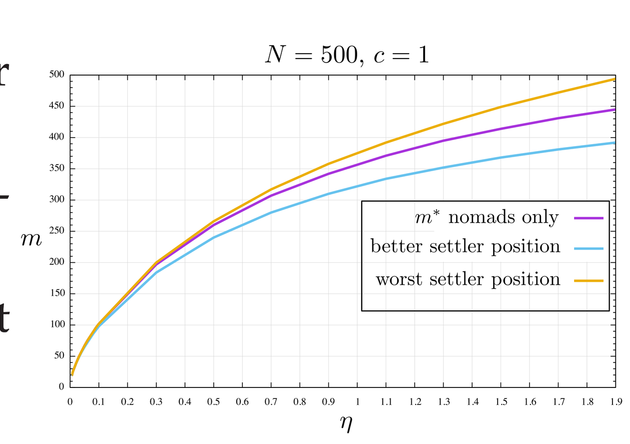
Evolution of the mean effective number of spots tried per agent

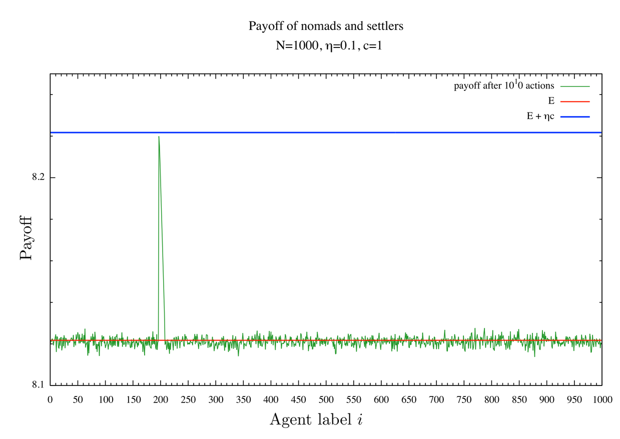


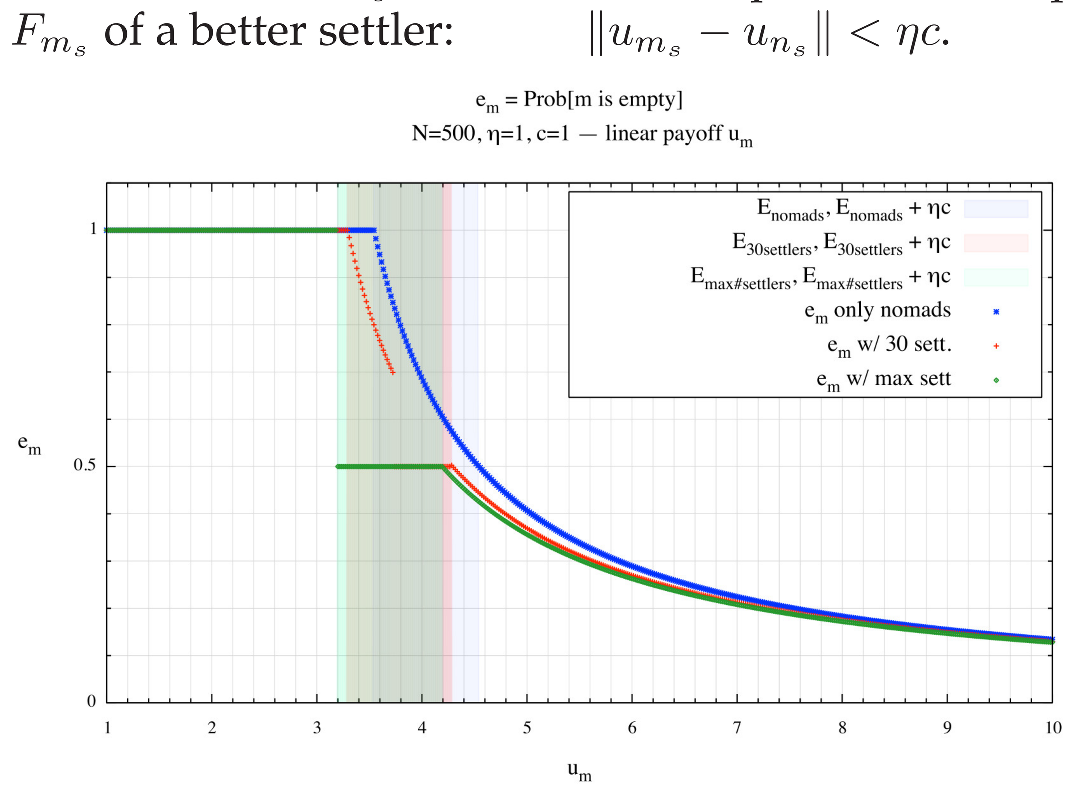
Safe middle places - Settler strategy

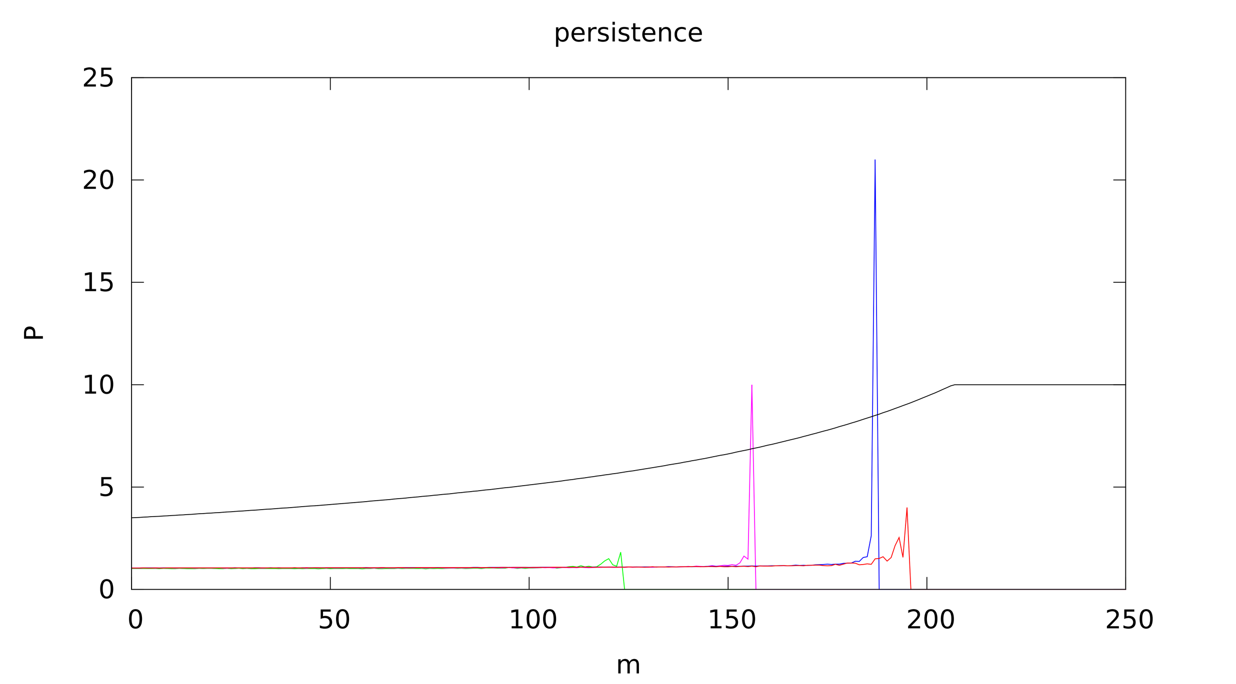
For settler strategies to be stable in the system:

* nomads should not be interested in trying a settler spot F_{m_s}: $\quad u_{m_s} \leq E + \eta c$.
* settlers in F_{m_s} should not be interested in becoming nomads: $\quad E \leq u_{m_s}$.
* settlers in F_{n_s} should not attempt to take the spot F_{m_s} of a better settler: $\quad \|u_{m_s} - u_{n_s}\| < \eta c$.









References

[1] *The Theory of Games and the Evolution of Animal conflicts*, J.Maynard Smith, J.Theor.Biol.(1974) **47**, 209-221.
[2] *Born Under a Lucky Star?*, N. Hanaki, A. Kirman, M. Marsili, Journal of Economic Behavior & Organization (2009) **77**, 2009-003.