**TRACE document**

This is a TRACE document (“TRAnsparent and Comprehensive model Evaludation”) which provides supporting evidence that our model presented in:

Examination of Consumption in Italy Model.

Based off of:

Bravo, G., Vallino, E., Cerutti, A., K., & Pairotti, M., B., (2013). Alternative Scenarios of Green Consumption in Italy: an Empirically Grounded Model*. CoMSES*. Retrieved from: <https://www.comses.net/codebases/3708/releases/1.1.0/>

was thoughtfully designed, correctly implemented, thoroughly tested, well understood, and appropriately used for its intended purpose.

The rationale of this document follows:

Schmolke A, Thorbek P, DeAngelis DL, Grimm V. 2010. Ecological modelling supporting environmental decision making: a strategy for the future. Trends in Ecology and Evolution 25: 479-486.

and uses the updated standard terminology and document structure in:

Grimm V, Augusiak J, Focks A, Frank B, Gabsi F, Johnston ASA, Kułakowska K, Liu C, Martin BT, Meli M, Radchuk V, Schmolke A, Thorbek P, Railsback SF. 2014. Towards better modelling and decision support: documenting model development, testing, and analysis using TRACE. Ecological Modelling

and

Augusiak J, Van den Brink PJ, Grimm V. 2014. Merging validation and evaluation of ecological models to ‘evaludation’: a review of terminology and a practical approach. Ecological Modelling.

If this document includes **hyperlinks**, navigation back and forth along previously chosen links works via “ALT” + “←” or “ALT” + “→”.

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<*Do not edit this table of contents or the headings of the eight TRACE elements. Update page numbers of this TOC by right-clicking on it and choosing “update fields”. If your TRACE document is long and complex, you might want to add sub-headings; please use existing styles for this, e.g. Heading 2 in Microsoft Word. You can specify how many heading levels the TOC includes.*>

4 CONCEPTUAL MODEL EVALUATION

This TRACE element provides supporting information on: The simplifying assumptions underlying a model’s design, both with regard to empirical knowledge and general, basic principles. This critical evaluation allows model users to understand that model design was not ad hoc but based on carefully scrutinized considerations.

**Summary: the simulation was designed to examine the effects of locality on the performance of various agent strategies, as well as to examine the performance of the strategies themselves. The reasoning behind the choice of the localities and the selection of strategies is also discussed in the section below.**

The Evolutionary Competition Framework was created to try and find out under which circumstances cooperation would arise in an interaction based on the Prisoner’s Dilemma payoff matrix. Specifically, one of the main ideas behind the development of this framework was to examine whether the addition of repeated, local only interactions with other agents would allow cooperation to emerge as one of the better-performing strategies in such an environment. The reasoning behind the choice of such an environment is an attempt to represent a more real-world like scenario, and hope for results that are also closer to that of a real world, where cooperation is quite widespread (AXELROD XXX).

In our experiment, we have chosen to model not only a local neighborhood (shown as Local Only), as well as interactions with random agents across the simulation (Random Only), and a scenario in-between (Partially Local), to compare the impact of such local interactions have on the performance of the various strategies.

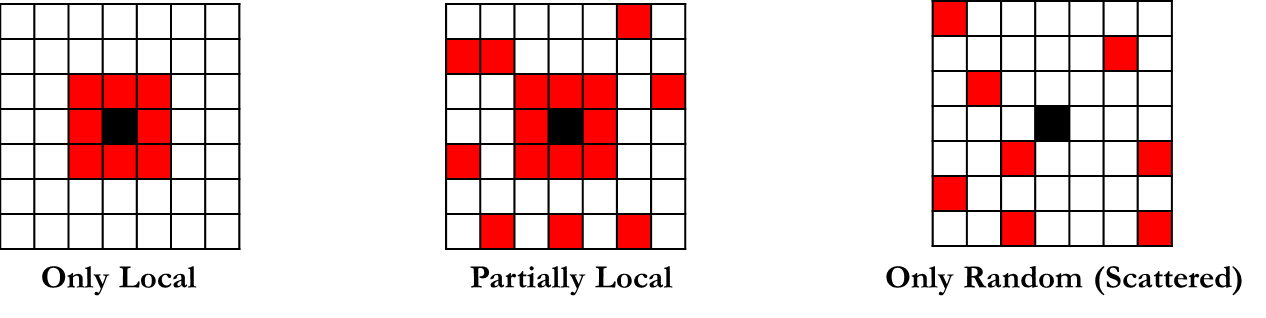


Figure XXX. Three types of neighborhood interactions used in the model.

To continue with the idea to represent real-world scenario as much as possible, each of our agents interacts once with its selected neighborhood (whether it is local, or randomly chosen across the simulation), without multiple iterations. This means that agents repeatedly interact with their immediate neighbors in Only Local simulation, but in a Random Only simulation are likely to interact only once with any given agent, which should lead to Defect being a much more viable strategy in simulation with less local interactions.

In addition to examining the impact of locality on the strategy performance, we have also introduced a variety of existing strategies from the literature to examine their performance in individual agents:

a. Cooperate: an agent cooperates unconditionally.

b. Defect: an agent defects unconditionally.

c. Random: an agent either defects or cooperates (unconditionally).

d. Tit for Tat: an agent cooperates in the first round, and then changes its strategy to that of its opponent in the previous round. Agents store opponents move in memory to determine their strategy in the next round. It always cooperates on the first encounter.

e. Pavlov: known as "win-stay, lose-shift," whereby an agent will cooperate as long as its neighbor has the same strategy as the agent, and it will defect if the neighbor has a different strategy. It also uses memory, but on first encounters it picks a random choice.

Since we were not completely satisfied with the existing individual strategies, we also introduced several original strategies based on the In-Group/Out-Group concept. (CITATION???). The idea behind these strategies was to examine whether cooperation could be shown as part of such more complex strategies. The strategies examined were as follows:

a. In-C-Out-D (In-Group Cooperate, Out-Group Defect): Agents always cooperate with members of their group, and defect when they interact with "outsiders".

b. In-C-Out-R (In-Group Cooperate, Out-Group Random): Agents always cooperate with members of their group, and either defect or cooperate when they interact with "outsiders."

c. In-R-Out-D (In-Group Random, Out-Group Defect): Agents randomly cooperate or defect with members of their group, and defect when they interact with "outsiders."

As part of this simulation, we wanted to compare the performance of these various strategies. Furthermore, we also examined how strategy performance changed when the Prisoner’s Dilemma payoff matrix was adjusted, and the locality of the neighborhood was changed.

The list of the strategies listed above is by no means meant to be exhaustive, and as indicated by the name of this model, the Evolutionary Competition Framework can be easily expanded to accommodate new strategy types, including individual and group strategies. Furthermore, it can also be modified to work based on a different type of Payoff Matrix, such as Stag Hunt, Hawk-Dove and any other game with a symmetric payoff.

5 IMPLEMENTATION VERIFICATION

This TRACE element provides supporting information on: (1) whether the computer code implementing the model has been thoroughly tested for programming errors, (2) whether the implemented model performs as indicated by the model description, and (3) how the software has been designed and documented to provide necessary usability tools (interfaces, automation of experiments, etc.) and to facilitate future installation, modification, and maintenance.

**Summary: The Evolutionary Competition Framework implementation has been verified by eliminating all code errors, confirmed to change behavior in accordance to changes in the input parameters, and its behavior was consistent with other implementation of the same model. The framework can be shared with other users, and the input parameters can be adopted to address various other interaction types between users beyond the Prisoner’s Dilemma.**

The Evolutionary Competition Framework model has been developed in the NetLogo 6.2.0 simulation tool, which provides an integrated interface for coding, documentation and interface of the simulation. Each model that is developed in NetLogo 6.2.0 can be saved as a standalone file, which contains the code, documentation and the interface developed in this program, and can be opened by any other user that has NetLogo 6.2.0 installed on their machines. The implementation verification has been done through the following methods.

5.1 This interface supports code verification in the coding interface, and notifies users of any run-time errors. Our code has been compiled successfully and was free of programming errors, and we were able to run the simulation without running into any run-time errors as well.

5.2 To verify that our model has been implemented correctly, we have varied the outputs and observed expected changes in model behavior:

a. Adjusting Defection-Award payoff value resulted in Defection strategy performing better at higher Defection-Award values, and Cooperation strategy performing better at lower Defection-Award values.

b. Adjusting the locality switch changed the interactions neighborhood, starting from local all the way to random

c. Adjusting the strategy switches resulted only in selected strategies being populated into the simulation.

5.3 Furthermore, the conceptual model has also been implemented using Agents.jl package of Julia programming language, which provided us with another way to verify whether the behavior of the agents in the model was consistent with our conceptual model, or was due to unexpected behavior of the underlying code. When utilizing identical starting parameters (payoff matrix values, strategies selected) we were able to reproduce simulation results between the two models.

The model currently supports user-based adjustments to the Defection-Award value via a slider, to allow us to explore the Prisoner’s Dilemma space of interactions. However, additional sliders can be added to adjust all other payoff values as well, as long as the interaction between agents remains symmetric (the payoff values do not differ between the two interacting agents).

6 MODEL OUTPUT VERIFICATION

This TRACE element provides supporting information on: (1) how well model output matches observations and (2) how much calibration and effects of environmental drivers were involved in obtaining good fits of model output and data.

**Summary: To verify the behavior of the model, we have examined edge cases, reduces the number of parameters examined, and compared the results to the predicted behavior based on the existing literature and our own calculations. Afterwards, to analyze the actual model output, we have utilized the BehaviorSpace extension of the NetLogo 6.2.0 program. This extension allows to automate and repeat simulations based on a set of input parameters, and output the results to an external file, such as a CSV file.**

Since this model does not rely on external data, all the variations in the model output are the result of stochasticity of the model itself – the randomness in the starting agent populations and positions, the random results of certain interactions, and the random order in which the agents were chosen to interact each round. To verify that the output matched the expected behavior, we have utilized two additional methods.

6.1 We have examined edge cases and reduced the number of parameters to examine the behavior with reduced interference:

a. To examine the effects of Defection-Award slider and Locality switch, we have reduced the strategies present in the simulation to Cooperate and Defect, since we are familiar with their behavior and they are the simplest strategies we have available. It allowed us to clearly see the expected rise in the performance of the Defect strategy when the Defection-Award slider was increased, as well as when the Locality switch changed from local only interaction to include random agents across the grid.

b. To understand behavior of the more complex strategies, we selected only the strategy in question and one of the simpler strategies (either Defect or Cooperate), and allowed the simulation to run for a certain amount of time, until the agent clusters coalesced from the initial random placement. Then we examined the behavior of these clusters, in particular the borders of their interactions with other clusters of agents.

6.2. By running simulations for very large amounts of time, we were able to compare the expected strategy performance based on the existing literature and that in our model. For example the Pavlov strategy was predicted to outperform Tit For Tat strategy, which only happened when we allowed the Pavlov strategy to start off interactions with unknown agents with a random choice. After making the adjustments to the strategy used, and to our code, the Pavlov strategy was able to outperform Tit For Tat strategy in almost all situations.

6.3 Utilizing the Inspect ability in NetLogo, we were able to track the behavior of individual agents, as well as their neighbors, along with the values of their attributes. This allowed us to understand why some changes took place, and whether there was an error in the logic of the code or understanding of how the code itself worked.

After utilizing the above methods, we were able to confirm that the strategies behaved as predicted, either in existing literature, or in our own expectations. Once we were assured that the strategies behaved correctly, we utilized an extension within NetLogo called BehaviorSpace. This extension allows users to construct batch experiments with a predefined set of parameters, which users are then able to repeatedly run for a specified number of runs.

We have tested all the combinations of strategies and locality switch listed below at 1.1, 1.5 and 1.9 Defection-Award slider value 50 times each, to ensure that the payoff matrix values remained equivalent to the Prisoner’s Dilemma payoff:

a. Five individual strategies together (Cooperate, Defect, Random, Tit For Tat, Pavlov), with separate experiments for the three Locality switch values (Local Only, Half Local Half Random, Random Only).

b. Five individual strategies together with one of the group strategies. We ran three different BehaviorSpace experiments for each of the group strategies (In-Group Cooperate, Out-Group Defect, In-Group Cooperate, Out-Group Random, In-Group Random, Out-Group Defect). All of these runs were done with Local Only setting of the locality switch.

c. We also ran an experiment with all eight strategies together, with the Locality switch set to Local Only

d. As a final experiment, we ran five individual strategies together with In-Group Cooperate, Out-Group Defect, as the best performing group strategy, with the Locality switch set to Half Local Half Random and Random Only.

These experiments allowed to thoroughly compare the behavior of strategies in various settings, and draw some interesting conclusions.