ODD protocol for the agent-based model COMMONSIM

Manuscript title: "COMMONSIM – Simulating the utopia of COMMONISM: Agents, networks, commons, group culture and inclusive social economic provisioning"

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1. Purpose

We present a novel approach for the development of concrete utopias via agent-based simulations. The utopian perspective investigated emphasizes the up- and outward scaling of a web of commons. This utopia highlights the complex adaptive relations between micro (the individual), meso (the commons) and macro (the society). The model features a novel micro foundation, based on critical psychology in general, and in particular on a distinction between sensual-vital and productive needs. Focus of the analysis lies on the meso level, i.e. the web of commons and its mechanisms of polycentric governance, stigmergy as well as social distributional conflict resolution via meta commons. These mechanisms are operative to coordinate provision of intermediary and final means, inter- and transpersonal care means as well as ecosystem cultivation via the production of sinks. The coordination mediates the satisfaction of needs in an ex ante signalling process, in stark contrast to usual ex post market exchange, in the multi-layered production network. Simulation experiments are conducted to demonstrate the reproductive capacities of the investigated utopia on macro scale under the assumption of different cultures and varying inter-cultural cooperation willingness. Two institutional responses to mitigate uncooperative behavior are explored.

2. Entities, state variables, and scales

2.1. Model overview

Following the utopia of Commonism developed by Sutterlütti and Meretz (2018, 2022), our simulation CommonSim is based on a model, which represents an artificial society with individual heterogeneous agents that interact in social networks for social provisioning. The following graphic represents all entities and flows (cf. Fig. 1). Each entity and the corresponding variables are introduced in the following.

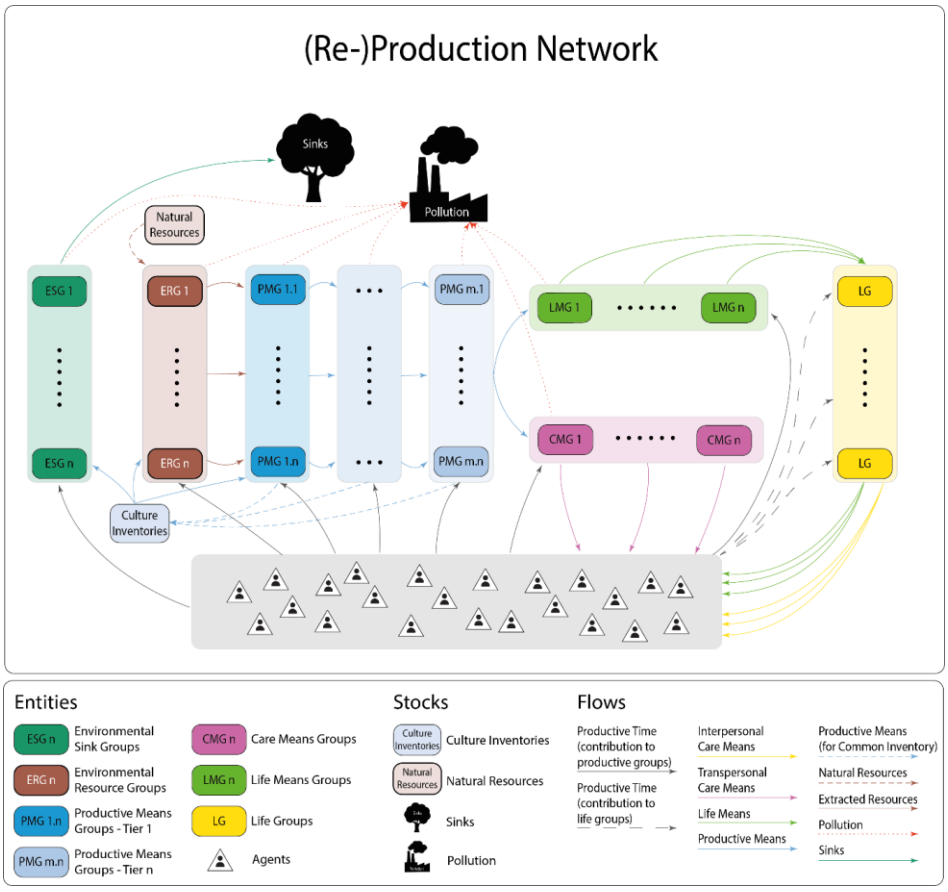

Fig. 1. Basic structure and flow-chart of the model

The networks represent the private and public spheres, they organize social life, structure social dynamics, form the basis for all reproduction and satisfaction processes and adapt to their members in reflexive terms. Each agent is part of at least one, at maximum two different immediate social networks, called groups. There are two types of groups: life groups and production groups. With one to ten members, life groups are the smallest and most intimate networks agents are part of; they represent family like structures plus extended circles of close persistent relations. Further, agents are also part of production groups that produce means (e.g. machines, wood, food or music) to produce other means or to satisfy sensual-vital needs. Agents are connected via links with the production groups, and thereby with other group members.

2.2. Agents

Each agent is a distinct and independent actor, characterized by different types of variables that guide its behaviour. The state variables (listed further below) can be divided into 6 main categories:

- Personal characteristics: Each agent has a fundamental set of values and personal traits that influence the decisions. The value constellation of the four characteristics defines the culture of an agent. There are four cultures: ecologists, traditionalists, modernists and random (see table 6 in section 5.Initialization for parameter combinations of the different cultures).
- Needs: Each agent has different types of needs, which it strives to satisfy by using means throughout the simulation.
    - Sensual-vital needs (SvN): Sensual-vital needs consist of three sub-categories (1) interpersonal care means $\left(icm_{i,t}^{target}\right)$, e. g. cleaning, cooking, taking care of children and elders; (2) transpersonal care means $\left(tcm_{i,t}^{target}\right)$, e. g. hospitals, schools, nursing homes; and (3) life means $\left(lm_{i,t}^{target}\right)$, e. g. food, music, housing.
    - Productive needs (PrN): Productive needs describe the wish of agents to participate actively in society. They are satisfied by contributing to the re-production processes in life- and productive groups. The agents like to be active for an exact number of hours they designated to each group.
- Conditions: Conditions describe the extent to which the needs are satisfied.
    - Sensual-vital needs conditions
    - Productive-needs conditions
    - Personal conditions
    - Condition of own groups
- Emotional evaluation: Agents have emotions about the personal-, group-, societal-, and environmental conditions which they value with respect to their sensual-vital and productive needs. Emotions influence the priorities of the agents (next section) and thereby influence the decision-making processes.
- Motivational evaluation: The motivational evaluation is similar to the emotional evaluation. While the emotional evaluation refers to the current situation, the motivational evaluation refers to expected future conditions.
- Priorities: All agents prioritize between different aspects of their lives. These priorities reflect the experiences in the past. They show how important something is to agents, which becomes relevant when they have to make decisions and when groups are confronted with limits and have to decide how to split the available means or hours among the agents.
    - Priorities of sensual-vital needs
    - Priorities of productive needs
    - Priorities of conditions

- Productive organizing variables: These variables indicate if an agent is happy with the productive group it is active in and, if not, to which group it would like to change to.

In the following, a concise list of agent variables and parameters is presented.

Agents' state variables and parameters:

(variable name as used in the code and, if applicable, the variable used in the equations provided in this document)

Variable name (code)	Description	Variable (equations)
Personal characteristics		
ego-level	Ego, a spectrum between egoistic and altruistic behaviour	$c_{i,t}^{ego}$
leisure-level	Leisure, a spectrum between leisure and activity-focus	$c_{i,t}^{leisure}$
eco-level	Eco, a spectrum between being indifferent and very concerned about environment	$c_{i,t}^{eco}$
prod-level	Prod(uctiveness), a spectrum between being indifferent and very concerned about output	$c_{i,t}^{prod}$
Care		
care-impact	Individual severity of extra care demand	$w_{i,t}$
Care-time-connex	Link between care demand and time spent by agents	ct_i
Sensual-vital needs (SvN)		
	Generic variable for received needs	$need_{i,t}^{current}$
	Generic variable for required needs	$need_{i,t}^{target}$
SvN-iCM-current	Recieved amount of interpersonal care means (icm)	
SvN-iCM-target	Required amount of interpersonal care means	$icm_{i,t}^{target}$
SvN-LM-current	Recieved amount of life means	
SvN-LM-target	Required amount of life means	$lm_{i,t}^{target}$
SvN-tCM-current	Recieved amount of transpersonal care means (tcm)	
SvN-tCM-target	Required amount of transpersonal care means	$tcm_{i,t}^{target}$
Productive needs (PrN)		
sleep-time	Assumed time agents are sleeping (cannot be active for this amount of hours)	
productive-time	Total hours an agent wants to be active	$pt_{i,t}^{target}$
PrN-LG-current	Time an agent spents in the life group	
PrN-LG-target	Time an agent wants to spent in the life group	
PrN-PrG-current	Time an agent spents in the productive group	
PrN-PrG-target	Time an agent wants to spent in the productive group	
Sensual-vital needs conditions		
	Generic condition variable	$cond_{i,t}^{k}$
	Generic condition variable, specified for needs	$cond_{i,t}^{need}$
SvN-cond-old	Past mean condition of sensual-vital needs in t-1	
SvN-iCM-cond-old	Past interpersonal care means condition: extent to which the needs are satisfied in t-1	
SvN-LM-cond-old	Past life means condition: extent to which the needs are satisfied in t-1	
SvN-tCM-cond-old	Past transpersonal care means condition: extent to which the needs are satisfied in t-1	

SvN-cond	Current mean condition of sensual-vital needs	
SvN-iCM-cond	Current interpersonal care means condition: extent to which the needs are satisfied	
SvN-LM-cond	Current life means condition: extent to which the needs are satisfied	
SvN-tCM-cond	Current transpersonal care means condition: extent to which the needs are satisfied	
P-LG-SvN-iCM-cond-gm	Groupmean of interpersonal care means condition of all members of an agent's life group	
P-LG-SvN-tCM-cond-gm	Groupmean of interpersonal care means condition of all members of an agent's life group	
P-LG-SvN-LM-cond-gm	Groupmean of life means condition of all members of an agent's life group	
Productive-needs conditions		
PrN-cond-old	Past mean productive needs condition in t-1	
PrN-LG-cond	Past condition of productive needs regarding life group: extent to which the needs are satisfied in t-1	
PrN-PrG-cond	Past condition of productive needs regarding productive group: extent to which the needs are satisfied in t-1	
PrN-PrG-cond-history	Timeline of past condition of productive needs regarding productive group: extent to which the needs are satisfied in the last 4Weeks	
PrN-cond	Current mean productive needs condition	
PrN-f-cond	Expected mean productive needs condition	
PrN-emo	Emotional evaluation of the satisfaction of mean productive needs	
PrN-moti	Motivational evaluation of the satisfaction of mean productive needs	
Personal conditions		
P-cond	Current total condition of the satisfaction of all needs (mean of productive & sensitive-vital needs)	
P-f-cond	Expected total condition of the satisfaction of all needs (mean of productive & sensitive-vital needs)	
P-emo	Emotional evaluation of total condition of the satisfaction of all needs (mean of productive & sensitive-vital needs)	
P-moti	Motivational evaluation of total condition of the satisfaction of all needs (mean of productive & sensitive-vital needs)	
P-cond-old	Past total condition of the satisfaction of all needs (mean of productive & sensitive-vital needs) in t-1	
Condition of own groups		
P-LG-cond-old	Past condition of the agent's life group	
p-PrG-cond-old	Past condition of the agent's productive group	
p-env-cond-old	Past environmental condition	
p-soci-cond-old	Past societal condition	
P-LG-cond	Current condition of the agent's life group	
p-PrG-cond	Current condition of the agent's productive group	
p-env-cond	Current environmental condition	
p-soci-cond	Current societal condition	
P-LG-f-cond	Futur condition of the agent's life group	
p-PrG-f-cond	Futur condition of the agent's productive group	
p-env-f-cond	Futur environmental condition	
p-soci-f-cond	Futur societal condition	
Emotional evaluation		
	Generic emotion variable	$emo_{i,t}^{k}$
SvN-emo	Emotional evaluation of the satisfaction of mean sensitive-vital needs	

SvN-moti	Motivational evaluation of the satisfaction of mean sensitive-vital needs	
SvN-iCM-emo	Emotional evaluation of the satisfaction of interpersonal care means needs	
SvN-iCM-moti	Motivational evaluation of the satisfaction of interpersonal care means needs	
SvN-tCM-moti	Motivational evaluation of the satisfaction of transpersonal care means needs	
SvN-LM-moti	Motivational evaluation of the satisfaction of life means needs	
P-LG-cond-emo	Emotional evaluation of the condition of the agent's life group	
p-PrG-cond-emo	Emotional evaluation of the condition of the agent's productive group	
p-env-cond-emo	Emotional evaluation of the environmental condition	
p-soci-cond-emo	Emotional evaluation of the societal condition	
Motivational evaluation		
P-LG-cond-moti	Motivational evaluation of the condition of the agent's life group	
p-PrG-cond-moti	Motivational evaluation of the condition of the agent's productive group	
p-env-cond-moti	Motivational evaluation of the environmental condition	
p-soci-cond-moti	Motivational evaluation of the societal condition	
P-LG-SvN-cond-gm	Groupmean of senstive-vital needs condition of all members of an agent's life group	
P-LG-PrN-cond-gm	Groupmean of productive needs condition of all members of an agent's life group	
P-PrG-SvN-cond-gm	Groupmean of senstive-vital needs condition of all members of an agent's productive group	
P-PrG-PrN-cond-gm	Groupmean of productive needs condition of all members of an agent's productive group	
P-wellbeing-emo	Overall emotional evaluation of all conditions	
emo-impact	Mean emotional evaluation of SvN-emo p-env-cond-emo p-soci-cond-emo	$emo_{i,t}^{mean}$
P-wellbeing-moti	Overall motivational evaluation of all conditions	
P-wellbeing-moti-old	Overall motivational evaluation of all conditions	
Priorities		
Priorities sensual-vital needs		
prio-SvN-iCM	Priority for interpersonal care means	
prio-SvN-tCM	Priority for interpersonal care means	
prio-SvN-LM	Priority for life means	$prio_{i,t}^{lm}$
Priorities Productive Needs		
	Generic priority variable	$prio_{i,t}^{pgs}$
prio-PrN-LG	Priority for life group	
prio-PrN-LMG	Priority for productive groups with the type LMG	
prio-PrN-PMG	Priority for productive groups with the type PMG	
prio-PrN-CMG	Priority for productive groups with the type CMG	
prio-PrN-ESG	Priority for productive groups with the type ESG	
prio-PrN-ERG	Priority for productive groups with the type ERG	
prio-PrN-PrG	Priority for the productive group the person is avtive in	
Priorities conditions		
prio-P-cond	Priority for personal condition	
prio-LG-cond	Priority for condition of own life group	$prio_{i,t}^{lg}$

prio-PrG-cond	Priority for condition of own productive group (group the person is active in)
prio-env-cond	Priority for condition of the environment
prio-soci-cond	Priority for condition of the society
Productive organizing variables	
prod-satisfied?	Registers a wish to change to a different productive group
change-to	Registers a wish to change in a different productive class, based on the priorities; only used if prod-satisfied? is false

Table 1: Agents' state variables and parameters

2.3. Groups

Life groups

Life groups produce interpersonal care means (icm), e.g. caring, cleaning & cooking. As an input, they only require person-hours. The output is directly redistributed to the members of the group. To organize production and provisioning, life groups have three types of variable:

- Production of ICMs: These variables organize the icm-production process
- Conditions: The variables in this category describe how well the life group is doing on different levels
- Life-Group group means: Life groups remember the mean of many agent-variables of all their members

In the following, a concise list of all life group variables is presented.

Life groups' state variables and parameters:

(variable name as used in the code and, if applicable, the variable used in the equations provided in this document)

Variable name (code)	**Description**	**Variable (equations)**
kind	Group type (LG for life groups)	
culture	Culture of group	
my-possible-cultures-list	Cultures the group is willing to cooperate with	
coop-prob	Probability to cooperate with other cultures	
update-group-culture-counter	Counter to asynchronize updates	
Production of ICMs		
iCM-labour-productivity	Productivity of the persons producing iCM: needed person-time for the production of one iCM	
iCM-current	Current level of interpersonal care means	
iCM-target	Target level of interpersonal care means	
time-available	Currently available person-time, in hours	
time-planned	Needed person-time to achieve iCM-target	
Conditions		
cond	Current condition, mean of time- and prod-cond	
cond-old	Past condition, mean of time- and prod-cond in t-1	
time-cond-old	Past time condition of life group in t-1 (relation of used time to available time)	
time-cond	Current time condition of life group in t-1 (relation of used time to available time)	

prod-cond-old	Past productive condition of life group (relation of iCM-current and iCM-target) in t-1	
prod-cond	Current productive condition of life group (relation of iCM-current and iCM-target)	
Life-Group group means		
SvN-iCM-gm	Mean of SvN-iCM-current of all members of the life group	
SvN-tCM-gm	Mean of SvN-tCM-current of all members of the life group	
SvN-LM-gm	Mean of SvN-LM-current of all members of the life group	$lm_{lgm,j,t}^{target}$
SvN-LM-needed	Life means the group requested from the life means groups	
SvN-LM-received	Life means the group received from the life means groups	
SvN-LM-target	Aggregated life means demand of all group members	
SvN-LM-current	Aggregated life means received by all group members	
SvN-cond-gm	Mean of SvN-cond of all members of the life group	
SvN-moti-gm	Mean of SvN-moti of all members of the life group	
SvN-emo-gm	Mean of SvN-emo of all members of the life group	
SvN-iCM-emo-gm	Mean of SvN-iCM-emo of all members of the life group	
SvN-iCM-cond-gm	Mean of SvN-iCM-cond of all members of the life group	
SvN-iCM-moti-gm	Mean of SvN-iCM-moti of all members of the life group	
SvN-tCM-cond-gm	Mean of SvN-tCM-cond of all members of the life group	
SvN-LM-cond-gm	Mean of SvN-LM-cond of all members of the life group	
SvN-tCM-emo-gm	Mean of SvN-tCM-emo of all members of the life group	
SvN-LM-emo-gm	Mean of SvN-LM-emo of all members of the life group	
SvN-tCM-moti-gm	Mean of SvN-tCM-moti of all members of the life group	
SvN-LM-moti-gm	Mean of SvN-LM-moti of all members of the life group	
PrN-emo-gm	Mean of PrN-emo of all members of the life group	
PrN-moti-gm	Mean of PrN-moti of all members of the life group	
PrN-cond-gm	Mean of PrN-cond of all members of the life group	
P-emo-gm	Mean of P-emo of all members of the life group	$emo_{group,j,t}^{k}$
P-LG-cond-emo-gm	Mean of P-LG-cond-emo of all members of the life group	
p-PrG-cond-emo-gm	Mean of p-PrG-cond-emo of all members of the life group	
p-env-cond-emo-gm	Mean of p-env-cond-emo of all members of the life group	
p-soci-cond-emo-gm	Mean of p-soci-cond-emo of all members of the life group	
P-moti-gm	Mean of P-moti of all members of the life group	
P-LG-cond-moti-gm	Mean of P-LG-cond-moti of all members of the life group	
p-PrG-cond-moti-gm	Mean of p-PrG-cond-moti of all members of the life group	
p-env-cond-moti-gm	Mean of p-env-cond-moti of all members of the life group	
p-soci-cond-moti-gm	Mean of p-soci-cond-moti of all members of the life group	
p-cond-gm	Mean of p-cond of all members of the life group	
LG-wellbeing	Mean wellbeing (satisfaction) of all members of this groups	

Table 2: Life groups' state variables and parameters

Productive groups

The artificial economy rests on a relatively complex production chain, involving six different sectors (see Fig. 1); some of them producing intermediary and some final means. Each means to be produced requires various inputs without which the production cannot be actualized. All means are produced by productive groups, except interpersonal care means, which are provided by life groups themselves. All productive groups have a group culture, which reflects the culture of the majority of its members. This

becomes relevant in the coordination mechanisms. The model includes the following productive groups:

Environmental resource groups (ERGs) extract the natural resources and prepare them for further use. Apart from the resource stock, they need machinery $\left(x_{j,t}^{pm}\right)$ and person-hours $\left(x_{j,t}^{ph}\right)$. ERGs receive the needed machinery from a cultural specific meta inventory, which is a storage for machinery that all productive means groups of the same culture (see below) fill during the production process. If the cultural specific meta inventory is empty, they can receive machinery from the productive means groups. Apart from producing resources, ERGs create pollution and destroy sinks during the production process.

Environmental sink groups (ESGs) produce the sinks that sequestrate pollution from the biosphere, for example by cultivating eco systems. As an input, they need machinery and person-hours. Like ERGs, ESGs receive machinery from the cultural specific meta inventory, or if needed, from the productive means groups. ESGs observe the level of accumulated and planned pollution for production.

Production means groups (PMGs) produce means of production, which can be understood as machinery or intermediary means needed by all other productive groups as an input. PMGs are located on different tiers. In the presented simulation, three tiers are implemented, however, the number is scalable. Generally, each sector needs person-hours and means of production produced by the previous tier, only the first tier in the chain additionally needs resources $\left(x_{j,t}^{r}\right)$ produced from the resource mining group. PMGs on the first tier also receive machinery from the cultural specific meta inventory, like ERGs and only from other production groups if the meta inventory is empty. All PMGs also create pollution during the production process.

Life means groups (LMGs) produce the final life means (lm) that agents consume. The means are produced with person-hours and machinery (produced by the last tier of PMGs) and the final output is delivered to the life groups, which then distribute it to their members. The production process of the LMGs also creates pollution.

Care means groups (CMGs) produce transpersonal care means (tcm), e.g. schools & hospitals. As an input, person-hours as well as machinery produced by the lowest tier of the PMGs is necessary. The output is delivered to the agents directly. In difference to life means, care means cannot be stored in any inventories. Moreover, the planning process functions differently in CMGs than in all the other groups.

In the following, a concise list of all productive group variables is presented. All productive groups have the same variables and parameters. The setup and development however vary between the sectors (as can be seen in section 5: Initialization).

Productive groups' state variables and parameters:

(variable name as used in the code and, if applicable, the variable used in the equations provided in this document)

Variable name (code)	**Description**	**Variable (equations)**
kind	Group type, sector of the group (PMG LMG CMG AG ERG ESG)	
Sector-level	Only applicable for PMG: sector tier	
culture	Culture of the group, dependent on culture of members	
prod-inclusiveness	Inclusiveness of accepting new people to the group	

update-group-culture-counter	Counter to asynchronize updates	
	Exclusion parameter	$ex_{i,t}$
my-possible-cultures-list	Cultures the group is willing to cooperate with	
coop-prob	Probability to cooperate with other cultures	
betweenness-centrality	Betweenness centrality of the group	
closeness-centrality	Closeness centrality of the group	
Production		
labour-productivity	Productivity of the persons: needed person-time for the production of one mean	a_4^{sector}
time-needed	Additional person time needed to reach the targeted production (gap between available and planned time)	
time-available	Currently available person-time, in hours	$x_{j,t}^{ph}$
time-used	Person time used during the production process	
time-planned	Person time needed to reach the targets production	
depreciation	Capital depreciation	a_8^{sector}
pm-intensity	Capital intensity parameter: needed production means (machines) for the production of one mean	a_5^{sector}
available-machines	pm-intensity * PM-current	
available-resources	ER-intensity * ER-current	
PM-current	Production means currently available in units	$x_{j,t}^{pm}$
PM-target	Production means needed to reach the planned output	
PM-needed	Additional production means needed to reach the targeted production (gap between available and planned production means)	
PM-received	Production means received	
ER-current	Resources currently available	$x_{j,t}^{r}$
ER-target	Resources needed to reach the planned output	
ER-needed	Additional resources needed to reach the targeted production (gap between available and planned resources)	
ER-received	Resources received	
ER-intensity	Resource intensity parameter: needed resources for the production of one mean	a_6^{sector}
Demand		
total-demand	Total amount of means demanded from the group	
total-provision	Total amount of means produced by the group	
demand-history	Total amount of means demanded from the group in th epast 4 weeks	
Output		
planned-output	Planned production	
output	Produced means	$q_{j,t}$
output-history	Produced means in the past 4 weeks	
prod-adjustment	Adjustment of the planned production volume	
Inventory		
inventory	Current amount of produced means in the inventory	
reserve-target	Planned inventory left over after delivery of means	
waste-rate	% of inventory that is destroyed after each week	a_7^{sector}
Relations to the environment		
planned-emission	Expected emissions caused during the production process	

planned-sink-destruction	Expected destruction of sinks caused during the production process	
emission	Total emissions caused per produced output	
emission-intensity	Emissions per produced unit	
emission-intensity_abs	Absolute emissions per produced unit	
sink-intensity	Sinks destroyed during the production process of one mean	
Group conditions		
cond-old	Past condition, mean of time- and prod-cond in t-1	
cond	Current condition, mean of time- and prod-cond	
time-cond-old	Past time condition of group in t-1 (relation of used time to available time)	
time-cond	Current time condition of group in t-1 (relation of used time to available time)	
PM-cond-old	Past productive mean condition of group (relation of PM-current and PM-target) in t-1	
PM-cond	Current productive mean condition of group (relation of PM-current and PM-target)	
prod-cond-old	Past productive condition of group (relation of iCM-current and iCM-target) in t-1	
prod-cond	Current productive condition of group (relation of iCM-current and iCM-target)	
planning-cond-old	Past planning condition of group (relation of planned-output and output) in t-1	
planning-cond	Current planning condition of group (relation of planned-output and output)	
demand-cond-old	Past demand condition of group (relation of provision and demand) in t-1	
demand-cond	Current demand condition of group (relation of provision and demand)	
ER-cond-old	Past resource condition of group (relation of ER-current and ER-target) in t-1	
ER-cond	Current resource condition of group (relation of ER-current and ER-target)	
eco-cond-old	Past eco condition of group (relation of own emissions to emissions of other groups) in t-1	
eco-cond	Current eco condition of group (relation of own emissions to emissions of other groups)	
Group mean of group-members conditions		
SvN-cond-gm	Mean of SvN-cond of all members of the group	
SvN-LM-gm	Mean of SvN-LM-current of all members of the group	$lm_{pgm,j,t}^{target}$
SvN-tCM-gm	Mean of SvN-tCM-current of all members of the group	
SvN-iCM-gm	Mean of SvN-iCM-current of all members of the group	
SvN-iCM-cond-gm	Mean of SvN-iCM-cond of all members of the group	
SvN-iCM-emo-gm	Mean of SvN-iCM-emo of all members of the group	
SvN-iCM-moti-gm	Mean of SvN-iCM-moti of all members of the group	
SvN-LM-cond-gm	Mean of SvN-LM-cond of all members of the group	
SvN-LM-emo-gm	Mean of SvN-LM-emo of all members of the group	
SvN-LM-moti-gm	Mean of SvN-LM-moti of all members of the group	
SvN-tCM-cond-gm	Mean of SvN-tCM-cond of all members of the group	
SvN-tCM-emo-gm	Mean of SvN-tCM-emo of all members of the group	
SvN-tCM-moti-gm	Mean of SvN-tCM-moti of all members of the group	
SvN-emo-gm	Mean of SvN-emo of all members of the group	$emo_{group,j,t}^{k}$

SvN-moti-gm	Mean of SvN-moti of all members of the group
PrN-cond-gm	Mean of PrN-cond of all members of the group
PrN-emo-gm	Mean of PrN-emo of all members of the group
PrN-moti-gm	Mean of PrN-moti of all members of the group
P-emo-gm	Mean of P-emo of all members of the group
P-LG-cond-emo-gm	Mean of P-LG-cond-emo of all members of the group
p-PrG-cond-emo-gm	Mean of p-PrG-cond-emo of all members of the group
p-env-cond-emo-gm	Mean of p-env-cond-emo of all members of the group
p-soci-cond-emo-gm	Mean of p-soci-cond-emo of all members of the group
P-moti-gm	Mean of P-moti of all members of the group
P-LG-cond-moti-gm	Mean of P-LG-cond-moti of all members of the group
p-PrG-cond-moti-gm	Mean of p-PrG-cond-moti of all members of the group
p-env-cond-moti-gm	Mean of p-env-cond-moti of all members of the group
p-soci-cond-moti-gm	Mean of p-soci-cond-moti of all members of the group
Group mean of characteristics of members	
ego-level-gm	Mean ego-level of all members of the group
eco-level-gm	Mean eco-level of all members of the group
prod-level-gm	Mean of prod-level of all members of the group
leisure-level-gm	Mean leisure-level of all members of the group

Table 3: Productive groups' state variables and parameters

3. Process overview and scheduling

3.1. Overview timing of events

Time in the simulation is modelled in discrete time steps. One tick represents one week. All events are carried out at every time step, in the order as they are presented below.

Group updates

- All productive groups update the current conditions: time condition, production condition, demand condition, resource condition (only PMG1), planning condition (for all except ESG), ecological condition, overall group condition (mean of all other conditions)
- All life groups update the current conditions: Time condition, Production condition

Group signals

- Productive groups signal to agents that the sector needs more help, if they had a lack of people in the past round, contacted agents increase priorities slightly

Agent updates

- Agents update their conditions based on the experiences in the past period (see equation 8 in section 3.2.)
- Agents update their emotions and motivation (see equation 9 in section 3.2.)
- Agents calculate their need for care
- Agents update their sensual vital needs (see equation 2-5 in section 3.2.)
- Agents update their wellbeing
- Agents update their priorities (see equation 10-12 in section 3.2.)
- Agents update their productive needs (see equation 6-7 in section 3.2.)
- Agents update their characteristics (every 24 ticks, asynchronously) (see equation 1 in section 3.2.)

Groups plan production (ex-ante coordination)

- Life groups collect the information how many life means their members would like and send this information to the Life Means Groups
- Life Means Groups (LMGs)

    - LMGs plan production based on the orders received from the life groups (agents needed and production means needed)
    - LMGs try to find and enrol new members
    - LMGs order the needed production means from the lowest-tear production means groups
- Care Means Groups (CMGs)
    - CMGs plan production based on the past demand (only sector applying ex-post coordination)
    - CMGs try to find and enrol new members
    - CMGs order the needed production means from the lowest-tear production means groups
- Production means groups (PMGs (tiers n – 2 → starting with highest-tear PMGs, moving stepwise to the next lower tiers, until second-tier PMGs are reached))
    - PMGs plan production based on the orders received from the previous groups (agents needed and production means needed)
    - PMGs try to find and enrol new members
    - PMGs order the needed production means from the next higher-tear production means groups
- Production means groups (PMGs (tier 1))
    - PMGs (tier 1) plan production based on the orders received from the previous groups (agents needed and production means needed)
    - PMGs (tier 1) try to find and enrol new members
    - PMGs (tier 1) order the needed production means first from the meta-inventory, if this does not cover all production means needed, then they order from one of the other PMGs
    - PMGs (tier 1) order the needed resources from the first from environmental resource groups
- Environmental resource groups (ERGs)
    - ERGs plan production based on the orders received from the PMGs on tear one (agents needed and production means needed)
    - ERGs try to find and enrol new members
    - ERGs order the needed production means first from the meta-inventory, if this does not cover all production means needed, then they order from one of the PMGs
- Environmental sink groups (ESGs)
    - ESGs plan production based on the forecasted emissions from all other productive groups
    - ESGs try to find and enrol new members
    - ESGs order the needed production means first from the meta-inventory, if this does not cover all production means needed, then they order from one of the PMGs

Production and delivery by productive groups

- ERGs produce resources and deliver these to the PMGS on tear 1
- PMGs (starting with tear 1, moving stepwise to the next higher tears, until tear n is reached) produce productive means and deliver these to the PMGs in the tear below
- PMGs (tear n) in the final tear produce productive means and deliver these to the CMGs and LMGs
- LMGs produce life means and deliver these to the life groups
- CMGS produce transpersonal care means and store them until needed
- ESGs produce sinks, which are added to the global sink stock

Biophysical processes

- Pollution levels are reduced by the sinks

Care consumption

- Agents contact CMGs and receive, if possible, the requested transpersonal care means

Production and delivery by life groups

- Life groups check how many interpersonal care means their members need
- Life groups produce interpersonal care means
- Life groups distribute interpersonal care means to their members

- Life groups distribute the life means they received from the LMGs to their members

3.2. List of equations

Equation numbers correspond to number in the paper publication.

Agents

Personal characteristics (update of all four characteristics):

$$c_{i,t}^{k} = c_{i,t-1}^{k} + \left(\left(0.5 * \ c_{pgc,ideal}^{k} + 0.5 * c_{lgc,ideal}^{k}\right) - c_{i,t-1}^{k}\right) * 0.05 * \left(1 - c_{i,t-1}^{ego}\right) \quad (1)$$

Sensual vital needs (target values for icm, tcm, lm):

$$icm_{i,t}^{target} = icm_{min} + w_{i,t} * icm_{min} * a_1 * \left(0.5 + \left(N\left(c_{i,t}^{ego}; 0.1\right)\right)\right) \quad (2)$$

$$tcm_{i,t}^{target} = tcm_{min} + w_{i,t} * tcm_{min} * a_1 \quad (3)$$

$$gi_{i,t} = \left(mean\left(lm_{pgm,j,t-1}^{current}; lm_{lgm,j,t-1}^{current}\right) - lm_{i,t-1}^{current}\right) * c_{i,t}^{ego} * ei_{i,t} * \left(randomfloat\left(1 - c_{i,t}^{eco}\right)\right) \quad (4)$$

$$lm_{i,t}^{target} = lm_{i,t-1}^{current} * \left(1 + randomfloat\left(c_{i,t}^{ego} * wi_{i,t}\right) + gi_{i,t}\right) \quad (5)$$

Productive needs (target value productive time):

$$pt_{i,t}^{total} = 112 * \left(1 - c_{i,t}^{leasure}\right) * \left(1 + \frac{\left(1 - emo_{i,t}^{mean}\right)}{2}\right) \quad (6)$$

$$pt_{i,t}^{target} = pt_{i,t}^{total} * \left(1 - \left(\left(1 - w_{i,t}\right) * ct_i\right)\right) \quad (7)$$

Conditions:

$$cond_{i,t}^{need} = \frac{need_{i,t}^{current}}{need_{i,t}^{target}} \quad (8)$$

Emotions:

$$emo_{i,t}^{k} = emo_{i,t-1}^{k} + \left(emo_{group,j,t-1}^{k} - emo_{i,t-1}^{k}\right) * a_2 * \left(1 - c_{i,t}^{ego}\right) \quad (9)$$

Priorities:

$$prio_{i,t}^{svn-k} = prio_{i,t-1}^{svn-k} + \left(randomfloat\left(\left(\left(1 - emo_{j,t}^{svn-k}\right) + moti_{j,t}^{svn-k}\right)/2\right)\right) + 0.5 \quad (10)$$

$$prio_{i,t}^{lg} = prio_{i,t-1}^{lg} + \left(1 - emo_{group,j,t}^{k}\right) * a_3 * c_{i,t}^{ego} \quad (11)$$

$$prio_{i,t}^{pgs} = prio_{i,t-1}^{pgs} + \left(1 - emo_{group,j,t}^{k}\right) * a_3 * \left(1 - c_{i,t}^{ego}\right) \quad (12)$$

Groups:

Production function:

$$q_{j,t} = a_4^{sector} * min\left(a_5^{sector} * x_{j,t}^{pm}\right)\left(x_{j,t}^{ph}\right)\left(a_6^{sector} * x_{j,t}^{r}\right) \quad (13)$$

4. Design concepts

4.1. Basic principles

We present a novel approach for the development of concrete utopias via large-scale in-silico experiments, operated through computational social simulations, in particular agent-based simulations. Theoretically, the utopian perspective investigated is aligned with the radical commons discourse (Ruivenkamp & Hilton 2017) and in particular with the conception of "commonism" (Sutterlütti & Meretz 2018; 2022). This commons-based utopia highlights the complex relations between micro (the individual), meso (the commons) and macro (the society). It is, to our knowledge, the first approach developing a thorough micro foundation, i.e. critical psychology (Holzkamp 1983; 2023), a clear meso conception of the dynamics of commons and their constituent practices of commoning (de Angelis 2017) as well as a discussion of political economic processes and structures crystallizing on the societal level of commons.

The allocation of means is one of the central challenges in the artificial commons society. To demonstrate the resilience of the model depending on different assumptions of exclusive and inclusive allocation behaviour, we conduct a series of simulation experiments to test different allocation mechanisms within COMMONSIM. In particular, we test the robustness of commonism in context of exclusion and inclusion between cultures, as aforementioned, coordination by: (1) inclusive allocation, (3) culture dependent allocation and (3) exclusive allocation. These three setups correspond to our baseline scenarios:

(1) Exclusive allocation: Groups only want to sent means to and receive means from groups with the same culture.

(2) Inclusive allocation: Groups are agnostic about the culture of the other groups. They don't distinguish between the groups, regardless of their culture, and potentially receive from and sent to all other groups.

(3) Culture dependent allocation: The groups behave differently, depending on their culture. The default is the inclusive allocation mechanism. However, based on the exclusion parameter $(ex_{i,t})$, a group may act on the exclusive allocation mechanism. The exclusion parameter is culture specific, the value is the mean of the representative value of the ego-level and productive-level of each culture. With the probability of $(ex_{i,t})$, a group updating the network may replace the inclusive mechanism with the exclusive. The result is that it may delete links to groups of other cultures or prohibit the creation of links to groups from other cultures. Groups with a high exclusion parameter therefore have much less links to groups with other cultures than the ones with a low exclusion parameter.

On top of this, we test two different institutional mechanisms (common inventory, indirect reciprocity) for the case of exclusive allocation, on their capacities to stabilize reproduction on the whole.

(a) *Common inventory:* The common inventory mechanisms is a centralized planning mechanism, which implements more cooperation between the cultures. Instead of the culture specific meta inventories, all productive groups contribute to a common inventory, which is accessible for all ERGs and PMG1s, regardless of their culture.

(b) *Indirect reciprocity*: The indirect reciprocity mechanism is a decentralized institutional mechanisms, which facilitates a reaction to crisis based on group interaction. Groups are willing to support each other if they expect a favorable treatment of their own culture. This may induce a long-term change of norms & cooperation behavior, as will be tested in the experiments. The indirect reciprocity mechanism functions in the following way: If productive-groups face a shortage of available production means, they seek support from other productive-groups in the same sector by asking for production means. The contacted group

decides to share the own production means (not the produced means but the ones used for production) on two premises: own production targets are reached at least 90%, and the group asking for help sends means to the culture of the helping group. If both conditions are met, the transaction takes place and 10% of the production means are transferred from the helping to the asking group. If the group in need does not receive support because it does not meet the criterion of cooperation with another culture, it increases the cooperation-willingness. If a threshold (x) is passed, it adds more cultures to the possible cooperation partners. This increases the chances that it receives support in the future.

For parameter settings of all experiments see section 5 on initialization.

4.2. Emergence

The baseline model is tested on behalf of exclusive-, inclusive allocation, as well as a culture-dependent allocation mechanism. Inclusive and culture dependent allocation show stability of the system, in which the needs of the agents can be satisfied. Exclusive allocation however cannot provide stability for groups with certain cultural traits. Results of the two different institutional mechanisms tested in the context of the exclusive allocation mechanism (common inventory and indirect reciprocity) indicate the success of both mechanisms to stabilize cooperation on large scale, although with different dynamics on the meso level analysis of the networks' complexity.

4.3. Adaptation

All agents adapt the needs for life means based on the past consumption and the consumption in the network. They adapt the need for inter- and transpersonal care means depending on the care parameter ($w_{i,t}$). Moreover, they adapt their productive needs based on the emotional evaluation of the overall situation. The emotional evaluation is also adapted, based on the current conditions as well as the emotional evaluation of the other agents in their network. They adapt the priorities for the different needs and sectors based on the emotions and signals received from productive groups. Regarding their networks, agents can adapt a list of sectors they are willing to be active in, depending on their priorities, and can decide to leave the productive group in which they are currently spending time.

Groups adapt the targeted production volumes based on the requested means from the sector they deliver the means to (see Fig. 1. Basic structure and flow-chart of the model). If necessary, they increase the production volume by ordering more production means and by finding more agents that are willing to participate in the group.

4.4. Objectives

Agents are striving to fulfil their needs (sensitive-viral and productive needs). Since the production network is the basis for the satisfaction of needs, agents are also interested in making sure it is functioning well, hence they will change the priorities to become active in the sectors that need support.

Groups have the objective of producing as many means as requested, and in the case of ESG, as many sinks as needed.

4.5. Prediction

The general production mechanisms are not based on predictions, since the idea of commonism lies on ex-ante coordination, where the groups don't predict how much will be needed, but act upon the actual requests. Care means groups however function a little bit differently. They are planning their production volumes based on past demand. From this past demand, they are inferring how much will probably be needed in the future.

4.6. Sensing

There are different types of information, the agents can sense. First of all, they are able to perceive the actual and targeted sensitive-vital and productive needs, as well as the emotions of the agents in their networks (the agents that are part of the same life- or productive groups). Moreover, agents can receive information from the groups if they need more support and can perceive the overall environmental and societal condition.

Groups receive the information of requested means directly via links from the agents or groups to whom they deliver the means (depending on the sector). Groups can also receive the information with which cultures another group cooperates.

4.7. Interaction

An overview of all interactions can be seen in Fig. 1 (Basic structure and flow-chart of the model).

Agents spent time in life groups and productive groups and produce the different means. They receive transpersonal care means from care means groups (CMG) and receive interpersonal care means from their life groups (LG). They also receive life means from their life groups, which procure the life means on their behalf. Agents are influenced in their decisions/needs/emotions/priorities from the other agents they are connected with via the groups they are part of. Moreover, agents can receive signals from productive groups they are not part of, if these groups are facing difficulties and want to motivate agents to become active in these sectors.

Life groups communicate the life means wishes of their members to the life means groups (LMG). They receive the life means from the LMGs and distribute them to their members. Moreover, life groups produce the interpersonal care means based on the needs of the members and distribute them between the members after production.

Care means groups (CMG) receive production means (machines) from the last tier of production means groups. They distribute the produced transpersonal care means directly to the agents who request the means.

Life means groups (LMG) get the requests for life means from the life groups and receive production means needed for the production process from the last tier of production means groups. They sent the produced means to the life groups.

Production means groups (PMG) get the requests for the needed production means from the next tier (PMG1 from PMG2,...). The final tier (PMGn) collects the request from the life means groups. They sent the produced means to the same tier that sent the requests. The first tier (PMG1) requests resources from the environmental resource groups and receives production means from the culture specific meta inventory (a storage for production means, filled by all production means groups of the same culture).

Environmental resource groups (ERG) get the requests for resources from the first tier PMGs and sent the resources to the same groups. Like PMG1s, they receive the production means from the culture specific meta inventory.

Environmental sink groups (ESG) observe the environment and assess how many sinks are needed based on the information collected. Like PMG1s and ERGs, they receive the production means from the culture specific meta inventory.

All production groups (CMG, LMG, PMG, ERG, ESG) can also interact with groups in the same sector (and on the same tier, in the case of PMGs), under the indirect reciprocity mechanisms. If a group faces a crisis and has a lack of production means, they can contact the other groups and ask for a delivery of

production means (from their own stock). The contacted groups decide based on the condition of own productivity and cooperation behaviour from the asking group. For more details see section 4.1 Basic principles.

Moreover, all production groups produce pollution, which accumulates over time. The sinks sequest the pollution.

4.8. Stochasticity

Stochasticity in setup:

- The initial networks are assigned randomly
- The size of the life groups is a random number between 1 and 10
- The agent are initialized with random elements:
    - Characteristics are assigned based on the culture of the productive group they are part. The values of the characteristics are equally distributed in the range of the respective culture (see table 6 in section 5 on initialization)
    - Starting targets of agents are assigned based on a normal distribution around the variable icm-start (which can be set on the interface)
    - Priorities are assigned based on a normal distribution around the value 0.5

Stochasticity during the simulation:

- Agent updates:
    - Agents have an extra care need with a certain probability (Probability for care need, $prob_1$)
    - Target updates have a little random element, which can reduce and increase the targets slightly, the amplitude of the random element is given by the ego ($c_{i,t}^{ego}$) and eco ($c_{i,t}^{eco}$) parameter
    - Priorities are updated based on the emotions, the maximum change is given by the emotions, a random mechanisms implements a change up to the maximum change
- Group processes:
    - Groups who have too few members connect with a random agent that is generally willing to join the respective sector or is currently not part of any productive group
    - In the culture-dependent allocation setting, groups are falling back to the exclusive allocation with the probability of the exclusion parameter
    - In the indirect reciprocity setting, groups are willing to cooperate with other cultures with the probability of cooperation-willingness (coop-prob)

4.9. Collectives

All agents are part of life groups, which have 1 – 10 members. These groups do not change over time. Moreover, agents can be part of productive groups, which are larger groups, with often more than 100 agents (depending on the initial setup of number of agents and number of productive groups). The members of productive groups change over the course of the simulation. All groups are represented as individual entities. The agents are connected to the groups via links. Agents are affected in their needs and decisions by the networks (as described in subsection 4.3 Adaptation and 4.6 Sensing).

Cultures are another form of loose collectives. Each agent and every group belongs to one of the four cultures. While the culture influences the behavior of the agents in the form of the personal characteristics, groups act and make decisions based on the current culture. If there is a lack of agents in a sector, groups inform agents from the same culture to increase the priority for the sector in need. Moreover, groups update their networks based on the culture (depending on the chosen These

decisions include the creation of the networks (links to and from other groups via which means are sent and received).

4.10. Observation

The data was collected during the simulation of each experiment at every timestep with Netlogo's built-in BehaviorSpace experiment management engine to repeat experiments with different random seeds. Aggregate time series data was generated directly by BehaviorSpace. Data analysis and visualization was realized using the R language (with the ggplot2 package). Experiments were repeated 100 times with different random seeds, in order to inform on the stochasticity of the model. Overall, we conducted 500 runs in total, each with 2000 turns/ticks (~40 years in simulated time). The following variables were collected at every time step:

Agents:

- Mean motivation of agents
- Mean emotions of agents
- Wellbeing of agents
- Total planned and actual consumption of agents per tick
    - Interpersonal care means
    - Transpersonal care means
    - Life means
- Mean planned and actual time of agents spent in life groups
- Sector priorities of agents
- Minimum and mean conditions of agents
- Share of agents not in productive groups

Groups:

- Mean condition of productive groups per culture
- Culture inventories
- Size of sectors, measured in persons active in the respective sector
- Size of sectors, measured in person hours spent in the respective sector
- Number of groups per sector
- Number of groups per culture
- Mean size of productive groups per sector
- Mean number of links per sector
- Total demand of productive groups per sector
- Total output of productive groups per sector
- Mean betweenness centrality per culture
- Mean closeness centrality per culture
- Betweenness centrality of every production group at every step
- Closeness centrality of every production group at every step
-

5. Initialization

The initial settings used for the simulation experiments described in the manuscript "COMMONSIM – Simulating the utopia of COMMONISM: Agents, networks, commons, group culture and inclusive social economic provisioning" is presented in the tables below. These settings require high computational power, as provided by a simulation cluster for instance (used for the simulation experiments of the main manuscript). If the model is run on desktop computers, we recommend a slightly adapted,

reduced initialization (see “reduced init” in the table below for population size and number of groups), all other values can be the same. The reduced version is still demanding in terms of computational power, but should guarantee an appropriate testing environment. In the model version available on COMSES, the reduced version can be initialized by setting the chooser “Network-setup” to “reduced-REPE-setup”.

System setup	**Value**	**Variables used in equations**
Population size (slider on interface)	10000 (3000 for reduced init)	
Number of ERGs (slider on interface)	12 (4 for reduced init)	
Number of ESGs (slider on interface)	8 (4 for reduced init)	
Number of PMGs per sector (slider on interface)	12 (8 for reduced init)	
Number of PMG sectors (slider on interface)	3	
Number of LMGs (slider on interface)	12 (4 for reduced init)	
Number of CMGs (slider on interface)	8 (4 for reduced init)	
Number of connections	3	
Initial level of culture inventories	100000	
Waste rate of culture inventories	0.05	
Environment		
Initial level of pollution	0	
Initial level of sinks	50	
Sink productivity	1000	
Pollution multiplier	1	
Agents		
tcm minimum: Minimum demand of transpersonal care means	4	tcm_{min}
Initial demand of transpersonal care means	5	$tcm_{i,t0}^{target}$
icm minimum: Minimum demand of interpersonal care means	20	icm_{min}
Initial demand of interpersonal care means	21	$icm_{i,t0}^{target}$
lm minimum: Minimum demand of life means	3	lm_{min}
Initial demand of life means	5	$lm_{i,t0}^{target}$
Severity of care need	[0;1]	$w_{i,t}$
Probability for care need	0.07	$prob_1$
Link between care demand and time spent by agents	0.5	ct_i
Ego level	[0;1] (depending on culture, see table 6 below)	$c_{i,t}^{ego}$
Leisure level	[0;1] (depending on culture, see table 6 below)	$c_{i,t}^{leisure}$
Eco level	[0;1] (depending on culture, see table 6 below)	$c_{i,t}^{eco}$
Productivity level	[0;1] (depending on culture, see table 6 below)	$c_{i,t}^{prod}$
Characteristic trends of cultures	[0;1] (depending on culture, see table 7 below)	$c_{prg,trend}^{k} \wedge c_{lg,trend}^{k}$
General adaption rate of agent-to-group values	0.2	a_2
General adaption rate of agent priorities for life and productive groups	0.05	a_3
Multiplier of severity of extra care demand	2	a_1

Table 5: Agent and environment parameter initialization

Ecologist Culture	ego-level	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
	leisure-level	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
	eco-level	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
	prod-level	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
Traditionalist Culture	ego-level	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
	leisure-level	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
	eco-level	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
	prod-level	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
Modernist Culture	ego-level	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
	leisure-level	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
	eco-level	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
	prod-level	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
Random Culture	ego-level	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
	leisure-level	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
	eco-level	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
	prod-level	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1

Table 6: Agent characteristic combinations for each culture

	Ego-trend	**Leisure-trend**	**Eco-trend**	**Prod-trend**
Ecologist Culture	0.1	0.6	0.9	0.1
Traditionalist Culture	0.9	0.1	0.1	0.9
Modernist Culture	0.1	0.5	0.5	0.9
Random Culture	Randomfloat 1	Randomfloat 1	Randomfloat 1	Randomfloat 1

Table 7: Characteristic trends of cultures

Life Groups	
Groupsize	[2;10]
Labour productivity for production of one icm	1 / 7

Table 8: Life group parameter initialization

Productive Groups		**ESG**	**ERG**	**PMG1**	**PMG2**	**PMG3**	**LMG**	**CMG**
Labour productivity	a_4^{sector}	1	1.5	1.2	1	0.8	2.1	1
Productive means intensity	a_5^{sector}	1	1	0.6	0.6	0.6	0.4	0.4
Resource intensity	a_6^{sector}	-	-	1.4	-	-	-	-
Reserve target		-	0.6	0.8	0.6	0.2	0.2	0.2
Waste rate of inventory	a_7^{sector}	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Depreciation rate of productive means	a_8^{sector}	0.02	0.1	0.15	0.15	0.15	0.2	0.1
Pollution intensity		0.1	0.75	0.8	0.6	0.7	0.3	0.4
Absolute pollution intensity		1	100	1000	100	500	1	0.1
Sink intensity		-	1	-	-	-	-	-

Table 9: Productive group parameter initialization

6. Input data

The model does not use input data.

7. References

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