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The Emergence of Institutions for the Management of the Commons

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***Abstract*—In this paper we present an abstract replication of institutional emergence patterns observed in common pool resource (CPR) problems. We used the ADICO grammar of institutions as the basic structure to model both agents' strategies and institutions. Through an evolutionary process, agents modify their behaviours and eventually establish a management institution for their CPR system, leading to significant benefits both for them and for the commons as a whole. We showed that, even if our model has a high level of abstraction, by taking an evolutionary perspective and using the ADICO structure we are able to observe common institutional patterns. We confirm that institutions do indeed contribute to the sustainable management of common pool resource systems.**

Keywords: Common pool resource, institutions, norm, emergence, evolutionary modelling

I. Introduction

Four decades of research have shown that Hardin's *Tragedy of the Commons* [5], although frequently occurring in open access resources, can be avoided thanks to the building of carefully-designed endogenous institutions [1], [12], [13]. However, the specific processes leading to institutional change are often difficult to study in the field due to the large number of factors potentially involved, and because such processes often occur on temporal scales beyond the scope of most social science research [18]. Laboratory experiments may offer a way out of the problem, and they indeed significantly contribute to our understanding of the dynamics of common-pool resource (CPR) situations [14]. Nevertheless, the number and nature of factors that can be reasonably tested in the lab is limited. For instance, it is difficult to design experiments involving long-term interactions among participants or doing studies needing large samples of subjects. For these reasons, the development of commons management institutions needs also research going beyond what is reasonably to achieve in the lab or in the field.

Agent-based models (ABM) represent an interesting alternative to both methods. Their main advantage is that they allow to design virtual experiments using more flexible set of conditions than what is feasible in the lab and to analyse their long term dynamics more easily than what is possible in the field [2], [18]. Using ABMs, it is indeed possible to design complex models that are able to capture the effect of a large number of factors on CPR management. The outcomes may be subsequently compared with empirical findings to test the models ability to reproduce patterns and dynamics observed in the real world [8], [19], [21].

In this work, we present an ABM designed to replicate patterns of institutional emergence commonly observed in the field. It is based on the "grammar of institutions", first introduced by Crawford and Ostrom [3], and takes an implicit evolutionary approach to explain the dynamics of CPR management institutions as emerging from the beliefs and actions of users. This is in line with what we have learned from both commons research, including Ostrom's work [12], [13], [16], and institutional economics, with a specific reference to North [10], [11].

In our model, agents representing CPR users are endowed with a set of behavioural strategies based on the ADICO grammar [3], but can also learn by copying others or by exploring new possibilities. Moreover, when unsatisfied with the current state of affairs, they can engage in collective action in order to collectively manage their resource through an institution defined as an ADICO rule. Although in the first phases of its development, the current model is already able to replicate common dynamics of institutional emergence and allows us to reach a better understanding of the process underlying the development of CPR management institutions.

The structure of this paper is as follows. Section II introduces the definition of institutions that will be used in the paper and provides background on common pool resource management problems. Section III defines our ABM allowing the emergence of institutions for CPR management. Section IV discusses simulation results. Finally, Section V gives the concluding remarks.

II. Background

A. Common-Pool Resource Systems

Common-pool resources are natural or man-made resources shared among different users [12]. This produces competition that often (although not necessarily) leads to their degradation or even to destruction. Many natural resources fall in this category and are today "chronically" overused. Examples are forests, fisheries, water basins, biodiversity and even the atmosphere.

Formally, the expression *common-pool resource* refers to a class of goods defined by two characteristics: a difficult *excludability* of potential beneficiaries and a high degree of *subtractability* (i.e., rivalry of consumption) [16]. Thus, the CPRs share characters with both private and public goods, namely a high subtractability with the former ones and a low possibility of exclusion with the latter ones. This makes the management of CPRs especially complex: as in the private good case, the consumption of resource units (e.g., extraction of timber from a forest, of water from a basin, etc.) by one user reduces the total quantity of units available to the other ones; as in the public good case, it is difficult to prevent any user from continuing to subtract units from an endangered resource (e.g. the ocean fisheries). This led Hardin to picture the commons problem as a social dilemma in his famous article *The Tragedy of the Commons* [5]. Formally, this can be seen as a n players version of the Prisoner's dilemma or, more properly, as a CPR game, as first proposed by Walker and colleagues [22]. In both cases, no user has rational incentives to limit his/her consumption and, hence, the possibility to avoid the resource degradation or destruction is extremely low.

Subsequent authors followed Hardin in presenting CPR management as a social dilemma and in formalizing it using different variations of the games above [4], [16]. These all share the idea that the rational equilibrium of the game is well below the collective optimum theoretically achievable by restricting resource use to a sustainable level. Nevertheless, in contrast with theoretical predictions, empirical research has shown that successful management of the resources can be achieved by building endogenous institutions [1]. More specifically, the "tragedy" is avoided thanks to institutions that define clear exploitation rights and create incentives to prevent resource overuse. In other words, the tragedy of the commons is the tragedy of open-access resources, not necessarily of well managed CPRs.

Being institutional building the main way out of the dilemma, the question becomes how to favour this process. Empirical research trying to answer this question has been summarized in Ostrom's "diagnostic approach" [15], which includes a large number of factors potentially affecting the outcome of interaction in CPRs situations. Nevertheless, selecting which factors are actually relevant in a given situation remains a non-trivial task. What is still missing in guiding this choice is a clearer picture of the mechanisms behind the emergence of institutions in CPR situation. ABMs represent an appropriate tool for this endeavour thanks to their capacity of linking the micro and macro-levels of social behaviour [6], [21]. However, a rigorous characterization of institutions becomes crucial to fully exploit the analytical capacity of these models.

B. Institutions

In economics, institutions are usually defined as "the set of rules actually used by a set of individuals to organize repetitive activities that produce outcomes affecting those individuals and potentially affecting others" [10].

Institutions enable interactions, provide stability, certainty, and form the basis for trust. They may however, keep people stuck in unsustainable behaviours or lead to biased power relations. If institutions fail to fulfil stability or to enable sustainable decisions, there are grounds for institutional (re)design [9], [13].

Institutional (re)design refers to the devising of new social arrangements, by examining existing arrangements and changing them if necessary [17]. In order to design institutions, one should be able to understand and analyse the institutional rules. Similarly, institutional frameworks such as Ostrom's *Institutional Analysis and Development* (IAD) framework were developed to study institutional change on the basis of a systematic analysis of the different components of a socio-ecological, system and their relations [13].

The IAD decomposition of a social-ecological system is presented in Fig. 1. Its key component is the 'action arena', in which participants interact and perform appropriation and provision activities. Besides the participants (who have access to resources and information among others), the action arena also includes action situations where the actual activities (or 'games') take place.

The activities in the action arena lead to patterns of interaction and outcomes that can be judged on the basis of evaluative criteria illustrated on the right side of Fig. 1. The action arena is influenced by attributes of the physical world (e.g., climate), the attributes of the community in which the actors/actions are embedded (e.g., demographics, shared beliefs), and the set of rules that govern actor behaviour. The rules of the game (i.e., the institutions) are a major influence actual on the structure of behaviours and interactions. Therefore, in the IAD framework much attention is given to institutions, which are structured using the *ADICO grammar of institutions* [3], [13].

C. The ADICO Grammar of Institutions

ADICO structures institutional statements into five components: A̲ttributes, D̲eontic, aI̲m, C̲ondition, and sanction (O̲r else). This structure summarizes institutional statements, facilitating the understanding of the formation and evolution of institutions [13].

a) Attributes: Attributes describe the participants in the situation to whom the institutional statement applies. For example, an attribute of an ADICO can be a 'student'.

b) Deontic Type: This components is used to distinguish between 'prescriptive' and 'non-prescriptive' statements. Deontic operators are *obligated*, *permitted* and *forbidden*. When an institutional statement has the deontic type 'obliged' the person *must* perform the action associated to the institution. For example, "a student is obliged to attend 50% of class A in order to be able to sit the exam". On the contrary, for institutions with the deontic type 'forbidden', actors are not allowed to perform the action associated to the institution. For example, "a student is not permitted to take a course twice". The deontic type 'permission' constitutes the action related to the institution or grant rights to participants with certain properties to perform an action. For example, "a student with GPA above 9 is permitted to take more than 100 credits per semester".

c) aIm: The aim component describes the action or outcome to which the institutional statement applies. In order

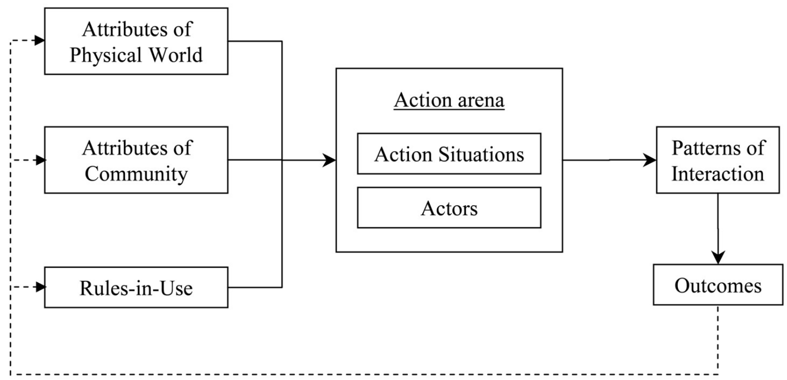

Fig. 1. The components of a social system in the IAD framework [16].

for an institution to influence behaviour, individuals must have a choice concerning its 'aim'. In other words, prescribing an action or outcome only makes sense if its negation is also possible. In the above mentioned examples of institutions, "take course", "sit exam" and "take credit" are the aims of those institutional statements.

d) Condition: Conditions are the set of parameters that define when and where an ADICO statement applies. If there is no condition stated, it implies that the statement holds at all times.

e) Or else: 'Or else' is the consequence of non-compliance to an assigned institutional statement. A common type of 'Or else' is a sanction.

According to the ADICO decomposition, an institutional statement can be divided into three different categories namely: rules, norms and shared strategies.

1) **ADICO**
A *Rule* is the most complete form of institutional statement, covering all five components of ADICO. In other words, rules have attribute, deontic type, aim, condition and 'or else'.
2) **ADIC**
A *Norm*[1] is an institutional statement without an explicit and unique 'or else' component.
3) **AIC**
A *Shared strategy* is an institutional statement where there are no sanctions or deontic type. These kind of statements represent behavioural patterns shared between individuals in a system.

In our model, as we will explain later, we assume that the emerging institutions are norms (of the ADIC type) meaning that agents are obliged to comply with the established institutions but they will not receive an explicit sanction for non-compliance.

[1]Referred to as 'social norm' or even 'moral' or 'ethic code' in multi-agent systems literature.

III. An ABM of Emerging Institutions

A. Model Overview

The model is implemented in Netlogo [23]. It takes the ADICO sequence as a starting point to allow institutions to emerge and evolve in an abstract CPR system. We use the ADICO structure in two different ways. First, we assume that the agents select and follow *individual strategies* structured by the 'A', 'I' and 'C' components of ADICO. Strategy change follows an evolutionary dynamics where unsuccessful agents *copy* other agents or randomly explore new possibilities (*mutation*).

Second, the ADICO sequence is used to structure the management institution that affects the behaviour of all agents. Note that the current model covers only the 'A', 'D', 'I', 'C' components of the ADICO structure but has no sanction. This means that it would be formally more proper to refer to it as a *norm*. However, since in the current version all agents comply with the institution, the distinction is practically irrelevant and we will continue to talk about "institutions". Future developments will include the possibility of rule-breaking for agents and sanctioning, hence including also the 'O' component.

The main feature of the model is that the institution derives bottom-up from agents' strategies through a voting system and can change through time following the evolution of agents' strategies.

B. Model Components

The model consists of the following components:

- Agents: the agents are nodes in a social network defining their neighbourhood. The network is defined in two different ways: (1) random network, (2) small-world network.
- Resource: there is only one resource that is shared between agents in the simulation. The agents gain energy by taking units from the resource. The resource is renewable; in each time step it (re)grows at a rate given by a logistic function with two parameters: the carrying capacity K and the reproduction rate r, which represents the maximum proportional increase of the resource in one time step. The specific function used is a standard

discrete-time logistic. The increase ΔR of the resource R at time t is given by:

$$\Delta R = rR\left(1 - \frac{R}{K}\right) \tag{1}$$

At the beginning of the simulation the resource is set at carrying capacity, while it subsequently changes depending on the amount harvested by agents and on equation (1).

- ADICO components:
  - A. The relevant statements apply to the single agent in case of individual strategies and to all agents in case of the establishment of an institutional rule.
  - D. The deontic is relevant only for the institution (since it is a rule, not a strategy) and is always of the 'obliged' type, which means that agents always follow their strategies or the institutional rule.
  - I. We assumed that all the actions an agent can possibly take are stored in a list. These actions are related to the common resource exploitation. The actions also influence the amount of energy the agents gain. For simplicity, we also assumed that the number of units extracted from the resource is equal to the energy gained by the agent. For example, `eat5` implies that the agent gains 5 units of energy, while the resource is decreased by 5 unit. There is also one action that does not influence the resource, but reduces the amount of agent energy (`eat-5`). This action is included in the action list to represent possible losses that an agent may face through inappropriate behaviour (e.g., fishers losing their boat while trying to fish during a storm).
  - C. We assumed that all the conditions an agent can possibly consider are stored in a list. The conditions specify when and where the agent is allowed to perform its selected action. At a given point in time, each agent has only one action-condition pair.
  - O. As written above, we assumed that all agents follows the rule when an institution is in place. As a consequence, this component becomes non-relevant.
- Institution: in the current model, only one institution at a time can rule the system. This institution, is established by a voting system. Throughout the simulation, the institution changes if the number of agents not performing well (i.e., energy level < 0) is higher than a certain threshold (Tab. I, `threshold for institutional change`). Furthermore, the institution can only change at certain time intervals given by the `institutional emergence time` parameter.

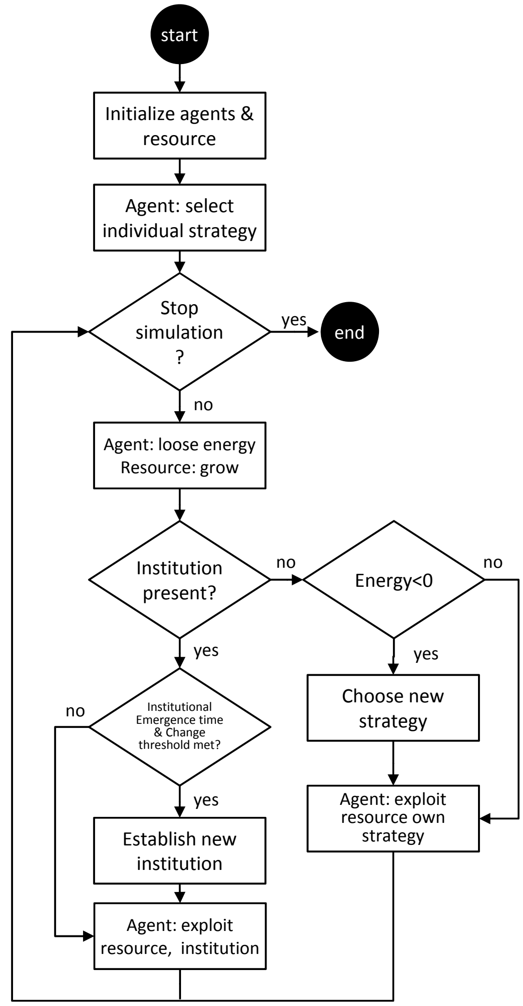

Fig. 2. The simulation procedure

C. Simulation Procedure

The simulation, depicted in the flowchart in Fig. 2, is described below:

- Model setup:
  1) each agent randomly selects a strategy, i.e. a combination of action-condition (AIC);
  2) the resource is initialized equal to the carrying capacity.
- Procedures occurring in every time step:
  1) the resource grows as explained above
  2) agents loose energy according to the `energy consumption` parameter
  3) agents gain new energy by exploiting the resource
  4) each agent checks its current energy level; if it is below 0, it chooses a different action-condition combination using one of the following two procedures:
     – mutation: with a given probability (Tab. I, `mutation rate`), the agent chooses the new action-condition pair (each one separately and randomly) as at the beginning of the simulation;

TABLE I
EXPERIMENTAL SETUP

Parameter	Values
actions	eat $[(n \times 2), 1 < n < 10]$, [-5]
conditions	(ticks mod 3) = 0, (ticks mod 2) = 0, energy <= 0, (ticks mod 20) = 0, (ticks mod 250) = 0, true
initial amount of resource (k)	5000 – 20000 (step 10000)
growth rate (r)	0.1 – 0.5 (step 0.2)
number of agents	100
energy-consumption	1 – 10 (step 5)
mutation rate	0.01 – 0.1 (step 0.05)
threshold for institutional change	0.4. 0.6, 0.8, 1
institutional emergence time	50, 100, 200, 500, 1000
number-of-links	2
rewire-prop	0.05

– copying: the agent chooses the action-condition of the most successful agent in his neighbourhood.

- Institutional change procedures occurring every `institutional emergence` time step:
  1) If a certain proportion of agents (`threshold for institutional change`, Tab. I) has energy below zero, there is call for institutional change. The most frequently used action-condition pair is selected as a new institution. From this point, the agents must comply with the institution, rather than performing their own action-condition pairs.

The simulation end after 2000 ticks or when the resource completely runs out.

D. Simulation Setup

The goal of this preliminary model is to see whether it is possible to replicate the qualitative dynamics of empirical CPR systems using an abstract model of institutional emergence and evolution. More specifically, we compared the outcomes of the CPR system under the institution and no-institution conditions. The underlying question is whether the agents and the resource are better off, when collectively selected institutions are present.

Tab. I shows the experimental setup, including the values used for the parameters introduced in the previous section. The parameter sweep resulted in 3240 runs which were repeated 100 times, which led to a total of 324,000 runs. Half of these runs allowed an institution to emerge, while the other half were without this possibility. For each run, the average energy of the agents, the average amount of resource, and the final selected institution were recorded.

IV. RESULTS

A. Resource and energy

The introduction of the institution affects positively both the amount of resource in the system and agents' energy. This remains true also controlling for the other simulation parameters (Tab. II and III). All parameters except the mutation rate have

TABLE II
OLS ON THE AMOUNT OF RESOURCE REMAINING AT THE END OF THE SIMULATION

	Estimate	Std. Error	t value	Pr(> $\|t\|$)
(intercept)	-4626.0191	38.1777	-121.17	0.0000
institution	3516.6743	15.8985	221.20	0.0000
K	0.5148	0.0013	403.87	0.0000
r	14135.1495	46.7691	302.23	0.0000
energy consumption	-56.1966	2.1591	-26.03	0.0000
institutional emergence time	-1.1240	0.0226	-49.71	0.0000
mutation rate	9.6372	215.9067	0.04	0.9644
threshold institutional change	-3530.4305	35.5500	-99.31	0.0000
R^2	0.4966			
$F(7, 320752)$	4.52e+04			0.0000

TABLE III
OLS ON THE AMOUNT OF AGENTS' ENERGY AT THE END OF THE SIMULATION

	Estimate	Std. Error	t value	Pr(> $\|t\|$)
(intercept)	-607.8326	16.1403	-37.66	0.0000
institution	58.8458	6.7214	8.76	0.0000
K	0.0915	0.0005	169.87	0.0000
r	3767.1631	19.7725	190.53	0.0000
energy consumption	-238.5417	0.9128	-261.33	0.0000
institutional emergence time	-2.5759	0.0096	-269.47	0.0000
mutation rate	-49.3257	91.2786	-0.54	0.5889
threshold institutional change	-60.1269	15.0294	-4.00	0.0001
R^2	0.3913			
$F(7, 320752)$	2.945e+04			0.0000

a significant effect on both dependent variables. The resource carrying capacity and renewal rate positively affect both the amount of resource available and the agents' energy, while the energy consumption negatively affects them. Especially interesting is to note that both the institutional emergence time and the proportion of agents needed to change the institution negatively affect both indicators, which means that the harder it is to build the institution the worse is the outcome for both the agents and the resource.

Although, the agents on average are better off when institution building is allowed, they do not necessarily reach an optimal situation. In most cases, the selected institution actually led to a condition when the available energy was below what the agents could have theoretically obtained from the resource; in some cases it was even below the energy gathered under the same parameter configuration in the no-institution condition. This is clear in Fig. 3, which shows the average amount of energy and resource at the end of the simulation under all the different institutional arrangements selected by agents.

To simplify the analysis, we selected two examples of resource condition characterized by difficult resource management (low carrying capacity and high energy consumption) and easier management (high carrying capacity and low energy consumption) respectively. Note that the extreme abundance

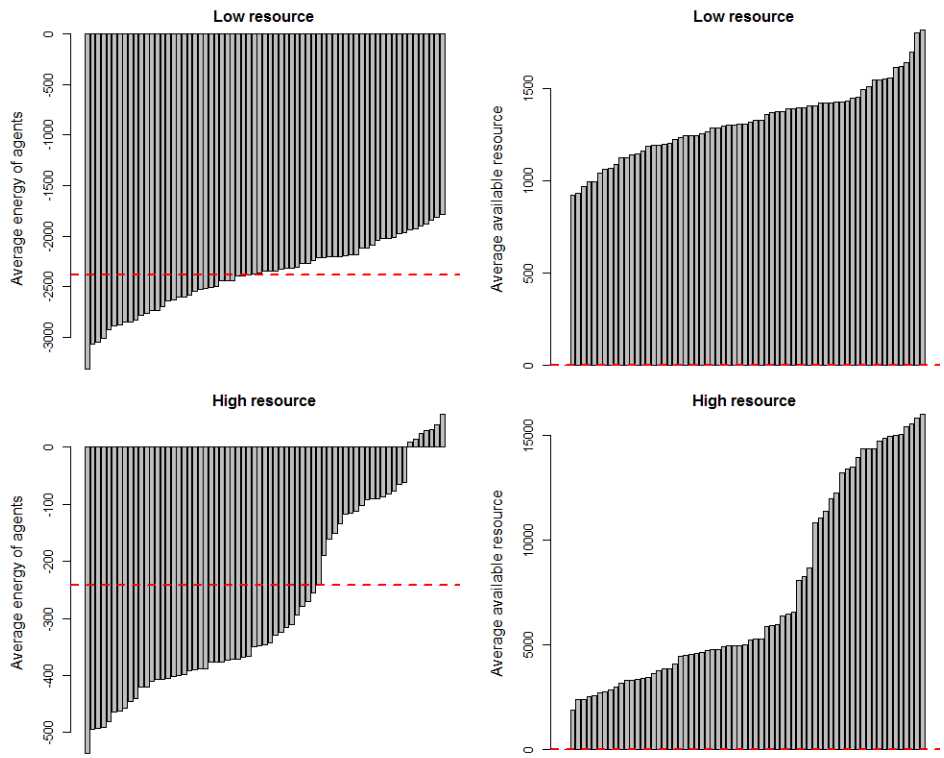

Fig. 3. Average energy of agents and resource left at the end of the simulation under various institutional arrangements in low and high resource conditions. Low resource is defined as $K = 5000$, $r = 0.1$ and energy.consumption = 10. High resource is defined as $K = 20000$, $r = 0.1$ and energy.consumption = 1. The dashed red lines represent the average energy and resource under the same parameter configurations in the no institution condition.

condition ($K = 20000$, $r = 0.5$) was not included in the analysis since the management of the resource under an open access rule was effective enough and agents never implemented a stricter institutional rule (see Tab. IV below).

Under all the selected institutions, the state of the resource at the end of the simulation was instead better than the no-institution case (Fig. 3). This is quite interesting since it implies that in no case the agents selected an institution making them using the resource more than in the open access situation. It is also worth noting that, under most of the selected institutional arrangements, the difference between the open-access and the regulated condition was quite dramatic, with the resource exploited at low to sustainable levels under all of the selected institutional arrangements and few signs of overuse. Especially relevant is the quasi-optimal use of the resource in the low resource condition, with withdrawal often approximating the maximum sustainable yield keeping the resource at intermediate levels under a majority of the selected institutions.

B. *Institutions*

On average, agents created an institution 2/3 of the times when the institutional emergence option was enabled. Notably, they only succeeded in doing it when the proportion of agents needed to change the current institution (the threshold for institutional change parameter) was lower 1. In other words, under the unanimity rules the process of institutional building never succeeded. The institutional emergence time parameter instead only showed a relatively small effect. Finally, the agents never created an institution when $K = 20000$ and $r = 0.5$, i.e., when the resource was so abundant and rapidly replenishing that no institution was actually needed to reach the survival level.

It is interesting to note how agents adapted their institution to the environment. Tab. IV shows the most common institution for each combination of K, r and energy consumption. The amount of energy "eaten" tends to increase with both the resource availability and the agents' requirements, while the modal institution becomes the "open access" one (["" ""]) for the highest values of K, r, especially under low energy consumption requirements.

To better analyze the changes in the institution due to different resource availability, we separated the institutional rule recorded at the end of the simulation into its *aim* and *condition* statements. Fig. 4 presents the resulting distribution under both a relatively low and a relatively high resource availability.

When the resource is scarce, agents tend to select relatively high withdrawals at distant intervals. This strategy clearly allow the resource to replenish between two different consumption steps. This said, the relatively even distribution of different institution visible in the upper row of Fig. 4 testifies the difficult adaptation of agents to a scarcity situation, where easy solution is available to have at the same time enough

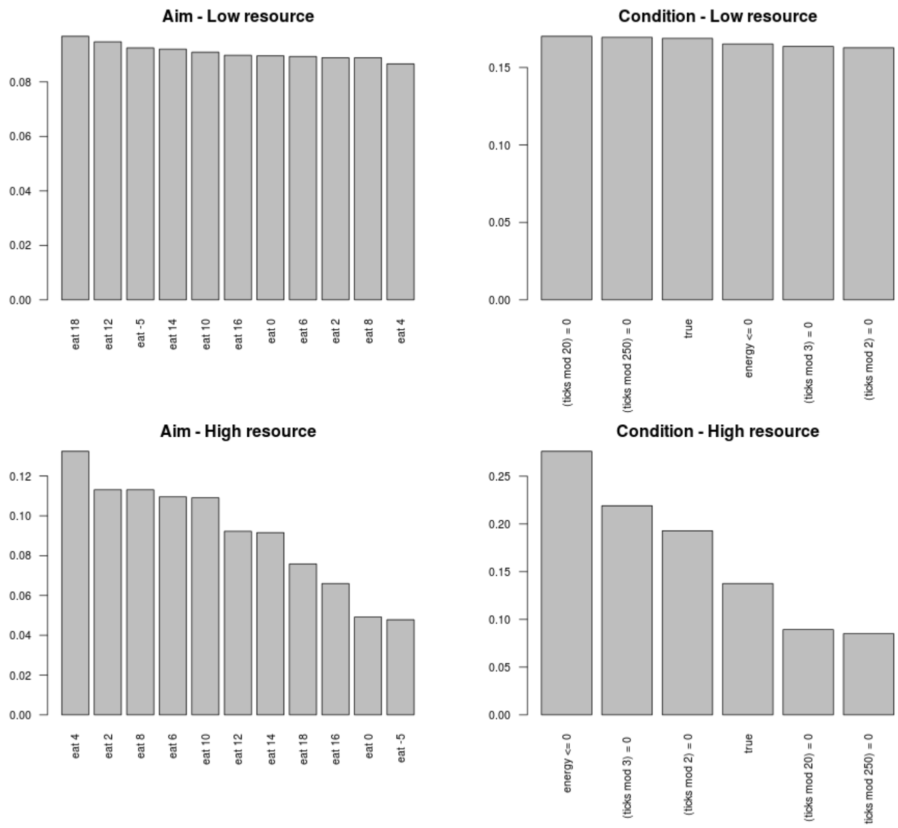

Fig. 4. Distribution of the Aim and Condition statements under low and high resource condition. Low resource is defined as $K = 5000$, $r = 0.1$ and energy.consumption = 10. High resource is defined as $K = 20000$, $r = 0.1$ and energy.consumption = 1.

energy for all and a resource kept at sustainable levels.

On the contrary, when the resource is abundant, relatively small but frequent withdrawals are consistently selected. In a majority of the cases, agents are simply allowed to consume a small amount of resource either when their energy becomes zero (condition: "energy $\leq$ 0") or even in every time step (condition: "true"). This allows them to maintain an optima level of energy without degrading the resource at a level beyond its renewal capacity.

V. Discussion and Conclusion

In this paper we presented a preliminary model based on the ADICO grammar of institution showing that an institution emerging through collective behaviour without centralized planning can help the management of common pool resources. Consistently with much empirical findings [1], [12], [13], we found that, in systems where institutional building was possible, both the agents' payoffs and the resource condition improved in comparison with situations where the agents were only allowed to follow their own strategies.

This result is consistent with the work of Smajgl and colleagues, who also model rule changes in social systems using the ADICO structure [20]. While Smajgl considered the selection of agents actions and global rules as two separate behavioural mechanisms in the system, we see emerging rules as ones that are the results of repetitions and commonality in individual strategies. Furthermore, agent behaviour and decision making in [20] is defined through internal and external variables such as incentives, motivation, goals and environmental conditions.

In the model presented in this paper, agents are simpler entities, which either randomly choose new behaviours or copy others. Another distinction between these two researches is that, while the resource dynamics in [20] only followed simple rules and presented no inter-temporal links, we explicitly modelled the resource change over time using prevailing bio-economics models and studied how these changes influence the emergence and evolution of rules.

Despite a much higher level of abstraction and the fact that we took an implicit evolutionary (copying, mutation, etc.) perspective, our results remain fully consistent with both Smajgl's ones and the ones of commons research [1]. Notably, we were still able to observe institutional dynamics similar to the ones found in empirical settings and to confirm that institutions do indeed contribute to the sustainable management of common pool resource systems. Especially interesting was the capacity of agents to adapt their institutions to resource availability. For instance, the fact that agents selected institutions allowing them to harvest only at distant intervals of time bears a clear resemblance with discussions going on during CPR experiments, where time-based strategies allowing the resource

TABLE IV
MODAL INSTITUTION FOR EACH COMBINATION OF K, r AND ENERGY CONSUMPTION

K	r	energy consumption	selected institution
5000	0.10	1	[” eat 2” ” energy <= 0”]
10000	0.10	1	[” eat 2” ” (ticks mod 2) = 0”]
20000	0.10	1	[” eat 18” ” energy <= 0”]
5000	0.20	1	[” eat 4” ” (ticks mod 3) = 0 ”]
10000	0.20	1	[” eat 2” ” (ticks mod 2) = 0”]
20000	0.20	1	[”” ””]
5000	0.50	1	[” eat 12” ” energy <= 0”]
10000	0.50	1	[”” ””]
20000	0.50	1	[”” ””]
5000	0.10	5	[” eat -5” ” (ticks mod 2) = 0”]
10000	0.10	5	[” eat 12” ” true”]
20000	0.10	5	[” eat 10” ” (ticks mod 2) = 0”]
5000	0.20	5	[” eat 10” ” true”]
10000	0.20	5	[” eat 10” ” (ticks mod 2) = 0”]
20000	0.20	5	[” eat 10” ” energy <= 0”]
5000	0.50	5	[” eat 12” ” (ticks mod 2) = 0”]
10000	0.50	5	[” eat 12” ” true”]
20000	0.50	5	[”” ””]
5000	0.10	10	[” eat 12” ” (ticks mod 2) = 0”]
10000	0.10	10	[” eat 8” ” true”]
20000	0.10	10	[” eat 10” ” (ticks mod 3) = 0 ”]
5000	0.20	10	[” eat 10” ” (ticks mod 2) = 0”]
10000	0.20	10	[” eat 4” ” energy <= 0”]
20000	0.20	10	[” eat 10” ” true”]
5000	0.50	10	[” eat 4” ” true”]
10000	0.50	10	[” eat 16” ” energy <= 0”]
20000	0.50	10	[”” ””]

to replenish were more often discussed and selected under the most challenging conditions [7].

Finally, it is worth noting that the model discussed in this paper represents only a starting point in our research on the mechanisms leading to institutional emergence and that there are many dimensions that can still be added to the model. First, as highlighted by Poteete and colleagues [18], although norm emergence has been studied to some extent, the emergence of rules is an area of research that requires special attention. By building a model using the ADICO structure, we focused our attention to the dynamics (or emergence) of rules. This means that, to be able to study rules in a more realistic way, we should at least add cheating and sanctioning mechanisms to our model. Following Ostrom's argument about the process of norms (ADIC statement) evolving into rules (complete ADICO statements including sanctions), we decided that a reasonable first step was to allow norms to emerge in the system with all agents abiding them. Nevertheless, future versions of the model will allow agents to decide whether they would comply with the institution or follow their own individual strategies through simple learning mechanisms. Finally, the current model allows only one institution to emerge at a time. In future versions, coexistence of various institutions and their possible conflicts will also be an interesting area to explore.

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