The Emergence of Oligarchy in Community Energy System

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Abstract. The iron law of oligarchy claims that the complex organisation will always end up in an oligarchy, no matter it was constituted originally. In that sense, the oligarchy should also happen in the Community Energy System (CES) as a complex self-govern common-pool resource system. The oligarchy situation raises the issue of the fairness and the health in the community since that subgroup of the member may steer the future decisions to be more favourable on one side than the others or may drive the rules to limit the active participation of others, or decrease the community cohesion. This paper specifically concerned with the emergence of oligarchy in the CES and the effect of the iron law of oligarchy on the health and the fairness in the CES. The result shows that the iron law of oligarchy occurs in CES, but it is needed to make CES has the level of fairness and health required to support its continuity

Keywords: community energy system, oligarchy, institutional, emergence, simulation, fairness

1 Introduction

Community Energy System (CES) has increasingly mentioned as the way to facilitate distributed (renewable) generation through the development of smart grid. The CES is defined by Smart Energy Special Interest Group (SESIG) [19, p. V] as

> "An energy generation, distribution, and storage system (where required) involving local community ownership and participation for the purpose of creating collective benefits for the community, including reduced bills, revenue generation, investment opportunity and community regeneration."

Consequently, the CES can be seen as a self-governed common-pool resource [23], since the community members are actively contributed in making and adapting rules that regulate the use of a common-pool resource [17]. Those rules are defined as a self-governing institution by Ostrom [18]. Hence, the institutional dynamic in the community plays a significant role in the development of CES.

However, such communities most likely have heterogeneity of endowments (skill, capital, leaderships, etc.) and interest in its population. It implies that some community members have more endowments and incentives to contribute to the system than the others. Since the institution is also dynamic, the result of this heterogeneity is that the participation in community meetings and engagement, where the decision upon several rules are determined, will be dominated by the more incentivized people, even in a fair and democratic setting.

As a consequence, the CES may end up in oligarchy situation, where the system is managed by a subgroup of members that have more interests or endowments, no matter how democratically constituted originally. This concept is known as *The Iron Law of Oligarchy* [13]. Consequently, this situation raises the issue of the justice in the community since that subgroup of the member may steer the future decisions to be more favourable on one side than the others.

The justice itself is defined as "central to well-functioning society with fairness being an expectation in day-to-day interaction" [9, p.2727]. Since the institutions are born from the interaction of the community member, the fairness will be the focus. In this case, the fairness is defined as a focal point that influences the legitimacy of process and outcome from day-to-day interaction in the community [9].

The healthy community is defined as "a community that relies on their ability to recognise and adapt to change and continually adjust their internal institutional structures to ensure their continuity" (Brown et al. cited in [9, p. 2728]).

This oligarchy situation also can deteriorate the health of CES by affecting several factors that contribute to the health of a community. The health of community can be measured using several factors: "cohesion (the ability to cooperate and work together), community mindedness (active participation), neighbourliness (supportive), accepting different points of view (ideas and newcomers), community support groups and communication networks" (Pepperdine cited in [9, p. 2728]). Since the system is mainly managed by a subgroup of members only, the Oligarch may steer the rules to limit the active participation of others, or decrease the community cohesion. As a consequence, this situation can aggravate the health of a community, so the continuity of such system will be at risk.

Therefore, This paper specifically concerns with the emergence of oligarchy in the CES and the effect of the iron law of oligarchy on the health and the fairness in the CES.

Due to the dynamic nature of CES and the bottom-up process in this self-governing system, the modelling and simulation approach will be used as the main method. In this case, the Agent-Based Model and Simulation (ABM&S) is used as the modelling approach.

The desk research was conducted to provide the input for conceptualising the model. It consists of the literature review, the exploration of theoretical background, and the exploration of CESs case studies in a form of energy cooperatives in Netherlands.

Then, the model conceptualisation translates the empirical and theoretical concept found in desk research into a formal model. The conceptual model will be structured in the IAD framework [16] due to the dynamic nature of the institution in this self-govern common pool resource system. Then, those concepts will be formalised into Agent-Based Model (ABM) implemented in NetLogo. After that, the model will be simulated, and the data analysis will be performed to extract the insight from the simulation result.

This paper is structured as follows. Section 2 defines our ABM of the emergence of oligarchy. Section 3 discusses the simulation result. Last, Section 4 provides the concluding remarks.

2 An ABM of Emerging Oligarchy in Community Energy System

2.1 Main Concept

The desk research has given us the concepts that can be inputted into the model. The result can be found in Appendix A. The fact that these concepts are extracted from the case studies make this model is uniquely applied for CES.

Since we are interested in the dynamic CES as a self-govern common pool resource, those inputs will be structured in IAD framework [17]. There are four main concepts of the model: (1) the agents, (2) the board, (3) the institution, and (4) the action arena. The big picture of this system is illustrated in Figure 1, which is adapted from the IAD framework by Ostrom [16] and the assumptions made are described in Appendix B.

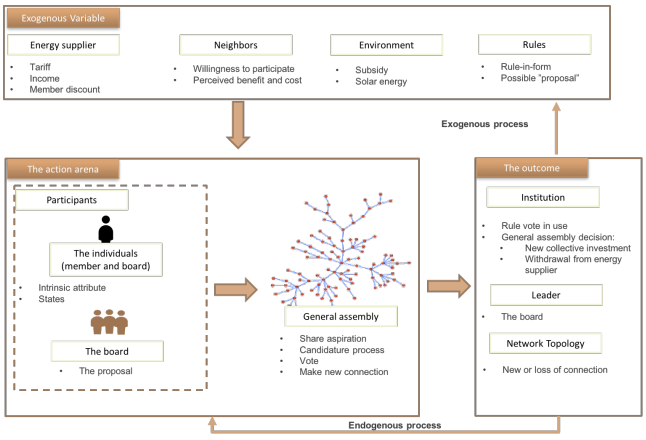


Fig. 1: The big picture of the model. Adapted from IAD framework [16]

Agent The agents are all cooperatives member in the model and heterogeneous in its properties (agent's state and attribute). They are connected in a scale-free network [21]. This network is dynamic, in which the agent can make a new connection based on the preferential attachment [22]. A subset of the member is the board, which represents the leader of the cooperatives.

Boards emerge and propose the change of the governing institution Since the agents are heterogeneous, some agents are more prototypical and more socially-attractive than the others. Those agents will opt to be a candidate for the board and will be voted by the member. The members will vote the candidates based on the similarity of aspiration and whether they are connected with the candidate or not. This process represents the emergence of the leader using the self-categorisation and the social-attraction process theory by Hogg et al. [10].

The board is an emergent phenomenon. It is because whether the agent chooses to be a board or not depends on the state of the agent. The state of the agent cannot be predicted since it is born as a consequence of the outcome of the exogenous and endogenous process in the action arena. Moreover, the process of assigning the board position is also done by voting, which makes the result is unpredictable from the agent level. Thus, the establishment of the board can be seen as an emergent behaviour.

After the board is established, the proposal of new institution will be determined by majority voting based on individual evaluation of each board members. The proposal of the new institution is limited into two: (1) the cooperatives make a new investment of the electricity generation (*shared strategy*), (2) the cooperatives must withdraw their cooperation with energy supplier (*rules*). The result will be called as ***what-to-vote case***. It can be option 1, option 2, both or neither of both. The proposal will be brought to the general assembly to be voted for.

Agents determine their individual aspiration: The outcome of the action arena will be evaluated based on the evaluative criteria. The evaluative criteria in this model are the perceived benefit and cost. The outcome is defined as the difference between the benefit and the cost. This outcome of the action arena will affect the state of the agents.

Then, based on their intrinsic attribute and their states, the agents will determine their individual aspiration. This individual aspiration contains whether they support the proposal from the board or not.

For example, if the board proposes to make a new investment in electricity generation (option 1), each member will evaluate whether they have enough balance to pay one share of the collective investment and whether they have enough willingness-to-participate more or equal to the investment threshold. If so, they will vote for the proposal as their individual aspiration.

If the board proposes to withdraw the cooperation with the energy supplier (option 2), each member will evaluate whether their profit from the coopera-

tion with energy supplier lower than the threshold. If so, they will vote for the proposal as their individual aspiration.

Action arena produces outcome that change the state of an agent There are three processes in this action arena: (1) the agents influence each others aspirations, (2) the agents vote for leader and institution (the rule-in-use), and (3) the agents add new connection if they attend this action arena.

First, the sharing aspiration among the agents is when the power plays. In this process, an agent that has the power lower than the power of the board at a particular time will be influenced. This particular agent is called **the follower**. The follower will copy individual aspiration of another agent *in the connection list and in their neighbourhood*, who has the most power and has is more power than themselves, no matter their position as a board or not. Thus, the follower is not programmed to copy the aspiration from the board directly.

The mechanism of the sharing aspiration also enables the model to produce **the contender** for the leader. The contender is the powerful agent who has never be a board but has a high influence on the community and has different aspiration from the board. The aspiration resulted from the sharing aspiration process is called collective aspiration.

Second, the agents vote in the general assembly. There are two options of voting procedure, the 50%+1 and the 2/3. The choice depends on whether the quorum (2/3 of the member attend the general assembly) is satisfied or not. It is assumed that the member cannot vote by proxy. The member will vote whether they accept the proposal from the board and the upcoming board.

Third, when an agent attends the general assembly, its number of connection increases. The agent will get one additional connection every time they attend the general assembly using the preferential attachment rule. Here, the agent connects randomly with another agent that has more connection.

Thus, there are three main outcomes of this action arena: **(1) the institution** (general assembly decision), **(2) the chosen board**, **(3) the change of network topology**. Those outcomes will affect directly to action arena (endogenous process) and the exogenous variable (exogenous process).

Since the general assembly decision and the board are a consequence of the interaction of the agents (sharing aspiration and vote), it can be claimed that the action arena is the place where the emergence of institution and leader happen.

2.2 Core Definitions

To evaluate the emergence of oligarchy and its effect on the health and the fairness in the CES, the oligarchy, the health, and the fairness has to be defined in the model.

The oligarchy Theoretically, the oligarchy situation is defined as the stable domination of the elected over the elector [13]. Thus, four main points have to be defined in the model to detect the oligarchy when it happens:

1. The Elected: The elected in this context is a group of the agent who has ever elected as a board. This group will be called the minority group.
2. The Elector: The elector in this context is the majority group, which is a group of the agent that has never become a board.
3. Stable: The stable part is defined as how often anyone in the minority group has been elected to a board. The more often the agent in this minority group is being elected, indicates the stability of the leadership from this minority group.
   Moreover, the minority group will be further grouped by its collective aspiration, so there is a possibility that there is more than one minority group at a time with different aspiration. The less number of minority group indicates the overall stability of this group.
4. Domination: The domination part is where the exercise of power comes along. It indicates how strong the minority group exercises its power. It can be measured by checking whether an agent will copy the aspiration from the minority group or not before the sharing aspiration happens.
   As mentioned before, the agents interact in a scale-free network topology. Thus, the domination here counts only the direct domination by the elected, which only happens when the agent has anyone in the minority group in its connection list.
5. The Oligarchy: From the definitions mentioned before, the oligarchy can be formulated as such:

   Oligarchy = Stable (elected level of minority group * 1 / number of minority group) * Domination (minority group over the elector)

The health of the community The health of the community is defined as the ability of a community to adapt to the change and adjust the institutional structure (Brown et al. in [9]). Pepperdine states several factors that contribute to the health of community such as "cohesion, community mindedness, neighbourliness, accepting different points of view, community support groups and communication networks" (cited in [9, p.2728]). In this case, there are only two factors that will be analysed further as the representative of healthy community factors, which are the community cohesion and the community mindedness.

1. Community Cohesion: Cohesion is defined as the ability to cooperate and work together through **decision making** and **leadership**, as a function of **a unified community** (Pepperdine cited in [20, p.58]). There are three important notions in the definition that need to be translated into the model: (1) the decision making, (2) the leadership, (3) the unified community.
   First, the *decision making* in the community happens in the general assembly, where the decisions are taken based on voting. Second, the *leadership* manifests in the process of determining the proposal brought to the general assembly. Thus, the *unified community* can be evaluated when the proposal brought by the board leads to the decision in the general assembly.

2. Community Mindedness: the community mindedness is the willingness of the community member to invest resources (**time**, skills, and **money**) and has **an active participation**. The willingness of community member to invest in time and have active participation can be valued from the attendance of the community member. The willingness to invest money can be evaluated from the average investment in **collective** electricity generation. The higher the value means, the more willing the community member to invest in collective electricity generation.
3. The health of the community: community cohesion + community mindedness

The fairness of the community The fairness is a focal point that influences the legitimacy of the process or the outcome from the interaction of community member [9]. In this definition, the fairness is approached using the **procedural perspective** and the **distributive perspective**.

From the procedural perspective, the fairness is perceived based on the existence of secrecy and the sufficiency community discussion. The quorum in this model can be an indication of the sufficiency community discussion. The 2/3 attendance rule (the quorum) is a common rule that has been applied in many voting procedures (e.g., UN general assembly).

From the distributive perspective, the fairness is influenced by whether the outcome favours to a particular group or not. Therefore, the more agent perceives the discrepancy of the outcome; its perceived fairness gets lower.

The combined effect of from the procedural perspective and the distributive perspective creates the perceived fairness of an agent. This perceived fairness is embedded in the community trust value of an agent. It is because when the people **perceived fairness**, they are more likely to **trust and accept** the decisions resulting from the process, and the institution that makes the decisions [9].

As a consequence, the fairness of the community can be evaluated by extracting the average community trust value of the cooperatives.

2.3 Model Dynamic

The model conceptualisation provides the baseline to build the model, which is shown in Figure 1. Then, those concepts need to be arranged so that it can model and simulate the dynamic of CES. In general, those concepts are translated into flow chart in Figure 2.

It starts with the initial condition, where there is no leader, institutional free, and a scale-free network structure among agents. Then, the agents attribute and initial state are initialised.

The general assembly is assumed to happen in every tick. So, every tick, the agent will evaluate the outcome of the general assembly and update its state. After that, the board will determine the proposal for institutional change. The proposal will be evaluated by each agent as their individual aspiration.

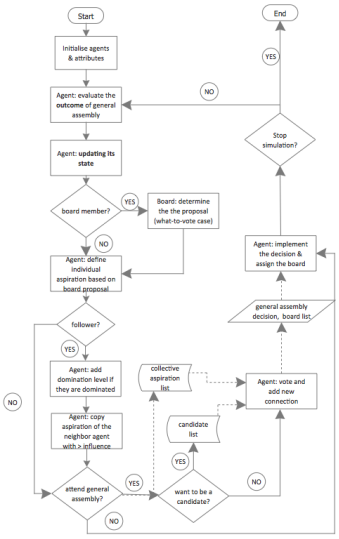


Fig. 2: Flow chart of model dynamics

Then, the agent will check whether they are *followers* or not. If they are, then their aspiration will be influenced by the more powerful agent. Thus, there is a possibility that its collective aspiration is different with its individual aspiration. The collective aspiration will be stored as a list to be voted in the general assembly. Worth to be noted that the collective aspiration list only contains the aspiration of the agent that opts to attend the assembly.

After that, the agent will be questioned whether it satisfies the requirement to be a board. If it is the case, then it will be a candidate that will be voted in the general assembly. Then, the voting will result in the possible new institution and the chosen board, which will be implemented by the agent.

The Emergence of Oligarchy Through this model dynamic, the oligarchy can emerge. First, the existence of board is a phenomenon of the emergence of leadership. Hence, which agent is chosen as the board and how often it is eventually chosen, which is the representative of the stable part of the oligarchy, cannot be deconstructed from th individual agent and it happens as a consequence of agents interaction in the action arena.

Also, the number of minority group and how powerful they are to dominate is a behavioural phenomenon that has no centralised control and yet behaves cohesively as a group [8].

Second, the domination of the minority group is unpredictable from the agent level. It is because the way the agent makes a new connection is random with a preferential attachment mechanism. So, the agent is not programmed to be connected with the minority group, even though the minority group might have many numbers of connections.

Moreover, the way agent is located randomly assigned. Thus, the agent will not always be able to copy the influence from the minority group directly. Also, the power of the agent is dynamically changing as a consequence of the outcome of the endogenous and exogenous process in the action arena. Thus it cannot be predicted in terms of the individual agent.

Since the formalisation of the oligarchy conveys the character of the emergent behaviour, it can be said that the oligarchy value in this model will be able to detect the emergence of oligarchy.

The Adaptability of the Oligarch The adaptability of the oligarchy is the ability of the minority group to adapts in case the shock happens (the oligarchy value in the system drop to zero). Thus they lose their ability to dominate.

Markus et al. [12] gather qualitative evidence of individual Ukrainian oligarchs, which focus on the wealth of the oligarchs (e.g., the wealth origin, business wealth, and amount of wealth) and analyse which strategies that increase the adaptability of the oligarch to the shock. It results that the indirect strategies give better adaptability to shock. These indirect strategies consist of party finance and media ownership.

Using this analogy, we can assume that the minority group will use the indirect strategy as the adaptive response when the oligarchy level drops to zero. Indeed, there are no such things like party finance and media ownership found in the CES case studies, but the essence of media ownership is about the propaganda coverage, which is a key asset in political struggle [12].

In this model, this propaganda coverage strategy can be applied by increasing the coverage of minority groups influence. Initially, the propaganda coverage will be 0. If the shock happens, it is assumed that the minority group can increase its propaganda coverage range by 10%. This propaganda coverage will increase its power to influence.

2.4 Simulation Setup and Parameterisation

The model is implemented in NetLogo (Appendix C). The input of the model contains many parameters with uncertain value (e.g., the thresholds). Consequently, the parameter sweep experiment with a large number of experimental model runs to vary the combination of parameters is needed. The parameters of interest are shown in Table 1.

It can be seen that we have to deal with large parameter space. Thus, the good balance between the accuracy of the result and the computational cost has to be managed. In this case, we are facing the trade-off between the number experiment, the repetition, and the time frame.

Latin Hypercube Sampling (LHS) is used to get a good granularity of the sample [14], thus guaranteeing the uniform sampling of the parameter space. We choose 30 ticks as a time frame since we assume that one tick = 1 year, so that is already long enough to see the oligarchy emerge.

We started with 50 experiments, 100 repetitions, and 30 ticks. Then, we increased the number experiment to 100 experiment, and evaluate the statistical feature of each session. Apparently, there is no significant difference in the statistical feature from each session, so the result from the first session is chosen to be analysed further.

3 Result

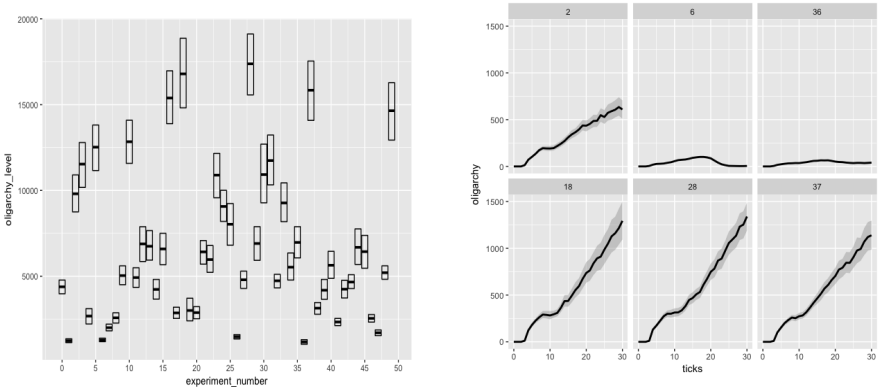
3.1 Oligarchy Analysis

The oligarchy level is defined as the sum of oligarchy value from tick 0 to tick 30. The oligarchy level from each experiment is shown in Figure 3. The graphs

No.	Parameters	Parameters space	Indicator
1.	attendance.thres	1 - 5	attribute of community
2.	investment.thres	0 - 0.8	attribute of community
3.	reduced.bill.thres	0.001 - 0.01	attribute of community
4.	withdrawal.thres	0 - 0.5	attribute of community
5.	subsidy	0 - 0.1	biophysical world
6.	discrepancy.thres	0 - 1	attribute of community
7.	coverage	0.1 - 1	rules
8.	mean.initial.conn	5 - 30	biophysical world
9.	initial.balance.std	500 - 2000	heterogeneity of endowment
10.	c.income.std	100 - 500	heterogeneity of endowments
11.	std.econsumption	100 - 500	heterogeneity of endowments
12.	std.time.avail	1 - 10	heterogeneity of endowments
13.	std.education	1 - 2	heterogeneity of endowments

Table 1: Parameter Sweep

represent three statistical summary variables: the mean and the upper and lower confidence limit without assuming normality. It can be seen that experiment number **2, 6, and 36** produce **low** mean of oligarchy level and experiment number **18,28,37** produce **high** mean of oligarchy level.



(a) Oligarchy level result.

(b) Oligarchy per case. Top = low oligarchy case. Down = high oligarchy case

Fig. 3: Oligarchy analysis result

Furthermore, the dynamic of oligarchy value during the time frame is plotted. It can be seen that even though the low oligarchy produces low mean in total, but **the oligarchy will still exist during the time frame**. Thus, the hypothesis regarding **the iron law of oligarchy in community energy system can be accepted.**

Furthermore, the Ordinary Least Square (OLS) regression is performed, and the result is presented in Table 2.

In this case, discrepancy threshold and investment threshold affect the oligarchy level positively. **The discrepancy threshold shows how tolerant the community with the unequal distribution of the outcome**. Here, the more tolerant the community, the more oligarchy situation more likely emerges. Moreover, the investment threshold indicates the barrier to invest in the energy generation technology. **The less barrier to investing, the more oligarchy situation becomes apparent.**

The coverage value represents the information spread-ability rules, which this information are the outcome and the individual aspiration. It results that the coverage value has positive influence to the oligarchy. The **more spreadable** the information in the community makes the **oligarchy becomes more apparent**.

Furthermore, the mean initial connection represents the initial connectivity in the community. This value has a positive effect on the oligarchy level. This result expresses that **the high connectivity** in the community **ease the minority to spread the dominance**, thus establishes the more stable dominion.

As aforementioned, there is a hypothesis that the heterogeneity in the population become the main variable that may provoke the oligarchy situation. Several indicators of heterogeneity of endowment have proven to be significant, which are the standard deviation of energy consumption, education, time availability and income. **The higher value of standard deviation represents the more diversity or heterogeneity** of a particular endowment in the population. However, the effects are different for each variable.

It is shown that heterogeneity of energy consumption has a negative effect on the oligarchy. The **more heterogeneous the population in energy consumption, the less oligarchy situation exist**.

This negative effect is also applied on the education level and time availability. **The more homogeneous education level and time availability** in the community corresponds with **the higher the oligarchy level**. On the other hand, the more heterogeneous the yearly income in the population positively affect the higher oligarchy level.

3.2 Health Analysis

As mentioned before, there are only two factors that will be analysed as the representative of the healthy community's factor, the cohesion and community mindedness.

In this case, the cohesiveness and the mindedness value is summed from tick 0 and tick 30, which the value is presented as the cohesion level and the mindedness level. Figure 4 shows that in the high oligarchy case, the community cohesion and the community mindedness has a higher value than in the low oligarchy case.

To analyse the effect of the oligarchy situation to the health, the OLS is performed. It results that the oligarchy has positive significant effect on the health of the community

	Estimate	Std.error	t-value	Pr(>| t |)
(Intercept)	7.624e+00	1.117e-01	68.268	0
attendance.thres	-1.551e-02	1.041e-02	-1.490	0.136265
investment.thres	-3.446e-01	5.206e-02	-6.619	0
reduced.bill.thres	-2.173e+00	4.603e+00	-0.472	0.636942
withdrawal.thres	8.898e-02	8.306e-02	1.071	0.284126
subsidy	8.125e-01	4.152e-01	1.957	0.050405 .
discrepancy.thres	1.551e+00	4.135e-02	37.514	0
coverage	1.587e+00	4.571e-02	34.723	0
std.econsumption	-3.639e-04	1.033e-04	-3.522	0
mean.initial.conn	-6.790e-03	1.388e-03	-4.893	0
initial.balance.std	2.288e-05	2.748e-05	0.833	0.404969
c.income.std	3.206e-04	1.041e-04	3.081	0.002077
std.education	-3.425e-01	4.162e-02	-8.230	0
std.time.avail	-1.972e-02	4.632e-03	-4.257	0
R-square	0.3696			
p-value	0			

Table 2: OLS on the oligarchy level.

	Estimate	Std.error	t-value	Pr(>| t |)
(Intercept)	4.529e+01	1.269e-01	356.80	0 ***
oligarchy.level	4.201e-04	1.353e-05	31.06	0 ***
R-square	0.1646			
p-value	0			

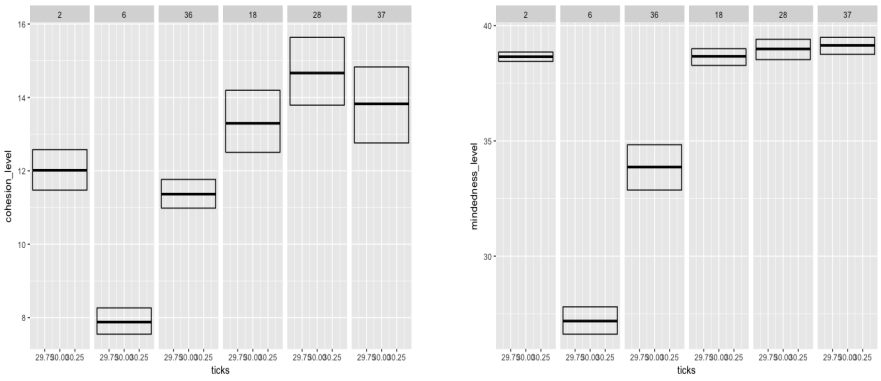
Table 3: OLS on the health level. Health level = sum of the health value from tick 0 to tick 30

3.3 Fairness Analysis

The fairness level is calculated by summing up the average community trust value of the cooperatives from tick 0 to tick 30. Figure 5 demonstrates that in high oligarchy situation, the perceived fairness is higher than in the low oligarchy ones. Furthermore, the OLS results that the oligarchy positively affects the fairness.

	Estimate	Std.error	t-value	Pr(>| t |)
(Intercept)	1.179e+01	3.445e-01	34.24	0 ***
oligarchy.level	7.541e-04	3.671e-05	20.55	0 ***
R-square	0.097			
p-value	0			

Table 4: OLS on the fairness level



(a) Cohesion level (b) Mindedness level

Fig. 4: level = sum of the value from tick 0 to tick 30. Each graph presents three things: the average of the value, the upper and lower confidence limit without assuming normality. Left to right = low to high case

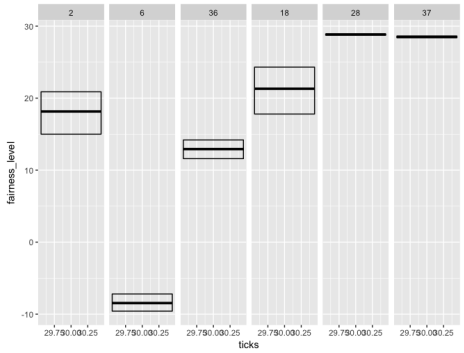


Fig. 5: Each graphs presents three things: the average fairness, the upper and lower confidence limit without assuming normality. Left to right = low to high case

3.4 Adaptability Analysis

The Hypothesis Figure 3a conveys that there is a tendency that the experiment that produces the higher mean of oligarchy has a higher deviation in value and vice versa. It means that, when the structure of action arena produces the low oligarchy value, the value most likely stick around for most of the repetition of the experiment.

The question is why. It seems like the oligarchy value has a positive correlation with the adaptability of the system. Therefore, when the less oligarchy value produces by the system, the system most likely has less adaptability. As

a consequence, the system produces stable low oligarchy value in most of the experiment run (the system becomes so rigid in low value).

Thus, the hypothesis is constructed that ***the oligarchy has a positive correlation with the adaptability of the system***.

The Shock The adaptability is visible when the system is in shock (the oligarchy value drops to 0). Therefore, Figure 6 shows the prop.value as an indicator of adaptive response when the shock happens.

It can be seen that in most of the cases, **the shock happens on around tick 10 and tick 20**. The difference is that in low oligarchy case (especially experiment no 6 and 36), the shock keeps going on.

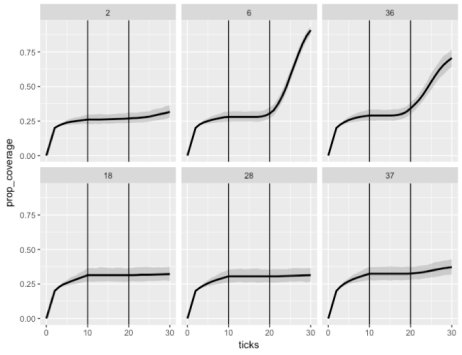


Fig. 6: Propaganda coverage value over 30 ticks. Top: low oligarchy case. Bottom: high oligarchy case

The System Adaptability To define the adaptability of the system, we have to look it from two different perspectives: **(1) the minority group perspective, and (2) the cooperatives perspective.**

From the minority group perspective, there are two main factors that can contribute to the loss of their adaptability, (1) the presence of many contenders, (2) the withdrawal of the individuals in minority group from the community. Those two conditions could lead unsuccessful adaptive response of the minority group.

From the cooperatives perspective, the adaptability is lost when the member loses its willingness to participate in the community. The combined effect of those can be an indicator of the adaptability of the system.

$$\text{Adaptability} = (1 \,/\, \text{contender}) * \text{count.minority.group} * \text{will.participate.cooperatives}$$

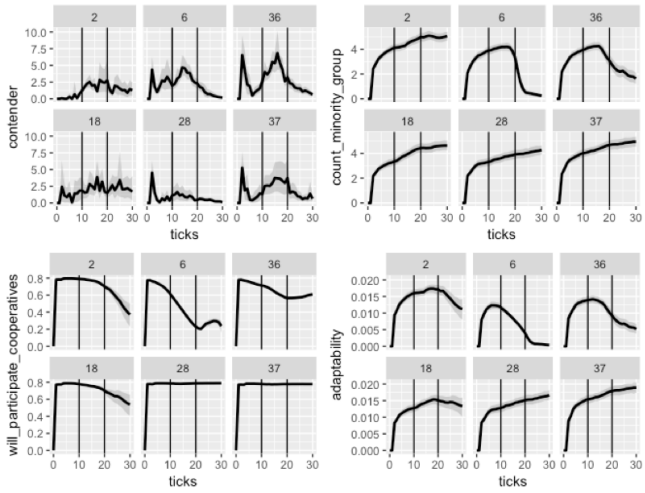


Fig. 7: The number of contender, The number of minority group, The average willingness to participate of the cooperative, The adaptability. Top: low oligarchy case. Bottom: high oligarchy case

It can be seen from the figure 7 that the adaptability of the system decreases rapidly in low oligarchy situation. From the visualisation, **the most contributing factor that leads to the loss of adaptability is the decreasing willingness to participate of cooperatives and the number of minority group after shock**.

It can be seen that **the shock is a bifurcation point that leads the system into two different paths**. One path leads to the major withdrawal of the individuals in the minority group and rapid decrements of willingness to participate. The others lead to more stable domination of the minority group and stable willingness to participate of the cooperatives.

The Correlation Then, the correlation test is performed to test the hypothesis using Kendall's tau method. It shows that there is a strong positive correlation between the oligarchy and adaptability of the system. It means that when **the structure of community enables the stable domination by the leader, the community most likely becomes more adaptive when the shock happens.**

	tau	p-value	remarks
adaptability.level	0.296	<2.2e-16	significant

Table 5: Kendall's tau correlation test on the oligarchy level to the adaptability level

4 Discussion and Conclusion

The case study of the cooperatives in the Netherlands shows two observed emergent patterns, which is the emergence of leader and the emergence of the institution. Since the leader holds the leadership and management position, they are usually the initiator of the change of institution.

In that process, the people in the community will interact and influence each other. The domination happens when the minority group can influence the aspiration of the majority. Then, the stability is apparent when the person on that minority group keeps re-elected. In this case, the oligarchy situation emerges.

Apparently, the strong presence of stable leadership is necessary to make CES have the level of fairness and health needed to support its continuity. It gives the adaptability to the system when the shock happens by keeping the cohesiveness, the participation, and the fairness of the community. Thus, the oligarchy affects positively to the health and the fairness of the community energy system.

Appendix A Desk Research Result

The case studies have given us the several concepts that can be inputted into the model. The fact that the inputs are extracted from the case studies make this model is uniquely applied to CES. The most prominent character of CES that differentiate it from the political or commercial organisation is the motivation underlying the participation of the member. Furthermore, the technology as the common-pool resource makes it different from the other community-based system with a "natural" common-pool resource, such as water, forest, etc.

Since we are interested in the dynamic CES as the self-govern common pool resource, those inputs will be structured in IAD framework [17]. From this documentation, some missing components can be identified, in which the assumptions have to be made.

A.1 Action Arena

Action arena is the place where the interaction happens. From the case studies, it can be concluded that the action arena, in this case, is the member meeting (member assembly), where the members meet and discuss the further development of cooperatives.

Action Situation

1. Participant: all the member of cooperatives
2. Positions: member and board
3. Actions:
   - Discuss and interact: the structure of interaction is unknown. Nevertheless, scale-free network structure has proven able to model the interaction in social network [7]. Thus, it is assumed that the interaction happens in this network topology
   - Select board
   - Decide collective investment or other development plans
4. Potential outcome:
   - Development policies
   - Collective investment
   - Elected board
5. Function that maps actions to outcome: Voting
6. Information: Since the board holds leadership and management positions, it is safe to assume that the board has better information
7. Cost and benefit assigned to action and outcome: Unknown from the case study. However, Ostrom [18] gives the framework for analysing institutional choice. This framework uses the perceived benefit and cost term from individual point of view

Participants

1. Individual preferences: From the case studies, we know that some of the member can opt to be a board, and can opt to attend the meeting

2. Individual processing capability: Since the board is assumed to have better information, the individual processing capability is different based on the position
3. Individual selection criteria: Unknown, but it can be assumed that it comes from the perceived benefit and cost of the individual
4. Individual resources:
   - Basic resources: money, skill, time
   - Specific resources: the investment in electricity generation technology

A.2 Exogenous Variable

Biophysical world

1. Energy supplier: The cooperatives usually have a formal contract with one energy supplier.
2. Technology: The common invested technology for electricity generation is solar panel
3. Subsidy scheme: such as poscoderoos

Attribute of community

1. The values of behaviour in the community:
   - Voluntarily work for board
   - Sustainability
   - Energy independence
   - Willing to participate and invest
   - Community trust
2. Distribution of resource: Distribution of ownership in collective investment is based on the investment share
3. Homogeneity of individuals: no clear statement from the case studies, but we can assume that the individuals are homogeneous in structure, but heterogeneous in resources (endowments)

The rules

1. Position rules: some case studies state that only member can be a board [1], [2], and others state that the external person can be a board [4]
2. Boundary rules: The membership is bounded by post code
3. Authority rules:
   - The board leads and manage the cooperatives. The board usually brings proposal for the development of cooperatives (e.g. the business case, or new investment opportunity)
   - All members have equally one vote
4. Aggregation rules: The total energy generation and consumption is managed by energy supplier
5. Scope rules: Only the member can vote in the general assembly. Some cases state that it is possible to vote by proxy [1].
6. Information rules: The board has better information than the member

7. Payoff rules:
   - For every investment in electricity generation, the member get the reduction of electricity bill (they only pays the offset between electricity generation and electricity consumption)
   - Some cases state that the energy supplier gives member discount to the cooperatives

Appendix B Model Assumption

Some assumptions have to be made to fill the missing component in IAD framework and to formalise it into the model. This section summarises those assumptions. The assumptions will be documented based on its place in the IAD framework.

Action Arena It is assumed 1 tick = 1 year. It is assumed that there is only one general assembly per year.
Action Situation

1. Participant: initial cooperatives = 200 (Vallei Energie = 235 [2], De Ramplaan = 220 [6])
2. Actions:
   - It is assumed that the interaction between agent is structured in scale-free network, and limited to certain range of coverage. It is assumed that the coverage value represent the information spread-ability in the community
   - It is assumed that the member can only add new connection if they attend to the general assembly
   - There is no reduction of number connection if the agent chooses to not attend in general assembly meeting
3. Potential outcome:
   - Development policies: withdrawal from energy supplier
   - Collective investment: It is assumed that the member can only invest one share
   - Elected board
     - If the general assembly decides to give salary to the board, the salary is assumed to be 200 euro per board member
     - Work.hour of the board is assumed to be 6 hours/ week, taken from the actual work hour of the board in De Ramplaan Cooperatives [1]
     - Maximum number of the elected board is three agents
4. Function that maps actions to outcome:
   - The member uses preferential attachment function to add new connection at the general assembly
   - There are two voting procedures, which are 50+1 and 2/3, based on whether the quorum is satisfied or not. The quorum is assumed to 2/3 of the total member of the cooperatives [1]

5. Information: Since the board holds leadership and management positions, it is safe to assume that the board has better information
6. Cost and benefit assigned to action and outcome: It is called the perceived benefit and cost in the model. The outcome = perceived benefit perceived cost

Participants

1. Individual preferences: The member prefers to choose a leader that has similar aspiration and located in their neighbourhood
2. Individual processing capability: Since the board is assumed to have better information regarding the market price and the investment in the cooperatives
3. Individual selection criteria:
   - How they define the individual aspiration
   - How they select whether they want to attend to the general assembly or not

Exogenous Variable Biophysical world

1. Energy supplier
   - The tariff is drawn from Qurrent energy tariff, which is 0.1903. The real.tariff represents kale inkooprijs in that table which is 0.035, and diff represent the fixed cost that needs to be paid (diff = tariff real.tariff) [5]
   - The member discount is assumed to be 17.5 / year, drawn from the member discount given by Qurrent to De Ramplaan Cooperatives [3]
2. Technology: Only one type of energy generation is included in the model, which is solar energy

Attribute of community

1. The values of behaviour in the community:
   - The willingness to volunteer and willingness to invest can be represented by the willingness to participate value, since it has positive correlation [11]
2. Distribution of resource:
   - Distribution of money: c.income represents the yearly income of an agent aimed to pay their yearly electricity bill. It is assumed that this yearly income to be normally distributed with average of 1500 / year and standard deviation of 200/ year [15] [p. 107]
   - Distribution of time availability: Time availability of each agent in cooperatives is assumed to be distributed normally with average 30 hours/week and standard deviation 10 hours/week. It is derived from the assumption that they have a full-time job in weekdays, and just want to allocate their free-time on the weekend to participate in ICES.

- Distribution of initial electricity consumption: Initial electricity consumption per household is assumed to be normally distributed with 6570 kWh/year in average and 500 kWh/ year in standard deviation [15] [p.107].
- Distribution of additional energy consumption: It is assumed that the electricity consumption grows at the same rate during the simulation. The rate is determined by a percentage of initial electricity consumption. The percentage is assumed to be normally distributed with mean = 0.2 and the standard deviation = 0.1 (add.e.consumption = random-normal 0.2 0.1 * e.consumption)
- Distribution of education: Education is assumed as a categorical variable with an integer value between 1 4. It represents four levels education in demographic data of Netherlands (university degree, higher vocational education, secondary vocational education, and high school)
- Distribution of initial number of connection: The distribution is based on exponential distribution to model the scale-free network [21]

3. Homogeneity of individuals: no clear statement from the case studies, but we can assume that the individuals are homogeneous in structure, but heterogeneous in resources (endowments)

The rules

1. Position rules: only member can be a board [1], [2]
2. Boundary rules:
   - The member of cooperatives cannot vote by proxy
   - The additional new member is limited to certain amount (10) at a given time
3. Scope rules:
   - If a member withdraws its membership, that particular agent cannot be a member again in the future
   - If the general assembly decides to withdraw the cooperation with energy supplier, the energy supplier will die (they cannot make the collaboration again in the future)
4. Information rules: The board has better information than the member

Appendix C NetLogo Model

The verification and final model can be found in this drive `https://drive.google.com/open?id=0B3n9a3Zi03owRm1WZ1k0S2ZhZ2M`

- final model = EP1.22
- verification model = EP1.22 (verification)
- the result = EP1.22 parameter sweep0-29 ,EP1.22 parameter sweep30-59, EP1.22 parameter sweep60-99
- the R script for data analysis = Data.Analysis.R

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