A Construct for Testing Effective Cooperation in Large-Scale Resource Social Dilemmas*

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Abstract

Social dilemmas are conflicts between individual rationality and general welfare. The literature explains how to evaluate effectiveness of cooperation based on trust mechanism in small-scale social dilemmas, but how to evaluate effectiveness of cooperation mechanisms in large-scale situations remain unknown until this paper. We designed a construct to test cooperation mechanisms used to promote cooperation in large-scale social dilemmas that involve resource depletion. The proposed construct integrates cooperation mechanisms like trust, perception of damage and cooperation as norm. Results suggest that the designed artifact explains how mechanisms promote cooperative behavior in large-scale social dilemmas that involve resource depletion. In these cases dynamic complexity affects cooperation. The research finally indicates how cooperation

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mechanisms can be effective to promote cooperation in the context of dynamic complexity in large-scale social resource situations.

Key words: Cooperation, Social Dilemmas, Mechanism, Large-Scale Situations, Dynamic Complexity.

1 Introduction

People face social dilemmas every day. A social dilemma is a conflict between individual rationality and the general interest of the group (Ostrom and Walker, 2005, 19). Commons, resources that might be depleted unless action or regulations are taken, are susceptible to suffer this kind of conflict because characteristics like sustractability and exclusion (See Table 1 on page 4). A short term individualistic rationality could produce over exploitation and pollution and reduce the availability of commons. However, groups can face and avoid this situation. The availability of commons depends of the way that the appropriators face social dilemmas. There are three possible ways to face social dilemmas: cooperation, private rights and markets, and the enforcement by an external agent (the state). Private rights and markets have showed problems when are used in large-scale dilemmas (Ostrom, 1990, 33). Because these alternatives are not always feasible options in large-scale social dilemmas, we are going to focus our work in cooperation as the feasible alternative.

Classical theories about cooperation are related to tree main sources: The Tragedy of the Commons (Hardin, 2009, 1243), The Logic of the Collective Action (Olson, 1971, 1) and The Prisoner's Dilemma (Luce et al., 1958). In this way, cooperation is not possible among rational individuals because them want to maximize their expected utility in the short term. These theories suppose individuals have perfect and complete information about situation and consequences for their decisions and they are considered a perfect rational beings. The possibility of communication is not important. As a consequence of these considerations, individuals create a dangerous situation that lead them to over exploitation of resources. Classic theories claimed that people are not able to escape from this situation by themselves. As a consequence of over exploitation, their payments are low (Hardin, 2009). For these theories, the two ways to avoid this situation are to enforce agreements to reduce the appropriation by an external agent (Hardin, 2009, 1244) and define private rights of exploitation and markets (Smith, 1981, 439).

Humans face the problem of commons resources' conservation. Commons offer situations of social dilemma (Hardin, 2009, 1243) that sometimes lead to over exploitation (Ostrom, 1990, 27). Over exploitation, as a consequence of a social dilemma, can be avoided if the individuals cooperate for reducing their appropriation (Ostrom et al., 2002, 3). However, they could not decide to cooperate and appropriate at the level required to sustain the commons. If individuals follow their own interest in this situation, they will drive the situation to collective irrationality because all of them will receive low payments as a consequence of the reduction of the commons' productivity (Schlager, 2002, 801).

We can think the problem of the interdependence of human beings as a social dilemma. When an individual uses a commons, he can decide to use so much of the resource. If all of them decide the same, the resource's availability is threaten. The social dilemma is configured because the interdependence in this situation can produce a conflict on rationality. If group decides to use so much resource, they can produce over exploitation, congestion, and pollution. Thus, they can reduce their individual and group payments. Their individual rational decision in this situation of interdependence could drive to a condition against their own interest in short and long run. However, groups can avoid social dilemmas if they are able to promote cooperation to reduce their use. Today, social scientists accept the possibility of the cooperation and they work for a better understanding of the dynamic of cooperation [1] .

		Sustractability	
		Low	*High*
Exclusion	*Difficult*	Public Goods	Common Resources
	Easy	Club Goods	Private Goods

Table 1: Economic Goods, Exclusion, and Sustractability (Ostrom 2005, 24).

Table 1 on page 4 describes economic goods as function of sustractability and exclusion. Public goods and Common Resources are susceptible to social dilemmas and we can see how sustractability and exclusion determine if the problem to face is provision or appropriation.

Availability of the commons is related to the way that groups face social dilemmas through cooperation (Ostrom et al., 2002, 5). The work of scientists have been focused to improve our understanding about how human groups decide to cooperate. For this task, scientists use Game Theory (Von Neumann et al., 1953; Grimes-Casey et al., 2007; Plous, 1987), Econometric methodologies (Clark, 1976; Dasgupta and Heal, 1980; Ophuls, 1977), surveys, Experimental Economics (Smith, 1989), Celullar automata (Akimov and Soutchanski, 1994) and Field Experimentation (Ostrom et al., 2002). Recently, they had used System Dynamics (Castillo and Saysel, 2005) and Agent Modeling Methodologies (Fort, 2003; Janssen and Ostrom, 2006; Bousquet et al., 2001; Dalmagro et al., 2006) to design and test the effectiveness of new mechanisms. These works have improved our understanding about cooperation. In one of this, Ostrom (2000) proposed a principles for a collective action decision making theory in commons resources. Ostrom suggested a dynamic relation (a feedback loop) among reciprocity, cooperation and trust, and a set of situational variables that influence the dynamic of the cooperation in the appropriation of commons resources. Reciprocity includes the possibility to punish other when they do not support the agreements through low fines (Ostrom, 1990, 40). This theory was developed to explain cooperation in laboratory and field settings (Ostrom, 2000) (Ostrom et al., 1994, 145). The core relationship as the central component of the theory of cooperation is assumed as the main contribution to this research area.

Contemporary theories of collective action consider that cooperation is possible as a consequence of the possibility of communication in several rounds around the appropriation of the resource. Individuals develop reputation of cooperation from past rounds that enable new cooperation (Ostrom, 2000, 12). In the principles of rational decision making for collective action on commons resources, Ostrom offers a frame to explain cooperation based on the possibility of communication face to face. The frame is constituted by a core relations. Reputation, reciprocity and trust drive the change of cooperation according to initial conditions defined by situational variables (Ostrom, 2000, 13).

Ostrom suggested the following characteristics for the situation that meet the theory (Ostrom, 2000, 11):

- The situation provides deformed and delayed information even in laboratory and field settings.

[1] Elinor Ostrom received the Nobel Prize in Economics in 2009 for ”for her analysis of economic governance, especially the commons”

- The rationality of the individuals is bounded.
- The complexity of the situation is faced by simple rules that increases the complexity.
- The reciprocity implies to punish the free riders with fines that are gradually established

Contemporary cooperation theories suggest the auto regulation as a way to face social dilemmas. (Ostrom, 2000, 11) developed her theory of cooperation for small-scale social dilemmas to very specific conditions:

- There is face to face communication.
- Agreements are possible and enforceable.
- Groups have few members.
- Members have similar characteristics.
- There is perfect information about the state of the resource and the results of others actions.

These conditions are met by small-scale social dilemmas. However, these conditions are not met by large-scale social dilemmas.

People face large-scale resource problems that could be assumed as social dilemmas. Payoffs of the selfish is higher than from a non-selfish behavior while the public at large is worse off if most citizens act selfishly. Traffic jams, Electricity Crisis, Congestion in Internet, Climate Change, and many other can be explained as a social dilemma (Buck, 1998, 8).

Large scale resource social dilemmas have special conditions. We can offer some characteristics based on Markóczy (2007, 1931):

- There is not face to face communication, but there is some kind of information about the state of the resource and the others actions.
- Agreements are possible and enforceable.
- Groups have a lot of members.
- Members have not similar characteristics.
- There is not perfect information about the state of the resource and the results of others actions.
- There is dynamic complexity.

We described next two types of resource-related social dilemmas according to the scale and their characteristics: small and large-scale. We are going to claim that there is a gap in the theory of cooperation in Large-scale social dilemmas related to test the effectiveness of cooperation's mechanisms used in Large-scale resource dilemmas.

1.1 Gap: testing the effectiveness of cooperation's mechanisms in Large-scale social dilemmas

The effectiveness of cooperation's mechanisms like cooperation based in trust has been tested by experiments, field and model simulation settings. This is not the case in large-scale social dilemmas, because differences between conditions of situations. We claim is possible to test the effectiveness of cooperation's mechanisms used in large-scale social dilemmas.

1.2 Research Plan

We will develop a construct as a working theory to test the effectiveness of cooperation in large-scale social dilemmas. Then, based on the construct we will develop system dynamics models to evaluate cooperation mechanisms used in tree large-scale social dilemmas cases. We will propose also criteria to test cases and the effectiveness of the mechanism studied. Our study will be developed according to the System Dynamics methodological guidelines.

Methodological requirement	Characteristics from the Problem
Feedback	Information feedback
Delays and perception	Dynamic Complexity
Average behavior representation	Group decision making
Explanation capacity	Evaluation of mechanisms to improve cooperation
Representation of dynamic decision making	Iterative and repetitive decision making

Table 2: Methodological requirements to evaluate effectiveness of cooperation mechanism in large-scale social dilemmas

2 Method

In this paper we used System Dynamics methodological guidelines (Forrester, 1961, 17) (Barlas, 1996, 184). System Dynamics was applied to guide the design of dynamic hypothesis, the models and the design of the computer simulation experiments.

We used criteria to test the effectiveness of mechanisms of cooperation in large-scale social dilemmas. The method used to close the gap required to meet the methodological requirements are presented in Table 2 on page 7.

We claimed that System Dynamics is the best alternative to study this situation because meets all the requirements of situation. We summarized the characteristics for Large-Scale Social Dilemmas involving Resource Depletion situations (Dynamic Complexity, Information required, Explanation Capacity, Bounded rationality and micro macro link type). Next we checked if some available tools support the requirements of the situation. (See Table 3 on page 8). The decision about how much resource an individual appropriates is influenced by dynamic complexity that is established by physical and institutional arrangement that conditioned the interaction among them (Cardenas, 2000, 305) (Sterman, 2000, 21). The information process was understood as conditioned by the bounded rationality theory (Simon, 1955, 100) (Ostrom, 2000, 9). The bounded rationality theory defines the individual's rationality as limited. For that, people apply simple rules to face dynamic complexity situations. This strategy used to face the situation increases the complexity and produces contra-intuitive behavior as a response of decisions and actions (Sterman, 1989, 301). Humans do not know all consequences of their actions. The information about situation is deformed and delayed. The situation overcomes the cognitive capacities of the individuals. Information about cooperation and damage (punishment) change over time and influence the information and decision process. People do not change their perceptions and decision immediately as information changes. Individuals forecast according to their perception of the situation, they never change their intuition about the future. Our models express the explanatory mechanism that includes the representation of the dynamic complexity and the information process that affects the individuals decision making.

The cases selected were faced with criteria for large-scale social dilemmas. These criteria allowed to assure that the cases were presenting large-scale social dilemmas (See Table 4 on page 8.

We proposed also criteria for testing effectiveness of mechanisms for cooperation used in large-scale social dilemmas (See Table 5 on page 9).

We applied the following research plan. First, we designed the construct as a dynamic hypothesis. Then, we selected each case, testing if the case had a large-scale

Tools / Criteria	Dynamic Complexity	Quality of Information Required	Explanation Capacity	Aggregation level	Support Bounded Rationality?	Micro macro link type
Econometric	no	Complete and perfect	Low	Low	No	Undefined
Optimization	no	Complete and perfect	High	Low	No	Undefined
Game Theory	no	Complete and perfect	Low	Low	No	Methodological Individualism
Experimental Economics	yes	Accept Biased Information	Low	Low	Yes	Undefined
Agents	yes	Accept Biased Information	Low	Low	Yes	Methodological Individualism
Cellular Automata	yes	Accept Biased Information	Low	Low	Yes	Methodological Individualism
System Dynamics	yes	Accept Biased Information	High	High	Yes	Average Behavior

Table 3: Characteristics of the situation vs Tools Available

Criteria	**Elements**
Is there a conflict of rationality?	Individual rationality Collective objective
Type economic good	exhaustible common resource overuse of the resource High sustractability Difficult exclusion
Group	10 individuals or more no shared characteristics No face to face communication There is feedback There is information delays There are difficulties in perception Infinite rounds
Intervention	Perception of damage Possibility of restriction
Learning	Cooperation as norm

Table 4: Criteria about situation as large-scale social dilemma.

social dilemma. Later, we developed a model integrating mechanisms, the construct and relevant elements of the case. Finally, we evaluated the effectiveness of the mechanisms for promoting cooperation in large-scale social dilemmas. The steps followed were:

- Design of the construct.
- Selection of the cases.
- Modeling of cases based in situation and construct.
- Test of construct, hypothesis and dynamic hypothesis.
- Evaluation of effectiveness of the mechanisms.

In every step we applied criteria to assure an answer to the gap. We proposed to design a construct to test the effectiveness of cooperation mechanisms applied in large-scale social dilemmas. According to this, we confronted criteria vs case and performance of the mechanisms for promoting cooperation in every studied situation. Table 6 on page 9 presents the research activities and sub-activities including testing based on criteria.

Criteria	Elements
Resource	A sustainable use of the resource was achieved?
Cooperation	Is the cooperation generated sustainable? Is Cooperation tending to a Pareto Superior?
Learning Cooperation	Are the mechanisms promoting cooperation as norm?
Temptation for free riding	Is temptation to free ride controlled?
Perception of damage	Is the mechanism of perception of damage promoting cooperation?
Trust	Is cooperation promoted besides no favorable initial conditions?
Dynamic Complexity	Are mechanisms facing conditions of Dynamic Complexity?

Table 5: Criteria of effectiveness proposed to evaluate mechanisms used in large-scale resource social dilemmas

Main Activity	Sub-activities
Design of the construct	Expression as a dynamic hypothesis
Selection of the case	Checking criteria
Evaluation of the effectiveness of the mechanisms	modeling Simulation Apply effectiveness criteria

Table 6: Research activities

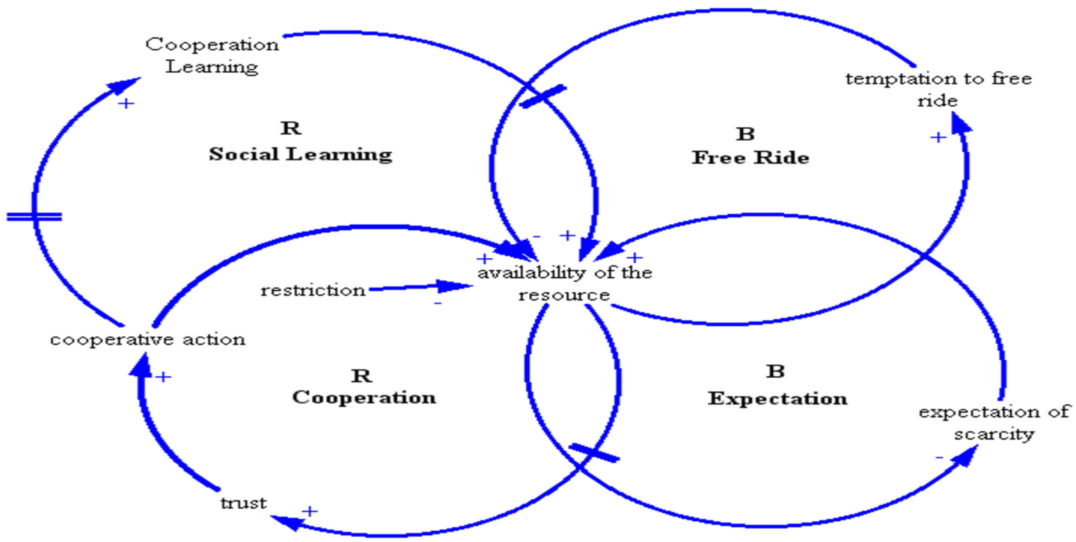


Figure 1: The Construct designed to test the effectiveness of three mechanisms: cooperation by trust, cooperation as norm, and cooperation as perception of damage, expressed as a General Dynamic Hypothesis

3 Results

We developed a construct to test the effectiveness of cooperation's mechanisms used to face social dilemmas in large-scale situations. We applied the construct to three cases: The Colombia's 1992 and the California's 2001 electricity crisis. As a third case, we studied the effectiveness of cooperation mechanism's to face the social dilemma about the concentration of CO_2 in the Atmosphere.

3.1 The Construct

The construct designed is able to test the effectiveness of three mechanisms: cooperation by trust, cooperation as norm, and cooperation as perception of damage. The mechanisms were used to face temptation to free ride in large-scale social dilemmas, because the conflict between the group welfare and the individualist rationality. The construct designed is presented on Figure 1 on page 10. We expressed the construct as a dynamic hypothesis, because we claimed our construct is a working theory that explains how mechanisms are connected as a unit to face free riding in large-scale social dilemmas. Using System Dynamics, we applied the construct and modeled for each case for testing the effectiveness of cooperation's mechanisms dynamically.

The construct was used to guide the design of models for each study case. We used the simulation models to test the effectiveness of cooperation's mechanisms used in that situation to face the social dilemma configured in each case.

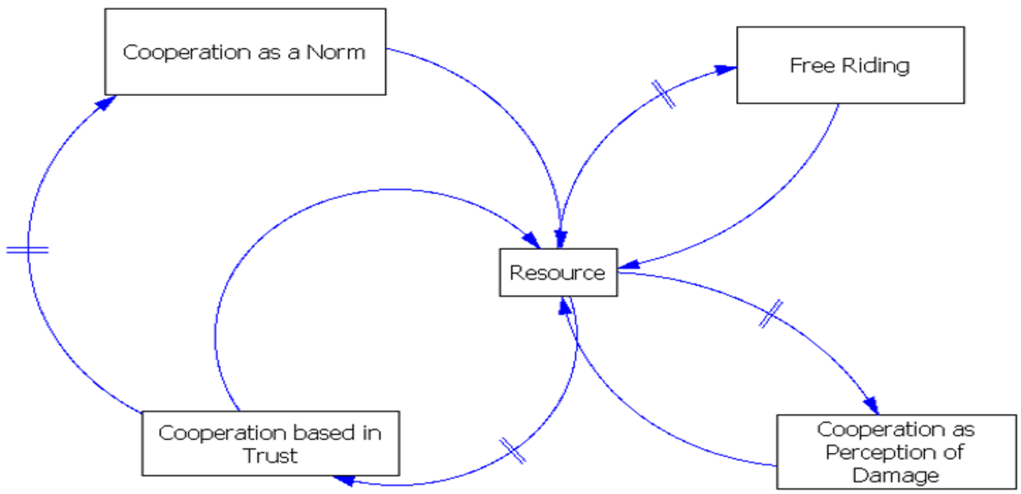


Figure 2: General Model Structure.

3.2 Model

All the models integrate four sectors related with each mechanism: cooperation as a norm, cooperation based on trust, and cooperation by perception of damage as is presented in Figure 2 on page 11.

3.3 Case 1: Colombia's 1992 Electricity Crisis

Colombia suffered an electricity crisis between 1992 and 1993 as a consequence of the ENSO (El Niño), a periodic increase of the temperatures around the Pacific Ocean. Later documents suggested that financial problems and the lack of maintenance of centrals powered with gas also played an important influence in that crisis (Comisión Evaluadora de la Situación Eléctrica y sus Perspectivas, 1992). In short term was not possible to increase the capacity. The only possibility to reduce the vulnerability of the system was cooperation[2]. We studied this situation as a large scale resource social dilemma. Despite the customers did not communicate face to face, the regulator could provide information about the state of the capacity of the system and the level of demand. The regulator assigned shortages as a punishment if people do not meet the social energy saving objective.

In 1991, the share of the electricity production was 78.1 % by hydro-power and 21.9 % obtained by gas generation. Colombia applied shortages and blackouts from march 2 1992 to April 1 1993 reducing 25 % of the demand. The average cost per week was calculated between US 25 and 45 million (Comisión Evaluadora de la Situación Eléctrica y sus Perspectivas, 1992).

There were two specially problematic behaviors in this crisis like is presented on

[2]This is related to Management of the Demand.

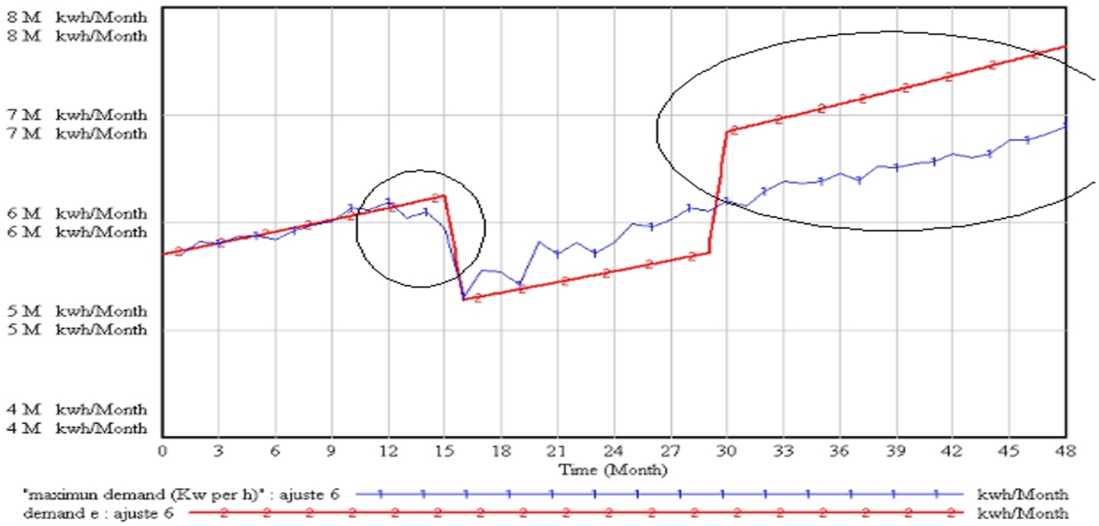


Figure 3: Effects on perception of threat of blackout and cooperation on demand 1992 Colombia electricity crisis. *(Demand: Data in blue, Theoretical shortage in red)*

Figure 3 (page 12). First, people reduced their demand before the beginning of the rolling blackouts. Second, after the crisis people kept the same level of energy demand. We claim for the first situation, that there was a perception of damage that produced the reduction of the demand. This is the mechanism we called cooperation by perception of damage. For the second situation, we claim that people learned to cooperate because the mechanism of cooperation as norm. People were able to apply a new norm of cooperation that kept demand at the same level achieved in the period of blackouts after the end of the blackouts' period. During the crisis, people face the social dilemma using three mechanisms considered. On the time of blackouts, people face temptation to free ride with the mechanism of cooperation based on trust.

3.3.1 Construct for the Colombia's 1992 Electricity Crisis

3.4 The construct for the Colombia's 1992 Electricity Crisis.

The Construct expressed as a dynamic hypothesis is defined by the following feedback loops:

- Expectation. This feedback loop considers the dynamic effect that threat of blackouts has to customers. When the regulator informs about margin and the objective to avoid blackouts, people is persuaded to reduce their demand. This feedback represents the cooperation's mechanism of perception of danger.
- Social learning. People could learn cooperation as a norm. This feedback loop represents the cooperation's mechanism of cooperation as norm.
- Cooperation. This cycle considers the effect of reputation about cooperation for saving electricity. A high reputation will produce or sustain cooperation to save en-

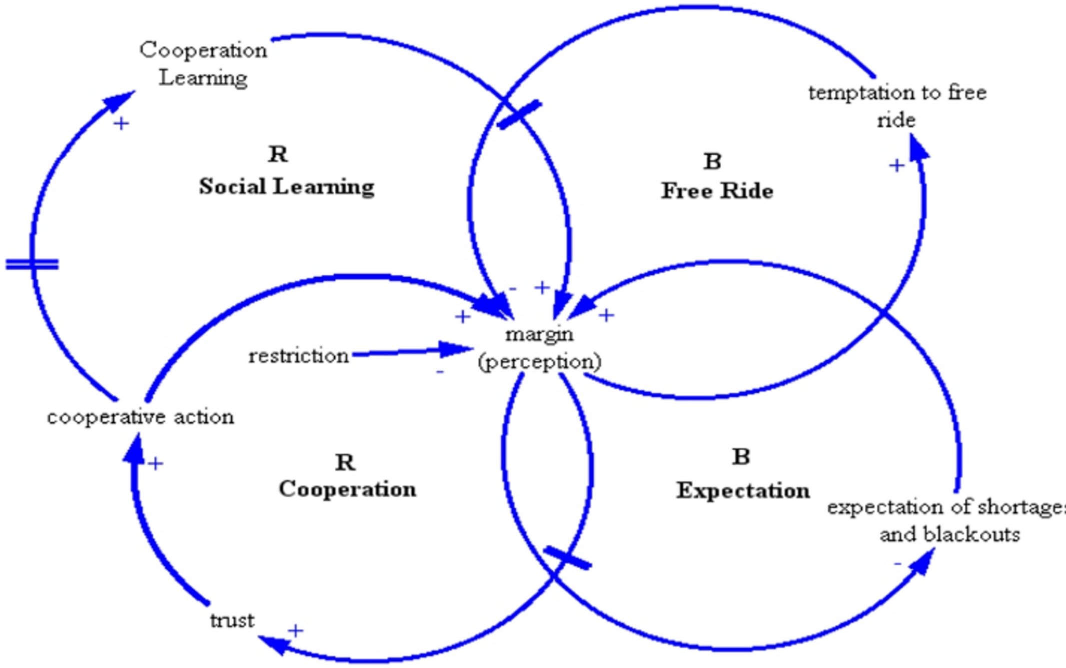


Figure 4: Dynamic Hypothesis about Colombia's 1992 Electricity Crisis

ergy. This feedback represents the cooperation's mechanism of cooperation based on trust.

- Free Ride. If people achieve high levels of cooperation, some of them could try to increase their demand.

Figure 4 on page 13 presents our mechanism expressed as a dynamic hypothesis for the Colombia's 1992 Electricity Crisis.

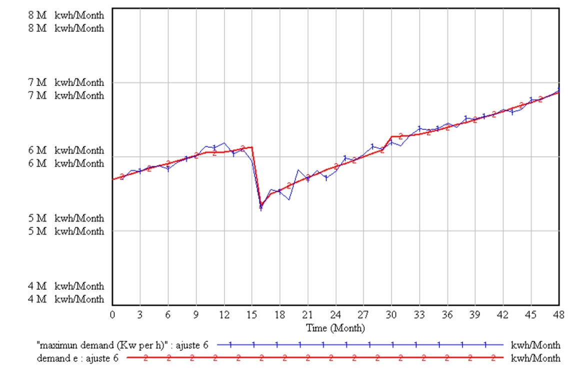
The Figure 7 on page 13 presents the model's variables endogenous, exogenous, and excluded.

Endogenous	**Exogenous**	**Excluded**
Demand Cooperation Trust Perception threat of blackouts Free Riding	Capacity Shortage	Electricity price GNP Climate

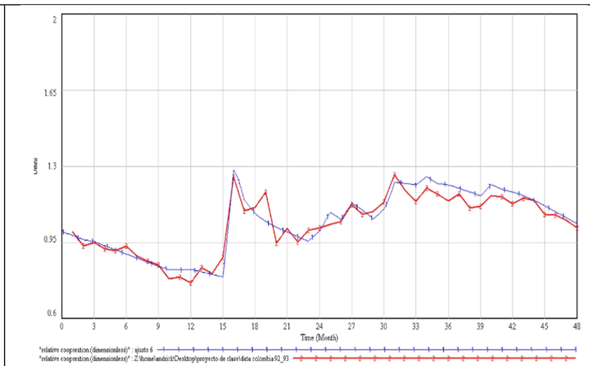
Table 7: Model boundary chart for Colombia'2000 Electricity Crisis model.

3.4.1 Simulation

Table 8 presents simulations for Demand and a proxy for cooperation based on the relative margin of the system. This simulation is based on the reference mode. Note that



A. Simulation and data 1992 Colombia electricity crisis (Demand: Data in blue, Model in red)



B. Simulation and data proxy Cooperation 1992 - 1993 Colombia electricity crisis. (Relative cooperation (proxy): Data in red, Model in blue)

Table 8: Simulation Colombia 1992 Crisis

model was able to offer an explanation about the behavior of cooperation during the crisis studied.

The model produced the behavior showed in Figure 8 on page 14. The simulation begins with a low margin. The threat of blackouts as a punishment and reputation of cooperation produce the dynamics of demand. However, temptation for free riding produces later a reduction for margin. This experiment produced cycles for demand.

Simulations present how the perception about blackouts produces a reduction in demand before blackouts. Long term cooperation explains how people could kept the demand at the same level after the blackouts as showed on part A Table 8 on page 14. If we consider the relative cooperation, we can compare data versus the simulation. Part B of Table 8 on page 14 allows us to consider the relative cooperation efforts.

3.4.2 Effectiveness test results

Table 9 on page 15 presents the results for applying criteria to test the effectiveness of cooperation in Colombia's 1992 electricity crisis assumed as a large-scale social dilemma.

3.5 Case 2: California's 2000 Electricity Crisis

On 2001, the North American Electric Reliability Council (NERC) forecasted shortages (250-700 hours) and blackouts for California (North American Electric Reliability Council, 2001). Several other sources expected a damage to economy (Between US 2 billions to 20 billions (AUS Consultants, 2001; Bay Area Economic Forum, 2001). However, the shortages were not applied at the level predicted initially. Goldman et al. (2002) suggests that the shortages were not applied as a result of the savings of the consumers. Goldman proposed that savings of 6 % in mean demand and 8 % in peak demand Goldman et al. (2002, 120). That paper also suggests that the savings can not be explained as a effect of an economic crisis or as a more cold summer. This savings avoid between 50-160 hours of shortages (Goldman et al., 2002, 118). Markóczy suggested that the California electricity crisis was a resource social dilemma that was overcame thought cooperation (Markóczy, 2007, 1).

Criteria	Evaluation
Resource Is achieved a sustainable level of the resource?	Yes, but is required to operate the mechanism more time.
Cooperation Is sustainable? Is achieved a Pareto Superior?	Yes, but more effort is required in the long run to support cooperation. Yes, but more effort is required in the long run to keep the level of collective action near to the Pareto Superior.
Cooperation learning Are mechanisms promoting cooperation as norm?	Yes.
Temptation to free ride Is controlled the temptation to free ride?	Cooperation based in trust, perception of damage and cooperation as norm kept the level of free riding low.
Perception of damage Did perception of damage improve cooperation?	Perception of damage improved cooperation before rolling blackouts.
Trust Is cooperation promoted besides path dependence of trust?	Mechanisms were able to promote cooperation besides path dependence of trust.
Dynamic Complexity Are the mechanisms effective to mitigate the effects of Dynamic Complexity ?	The time of residence of all mechanisms are enough to mitigate the effects of Dynamic Complexity.

Table 9: Evaluation of the effectiveness of mechanisms applied to promote cooperation during Colombia 1992 electricity crisis.

We suggest the following reasons to claim that the electricity crisis can be assumed as a common shared facility that can be affected by social dilemmas:

- there is congestion.
- price does not offer enough incentives to reduce the demand at generation capacity level.
- there is a conflict between individual and collective rationality.
- the electricity that one costumer uses is not more available to others.
- the electricity demand is inelastic to price changes.

People in California kept the lights on, as Goldman said in 2002. However, other hypotheses instead cooperation were claimed. Studies suggested that temperatures was low in 2001, and this explains the reduction on electricity demand. (Goldman et al., 2002) suggested that data did not support to the temperature hypothesis as explanation of the reduction in 2001 California Electricity Crisis. Economy was part of another hypothesis. For this claim, people reduced their demand as a consequence of a slow down of the economy. However, data did not support such claim. Gross Product grown 2.3 % and employment also increased 0.8 % in august 2001 in comparison to the same month of 2000 (Bay Area Economic Forum, 2001, 10).

In the same way of the Colombian Case, we considered in the model of California four sectors: energy demand, free riding, trust, and perception of threat of shortages.

Figure 5: Simulation and data for Demand California Electricity Crisis 2001. *(Demand: Data in red, Model in blue)*

3.5.1 Simulation

Our model offers an explanation to reduction in California Electricity Crisis. Figure 5 on page 16 presents data and simulation for demand. Note the behavior of the model around the year 2001. The model behavior offers to support our claims about the change of demand as a consequence of the perception of damage by the threat of blackouts.

3.5.2 Effectiveness test results

Table 10 on page 17 presents the results for applying criteria to test the effectiveness of cooperation in California's 2001 electricity crisis assumed as a large-scale social dilemma.

3.6 Case 3: Cooperation for reducing of CO_2 concentration in the atmosphere as a Large-scale resource social dilemma

Most documented explanation about Climate Change claims that the greenhouse gases effect has high influence on temperature (IPCC, 2007, 93). The atmosphere keeps some heat according to the effect of green house gases like CO_2, that has been increased as a consequence of industrial activity mainly (IPCC, 2007, 95). As global shared facility, climate is vulnerable to social dilemmas because individuals and nations can benefit in the short run from greenhouses emissions, while all of us pay the costs (Buck 1998,2; National Research Council 2002,5). To reduce global warming emissions of greenhouse gases (GHGs) must fall below the rate at which GHGs are removed from the atmosphere. However, people do not understand the dynamics of the climate change (Sterman and Sweeney, 2002, 207).

Criteria	Evaluation
Resource Is achieved a sustainable level of the resource?	Yes, but is required to operate the mechanism more time.
Cooperation Is sustainable? Is achieved a Pareto Superior?	Yes, but more effort is required in the long run to support cooperation. Yes, but more effort is required in the long run to keep the level of collective action near to the Pareto Superior.
Cooperation learning Are mechanisms promoting cooperation as norm?	Yes, but more time applying mechanisms is required to sustain cooperation more time.
Temptation to free ride Is controlled the temptation to free ride?	cooperation based in trust, perception of damage and cooperation as norm kept the level of free riding low.
Perception of damage Did perception of damage improve cooperation?	Perception of damage improved cooperation before rolling blackouts and promote collective action.
Trust Is cooperation promoted besides path dependence of trust?	Mechanisms were able to promote cooperation besides path dependence of trust.
Dynamic Complexity Are the mechanisms effective to mitigate the effects of Dynamic Complexity ?	The time of residence of all mechanisms are enough to mitigate the effects of Dynamic Complexity.

Table 10: Evaluation of the effectiveness of mechanisms applied to promote cooperation during California 2001 electricity crisis.

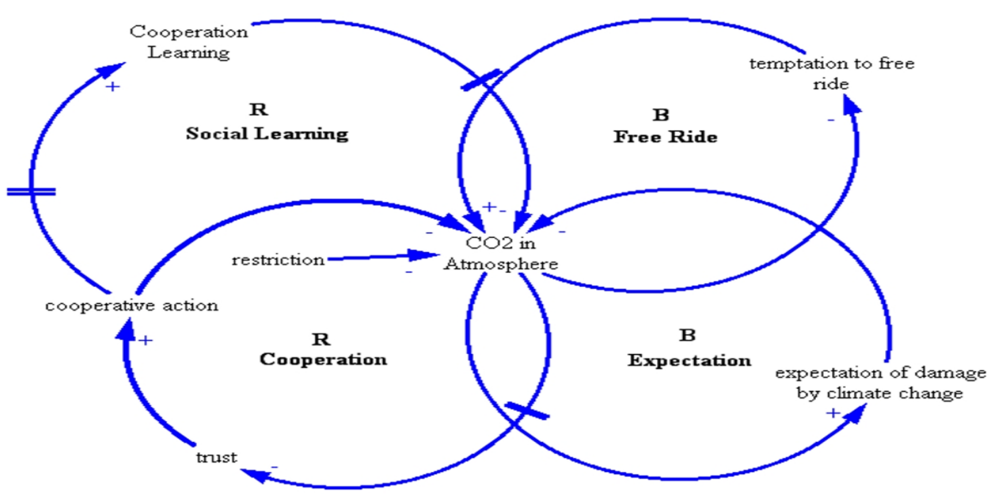


Figure 6: Dynamic Hypothesis Cooperation in CO_2 reduction in atmosphere.

We proposed our Dynamic Hypothesis as an expression of the mechanism for cooperation for large scale resource social dilemmas . We claim that only people will recognize a threat of damage about climate and the emissions on GHGs if they find a strong relation between the emissions of GHGs and the effects of global warming as the extreme events. Only this recognition will produce enough pressure to reduce the emissions. Our hypothesis is presented in Figure 6 on page 17.

The model boundary chart for for testing the effectiveness of cooperation's mechanisms to reduce concentration CO_2 in the atmosphere is presented in Table 11 on page 18.

Endogenous	Exogenous	Excluded
CO_2 emissions Cooperation Trust Perception threat of damage Free Riding	Objective	Economy

Table 11: Model boundary chart for testing the effectiveness of cooperation's mechanisms to reduce concentration CO_2 in the atmosphere.

We use the same four sectors: trust, perception of damage, long term cooperation, and CO_2 emissions. Table 11 on page 18 presents the model boundary chart for the model of cooperation to reduce the emissions of CO_2 as a Large-scale resource social dilemma.

3.6.1 Simulation

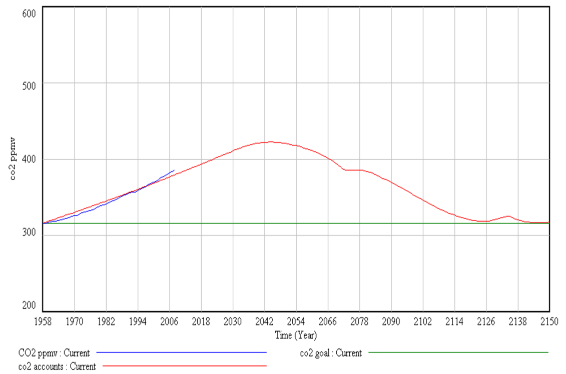
We present simulation experiments about cooperation as an institution to reduce CO_2 emissions. The model suggests that the life time of long term cooperation is the difference between failure or success. Table 12 part A on page 19 presents the behaviour of CO_2 with a very low life time for cooperation as a norm. It is not possible to reduce CO_2 level. Table 12 part B on page 19 shows the simulation for a very high life time for cooperation as a norm. In this simulation, long term cooperation is able to drive to a reduction of CO_2.

3.6.2 Effectiveness test results

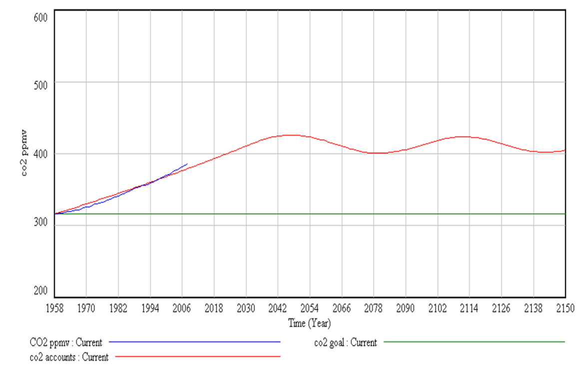
Table 13 on page 19 presents the results for applying criteria to test the effectiveness of cooperation in CO_2 crisis assumed as a large-scale social dilemma.

3.7 Sensibility Analysis

The sensibility analysis applied offers information about the confidence of results. According to these test, dynamic complexity affects the performance of the cooperation's mechanisms applied to face large-scale social dilemmas. This is more critical if the case has inertia and long delays. Table 14 on page 20 presents a sensibility analysis about the effect of information delays and recognition of trends in all the cases reviewed.



A. Simulation low life time long term cooperation in reduction of CO_2 concentration in atmosphere. CO_2 data in blue, CO_2 model in red, Objective in green.



B. Simulation high life time long term cooperation in reduction of CO_2 concentration in atmosphere CO_2 data in blue, CO_2 model in red, Objective in green.

Table 12: Simulation low and high life time long term cooperation in reduction of CO_2 concentration in atmosphere.

Criteria	**Evaluation**
Resource Is achieved a sustainable level of the resource?	Yes. To achieve a sustainable level of cooperation enough residence time is required for cooperation as norm and perception of damage.
Cooperation Is sustainable?	Yes, but more effort is required in the long run to support cooperation. A carefully design is required to sustain cooperation in the long run because inertia and Dynamic Complexity.
Is achieved a Pareto Superior?	It is possible, but more effort is required in the long run to keep the level of collective action near to the Pareto Superior. This is possible using more residence time.
Cooperation learning Are mechanisms promoting cooperation as norm?	Yes, but is more difficult because delays and inertia.
Temptation to free ride Is controlled the temptation to free ride?	Cooperation based in trust, perception of damage and cooperation as norm kept the level of free riding low if life time used is high for all mechanisms.
Perception of damage Did perception of damage improve cooperation?	Perception of damage improved cooperation, but its effectiveness depended of the life time of the mechanisms.
Trust Is cooperation promoted besides path dependence of trust?	Mechanisms were able to promote cooperation besides path dependence of trust.
Dynamic Complexity Are the mechanisms effective to mitigate the effects of Dynamic Complexity ?	The time of residence of all mechanisms are critical to mitigate the effects of Dynamic Complexity. This is the key variable to keep mechanisms' effectiveness.

Table 13: Evaluation of the effectiveness of mechanisms applied to promote cooperation in CO_2 concentration crisis.

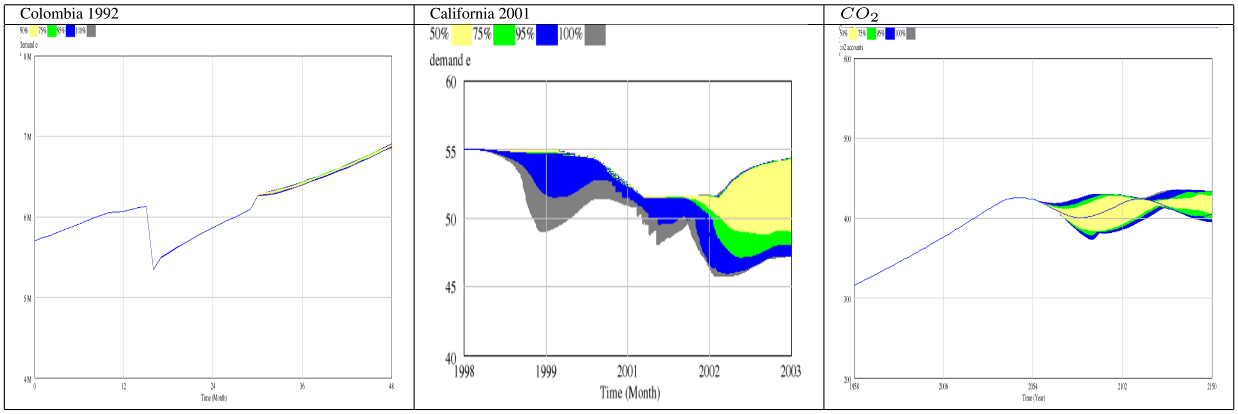


Table 14: Effects of information delays and trends

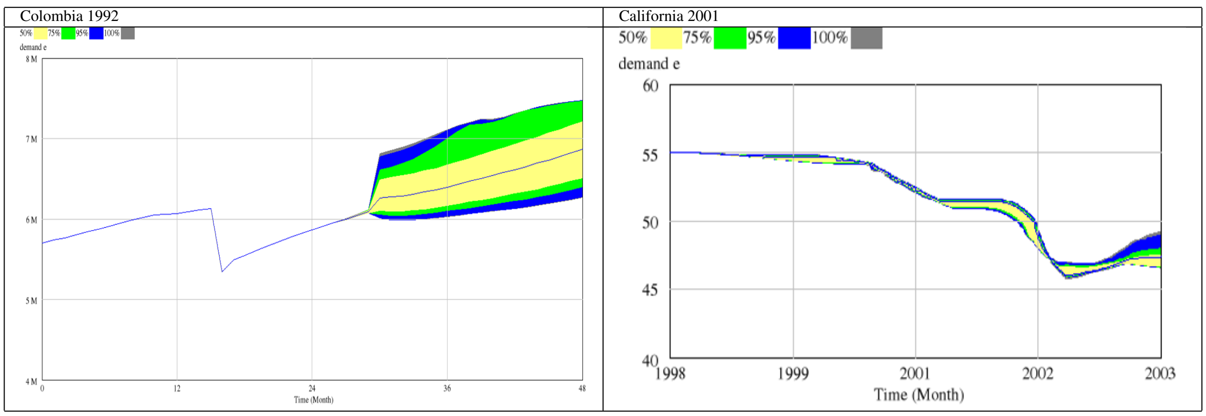
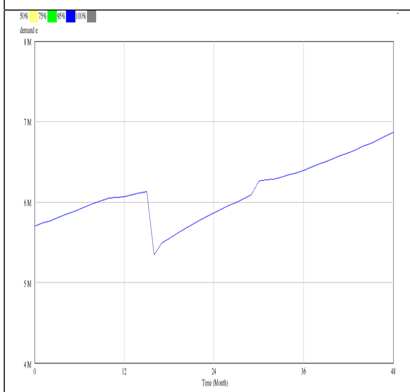


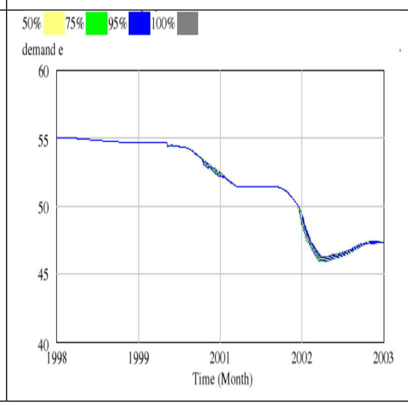
Table 15: Cooperation as Norm: life time Sensibility Analysis

Table 15 on page 20 presents a sensibility analysis about life time in the mechanism Cooperation as Norm in all the cases reviewed.

Table 16 on page 21 presents a sensibility analysis about life time in the mechanism Cooperation based on Trust in all the cases reviewed.

Colombia 1992	California 2001	CO_2





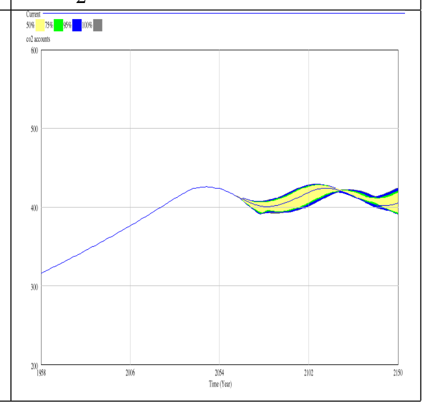


Table 16: Trust average lifetime Sensibility Analysis

4 Discussion

We have presented a construct to test the effectiveness of cooperation's mechanisms in Large-Scale Social Dilemmas involving resource depletion. The construct integrates cooperation mechanisms from the theory of cooperation for small scale resource social dilemmas (mechanism of cooperation based in trust) (Ostrom, 2000, 13), perception of punishment as damage (mechanism of cooperation based on perception of damage) (Schelling, 1958, 5), and cooperation in the long run (mechanism of cooperation as a norm) (Biel et al., 1999). We developed three models based in our construct with elements of dynamic complexity as no linear relationships, delays, and perception of trends (Sterman, 1989, 301). We used guidelines from System Dynamics (Forrester, 1961, 60) (Sterman, 2000, 83).

Our simulation models suggest:

- The construct offers a frame to test the effectiveness of cooperation mechanism's in Large-Scale Social Dilemmas involving resource depletion in general.
- Besides different conditions, our results suggest cooperation requires feedback about the results of cooperative actions. This could be an important factor to consider in Large-Scale Social Dilemmas involving resource depletion situations conditioned by dynamic complexity.
- Dynamic complexity is a key concept required to understand the effectiveness of cooperation mechanisms in Large-Scale Social Dilemmas involving resource depletion. The models designed have strong delays, structures to represent changes in perceptions, no linear relationships.
- It is possible to develop cooperation besides a history of cooperation in Large-Scale Social Dilemmas involving resource depletion. Models assumed zero initial experiences about cooperation for each case. However, cooperation is promoted by mechanisms.
- People after a crisis can adopt norms of cooperation and support cooperation before a strong restriction and a process of development of trust and cooperation in the short run.

These results are connected with the Literature. We offer our construct to test the effectiveness of cooperation mechanism's in Large-Scale Social Dilemmas involving resource depletion. The effectiveness of the cooperation's mechanism based on trust has been test in laboratory and field settings (Ostrom, 2000, 15), but we did not find papers for testing effectiveness of cooperation' s mechanism in large-scale social dilemmas. The question about the possible application of the small dilemmas theory for explaining large scale situation is an open question (See McGinnis and Ostrom (2008, 189) and Foddy (1999, 189)).

People have problems to face situations conditioned by dynamic complexity. To manage a simple inventory (Sterman, 1989, 337) or drive a natural resource (Moxnes, 1998) is problematic because dynamic complexity. The core feedback loop for cooperation in Small-dilemmas (Ostrom, 2000, 13) requires information about the results of cooperation to promote new cooperation. Delays, perception, and no linear relationships affect also the performance of cooperation. The cooperation's mechanism used in large-scale social dilemmas require information feedback to be effective.

The core relationship of cooperation (Ostrom, 2000, 15) suggests that cooperation presents path dependence (Castillo and Saysel, 2005, 450). The construct designed proposes an explanation about how cooperation's mechanisms used in Large-Scale Social Dilemmas improves cooperation besides a history of poor results in cooperation.

Results suggests that feedback about the outcome of cooperation is crucial to promote new cooperation. Situations conditioned by dynamic complexity could offer difficulties to institutions and mechanisms for cooperation. This could be useful to design institutions to face Large-Scale Social Dilemmas involving resource depletion using cooperation's mechanisms like reduction of CO_2 in atmosphere with cooperation.

5 Conclusion

We designed a construct to test cooperation mechanisms used to promote in large-scale social dilemmas that involve resource depletion. The proposed construct integrates cooperation's mechanisms like trust, perception of damage and cooperation as norm. Results suggest that the designed artifact explains how mechanisms promote cooperative behavior in large-scale social dilemmas that involve resource depletion. We developed tree System Dynamics Models based on our construct about Colombia's 1992 and California's 2001 Electricity Crisis, and an institution based on cooperation to reduce the atmospheric CO_2 concentration. Results suggest that the construct is able to test the effectiveness of cooperation's mechanisms in Large-Scale Social Dilemmas involving resource depletion. Delays, perception, and no linear relationships affect also the performance of cooperation's mechanisms. We proposed an explanation about how cooperation's mechanisms could be used to promote cooperation in groups without history of cooperation. We suggest that besides the specific conditions of large scale situations, cooperation requires feedback information about the results of collective action, and for this understand how dynamic complexity affects cooperation is a key to design institutions and mechanisms to face Large-scale resource dilemmas like the reduction of the concentration of CO_2 in the atmosphere. The research finally indicates how cooperation mechanisms can be effective to promote cooperation in the context of dynamic complexity in large-scale social resource situations.

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