Ethics in Progress (ISSN 2084-9257). Vol. 8 (2017). No. 1,
Art. #10, pp. 156-173. Doi: 10.14746/eip.2017.1.10

Social Dilemmas in Environmental Economics and Policy Consideration: A Review.

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1. Introduction

Many crucial environmental problems may be considered social dilemmas. Every time the access to an exhaustible resource is shared between multiple individual or collective actors we are potentially facing a social dilemma, where the most profitable individual behavior does not lead to the best collective payoff. Often social dilemmas emerge when people share access to resources and are thus somehow competing in the appropriation process of the common properties. They are situations "in which individual rationality leads to collective irrationality. That is, individually reasonable behavior leads to a situation in which everyone is worse off than they might have been otherwise" (Kollock 1998, 183). These situations are especially concerning because, along with leading to behavior which ultimately brings negative consequences for all the individuals, they also have extremely negative consequences on the resources themselves. As can easily be imagined, these premises can be found in climate change issues, sustainable management of marine environments, forests, energy management and a wide range of other circumstances. As the challenges posed by the ecosystems increase worldwide, knowing how social actors react to bindings and incentives is crucial to the development of policies that stimulate cooperation and virtuous behavior. Moreover, to be able to understand how individuals who face changes in their ecosystems would react to such changes, it is imperative to recognize which are the situational properties influencing their behavior even in relatively stable conditions. This may contribute to the formulation and hopefully to the introduction in advance of policies that could, at least, mitigate the dangers that decreasing resources would pose in such environments. The experimental approach to the set of problems in the commons allows for testing hypotheses under controlled conditions and even if, especially for laboratory experiments, the results lack the external validity necessary for extending the results to real-world populations, they are very effective in testing and developing theories (Poteete, Janssen & Ostrom 2010). Traditional economic approaches towards this class of problems, based on the rational-choice model of actors, lead to the conclusion that the most probable result of these processes is the well-known 'tragedy of the commons' as

predicted by Hardin (1968). Evidence from case studies, field experiments and laboratory experiments, on the other hand, suggest that this is neither the only nor the most common outcome of the social dilemmas (e.g. Ostrom 1998).
This paper will review some important findings among the existing literature about social dilemmas with a particular focus on the theoretical work as well as the findings coming from laboratory experiments.

2. Public Goods and Common-Pool Resources

The particular class of problems described in the introduction are often modeled either as a common-pool resource dilemma or as a public good dilemma. Traditionally a common-pool resource dilemma, when created in experimental conditions, consists in a game in which a common resource may be accessed by multiple players. Collecting some of the resource is beneficial for the harvesting player, and is the only way for him to obtain a payoff, but it reduces the amount of the resource available to the other players. A public good dilemma, instead, is modeled after a situation in which the subjects have money in a personal account. Contributions from their personal account to a public good are multiplied by a certain factor and then redistributed equally among all the players. The main difference between these two types of dilemmas lies in the rivalry of consumption. While the public good's benefits in principle can be enjoyed by any number of individuals, the common-pool resource is limited and thus any individual using it is deducting some kind of good from the collectivity (see e.g. Ostrom 1994). In the CPR games, the participants have to deal mainly with an appropriation problem, while in PG games the main issue is provision. Despite these considerations, many authors treat both dilemmas as similar, if not equivalent, with the only difference lying in diverse representations of the same problem. Indeed, the similarities are clear – both dilemmas can be reduced to a prisoner's dilemma game – but while these two games are equivalent under the Homo Oeconomicus assumption, they are treated in substantially different ways in real-world situations. The most evident reason, as stated by Gintis (2000) is that the status quo is essentially the opposite: in the public good class of games it consists in keeping all of the money in one's private account, meaning no cooperation at all. On the contrary, in the common-pool resource games the status quo is not using the resource at all, which is the most cooperative behavior. An experimental study from Apesteguia and Meier-Rigaud (2006) suggests also that, while the contributions in the two games tend to be statistically different, there are still strong behavioral similarities. In both cases (in a non-framed standard game, i.e. where the players can't communicate and there is no punishment for noncooperators or reward for cooperators) the

players' average contributions start close to the Pareto optimum[1] and tend to move towards the Nash equilibrium[2] over time.

3. Decision-Making Theory

Analyzing the dilemmas using expected utility theory, the prediction would be, contrary to what is usually found in experiments, that the players try to maximize their income by behaving according to rational assumptions. The expected utility theory is the most used paradigm for decision-making in economics, and stems from the rational choice theory, which assumes that people optimize their decisions in a self-interested way. Both of these theories include some assumptions on the behavior of individuals, leading to the definition of a *homo oeconomicus*, which is a portrayal of humans as completely and consistently rational decision-makers, who pursue their self-interest. In practical terms, assuming rational actors, and thus embracing the rational choice model of actor, coincides with accepting the expected utility theory as a description of the decision method of the actors. An in-depth analysis of the expected utility theory in particular, and of the rational choice theory in general, is out of the scope of this article, however it is important to note that, based on them, cooperation in most of the common resources problems would never happen, and most resource users would act according to the Nash equilibrium. The presence of cooperation in social dilemmas would be explained only by considering it an error or the result of confusion. Andreoni (1995) tested this hypothesis, revealing that half of the analyzed cooperators in the sample were not confused about incentives, understood free-riding, but instead chose to cooperate due to preferences for kindness and cooperative behavior. Andreoni's work is not the first to suggest that the expected utility theory is often unable to provide a reasonable estimate of people's behavior. As mentioned by Henrich, Boyd *et al*. (2005, 3), "Literally hundreds of experiments in dozens of countries using a variety of game structures and experimental protocols suggest that in addition to their own material payoffs, subjects care about fairness and reciprocity, are willing to change the distribution of material outcomes among others at a personal cost to themselves, and rewards those who act in a prosocial manner". It is clear, then, that the expected utility theory, as it is, is not

[1] The Pareto optimum, or Pareto efficiency, is defined as a situation where, given a group of people, it is impossible to improve the situation of an individual without worsening the situation for another individual. In other terms, it is the optimal allocation of resources.

[2] The Nash equilibrium is a concept in game theory in which no individual, knowing the other individuals' choices, has any incentive in changing its own strategy. In Common-Pool resource problems, the Nash equilibrium is often analogous to a non-cooperative strategy, where all the resource users use the resource as much as it is economically advantageous to them.

a good predictor of choice behavior in the commons and in many other complex decision environments, given that it is not able to capture many issues of the decision-making process. Of course, this does not allow us to ignore the usefulness of this theory altogether, but it limits its adoption as a predictive tool.

Many attempts have been made to find a more efficient human decision theory, both related to social dilemmas and to decision processes in general. Despite the large amount of empirical studies, a widely accepted theory of decision making in social dilemmas still does not exist (Weber, Kopelmann & Messick 2004). However, by looking at the results of these studies, we can infer that people seem to react also to changes in the situation that are not explained by standard economic theory (i.e. to non-economic incentives).

Ostrom's approach to the problem is based on an analysis strongly rooted in noncooperative game theory. The experimental and real-world evidence suggests that, in an environment without communication, norms and sanctions, the predictions derived from such theoretical models are close to the aggregate behavior observed. On the other hand it is shown that, at an individual level, behavior does not conform to predictions, but has some regularities that could be a consequence of the heuristics adopted (Ostrom, Gardner & Walker 1994). It is anyways made clear that the assumption of rationality in the noncooperative games is intended to be a powerful tool to compare predictions and results, and not a description of the actual decision processes. In other words, while rational choice theory and the concept of expected utility as the main driver of human decisions can be extremely useful in order to build predictions and hypotheses, it is not a good descriptive tool. At the same time, no other decision theories proved to be as effective in predicting behavior on very large scale, and no other decision theory translates as well into mathematical models, making it the most broadly-embraced approach for both its efficacy, and ease of application to a wide array of fields.

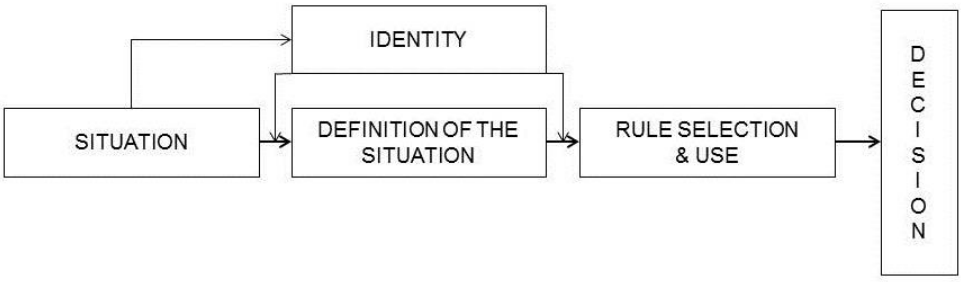

Figure 1. The Appropriateness Framework (Weber, Kopelmann, & Messick, 2004)

In order to obtain an alternative model able to provide a more accurate description March (1994) suggests a framework to understand individual choice that takes into account the aforementioned discrepancies and tries to explain them. The "logic of appropriateness", contrasting with rational choice

models, tries to focus on the social nature of the dilemmas. The actors, according to this framework, choose rules of behavior that are both depending on their personal preferences and on the situation in which they are involved, as can be seen in Figure 1. The properties of the situation may also be addressed as the framing of the situation. The decision maker interprets those properties and comes up with a definition of the situation. Then, he chooses a rule to use in the decision process, which he believes is the appropriate rule for the situation in which he finds himself. It is worth stating already that, even if the behavior is not assimilable to the one expected from a rational actor, it still reacts, in a significant way, to economic factors. This is shown e.g. by Croson *et al*. (2000), who found out that a positive variation of the value of the public good, in comparison to the value of the private good necessary to provide it, enhances the chances of cooperative attitudes. This suggests that the actual economic factors of the situation, other than somehow being computed by the actors, also play a part in the choice of the rule that he will be using.

4. Rules of Thumb

Recent research in behavioral economics and social psychology suggests that decision makers tend to adopt rules of thumb or heuristics rather than maximizing the potential outcomes (e.g. Bargh & Chartrand 1999, Brandstätter, Gigerenzer & Hertwig 2006). This means that, instead of acting according to the rational choice theory, they do not tend to consider the decisions they face in strict mathematical terms, and choose the alternative that allegedly allows them to maximize their utility, but instead they adopt less cognitively demanding decision processes (e.g. choosing the option that they perceive as the most preferred by their peers, or choose one option that they chose already in the past). Extensive research has been conducted with the objective of understanding the actual decisional processes and rules adopted in complex and uncertain contexts, encompassing Simon's work on bounded rationality, Kahneman and Tversky's prospect theory and Gigerenzer's fast and frugal heuristics (see, e.g., Simon 1983, Kahneman & Tversky 1979, Gigerenzer 2008). Simon (1955) postulated that the discrepancies observed between the real-world scenarios and the outcomes expected by the rational choice theory are explained by limits in time availability, information availability, and cognitive limitations of the decision-makers. Kahneman and Tversky's prospect theory (1979), expanded on Simon's considerations, introducing the idea that cognitive and situational limitations are not enough to account for the substantial differences between observed behavior and the expected utility theory, and thus, even though still based on it, the prospect theory introduces new concepts, such as risk aversion, certainty effects, and decision weights instead of probabilities, and considers them not as limitations, but as intrinsic

properties of decision-makers. Finally Gigerenzer (1996) introduced the concept of heuristics, suggesting that rationality is an adaptive tool, and instead of assuming that decision-makers act accordingly to the expected utility theory, but with biases and limitations, scholars should instead consider that decisions are made following a multitude of heuristics, or simple decision rules, whose outcomes may, sometimes, lead to the same results. For the purpose of this work, we can infer that focusing on the outcomes of the use of a rule is often a good indicator of the rule that was used in collective dilemmas, on the micro level (i.e., if a resource was shared equally by its direct users, most likely they deemed a heuristic that led them to share it equally the most appropriate for the situation). The rule adopted is, as a matter of fact, heavily involved with what the actor thinks is the appropriate outcome of the decision, as the outcomes of framed experiments suggest. If the individual considers the equal sharing of the resource to be the right outcome in a common-pool resource game with four players, then he will probably adopt the rule of equality as a decision heuristic, and take possession of one fourth of the resource (see e.g. Samuelson & Allison 1994). Furthermore, as stated by El-Gamal and Grether (1995), the hypothesis of a relative homogeneity between actors's decision rules does not find enough support. The authors conducted a set of experiments in order to verify if it is reasonable to state that generally, in the same type of task, all the participants tend to adopt the same decision rules. Their results suggest that it is reasonable to assume that in any given situation, different subjects might rely on different decision rules, and they might also change them depending on the outcome, meaning that, even in the same exact situation, we cannot reasonably expect different people to adopt the same behavior.

Gunnthorsdottir, Houser and McCabe´s (2007) research, based on a Public Good experiment, suggests that a subject's initial public contribution is a useful measure of cooperative disposition. This is an important finding and proves that it is often useful to categorize the subjects depending on their attitude towards cooperation, since their behavior is in many cases consistent between various games. For the purpose of analysis and experimental set-up, the most commonly used differentiation is between free-riders and cooperators. The latter category is often split into various types of contributors depending on what conditions lead them to adopt cooperative behaviors. One of the most common classifications, proposed by Fischbacher, Gächter, and Fehr (2001), consists of conditional cooperators, who cooperate if others cooperate, triangle contributors, who increase their contributions depending on other subjects' contributions up to a certain level, after which they start to contribute less, and other contributors, who do not fit in any of these two categories, but are not either pure free-riders.

5. Framing and Incentives

5.1 Communication

Communication has been found to be an important incentive for cooperation in many experiments. Brosig, Weimann and Ockenfells (2003) tested the influence of communication and communication media by conducting seven Public Goods experiments, allowing for different communication media. Their results show that, while people in social dilemmas use communication as a tool to coordinate their efforts, the outcomes strongly depend on the communication medium. Also, even if all types of communication have a positive effect on cooperation levels, face-to-face communication seems to be the only one to produce, in the end, both high cooperation levels and high stability of such levels.

Janssen *et al.* (2010), used an artificial experimental environment to consider also spatial and temporal dynamics, to recreate the dynamic environment in which the dilemmas occur in real life situations. In this case it is again verified with high levels of significance that communication helps subjects to achieve better final payoffs and to manage a CPR more efficiently. This is a further confirmation that communication between actors is beneficial, also with dynamic resources.

Another important distinction is whether communication is allowed on a repeated basis or if it is only a one-shot, pre-play coordination mechanism. As noted by Ostrom (1992), even if the subjects can communicate, the game equilibria remain the same and should not, then, make a difference in the outcomes for rational individuals, if we assume them as strictly rational in a traditional sense. This is because, according to the expected utility theory, communication without the means to introduce punishment or other binding agreements should not have an effect. The results, on the other hand, suggest that communication may push individuals to adopt decision rules more adherent to the social aspects of the dilemmas and thus to more cooperative behavior.

As shown experimentally by Hacket, Schlager and Walker (1994), communication may also be an effective mechanism to promote efficient resource use in more complex decision environments, such as when there is heterogeneity between subjects. The adopted rules may differ, ranging from equal sharing of the resource, to equal final outcomes for the participants, but the increase in efficiency in the management of the common resource is constant throughout the treatments observed. An interesting addition to this topic is brought forward by Margreiter, Sutter and Dittrich (2005), who verify that heterogeneity could facilitate or impede coordination when the actors could manage a CPR, by voting on appropriation rules. The outcome of this research is that, when allowed to vote, homogeneity leads to more efficient groups, but after a learning process the efficiency levels in heterogeneous groups tend to get closer to the homogeneous ones. These findings support the

assumption that, also in complex choices, most forms of communication may lead to efficient management and help subjects to overcome other obstacles to efficient resource use. Findings consistent with this assumption are also found in experiments on public good (see for example Tavoni *et al.*, 2011), and generally confirm that also in that class of social dilemmas communication increases cooperation dramatically.

5.2 Uncertainty

Uncertainty on the properties of the resource or of the good to be provided has is generally found to be an obstacle to cooperation in social dilemmas. Budescu, Rapoport and Suleiman (1990) tested this hypothesis in a common-pool resource game. When uncertainty about the size of the resource was introduced the amount of tokens harvested by each player increased. This effect, according to the authors, seems to be generated by a tendency to overestimate the resource size when it is not known. Dannenberg, Löschel, Paolacci, Reif and Tavoni (2011) obtained similar results in a Public Goods game that tested the effect of both risk and ambiguity relative to the amount of tokens necessary to provide the public good. The results support the hypothesis that uncertainty in both forms is a negative incentive for subjects and, in absence of trust between them, leads to failure in cooperation. A potential explanation is that, in conditions of uncertainty, the actors tend to rely on the behavior of their peers, thus acting as conditional cooperators. Anyway, early action and trust between the subjects can influence them to cooperate more in this situation. The importance of trust in mitigating the negative effect of uncertainty is confirmed by Wit and Wilke (1998). In a Public Goods experiment they verified that a reduction in cooperation occurs, under uncertainty, only if it is accompanied by high social uncertainty too. In this case, when the range of the previous contributions of the other participants, communicated by the experimenters to the subjects, was high, the chance of cooperative behavior decreased. On the other hand, when the range was low, there was no significant difference between the treatments with or without environmental uncertainty.

However, findings contradicting the previous evidence are shown by McAllister, Tisdell, Reeson, and Gordon (2011). In an experiment modeling the livestock mobility in semiarid systems the authors found out that, when subjects find it very important to create and maintain long-time relationships, they might adopt cooperative strategies. As a conclusion, exogenous variability and uncertainty may also trigger cooperative strategies. Once again, the context may play a crucial role in the rule selection process of the individuals.

5.3 Punishment and reward

Punishments and rewards in common-pool resources and public goods have been tested as incentives for cooperation, as the results could be clearly very useful in developing policies. Both interventions may be of endogenous or exogenous nature. So far experimental results (e.g. by Sutter, Haigner & Kocher

2010) suggest that endogenous forms of intervention may enhance cooperation more than the exogenous forms, at least for what concerns punishments. Another consideration is that often, in experimental settings, endogenous punishment involves a cost, which has to be paid by a subject in order to punish a noncooperator. It has been shown (e.g. Ostrom 1994, Rockenbach & Milinski 2006) that costly, endogenous punishment tends to be used by actors, contrary to what rational-choice approaches would predict. The subjects are willing to pay to be able to punish non-cooperators, even if this is clearly going to lower their personal, final payoff. This leads to results that, in baseline experiments without communication between actors, are not far from the Nash equilibrium. On the other hand punishment, if coupled with the possibility of communication between the actors, can even enhance the cooperative behavior and move the outcomes closer to the Pareto-optimum. As shown by Ostrom (1992), a costly sanctioning system without communication can even reduce net wield, while the most efficient sanctioning system is the one that allows subjects not only to communicate, but also to choose if they would like to have the possibility of punishment and how should this punishment work. The experiments conducted show that in this last option the defection rate from the agreements between the participants is extremely low.

Milinski, Semmann and Krambeck (2006) in a laboratory experiment, debated instead of the effects of rewards, linked to the reputation of the subjects, on the cooperation in a public good game. As can be expected, the results show that there's a huge difference in the reactions of a subject to rewards or punishments. Alternating an indirect reciprocity game and a Public Good game in which the reputation of the actors was common knowledge they found out that, as long as a reward for cooperation is expected, the management of the common resource – in this case the public good – is more efficient and the net wield of the participants increases.

It is also worth noting that, relating to this, Andreoni (1995) shows that a positive framing, ceteris paribus, leads to better results than a negative framing. In his work, he conducted two sets of Public Good experiments, with opposite framing. In the first case, the subjects are contributing to a public good with their private money, while in the second experiment they may use public money to purchase private goods for them. The incentives and values are the same, but the participants have shown more cooperative attitudes when the problem is presented as a positive externality rather than a negative externality. This may suggest also the hypothesis that a rewards system may be a better choice than a sanctioning system in the management of the Commons. For now, experimental evidence doesn't confirm this hypothesis. In the aforementioned work Sutter, Haigner and Kocher (2010), found that, while if able to choose subjects in Public Goods games opt for rewards instead of punishment, the latter intervention is more effective in sustaining high levels of cooperation.

5.4 Scarcity

Resource stock levels in common-pools, as noted by Blanco, Lopez and Villamayor-Tomás (2011), have received little attention by academic research, which have delivered inconclusive results as of yet. The field experiment conducted by the authors consisted of a Common-pool resource game, with exogenously changing resource levels. According to the results, subjects that find themselves in a situation of extreme scarcity tend to increase appropriation, leading to even worse conditions for the resource. On the same topic contrasting results have been obtained by Osés-Eraso and Viladrich-Grau (2007): the conclusion of their laboratory experiment, whose objective was to estimate agents' concern for resource scarcity is that, as the resource becomes scarcer, the appropriation level tends to decrease. They state, then, that the concern for scarcity might, in the end, enhance resource preservation. Based on this last model Blanco, Lopez, and Villamayor-Tomàs (2015) developed a field experiment in a Colombian watershed where, in conditions of extreme scarcity, they observed the resource users increasing their consumption. All these results support a hypothesis first suggested in 2009 by Ostrom. In the article the author stated that, based on field observations, before investing in self-organization the resource users need to observe some type of scarcity. In other words, only having experienced scarcity may lead them to change their behavior in order to preserve the resource. This happens, though, through a curvilinear effect: Conditions of moderate scarcity lead to less harvesting, while extreme conditions of scarcity lead to overuse and, possibly to the extinction of the resource. One of the main issues when talking about scarcity in natural resources is for sure the big difference between ecosystems in terms of ability to cope with the disturbances, and thus generalizing observations that apply to different resources is an especially difficult task (see, e.g., Folke . 2004). A very important aspect, finally, is that knowledge of the behavior and dynamics of the resource are also crucial in terms of influencing the users' decision processes. As stated by Schill, Lindahl, and Crépin (2015), the likelihood of a regime shift, a sudden and potentially permanent change that modifies the resource substantially, influences the resource users' collection patterns, so that the menace of a future change can lead them to develop more cooperative agreements that, ultimately, can lead to more sustainable harvesting processes. More conclusions on this aspect will be drawn in the conclusion, but it is important to underline already that all these aspects are strongly tied to a deep knowledge of the resource, of its dynamics and of its current status. In other words, scarcity is indeed a measurable aspect, but it would be unsafe to assume that the resource users receive an immediate feedback. Therefore, it is also important to make sure that a change in behavior of the resource users can be expected only in those cases in which they are aware of a potential situation of scarcity or of whatsoever danger it might be in.

5.5 Group size

As stated by Ostrom (2002), the effect of group size on cooperation in social dilemmas is still not clearly understood, and the existing evidence is contradicting. Both negative effects of group size on the frequency of cooperative strategies and no effects at all have been found in both laboratory and field situations. One of the plausible reasons is that, as group size increases, other aspects of the situations are also modified.

The findings of Allison, McQueen, Schaerfl and Lynn (1992) are a clear example of the complexity of the effects of group size. They verified with a set of experiments two distinct aspects: the difference between a partitioned (solid blocks) and a non-partitioned resource (sand), and the group size. In this case, as the number of members of the group increased, the cooperation efforts of the subjects tended to decrease in presence of a non-partitioned resource, while there was no significant group size effect with a partitioned resource.

5.6 Further aspects

Other aspects of social dilemmas have been tested. As stated by Marwell and Ames (1980) the behavior in a public goods game is resilient to different aspects and incentives. The presence or absence of a provision point, the experience of the participants and, to some extents, the amount of money at stake does not influence subjects in a radical way in the experiments conducted by the authors. The high stakes have somehow proven to be the strongest of the three aspects analyzed, but not even a fivefold increase in the money at stake was enough to radically change the behavior. Their findings suggest that further increasing the sums may lead to a behavior closest to the one foreseen by the rational-choice theory. Following this suggestion, we can infer that the behavior in public goods games is resilient to many properties, and thus many of them have to assume extremely high values to influence the subjects.

6. Conclusion

As already stated, there are many aspects in social dilemmas that influence their outcomes and may determine if cooperative behaviors will emerge or not. Clearly, experimental efforts are useful to disentangle the different traits that, in real-world situations, determine the final use of resources. Anyway, aspects which are specific to the environment the resource is in (e.g. ecological and geographical properties of the area) are still expected to play a significant role. At the same time, also cultural and social properties of the groups, which may be hard to test in experimental settings, may drastically influence the inclinations. Another central point is that every social dilemma, while having similar bases, is different. As shown in this review often these dilemmas are modeled after Public Good games or Common Pool Resource games. This review tried to encompass both classes of games without focusing separately on the different types of dilemmas for two main reasons. The first is that the effects on

cooperation of different properties tend to be consistent in all types of dilemma in their effects. The second reason is that being able to generalize which properties might favor cooperation, regardless of the particular aspect of the situation, is indeed a valid objective to pursue.

While this review does not plan to provide exhaustive policy suggestions, but instead aims at highlighting some aspects of the social dilemmas that have been empirically proven to be pivotal in the emergence and sustenance of cooperation among resource users, it is nevertheless important to emphasize where these aspects could play a role in policy development. The first conclusion that can be drawn from previous studies is, surely, that a general strategy cannot and should not be developed. The inherently different social, ecological, political, and economic characteristics of each social-ecological system call for very different approaches. Nevertheless, we can infer that several aspects should be kept in consideration in almost every case. First of all, a wide body of evidence suggests that communication between the resource users should be fostered as much as possible. This can lead to better coordination, cooperation between the actors and, ultimately, a better management of the resource. Fostering communication among the users can also give birth to informal forms of monitoring of the resource use, that appear to be crucial in those cases where institutions are not present, unwilling, or not able to develop a formalized monitoring system (see, e.g., Yami, Vogl & Hauser 2009). Furthermore, even if, to our knowledge, it has not yet tested empirically as of yet, communication might, in some cases, help in the diffusion of information on the resource, potentially reducing uncertainty and allowing all the users to obtain the same information on the status and dynamics of the resource. This is of particular interest because many studies observed negative effects of uncertainty – regarding both the resource's and the other users' behavior – on the emergence of cooperative strategies. As already mentioned, though, some exceptions are possible (McAllister, Tisdell, Reeson & Gordon 2011, mentioned in Paragraph 5.2), which reminds us of the need to develop different policy strategies tailored on the different social, ecological, and political environments.

Monitoring and punishment have been shown to be useful in terms of maintaining cooperation among the resource users. Rewards, as opposed to forms of punishment, have been suggested to be more effective in the long term (Andreoni 1995, and Sutter, Haigner & Kocher 2010). However, when thinking about policy interventions, it is useful to remember that giving rewards is often a more difficult process for institutions that might require, for this, resources that are not available or cannot be easily (re)allocated. Implementing punishments for resource users that do not comply with present rules can then be an alternative, especially in those cases where an infrastructure is already present, i.e. when a monitoring system is already in act.

Finally, the studies on research scarcity suggest that it is important, for the users, to be informed both on the resource's dynamics, and on possible thresholds and risks that could lead to regime shifts or generally to a lower productivity of the resource. This can lead to higher rates of compliance with the rules, and as a deterrent to short-sighted harvesting behavior. Previous experience with scarcity events, while not a phenomenon that can be controlled by policy-makers, has also been suggested, by previous research, as a possible positive factor in the emergence of cooperative behavior. This once again stresses the importance of communication and information transmission among the users.

As a conclusion to this review, it is important to highlight that, while the insight coming from experimental research in environmental economic has been able to pinpoint some very relevant aspects to the management of the Commons, which should be considered when developing policies, it is also crucial to remember that, as stated by Ostmann (1998, 119):

> There are important categorical differences between the researcher's model of a common, the real world phenomenon, and the experimental situation that the subjects have to deal with. Acknowledging these differences we have to admit that no direct conclusions (...) can be drawn from experimental results.

This strong statement raises a very critical point, and reminds us that each approach, and in particular the experimental approach, comes with trade-offs. Researchers, and policy-makers to an even high degree, should always be very wary of extending results to a field, situation, environment, or society different from the ones they were obtained in. Undeniably, then, the high degree of complexity of each and every real-world scenario will need critical thinking, in-depth analysis, and reliance on multiple methods and approaches to develop effective strategies.

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Social Dilemmas in Environmental Economics: A review

Abstract.
Many crucial environmental issues lead to social dilemmas, in which the personally optimal solution, and the socially optimal solution diverge. Finding a solution to this dilemma is extremely important to allow a good and sustainable management of many exhaustible natural resources. This is especially true when the resource users need to develop collectively a set of rules or practices, and the institutions are unable to provide, or enforce, effective regulations. A few examples are forests, and fisheries, but also carbon emissions. This review presents a selected number of results coming from field observations, laboratory experiments, and theoretical work, which pinpoint some of the more crucial aspects of these decision environments. Knowing which incentives and situational aspects may motivate resource users to adopt a more or less cooperative behavior can potentially be of pivotal importance to develop effective policies and regulations. At the same time, the research we present is also of great interest for any diagnostic or explorative study that aims to study direct resource users, and their development of cooperative attitudes and practices.

Keywords: Decision theory, environmental economics, social dilemmas, resources, experiments.

Ethics in Progress (ISSN 2084-9257). Vol. 8 (2017). No. 1, Art. #10, pp. 156-173.

Doi: 10.14746/eip.2017.1.10