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Cooperative choice and its framing effect under threshold uncertainty in a provision point mechanism

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Abstract

This paper explores how threshold uncertainty affects cooperative behaviors in each of public goods provision and public bads prevention. The following facts motivate our study. First, resource and environmental problems can be either framed as public bads prevention or public goods provision. Second, the occurrence of these problems is characterized by the existence of thresholds which is interchangeably represented by "nonconvexity," "bifurcation," "bi-stability," or "catastrophes." Third, the location of such a threshold is mostly unknown to observers. We employ a provision point mechanism with threshold uncertainty, and analyze the response of cooperative behaviors to uncertainty and to the framing in each type of social preferences categorized by a value orientation test. We find that aggregate framing effects are negligible, though response to the frame is opposite to the type of social preference in each subject. "Cooperative" subjects become more cooperative in negative frames than in positive frames, while "individualistic" subjects are less cooperative in negative frames than in positive ones. This implies that insignificance of the aggregate framing effect arises from the behavioral asymmetry. We also find the percentage of cooperative choices non-monotonically varies with the degree of threshold uncertainty, irrespective of framing and value orientation. More specifically, the degree of cooperation is highest in the intermediate level of threshold uncertainty, whereas it sharply drops as the uncertainty becomes sufficiently large.

Key Words: Cooperative choice, Framing effects, Threshold uncertainty, Provision point mechanism

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1 Introduction

Many public goods (bads) are only provided (prevented) if the contributions (i.e., the degree of cooperation) meets or exceeds some threshold. Throughout this paper, we call this collective decision setup as a "provision point mechanism (PPM)" following Davis and Holt (1992). A simple example of public goods provision is a decision of whether to provide a public project or not based on a majority voting rule, while that of public bads prevention is open-access fishery management with a threshold level of fishing efforts that leads to the exhaustion of fish stock, so-called "bifurcation" (See Clark (1990), page 19 for bifurcation). Reflecting its increasing importance, several studies have examined both theoretical and empirical natures of cooperative behaviors in that setting (See, e.g., Bagnoli and Lipman (1989), Marks and Croson (1998), Marks and Croson (1999), Cadsby and Maynes (1999), Rondeau et al. (2005) and McBride (2006)).[1]

An effect of threshold uncertainty on cooperative behaviors has been studied in the literature of the PPM (Suleiman (1997), Nitzan and Romano (1990) and McBride (2006)). Agents are often uncertain about a threshold level of public provision mainly due to the two reasons (See, e.g., Wit and Wilke (1998)). The first reason is "social uncertainty." This could be represented by a situation where we do not know in advance how many other people in a group will cooperate. Therefore, the source of uncertainty comes from behaviors of other people in a group. The second reason is "scientific uncertainty." This is the case, for example, we are uncertain about how much cooperative effort will be needed to provide (prevent) a public good (bad). The source of uncertainty is the lack of our scientific knowledge. In this paper, scientific uncertainty is our main interest.[2] Therefore, we consistently use threshold uncertainty referring to the type of scientific uncertainty and we manipulate its degree in a

[1] There are many other examples in a real world. These include a possible disintegration of the Antarctic Ice Sheet, irreversible global warming and eutrophication for lakes (See, e.g., Naevdal (2006), Ulph and Ulph (1997) and Carpenter et al. (1999)). A common feature of these environmental and natural resource problems is the existence of threshold, though its location is not known to human beings.

[2] Here we use the term "uncertainty" to refer to the events with probability distribution, which should be distingusihed from "ambiguity" where even probability cannot be assigned for each event.

series of economic experiments, keeping social uncertainty constant.

The existence of such threshold uncertainty is theoretically shown to have profound effects on cooperative choices. Bagnoli and Lipman (1989) first demonstrate that the PPM without threshold uncertainty has important efficient properties that can lead to the first best outcome of cooperation. However, once threshold uncertainty is introduced, more complex theoretical results arise such as a possibility of inefficient cooperation in Nash equilibria. For instance, Nitzan and Romano (1990) confirm that an efficient property collapses in the presence of threshold uncertainty. The recent work by McBride (2006) finds that equilibrium cooperation could become higher under an increased threshold uncertainty when the public good's value is sufficiently high. This is because increases of uncertainty raise individual's probabilities of being pivotal in providing a public good.

Although there exists aforementioned theoretical works on cooperative behaviors under threshold uncertainty, empirical research has been highly scarce. To the best of our knowledge, Suleiman et al. (2001) is the first empirical study that examines the effect of threshold uncertainty and demonstrate that cooperation increases in higher threshold means and it decreases with the threshold uncertainty. Furthermore, they argue that a higher threshold means can moderate the adverse effect of threshold uncertainty on cooperation as an interaction effect. Another important empirical work is provided by McBride (2008). The study seeks to test a set of the theoretical predictions derived in McBride (2006), and identifies that the experimental results weakly support the theory.[3]

Given these empirical evidences, several important questions remain to unsolved. A first open question is "How does cooperative behavior change with the degree of threshold uncertainty?" Throughout this paper, the degree of threshold uncertainty refers to the variation

[3]More specifically, he sought to test the theoretical prediction that equilibrium cooperation could become higher (lower) under an increased threshold uncertainty when the public good's value is sufficiently high (low). Note that the focus and the experimental designs in his study are different from ours in a number of ways, which we will explain later. We employ "across subjects" designs and pay more attention to (i) the role in threshold uncertainty by varying a wide range of its degree, holding the value of public goods fixed, as well as (ii) the effects of positive and negative frames on cooperation, which are quite important in resource and environmental economics.

or the variance of threshold distributions. This is motivated by the fact that resource and environmental problems come with threshold uncertainty and its degree depends on scientific uncertainty (See, e.g., Naevdal and Oppenheimer (2007)). However, there has been no systematic analyses to this question despite its importance in the real world. For instance, how much to mitigate the degree of threshold uncertainty through scientific research is becoming highly controversial as in the discussion of global warming problems. This is supported by a series of reports that the degree of scientific uncertainty on global warming highly affects people's actual cooperative attitude to this event (See, e.g., Oppenheimer (1998) and Cookson (2009)).

A second open question is "how does the difference in the framing affect cooperative behaviors in the presence of threshold uncertainty?" We are interested in this because a collective decision such as environmental and resource problems can be either framed as public bads prevention or public goods provision. These are referred to as a "negative" or "positive" frame, respectively. Although several studies have established the existence of framing effects in a standard voluntary contribution mechanism (VCM) (See Andreoni (1995), Park (2000) and Willinger and Ziegelmeyer (1999)), empirical evidence of framing effects on the PPM does not reach consensus yet. Sonnemans et al. (1998) is the only previous work that empirically analyzes the existence of framing effects in the PPM without threshold uncertainty. They show that a positive frame yields higher cooperation in the PPM. However, Park (2000) note that their experimental results are compounded by strategic effects or social uncertainty due to their experimental setup such as employing partner designs.

A third open question is "Is there any heterogenous response of cooperative behaviors to the uncertainty as well as to the framing depending on the type of people?" Although there are several researches which have identified some responses to the framing focusing on each type of people (Park (2000) and Sonnemans et al. (1998)), no works have analyzed the heterogeneous response to both framing and uncertainty in a systematic way under PPM. As mentioned earlier, Park (2000) and Sonnemans et al. (1998) identify the responses to

the framing in the VCM and PPM, respectively, but they do not analyze the response to the uncertainty focusing on the type of people.[4] In this sense, the answer to this question is unidentified especially in PPM, and should be able to give some policy implication for environmental problems as well as disaster management especially on the direction of a change in cooperation depending on the type of society (or people) as well as the degree of uncertainty.

To answer the questions, we first implement a value orientation test to identify the type of people such as "individualistic" and then experimentally analyze how the degree of threshold uncertainty affects cooperative behaviors by varying the degree. Contrary to previous works such as Suleiman et al. (2001) and McBride (2008), our focus is on the effect of the degree of threshold uncertainty on cooperation rather than the threshold mean levels. Therefore, we systematically manipulate the threshold uncertainty, fixing threshold means around some level in the experiments. By focusing only on the change in the degree of threshold uncertainty, cooperation levels predicted by Nash equilibrium increase and then decrease with the degree of threshold uncertainty, i.e., a single-peaked (or inverted U-shaped) over the degree, and we seek to confirm whether experimental results qualitatively follow this theoretical prediction.[5] Second, we examine an existence of framing effects in a PPM. For these purposes, our experiment controls strategic effects and social uncertainty with random rematching of group members. These features make distinction from the previous studies.

We obtain two novel results in this experimental research. First, aggregate framing effects are negligible, though the response to the frame is opposite depending on the type of social preference in each subject. "Cooperative" subjects cooperate less, whereas "indivisualistic" subjects cooperate more in a public goods setting than in a public bads setting. This implies

[4]Furthermore, Park (2000) points out that the results on the response to the framing in Sonnemans et al. (1998) would be confounding due to the use of partner design.

[5]Suleiman et al. (2001) also manipulated the degree of threshold uncertainty, but they simply employ two different levels. Therefore, their finding can tell only whether cooperation increases or not with it. In contrast, our research uses a wider range of threshold uncertainty with four different levels, and we identify that the degree of cooperation predicted by Nash equilibrium becomes a single-peaked over the domain of threshold uncertainty. This is another unique feature of this study.

that insignificance of the aggregate framing effect arises from the behavioral asymmetry. Second, the percentage of cooperative choices non-monotonically changes as the degree of threshold uncertainty increases, irrespective of framing and the type of value orientation. More specifically, we find that the degree of cooperation is the highest in the intermediate level of threshold uncertainty, whereas it sharply drops as threshold uncertainty becomes sufficiently large. By and large, we say that the changes of cooperative behaviors in response to the degree of threshold uncertainty are qualitatively consistent with Nash predictions.

The results have several policy implications. Concerning the framing effects, employing a PPM to induce more cooperation under a negative frame can be more effective than the VCM. This is because our results show insignificance of aggregate framing effects in the PPM. However, this result should be understood with caution. That is, the composition of population with respect to social preferences can determine whether aggregate framing effects are present due to asymmetric responses to the framing. The experimental results also suggest that reducing threshold uncertainty can enhance cooperation, whereas the degree of threshold uncertainty does not need to be reduced to nil. This would give rise to an optimal strategy of scientific research on threshold uncertainty in a real world problem. That is, the scientific research to reduce the uncertainty with respect to a location of threshold deserves some effort. However, an attempt to pinpoint its location might not make sense if we consider the cost of research as well as its negligible impact on cooperation.

The organization of this paper is as follows: Section 2 describes the experimental designs and procedures. In section 3, we present experimental results with some statistical analysis on the hypotheses. Final section offers some discussion and concluding remarks.

2 Experimental design

2.1 Experimental procedure

The economic experiment was carried out in the computerized experimental laboratory of Yokohama National University, and comprises eight sessions each involving 40 subjects for a total of 320 subjects and 10 decision-making periods for each session. They were volunteers from undergraduate students in various fields except economics, participated in one session only and made an average of $20 based on cumulative earnings. One session took about one hour and it consists of two stages: In the first stage, a value orientation experiment was conducted and a voluntary contribution experiment was followed in the second stage. With a value orientation experiment, we categorize subjects into five types depending on each subject's social goal: 1. Competitors—those who want to be better off than others; 2. Individualistic—those who want to do best for themselves; 3. Cooperative—those who try the best for both themselves and others; 4. Altruistic—those who want to do best for others; 5. Aggressive—those who want to do worst for others. The procedure in this part strictly follows Park (2000) and thus further explanations are omitted.

In the second stage, eight treatments of a voluntary contribution game were implemented. In a single session, one treatment is solely implemented so that a subject experienced only one condition and we have independent samples. Each subject was randomly assigned to a group of five people and rematched in every decision making round. In each round, each subject was asked to make a choice between Yellow and Blue where she did not know the identity of group members, but she knew that group members are shuffled in each round. A series of these experimental designs associated with the formation of the group members was employed to keep the strategic effects or social uncertainty as constant.[6] After each

[6]We admit that this way is not perfect to keep social uncertainty constant, however it is one of the best possible ways to make our results comparable with other previous studies focusing on framing effects such as Andreoni (1995); Park (2000). For this purpose, we were also careful about the composition of subject types in a session. Fortunately, our subject pools across sessions are homogeneous in the sense that $60 \sim 70\%$ is 'individualistic,' and the rest is 'cooperative' type of subjects. This guarantees that session-wise effects for social uncertainty are minimized that may derive from heterogeneous subject pools across different sessions

round, subjects were informed about the resulting payoff. The earnings for each subject were calculated by applying some exchange rate to cumulative earnings accrued from 10 rounds at the end of a session.

2.2 Treatments

Eight treatments of a voluntary contribution game were conducted at the second stage of experiments in this research. The basic design of games, which is common in all of the eight treatments, is based on the one adopted in Sonnemans et al. (1998). It is designed as neutral as possible by avoiding words such as "cooperation," or "contribution," and instead "Yellow" and "Blue" represent a choice of each individual between cooperation and defection in the experimental instructions or material presentations. Therefore, actual earnings depend on the private choice of Yellow or Blue as well as the choices of others in the same group.

There are two important key factors characterizing the difference of treatments: 1. framing and 2. the degree of threshold uncertainty. As for framing, we follow the procedure adopted by Sonnemans et al. (1998). Table 1 summarizes a public goods provision game of positive frames without threshold uncertainty. Subjects were asked to determine whether to contribute 60 cents (Yellow) or not (Blue). If more than three members in a group give 60 cents (Yellow), everybody receives a group-revenue of 245 cents, otherwise a group revenue is 60. On the other hand, table 2 summarizes a public bads prevention game of negative frames. The choice had to be made on whether to take 60 cents (Yellow) or not (Blue). If two or fewer members take 60 cents, everybody receives a group-revenue of 185 cents, otherwise zero. The incentives in the two treatments are identical and the difference solely comes from the framing of problems.

Next, threshold uncertainty is added on the above baseline treatments. A discrete uniform distribution is chosen with the support of three types in a positive frame: $\{2, 3\}, \{2, 3, 4\}$ and $\{1, 2, 3, 4, 5\}$. For instance, a discrete uniform distribution of threshold uncertainty with the support of $\{2, 3, 4\}$ represents a situation where subjects are uncertain about the threshold

Individual earning with yellow choice: -60
with blue choice: 0

Group Revenue

# of yellow choices	0	1	2	3	4	5
Group Revenue	60	60	60	245	245	245

Table 1: Positive framing of public goods provision

Individual earning with yellow choice: 60
with blue choice: 0

Group Revenue

# of yellow choices	0	1	2	3	4	5
Group Revenue	185	185	185	0	0	0

Table 2: Negative framing of public bads prevention

level of public goods provision, but they know it would be either of 2, 3 or 4 with equal probability of 1/3. For the above three treatments to be incentive-wise identical to the one of negative frame treatments, three different supports of $\{2,3\}, \{1,2,3\}$ and $\{0,1,2,3,4\}$ for negatives frames were prepared. For example, threshold uncertainty with a discrete uniform distribution under support $\{2,3,4\}$ in a positive frame is corresponding to the one under support $\{1,2,3\}$ in a negative frame. Likewise, threshold uncertainty with supports of $\{2,3\}$ and $\{1,2,3,4,5\}$ in a positive frame corresponds to the one with supports of $\{2,3\}$ and $\{0,1,2,3,4\}$ in a negative frame, respectively.

In summary, there are four treatments for each frame and total eight treatments and note that $G0, G1, G2, G3$ are incentive-wise identical with $B0, B1, B2, B3$, respectively (See the 4th row of table 3). Table 3 summarizes all of the information related to the experimental treatments. $G0, G1, G2$ and $G3$ denote public goods provision experiments with different degree of threshold uncertainty. The number of $0, 1, 2$ and 3 in the notation increases with the degree of threshold uncertainty in treatments. On the other hand, $B0, B1, B2$ and $B3$ denote public bads prevention experiments and its number can be interpreted in the same way. As mentioned earlier, our experiments consists of eight sessions each of which

Table 3: Summary of experiment treatments

Treatments	G0	G1	G2	G3	B0	B1	B2	B3
Frame	Positive	Positive	Positive	Positive	Negative	Negative	Negative	Negative
Threshold uncertainty (Uniform distribution)	None	{2, 3}	{2, 3, 4}	{1, 2, 3, 4, 5}	None	{2, 3}	{1, 2, 3}	{0, 1, 2, 3, 4}
Incentive-wise equivalent to	B0	B1	B2	B3	G0	G1	G2	G3
Nash equilibriua (# of cooperative choices)	0 or 3	0 or 3	0 or 4	0	0 or 3	0 or 3	0 or 4	0

implements only one treatment out of $\{G0, G1, G2, G3, B0, B1, B2, B3\}$. In each session, 40 subjects were employed, and in total 320 subjects participated in our experiments.

For each treatment, we can make theoretical predictions based on Nash equilibrium concept under risk neutral agents. For $G0, B0, G1$ and $B1$, there are two pure Nash equilibria: (i) one asymmetric Nash equilibrium in which three players choose cooperation and (ii) one symmetric Nash equilibrium in which all players do not cooperate. For $G2$ and $B2$, there are two pure Nash equilibria: (i) one asymmetric Nash equilibrium in which four players cooperate and (ii) one symmetric Nash equilibrium in which zero players cooperate. Finally, for $G3$ and $B3$, there is only one pure Nash equilibrium in which zero players cooperate. All of these theoretical predictions are valid in our experiment because a game in each round can be considered static due to a stranger design of partners in a group. Finally, the 5th row of table 3 summarizes the information about Nash predictions in each treatment.

3 Experimental result

In this section, we present the experimental results by referring to the level of 'cooperative choice' in every treatment. In the public goods experiment, a choice of Yellow corresponds to what we call the cooperative choice, while Blue is a cooperative choice in a public bads game.

3.1 Framing effects

We show the effect of framing on cooperative choices. The results in treatments $G0, G1, G2$ and $G3$ are compared with those in treatments $B0, B1, B2$ and $B3$, respectively. Table 4 displays the percentage of cooperative choices for each treatment where the rows of 'individualistic,' 'cooperative,' and 'all' correspond to the percentage of cooperative choices for each value orientation as well as pooled subjects. Since two types of 'individualistic' and 'cooperative' occupy more than 90% of a subjects pool, the results on these two types are only reported together with their aggregation results of "all" category.

First, we focus on the results of pooling all subjects (See the results in the 'all' row of table 4). A direct comparison between goods and bads settings for each degree of threshold uncertainty in 'all' row reveals that there is a small difference in cooperative choices (Compare the percentage of cooperative choice between goods and bads settings in 'all' row of table 4. That is, $G0(39.5\%)$ vs. $B0(35.5\%)$, $G1(41.7\%)$ vs. $B1(41.0\%)$, $G2(46.5\%)$ vs. $B2(43.2\%)$ and $G3(34.2\%)$ vs. $B3(27.5\%)$. Overall, a percentage of cooperative choices in goods settings appears to be slightly higher than that in bads settings.

Next, figure 1 consists of four subfigures. It exhibits the percentage of cooperative choices of 'all' subjects per period in both frames for each level of threshold uncertainty. Subfigures correspond to the results of cooperative choices for a threshold level of $\{0, 1, 2, 3\}$, respectively. This visualization of cooperative choices per period in pooling all subjects suggests that there might be no obvious difference between goods and bads settings. However, the 'all' row of table 4 shows that there seem to be a small distinction between them.

The statistical significance of these differences can be checked by Mann-Whitney rank-sum nonparametric test following Park (2000). This test is implemented using the percentage of cooperative choice per period as observations and we contrast the cooperative behavior in goods settings with that in bads settings for each level of threshold uncertainty $\{0, 1, 2, 3\}$. The results in table 5 suggest that there is no statistical significance in the percentage of cooperative choice for all levels of threshold uncertainty. This implies that framing effects

Table 4: Percentage of cooperative choices per value orientation as well as for all subjects per treatment

	0		1		2		3	
	G0	B0	G1	B1	G2	B2	G3	B3
Individualistic	38.0% (27)	27.3% (30)	39.8% (31)	32.4% (25)	39.2% (26)	41.8% (22)	31.6% (25)	22.4% (25)
Cooperative	38.9% (10)	55.5% (9)	52.8% (7)	65.0% (12)	60.0% (9)	47.1% (7)	32.3% (12)	41.6% (12)
All	39.5% (40)	35.5% (40)	41.7% (40)	41.0% (40)	46.5% (40)	43.2% (40)	34.2% (40)	27.5% (40)

Notes: A number of subjects corresponding to each value orientation and its total is given in parentheses.

are not so significant in pooling all subjects for each level of threshold uncertainty.

3.1.1 Framing effects of cooperative choices per value orientation in each frame

Framing effects of 'individualistic' subjects

We discuss the framing effects of cooperative choices per value orientation for each level of threshold uncertainty. First, we focus on framing effects of 'individualistic' subjects. The first row of 'individualistic' in table 4 reveals a percentage of cooperative choices in 'individualistic' subjects for each treatment. A direct comparison of the percentages between goods and bads settings shows that individualistic subjects are more cooperative in goods setting for a threshold uncertainty level $\{0, 1, 3\}$, while they are less cooperative for an uncertainty level of $\{2\}$ (See the row of 'individualistic' in table 4 and notice that $G0(38.0\%)$ vs. $B0(27.3\%)$, $G1(39.8\%)$ vs. $B1(32.4\%)$, $G2(39.2\%)$ vs. $B2(41.8\%)$ and $G3(31.6\%)$ vs. $B3(22.4\%)$).

Figure 2 provides the percentage of 'individualistic' cooperative choices per period in both frames for each level of threshold uncertainty. Subfigures 2(a), 2(b), 2(c) and 2(d) correspond to the results of 'individualistic' cooperative choices for a threshold level of $\{0, 1, 2, 3\}$, respectively. These subfigures shows individualistic subjects tend to be more cooperative in goods setting (See, e.g., subfigures 2(a), 2(b) and 2(d)), otherwise the difference of cooperative choices per period for each threshold uncertainty level seems not to be so significant

(See subfigure 2(c)).

Mann-Whitney rank-sum tests are conducted to examine whether there is a framing difference of 'individualistic' cooperative choices by using the percentage of cooperative choice per period as observations. The results in table 6 suggest that the difference of 'individualistic' cooperative choices is statistically significant on each of $G0$ vs. $B0$, $G1$ vs. $B1$ and $G3$ vs. $B3$, and individualistic subjects cooperate more in these goods settings, while it is not significant on $G2$ vs. $B2$. From these visual observations and statistical results, 'individualistic' subjects are found to become more cooperative in goods settings than in bads settings, or the framing effects may be not so significant.

Framing effects of 'cooperative' subjects

Next, our analysis turns to 'cooperative' subjects. First, the 2nd row of 'cooperative' in table 4 shows a percentage of cooperative choices in 'cooperative' subjects for each treatment. It is important to note the percentage of cooperative choices in goods settings is lower than that in bads settings for some threshold uncertainty levels $\{0, 1, 3\}$ (See 'cooperative' row of table 4 and note that $G0(38.9\%)$ vs. $B0(55.5\%)$, $G1(52.8\%)$ vs. $B1(65.0\%)$, $G2(60.0\%)$ vs. $B2(47.1\%)$ and $G3(32.3\%)$ vs. $B3(41.6\%)$). It is in contrast with a conventional wisdom that goods settings (or positive) frames tend to yield a higher level of cooperation.

Figure 3 provides the percentage of cooperative choices of 'cooperative subjects' per period in both frames for each level of threshold uncertainty. Subfigures 3(a), 3(b), 3(c) and 3(d) correspond to the results of their cooperative choices for a threshold level of $\{0, 1, 2, 3\}$, respectively. We find cooperative type subjects tend to cooperate more in bads setting (See subfigures 3(a), 3(b) and 3(d)), otherwise the framing effects seem to be minor (See subfigure 3(c)). To confirm this tendency statistically, Mann-Whitney tests are applied in the same way. Table 7 shows that the differences on $G0$ vs. $B0$, $G1$ vs. $B1$ and $G3$ vs. $B3$ are statistically significant and it implies that 'cooperative' subjects cooperate more in bads frames. In contrast, the test result on $G2$ vs. $B2$ suggest no statistical significance with

respect to the framing effects.

Responses of value orientations to framing effects

In general, we have so far identified that 'individualistic' subjects tend to be more cooperative in goods settings, while 'cooperative' subjects show an opposite pattern, that is, they are less cooperative in goods settings. Reflecting the initial finding that aggregate framing effects by pooling all subjects are not statistically significant for all levels of threshold uncertainty, it seems that each of individualistic or cooperative subjects responds to the framing in an opposite direction and the overall effects on cooperative choices in 'all' cancels out each other. In other words, framing effects in 'all' subjects appear to be negligible because the directions of framing effects are opposite between individualistic and cooperative subjects and net impacts offset each other. While 'individualistic' subjects are more cooperative in goods settings and it is consistent with a conventional wisdom, our result on framing effects of 'cooperative' subjects is in contradiction to the previous findings in a standard voluntary contribution game.

To double-check the aforementioned results from a different perspective, we also present two additional figures 4 and 5, each of which comprises four subfigures. Figure 4 shows a percentage of cooperative choices of different value orientations (Individualistic vs. Cooperative) in goods settings for each level of threshold uncertainty, whereas figure 5 shows the same in bads settings. Each subfigure corresponds to the results of cooperative behavior in the difference between 'individualistic' and 'cooperative' subjects per treatment for each level of threshold uncertainty.

As expected, there is a general tendency that 'cooperative' subjects cooperate more often than 'individualistic' subjects, otherwise the differences appear to be insignificant (See each subfigure in figures 4 and 5). However, we note that the difference of cooperative behaviors between 'individualistic' and 'cooperative' subjects appears to be larger in bads settings than in goods settings except for a threshold uncertainty level of $\{2\}$ (For example, compare

subfigures 4(a) vs. 5(a), subfigures 4(b) vs. 5(b) and subfigures 4(d) vs. 5(d)). In fact, this is consistent with the corresponding z-statistics showing that the differences of cooperative behavior gets larger in bads settings than in goods settings (Compare tables 8 and 9 and observe the statistics of z with respect to $G0$ in table 8 vs. $B0$ in table 9 and z changes from .0.530 to 3.194. Likewise, compare the statistics on $G1$ vs. $B1$, $G2$ vs. $B2$ and $G3$ vs. $B3$ in tables 8 and 9). In summary, figures 4 and 5 show the behavioral asymmetry across value orientations as the response to the framing, which causes the aggregate framing effects to be negligible.

3.2 Effects of threshold uncertainty in each frame

3.2.1 Visual observation of the uncertainty effects

We discuss how cooperative choice changes with the degree of threshold uncertainty. Figure 6 consisting of two subfigures 6(a) and 6(b) shows the percentage of cooperative choices when the level of threshold uncertainty increases from 0 to 3. First, subfigure 6(a) shows the overall percentage of cooperative choices for each of public goods and bads settings. From this subfigure, we can see two general trends: (1) a percentage of cooperative choices in goods settings is larger than that in bads setting for all levels of uncertainty, and (2) the percentage of cooperative choices increases with the degree of threshold uncertainty up to the level of 2 in both goods and bads settings, but sharply falls when it goes level 3.

Next, we turn to the discussion of overall trends by looking at each type of value orientations in cooperative choices under both frames. Subfigure 6(b) reveals determinants of the two trends in subfigure 6(a). As we have mentioned earlier, more than 90 percent of our subject pool is dominated by "individualistic" and "cooperative" subjects based on value orientation tests, and thus we focus only on these two types.

We confirm from subfigure 6(b) that each type of value orientation in both frames follows the same pattern observed in figure 6(a); that is, as the degree of threshold uncertainty rises, the percentage of cooperative choices increases up to the middle. However, once threshold

uncertainty reaches level 3, subjects become less cooperative.

3.2.2 Statistical observation of the uncertainty effects

We now compare the cooperative choices across different levels of threshold uncertainty over 10 rounds in each frame. The results are reported in figure 7 where subfigures 7(a) and 7(b) correspond to the results in goods and bads setting, respectively. In these figures, the plots labeled by $G0, G1, G2$ and $G3$ indicate the percentage of cooperative choices for 'all' subjects over 10 rounds in a goods setting, while those by $B0, B1, B2$ and $B3$ does the same in a bads setting. Again, it can be confirmed that the percentage of cooperative choices under threshold level 3 tends to be less than others (Compare $G3$ vs. any other plots in subfigure 7(a), and $B3$ vs. any other plot in subfigure 7(b).) To confirm this observation statistically, we conduct a Mann-Whitney test of all possible pairs in each of goods and bads settings by taking the percentage of cooperative choice per period as observation. Table 10 summarizes the statistical results where subtables 10(a) and 10(b) corresponds to the list of statistics for every possible pair of threshold levels in each of goods and bads settings, respectively. For instance, a cell of row $G1$ and column $G0$ in subtable 10(a) exhibits z-statistics of 0.916 whose significance tells us whether the cooperative choices in the two treatments are statistically different. In this case, $z = 0.916 > 0$ can be interpreted that the percentage of cooperative choices in $G1$ tends to be larger than that in $G0$, but the difference is not statistically significant. For all other cells in subtables 10(a) and 10(b), it is interpreted in the same way.

First, subtable 10(a) reveals that test results associated with $G0$ are consistent with the visual observation shown in figure 6. That is, z-statistics rises from 0.916 up to 2.019 when the partner becomes $G1$ and next $G2$. Especially, a Mann-Whitney test on $G0$ vs. $G1$ shows stastical significance in terms of the difference and it can be concluded that subjects are more cooperative in $G2$ than $G0$. However, we can also observe a sudden drop in cooperative choices from z-statistics of -1.139 in row $G3$ and column $G0$, although it is not statistically

significant. The same type of results holds for all other cells in columns $G1$ and $G2$. In particular, we see that the test result on $G2$ vs. $G3$ is statistically significant at 5% level. In summary, subtable 10(a) provides the same type of trends we observed in the previous figures.

Second, subtable 10(b) also shows the same general pattern observed in subtable 10(a). That is, focusing on the test results associated with $B0$, we can see that z-statistics increases from 1.145 to 1.826 when the test partner changes from $B1$ to $B2$. However, once the partner becomes $B3$, the statistic suddenly drops to -2.134, which implies that the percentage of cooperative choices in $B3$ is considered low compared to that in $B0$. We can also realize that the same type of trends have occurred in the test results of columns $B1$ and $B2$, respectively, and also that z-statistics in row $B3$ is statistically significant and negative for all cases of row $B0, B1$ and $B2$. In summary, we conclude both from visual inspection and nonparametric tests that the degree of cooperative choices increases with the degree of threshold uncertainty up to the middle. However, once threshold uncertainty reach higher than a certain level, the degree of cooperation suddenly drops. This type of trends has observed both in public goods and bads settings.

3.3 Threshold uncertainty per value orientation

3.3.1 Result of "individualistic" subjects

In this subsection, we further analyze the effects of threshold uncertainty per value orientation on cooperative choices in each of positive and negative frame. First, we focus on the result of "individualistic" subjects. Figure 8 shows the percentage of cooperative choices for individualistic subjects over 10 rounds for each level of threshold uncertainty where subfigures 8(a) and 8(b) corresponds to positive and negative frames, respectively. In each subfigure, there are four different plots each of which represents the percentage of cooperative choices over 10 rounds for each threshold level. The labels of IndG0, G1, G2 and G3 correspond to the percentage of cooperative choices of individualistic subjects in a goods setting for

threshold levels of $\{0, 1, 2, 3\}$, whereas the labels of IndB0, B1, B2 and B3 are interpreted in the same way for a bads setting.

Close inspection of subfigures 8(a) and 8(b) reveals that the cooperative choices seem to be lowest when the threshold level is $\{3\}$ in both frames (See the plots of IndG3 and IndB0 in the subfigures). Also, the cooperative choices under the intermediate levels of threshold uncertainty such as $\{1, 2\}$ appear to be higher than the others (See the plots of IndG1 and IndG2 in subfigure 8(a) and those of IndB2 in subfigure 8(b)). To confirm these trends statistically, we again implement a Mann-Whitney test of all possible pairs in each of goods and bads settings, same as before. The test results are summarized in table 11. The two subtables 11(a) and 11(b) correspond to the test results under goods and bads settings, respectively.

Subtable 11(a) shows that all of the test results are insignificant under the positive frame although the sign of z-statistics follows the general tendency of cooperative choices as we described for aggregate data. That is, the cooperative choices are lowest when the threshold uncertainty level is $\{3\}$ and it reaches the highest when the threshold uncertainty is in the intermediate level such as $\{1, 2\}$.

Subtable 11(b) shows the test results under a negative frame. The results basically exhibits some statistical significance of the Mann-Whitney tests, which is basically consistent with our general observations on cooperative choices across various threshold levels (See statistical significance of $B0$ vs. $B2$, $B1$ vs. $B2$, $B1$ vs. $B3$ and $B2$ vs. $B3$). From visual observation and statistical testings conducted on the cooperative choice data for "individualistic" subjects, we could say that "individualistic" subjects cooperate less if the degree of threshold level gets too large, and they cooperate more if it is in the intermediate level.

3.3.2 Result of "cooperative" subjects

Finally, we focus on "cooperative" subjects across different levels of threshold uncertainty. Figure 9, which consists of two subfigures 9(a) and 9(b), shows the percentage of cooperative

choices for cooperative subjects in each of positive and negative frames. Again, we can confirm from these subfigures that both frames generally exhibit the same pattern. When the threshold level is $\{3\}$, the percentage of cooperative choices seems to be the lowest, and when it is 1 or 2, it is the highest. Following the same way as we did, we confirm these trends by running a Mann-Whitney test (See table 12). Except for one case of $B1$ vs. $B2$ in subtable 12(b), the statistical significance of z-statistics in both subtables conforms the general trends as observed in "aggregate" and "individualistic" data (See subtable 12(a) and 12(b)).

Reflecting what we have analyzed so far, we could generally say that the percentage of cooperative choices becomes the lowest when the threshold uncertainty becomes sufficiently large. However, it becomes the highest if the threshold uncertainty is in the intermediate level. This result seems to hold irrespective of the type of social preferences and frames, and suggests some implications for the percentage of cooperative choices under a risky situation: people cooperate more under an intermediate level of threshold uncertainty compared to the situation without the uncertainty. However, people's cooperation suddenly and statistically significantly drops when the uncertainty is recognized to be very large beyond a certain level.

4 Discussion and conclusion

This paper experimentally examined how the degree of threshold uncertainty affects cooperative choices in a provision point mechanism (PPM) under both positive and negative frames. This is the first systematic attempt that analyzes this issue by controlling strategic effects and social uncertainty. The novelty of our experiment comes from the fact that the degree of threshold uncertainty is widely varied in the way that the number of subjects in a group on a Nash equilibrium strategy increases and then falls as the degree of uncertainty gets increased.

We considered four different levels of threshold uncertainty in experimental design. Our

experiment reveals two main results. A first result is that aggregate framing effects are negligible in a PPM, irrespective of threshold uncertainty level. However, it is found that each type of people in social preference is responding to the framing in a different direction. "Cooperative" subjects become more cooperative in negative frames than in positive frames, while "individualistic" subjects are less cooperative in negative frames than in positive ones. Since a majority of subjects in our experiment consists of "cooperative" and "individualistic" types of people, the asymmetric behavioral response is the main reason why aggregate framing effects are insignificant. This result is in sharp contrast with that in Sonnemans et al. (1998).

However, we have to note several differences between our study and Sonnemans et al. (1998) with respect to the experimental setups. First, our experimental settings more closely follow Andreoni (1995) and Park (2000) rather than Sonnemans et al. (1998), in order to focus more on testing only framing effects. For instance, we employ a stranger design of random rematching in group formation every round as in Andreoni (1995) and Park (2000), while a partner design of keeping the same partners in a group is adopted in Sonnemans et al. (1998). In this sense, the result of this paper can be directly parallel to the important works on framing effects in VCM.

Here, our key question is why "cooperative" subjects become more cooperative in bads setting, while "individualistic" subjects show the opposite pattern. As we know, the goal for "cooperative" subjects is to do best for a society, and they are the type of people who wish a best outcome for a group in an experiment. Unlikely to the VCM, a PPM possesses multiple Nash equilibria and one of them leads to a Pareto optimal outcome when the degree of threshold uncertainty is not so large. It is our conjecture that, in this case, "cooperative" subjects feel more obligation to cooperate when they face a negative framing situation rather than positive ones. This may be due to their strong intrinsic motivations for a best outcome in a group under negative frames. On the other hand, the results on "individualistic" subjects in framing can be understood in the same way as the researchers claim in a VCM case.

The second result is that cooperation collapses when the degree of threshold uncertainty exceeds a certain level. In this experiment, we observed this type of situations when it reaches the threshold uncertainty level of 3 represented by the two experimental treatments of $G3$ and $B3$. This result gives us a policy implication to what happens in reality on natural resource management or environmental problems. Nowadays, scientists agree that many problems in environmental and natural resource management are characterized by threshold uncertainty. Our result explicitly suggests that the percentage of cooperative behaviors will not be so different as far as the degree of threshold uncertainty does not exceed a certain level. However, when it happens to be so large, cooperation cannot be sustained as in fishery collapses.

It is well-known that in many cases, scientific research can contribute to the reduction of threshold uncertainty. Our results suggest that scientific research is valuable if it can reduce the degree of threshold uncertainty from a large level to a middle level. By doing so, we can expect a positive impact on cooperative behaviors. However, if the scientific research just works in the way that it reduces the threshold uncertainty from a middle level to a tiny level or nil, it will not bring about more cooperation. Rather, it may even reduce cooperation.

Although our research and experiments have some limitations in a number of ways, it is our view that a set of results obtained in this paper yields some important message on cooperative behaviors under threshold uncertainty. We also believe that our research can be extended in a different way. For instance, an effect of threshold uncertainty can be tested in more general collective decision environment such as continuous contribution decision rather than a discrete choice of cooperation or not. The other direction we can explore is to introduce ambiguity rather than uncertainty where probability distribution of threshold is unknown. If our findings are confirmed under such general settings, it will give more important policy implications.

References

Andreoni, J. (1995). Warm-glow versus cold-prickle: The effects of positive and negative framing on cooperation in experiments. *Quarterly journal of economics*, 110(1):1–21.

Bagnoli, M. and Lipman, B. L. (1989). Provision of public goods: Fully implementing the core through private contributions. *Review of economic studies*, 56:583–601.

Cadsby, C. B. and Maynes, E. (1999). Voluntary provision of threshold public goods with continuous contributions: Experimental evidence. *Journal of public economics*, 71:53–73.

Carpenter, S. R., Ludwig, D., and Brock, W. A. (1999). Management of eutrophication for lakes subject to potentially irreversible change. *Ecological applications*, 9(3):751–771.

Clark, C. W. (1990). *Mathematical bioeconomics*. John Wiley and Sons, Inc., 2 edition.

Cookson, C. (2009). *Global insight: No melting of climate doubts*. Financial times. September 21.

Davis, D. D. and Holt, C. A. (1992). *Experimental economics*. Princeton university press.

Marks, M. B. and Croson, R. T. (1998). Alternative rebate rules in the provision of a threshold public good: An experimental investigation. *Journal of public economics*, 67:195–220.

Marks, M. B. and Croson, R. T. (1999). The effect of incomplete information in a threshold public goods. *Public choice*, 99:103–118.

McBride, M. (2006). Discrete public goods under threshold uncertainty. *Journal of public economics*, 90:1181–1199.

McBride, M. (2008). Threshold uncertainty in discrete public good games: An experimental study. *Economics of governance*, 11:77–99.

Naevdal, E. (2006). Dynamic optimization in the presence of threshold effects when the location of the threshold is uncertain—with an application to a possible disintegration of the Western Antarctic Ice Sheet. *Journal of economic dynamics and control*, 30:1131–1158.

Naevdal, E. and Oppenheimer, M. (2007). The economics of the thermohaline circulation—a problem with multiple thresholds of unknown locations. *Resource and energy economics*, 29(4):262–283.

Nitzan, S. and Romano, R. (1990). Private provision of a discrete public good with uncertain cost. *Journal of public economics*, 42:357–370.

Oppenheimer, M. (1998). Global warming and the stability of the west antarctic ice sheet. *Nature*, 393:325–332.

Park, E. (2000). Warm-glow versus cold-prickle: A further experimental study of framing effects on free-riding. *Journal of economic behavior and organization*, 43:405–421.

Rondeau, D., Poe, G. L., and Schulze, W. D. (2005). VCM or PPM?: A comparison of the efficiency properties of two voluntary public goods mechanisms. *Journal of public economics*, 89(8):1581–1592.

Sonnemans, J., Schram, A., and Offerman, T. (1998). Public good provision and public bad prevention: The effect of framing. *Journal of economic behavior and organization*, 34:143–161.

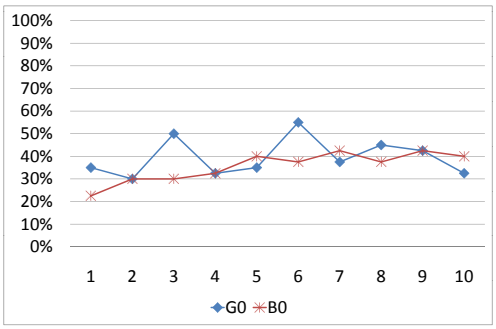
Suleiman, R. (1997). Provision of step-level public goods under uncertainty. *Rationality and society*, 9(2):163–187.

Suleiman, R., Budescu, D. V., and Rapport, A. (2001). Provision of step-level public goods with uncertain provision threshold and continuous contribution. *Group decision and negatiation*, 10:253–274.

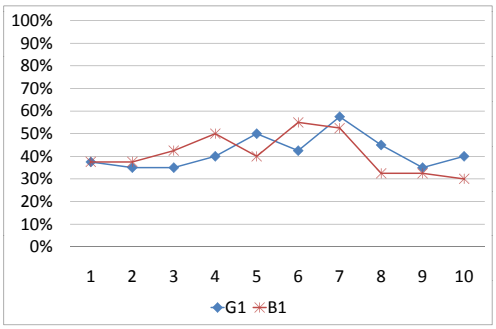
Ulph, A. and Ulph, D. (1997). Global warming, irreversibility and learning. *Economic journal*, 107:636–650.

Willinger, M. and Ziegelmeyer, A. (1999). Framing and cooperation in public good games: An experiment with an interior solution. *Economics letters*, 65:323–328.

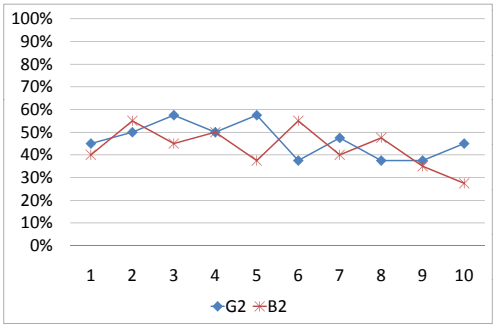
Wit, A. and Wilke, H. (1998). Public good provision under environmental and social uncertainty. *European journal of social psychology*, 28:249–256.



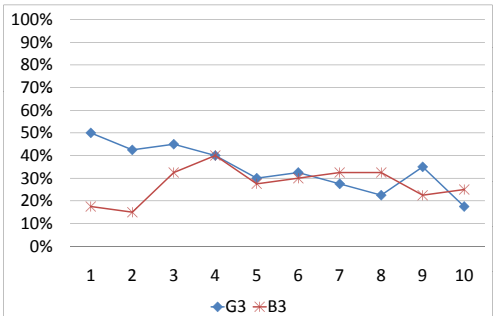
(a) $G0$ vs. $B0$



(b) $G1$ vs. $B1$



(c) $G2$ vs. $B2$



(d) $G3$ vs. $B3$

Figure 1: Overall framing effects for each level of threshold uncertainty

Degree of uncertainty	$G0$ vs. $B0$	$G1$ vs. $B1$	$G2$ vs. $B2$	$G3$ vs. $B3$
Mann-Whitney test	$z = 0.387$	$z = 0.380$	$z = 0.762$	$z = 1.520$

Note: $*$Significant at 10% level, $**$Significant at 5% level, $***$Significant at 1% level.

Table 5: Summary of Mann-Whitney tests: Overall framing effects

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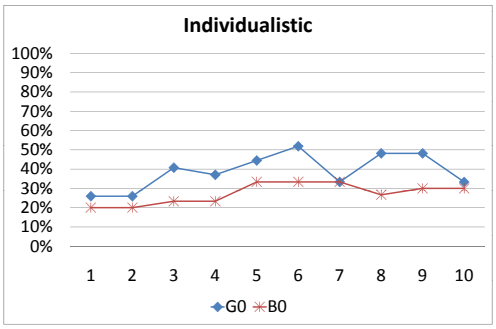
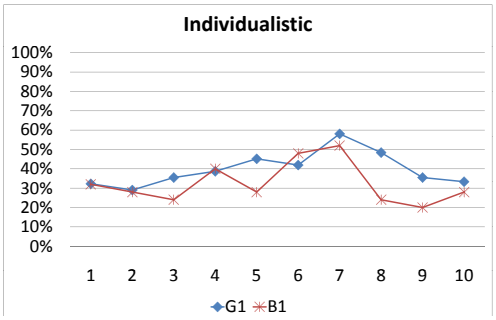
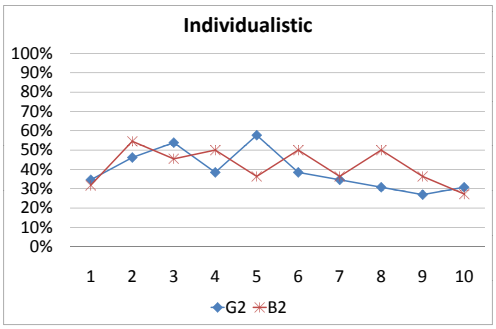


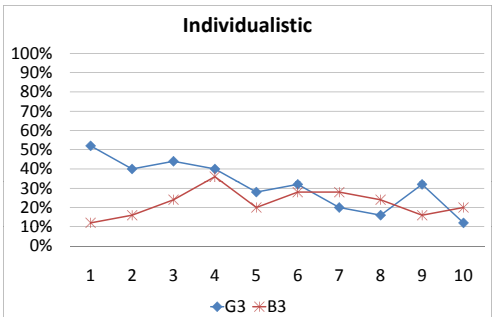
(a) $G0$ vs. $B0$



(b) $G1$ vs. $B1$



(c) $G2$ vs. $B2$



(d) $G3$ vs. $B3$

Figure 2: "Individualistic" framing effects for each threshold uncertainty

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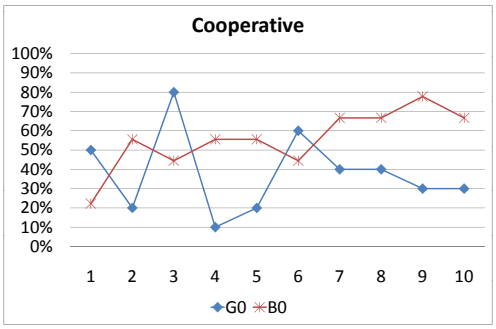
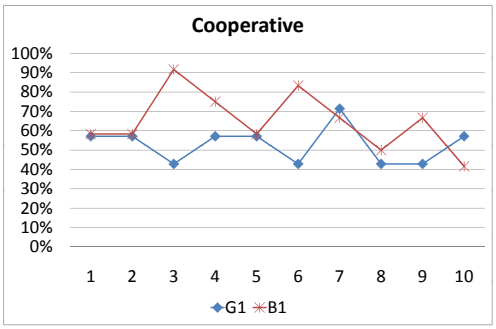
Table 6: Mann-Whitney test results: "Individualistic" framing effects

Degree of uncertainty	$G0$ vs. $B0$	$G1$ vs. $B1$	$G2$ vs. $B2$	$G3$ vs. $B3$
Mann-Whitney test	$z = 2.671 * **$	$z = 1.896*$	$z = -0.645$	$z = 1.711*$

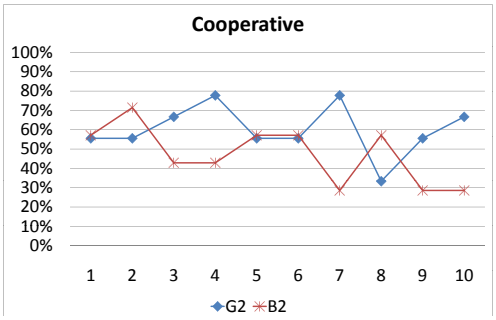
Note: $*$Significant at 10% level, $**$Significant at 5% level, $***$Significant at 1% level.



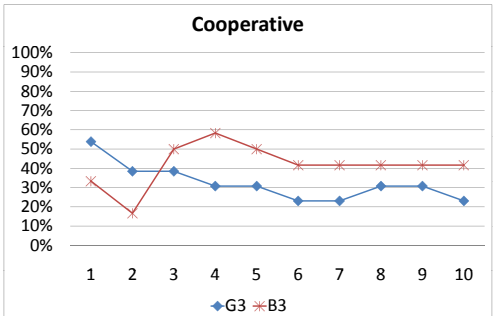
(a) $G0$ vs. $B0$



(b) $G1$ vs. $B1$



(c) $G2$ vs. $B2$



(d) $G3$ vs. $B3$

Figure 3: "Cooperative" framing effects for each threshold uncertainty

Table 7: Mann-Whitney test results: "Cooperative" framing effects

Degree of uncertainty	$G0$ vs. $B0$	$G1$ vs. $B1$	$G2$ vs. $B2$	$G3$ vs. $B3$
Mann-Whitney test	$z = -2.050 **$	$z = -2.222 **$	$z = 1.227$	$z = -2.299 **$

Note: $*$Significant at 10% level, $**$Significant at 5% level, $***$Significant at 1% level.

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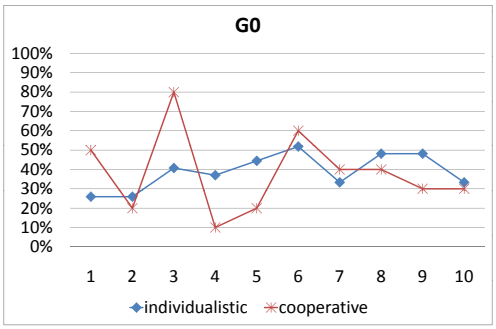
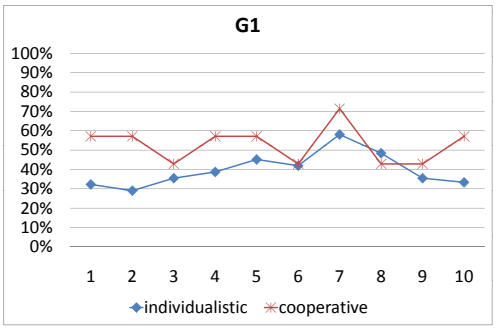
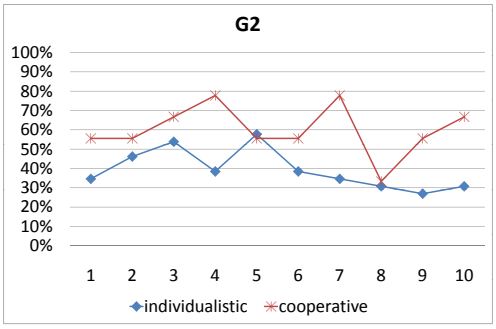


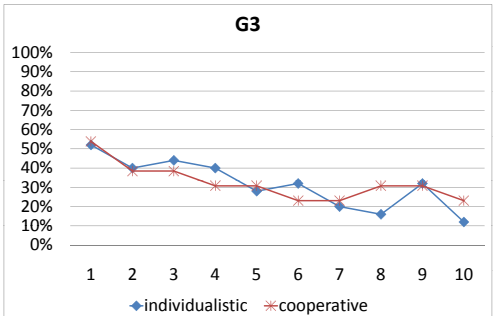
(a) Ind. vs. Coop. in $G0$



(b) Ind. vs. Coop. in $G1$



(c) Ind. vs. Coop. in $G2$



(d) Ind. vs. Coop. in $G3$

Figure 4: Cooperative choices per different value orientation in the goods setting

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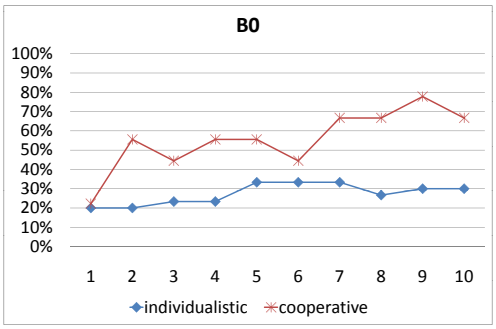
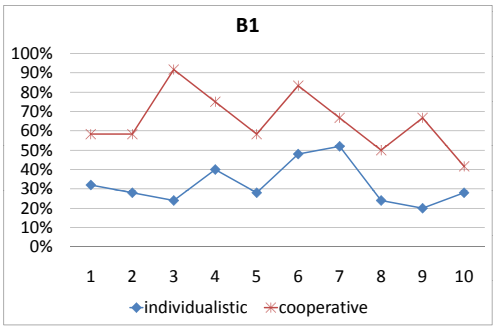
Table 8: Mann-Whitney test results (Ind. vs. Coop.): Cooperative choices of different value orientation in the goods setting

Degree of uncertainty	$G0$	$G1$	$G2$	$G3$
Mann-Whitney test	$z = -0.530$	$z = 2.524 **$	$z = 2.900 ***$	$z = -0.228$

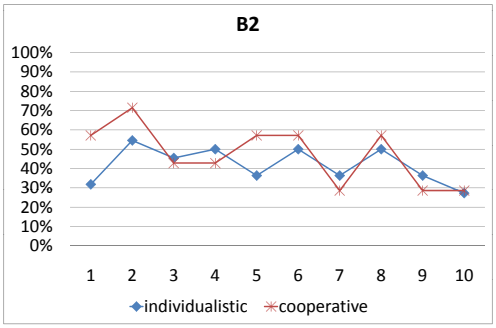
Note: $*$Significant at 10% level, $**$Significant at 5% level, $***$Significant at 1% level.



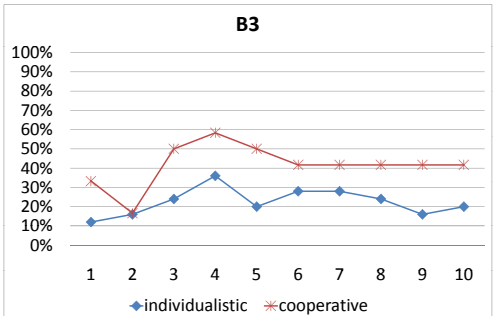
(a) Ind. vs. Coop in $B0$



(b) Ind. vs. Coop in $B1$



(c) Ind. vs. Coop in $B2$



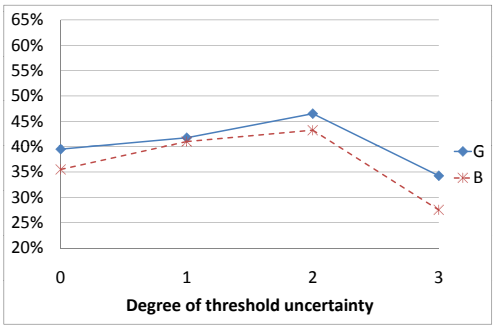
(d) Ind. vs. Coop in $B3$

Figure 5: Cooperative choices per different value orientation in the bads setting

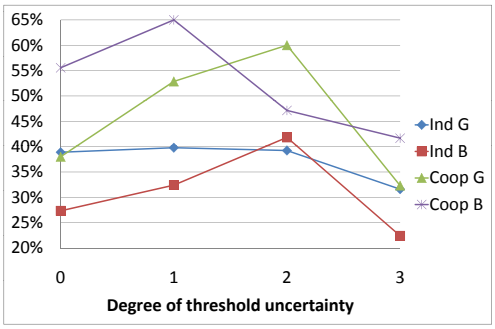
Table 9: Mann-Whitney test results (Ind. vs. Coop.): Cooperative choices of different value orientation in the bads setting

Degree of uncertainty	$B0$	$B1$	$B2$	$B3$
Mann-Whitney test	$z = 3.194 * **$	$z = 3.556 * **$	$z = 0.991$	$z = 3.205 * **$

Note: $*$Significant at 10% level, $**$Significant at 5% level, $***$Significant at 1% level.

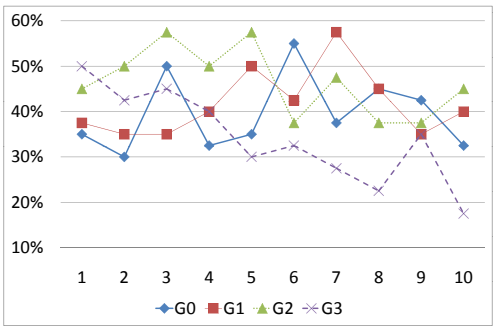


(a) Goods vs. Bads

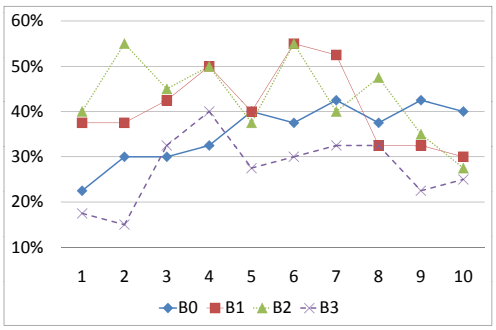


(b) Goods vs. Bads for value orientations

Figure 6: Cooperative choices for each degree of threshold uncertainty

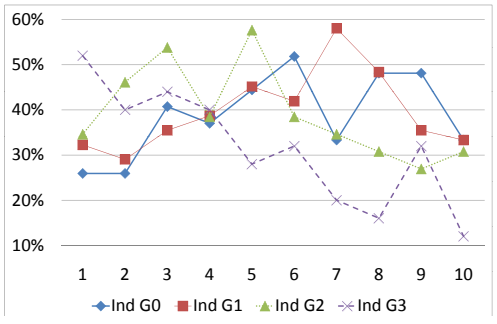


(a) Goods settings

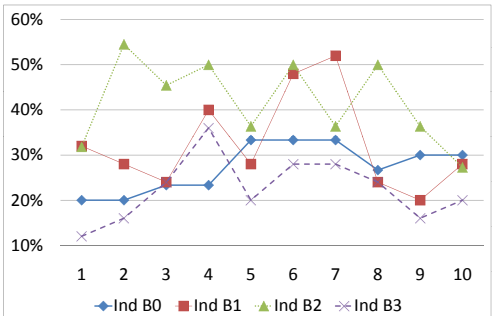


(b) Bads settings

Figure 7: Cooperative choices for each degree of threshold uncertainty over 10 rounds



(a) Goods settings



(b) Bads settings

Figure 8: Cooperative choices of "indivisualistic" subjects for each degree of threshold uncertainty over 10 rounds

Table 10: Mann-Whitney test results: Cooperative choices of different threshold uncertainties in the goods and bads setting

(a) Goods settings

Treatment	$G0$	$G1$	$G2$
$G1$	0.916		
$G2$	$2.019**$	1.489	
$G3$	-1.139	-1.598	$-2.507**$

(b) Bads settings

Treatment	$B0$	$B1$	$B2$
$B1$	1.145		
$B2$	$1.826*$	0.646	
$B3$	$-2.134**$	$-2.898***$	$-3.149***$

Note: $*$Significant at 10% level, $**$Significant at 5% level, $***$Significant at 1% level.

Table 11: Mann-Whitney test results: Cooperative choices of different threshold uncertainties for "individualistic" subjects in the goods and bads setting

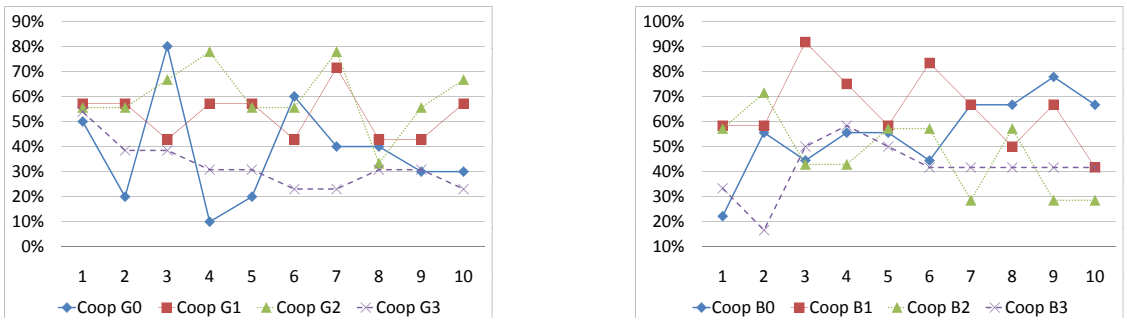
(a) Goods settings

Treatment	$G0$	$G1$	$G2$
$G1$	0.152		
$G2$	0.076	-0.454	
$G3$	-1.363	-1.514	-1.060

(b) Bads settings

Treatment	$B0$	$B1$	$B2$
$B1$	0.836		
$B2$	$3.193***$	$1.899*$	
$B3$	-1.523	$-2.222**$	$-3.493***$

Note: $*$Significant at 10% level, $**$Significant at 5% level, $***$Significant at 1% level.



(a) Goods settings

(b) Bads settings

Figure 9: Cooperative choices of "cooperative" subjects for each degree of threshold uncertainty over 10 rounds

Table 12: Mann-Whitney test results: Cooperative choices of different threshold uncertainties for "cooperative" subjects in the goods and bads setting

(a) Goods settings

Treatment	$G0$	$G1$	$G2$
$G1$	$2.067**$		
$G2$	$2.366**$	0.617	
$G3$	-0.228	$-3.538***$	$-3.603***$

(b) Bads settings

Treatment	$B0$	$B1$	$B2$
$B1$	1.223		
$B2$	-0.915	$-2.514**$	
$B3$	$-2.447**$	$-3.159**$	-0.996

Note: $*$Significant at 10% level, $**$Significant at 5% level, $***$Significant at 1% level.