

Article

Does Information about Personal Emissions of Carbon Dioxide Improve Individual Environmental Friendliness? A Survey Experiment

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Abstract: The purpose of this study is to identify factors that can change the environmental friendliness of individuals in the context of climate change issues in terms of values, beliefs, controllability, concern, attitude, intention, and behavior through a survey experiment, and to test the hypothesis that providing information about the amount of carbon dioxide (CO₂) emissions attributable to an individual with its threshold value motivates him/her to reduce that amount using statistical analyses (the Mann–Whitney test) and multivariate regressions (the ordered logit model). It is crucial to change the behavior of individuals as well as organizations to reduce the emissions of CO₂ for solving climate change issues, because the aggregate amount of individual CO₂ emissions is too large to ignore. We conducted a survey experiment to detect factors affecting the environmental friendliness of individuals. Subjects of the experiment were 102 students at Shiga University in Japan. They were randomly provided with communication opportunities, information about individual or group CO₂ emissions, and information about their threshold value. The finding is that provision of information about the amount of individual and group CO₂ emissions may be able to improve that person's environmental friendliness in terms of values, beliefs, concern, attitude, intention, and behavior.

Keywords: polycentric approach; climate change; survey experiment; environmental friendliness; individual CO₂ emissions; threshold value



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1. Introduction

Climate change due to emissions of greenhouse gases, such as carbon dioxide (CO₂), is damaging natural and human systems on Earth [1]. The data for the global land and ocean surface average temperature shows warming of 0.85 °C from 1880 to 2012 [1] (Pachauri et al., 2014), and global warming is expected to increase by 1.5 °C between 2040 and 2050 if it continues to rise at the current pace [2]. The current atmospheric concentration of CO₂ (398.5 ppm) has already exceeded a planetary boundary (350 ppm) [3,4]. We need to reduce CO₂ emissions by a minimum of 33% by 2055 in order for our emissions to stay below the high risk zone (550 ppm) in 2100 [5].

Climate change issues are a problem of the tragedy of the commons, because the use of atmospheric sinks for greenhouse gases is non-rival and non-excludable [6–8]. In the tragedy of the commons, freeriding pays from the viewpoint of each economic entity, because monitoring individual actions is almost infeasible in global environmental problems like climate change.

Multiple governing authorities working as a part of polycentric governance are likely to be effective in solving climate change problems on different scales [9–11]. Each unit in such a polycentric system independently develops norms and rules within various

domains, such as a firm, a local government, a national government, and an international regime [11]. A polycentric system allows each stakeholder to mutually monitor, learn, and adapt to environmental issues because of diversity on various scales.

In a polycentric system, every individual is one of the key players. In the context of CO₂ emissions, however, individuals generally do not know how much CO₂ they emit, nor do they have a standard for comparison that they can use to try to decrease their emissions. In contrast, organizations, such as firms and governments, have several measures that they can use to evaluate their performance in terms of CO₂ emissions and other environmental burdens [12–15].

We propose that providing every individual with information about his/her individual CO₂ emissions would encourage other citizens to reduce emissions and to behave in a more environmentally friendly manner. Although school climate strikes have gained momentum, they assume that organizations, not individuals, are to blame for CO₂ emissions. However, although the amount of CO₂ emitted by one individual is trivial, the aggregate amount of household CO₂ emissions is too large to ignore [16], and individual behavior is closely related to industrial production. We believe that a household can be motivated to reduce its CO₂ emissions if its members are informed about how changes in household behavior can have the desired effect [17,18]. This would also make parties who refuse to accept the need for CO₂ reduction (i.e., veto players) agree with climate mitigation, which is important for the success of polycentric systems [19].

Recently, there have been many pieces of scientific literature about the public perception of emissions and the relevant behavior in terms of climate change issues, but little is still known about the importance of information about personal emissions for people's self-improvement. This paper contributes to filling this significant gap. Previous studies in the fields of behavioral economics, environmental psychology, and sustainability sciences have evaluated the effects of information provision on people's pro-environmental behavior, e.g., [20–23]. For example, disclosing information about a participant's electricity usage to them decreases their electricity consumption [24], and providing a social target for reducing CO₂ emissions increases their willingness to pay for CO₂ emission reduction [25]. In general, non-monetary interventions (e.g., providing information about the participant's relative amount of energy usage, strong messaging, goal setting, commitment) may change people's attitudes and enhance their pro-environmental behavior [26]. Our approach in this study is distinct from similar previous studies in that subjects are provided with information about the threshold value (a standard) of CO₂ emissions, not the relative amount within a group [20,22–25].

In this study, we aim to identify factors that can change individual environmental friendliness in the context of climate change issues in the psychological categories of values, beliefs, controllability, concern, attitude, intention, and behavior via a survey experiment. In the experiment, we tested the hypothesis that providing information about the amount of CO₂ emissions attributable to an individual with a threshold value motivates him/her to reduce that amount. Subjects in the experiment were randomly provided with communication opportunities, information about individual or group CO₂ emissions, and information about their threshold value that we estimated based on the Japanese Intended Nationally Determined Contributions (INDC) in the Paris Agreement. We explain methods, analysis, and results in the following sections. Then, we discuss the implications of the results before giving concluding remarks.

2. Methods

2.1. Concepts of Measurement

For measuring the changes of individual environmental friendliness in the context of climate change issues, we focus on seven psychological categories: values (VAL), beliefs (BEL), controllability (CTL), concern (CON), attitude (ATT), intention (INT), and behavior (BEH). These categories are widely used in the field of environmental psychology and behavior to measure environmental friendliness [27–31].

The definitions of the seven categories in our study are provided as follows. Values (sense of value) are norms that an individual has accepted about nature and human action. Beliefs are individual thoughts or feelings regarding the relationships between human activities and the environment based on his/her individual experiences, contexts, and values. Controllability describes individual judgements on people's capacity to control environmental issues. Concern encompasses individual interests in climate change issues, environmental conditions, pro-environmental technologies, environmental policies, and so on. Attitude describes individual ways of evaluating environmental problems, climate change issues, and one's own lifestyle. Intention is an individual commitment to behave in an environmentally friendly manner. Behavior is individual action on climate change issues.

Some previous studies in the field of environmental psychology and behavior have attempted to clarify the relationships among the psychological categories [32–34]. However, we should note that the analysis of the correlation or causality between those psychological categories is outside of the scope of this paper. Experimental designs of the previous studies are different from ours.

2.2. Subjects

The subjects of the experiment were 102 students majoring in either economics or data science at Shiga University, a national university in Japan. Similar experiments targeting university students have been conducted in the past [35–39]. The discrepancy in responses from students and relevant professionals is not large [40].

To solicit participation, we advertised the study by putting up posters on campus and sending out emails. We originally collected the contact information of 119 interested persons before the start of the experiment. All of these 119 persons were asked to complete the entry survey online, which 109 persons out of the 119 did. We set the sample size to at least 10 respondents in each of the ten treatment groups in advance and randomly distributed the 109 persons to the ten groups. However, 102 persons out of 109 participated in the treatment stage of the experiment. They were treated as the subjects of this experiment.

Before the experiment commenced, we told the participants that private information would be kept confidential and came to an agreement with all subjects in terms of the conditions of the experiment. Then, we obtained written, informed consent for their participation.

2.3. Experimental Design

In this experiment, participants completed four steps: (i) entry survey, (ii) pre-survey, (iii) treatment, and (iv) post-survey.

Entry survey: All subjects were asked to complete an entry survey prior to the day of the experiment. Although gasoline consumption should be included, we target the following six items instead, considering the difficulty of response and calculation. They answered questions about their monthly consumption of electricity (kWh), water (m³), city gas (m³), liquefied petroleum gas (LPG; kg), diesel (ℓ), and kerosene (ℓ), as well as their socioeconomic characteristics. We used these data to calculate each participant's individual CO₂ emissions based on the CO₂ emission factor for each energy source as follows: 0.496 (kg CO₂/kWh) for electricity, 0.54 (kg CO₂/m³) for water, 2.23 (kg CO₂/m³) for city gas, 3.00 (kg CO₂/kg) for LPG, 2.58 (kg CO₂/ℓ) for diesel, and 2.49 (kg CO₂/ℓ) for kerosene [41,42]. For participants who were unable to provide data about part of their monthly energy consumption, we used the average energy consumption of all participants who answered that question after cutting both the upper and lower 10% of the figures to decrease the effects of outliers.

Pre-survey: To measure environmental friendliness in the context of climate change issues in the seven psychological categories, we administered a pre-survey consisting of 70 questions (Tables A1–A7 in Appendix A) to each subject between January 20 and 22, 2020. We asked 10 questions in each of the following seven categories that are commonly

used in studies of environmental psychology and behavior: values (sense of values), beliefs, controllability, concern, attitude, intention, and behavior [27–31]. The original questions and categories are based on previous research conducted in different contexts [29,43–49], but were modified, customized, and adapted to the current context of Japanese society (Tables A1–A7 in Appendix A). Answers to each question were provided based on a five-point Likert scale.

Treatment: For the treatment stage of the experiment, the 102 participants were randomly divided into ten groups with different treatments (Table 1). One of the experimental treatments is the provision of information about the threshold value. We used 85.7 kg per person per month as the threshold value based on the following information. The target amount of CO₂ emissions in the household sector is 0.601 times smaller than the amount of CO₂ emissions in 2013 [50]. We calculated the amount of monthly CO₂ emissions for each energy source of the Japanese household sector in 2013 using the data provided by the Greenhouse Gas Inventory Office of Japan [51]. We then multiplied the aggregate amount by 0.601 to obtain 85.7 kg. Subjects in Groups 5 and 6 (Table 1) compared their individual emissions with this threshold. Furthermore, we multiplied the figure, 85.7 kg, by the number of subjects in a group to obtain the group threshold. Thus, subjects in Groups 9 and 10 (Table 1) compared their group emissions with that group threshold in the experiment. When we gave participants the information about the threshold value, we explained it as follows: “We are providing the threshold value so that you can compare the amount of your (or your group’s) CO₂ emissions with it. The threshold value indicates the amount of CO₂ emissions that we must not exceed. Thus, you can simply compare them. If the amount of your (or your group’s) CO₂ emissions exceeds the threshold value, it is considered unsustainable.” Figure A1 in Appendix A shows a sample feedback sheet with information about the amount of CO₂ emissions per month with the threshold value. Subjects also received information about its component percentages (Figure A2 in Appendix A).

Table 1. Experimental conditions for ten groups.

Group	N	Treatment			
		Communication	Individual Emissions	Group Emissions	Threshold
1	9				
2	7	✓			
3	11		✓		
4	10	✓	✓		
5	10		✓		✓
6	11	✓	✓		✓
7	10			✓	
8	10	✓		✓	
9	12			✓	✓
10	12	✓		✓	✓

Members of Group 1 (the control group) had no opportunity for communication and were given no information about their level of CO₂ emissions or the related threshold value. Participants in some groups had the opportunity to communicate with each other for 25 min to discuss potential measures for reducing their CO₂ emissions. Additionally, participants in some groups were provided with information about their individual emission levels or the total amount of emissions of their group, and the threshold of the emissions was provided to some groups. For example, members of Group 6 had the opportunity to communicate about possible measures for reducing individual CO₂ emissions and were given information about their individual CO₂ emission levels, as well as the CO₂ emission threshold. Participants were able to compare their emission levels with the threshold value and find out whether their amount was above or below the threshold.

Post-survey: In the last step of the experiment, each subject completed the post-survey between January 27 and 29, 2020 (one week after participating in the treatment phase of the experiment). The post-survey contains the pre-survey questions but in a different order. Each subject received 2000 Japanese Yen (19.35 US dollars) as a reward for completing all steps of the experiment.

2.4. Data Analysis

We obtained each participant's responses to the 70 questions of the pre- and post-surveys. The five-point Likert scale values of the answers were sorted in descending order for each question, with higher values indicating greater environmental friendliness. Using the results of the pre- and the post-surveys, we conducted two kinds of analyses: the Mann–Whitney test on the difference of average changes in the aggregate score in each category (values, beliefs, controllability, concern, attitude, intention, and behavior) between different treatment groups, and an ordered logit model to explain changes in responses between the pre-survey and the post-survey for each question.

In preparation for the Mann–Whitney test, allocating an integer number (1–5) to the sorted Likert scale values for each question in ascending order, we calculated the aggregate scores of the integer numbers in each of the seven categories. Then, deducting the total score of the pre-survey from that of the post-survey, we obtained the amount of change in the aggregate scores in each category. To be precise, those Likert scale values are ordinal scales, and thus it is not considered correct to aggregate or deduct the answered values in the categories. However, as is often the case with this type of survey analysis, we conducted the calculations for analyzing the tendency of the impacts that can be attributed to different experimental treatments.

We carried out the statistical tests on the difference in the average amount of change between distinct treatment groups (Table 2). First, we tested the difference between the groups with and without a communication opportunity (Groups 2, 4, 6, 8, and 10 vs. Groups 1, 3, 5, 7, and 9 in Table 1), using the Mann–Whitney test. Second, we tested the difference among groups without any information about emissions (Groups 1 and 2), with information about individual emissions (Groups 3, 4, 5, and 6), and with information about group emissions (Groups 7, 8, 9, and 10), using the Mann–Whitney test for specifying the difference between any two groups out of the three. Third, we tested the difference between the groups having information about individual emissions with their threshold value (Groups 5 and 6) and the groups having information about individual emissions without their threshold value (Groups 3 and 4), using the Mann–Whitney test. Fourth, we tested the difference between the groups having information about group emissions with their threshold value (Groups 9 and 10) and the groups having information about group emissions without their threshold value (Groups 7 and 8), using the Mann–Whitney test.

Table 2. List of sets of treatment groups for statistical test.

Test	Description of Two Groups	N	Comparison Groups
1	<i>with</i> communication	52	2, 4, 6, 8, and 10
	<i>without</i> communication	50	1, 3, 5, 7, and 9
2	<i>without</i> any information about emissions	16	1 and 2
	<i>with</i> information about individual emissions	42	3, 4, 5, and 6
3	<i>without</i> any information about emissions	16	1 and 2
	<i>with</i> information about group emissions	44	7, 8, 9, and 10
4	information about <i>individual</i> emissions	42	3, 4, 5, and 6
	information about <i>group</i> emissions	44	7, 8, 9, and 10

Table 2. Cont.

Test	Description of Two Groups	N	Comparison Groups
5	information about individual emissions <i>with</i> their threshold value	21	5 and 6
	information about individual emissions <i>without</i> their threshold value	21	3 and 4
6	information about group emissions <i>with</i> their threshold value	24	9 and 10
	information about group emissions <i>without</i> their threshold value	20	7 and 8

Next, we applied an ordered logit model to the changes in responses to each question between the pre-survey and the post-survey. The changes were measured as an ordinal scale, because we set the five-point Likert scale values for the answers in the survey. Thus, an ordered logit model was used. In these regressions, the dependent variable is the degree of the change in response, measured as an ordinal scale. If the answer that an individual provided to a question in the pre-survey is 1 and the corresponding answer in the post-survey is 4, the environmental friendliness in terms of the question increases by 3 points. The degree of change ranges from -4 to $+4$ points for each question. The independent variables are the conditions of the treatments and some socio-economic characteristics (Table A8 in Appendix A).

3. Results

Figure 1 shows statistically significant differences between distinct treatment groups in terms of changes in respondents' scores of environmental friendliness in the context of climate change issues from pre-survey to post-survey in the seven psychological categories. We identify five meaningful differences with statistical significance out of 42 tests.

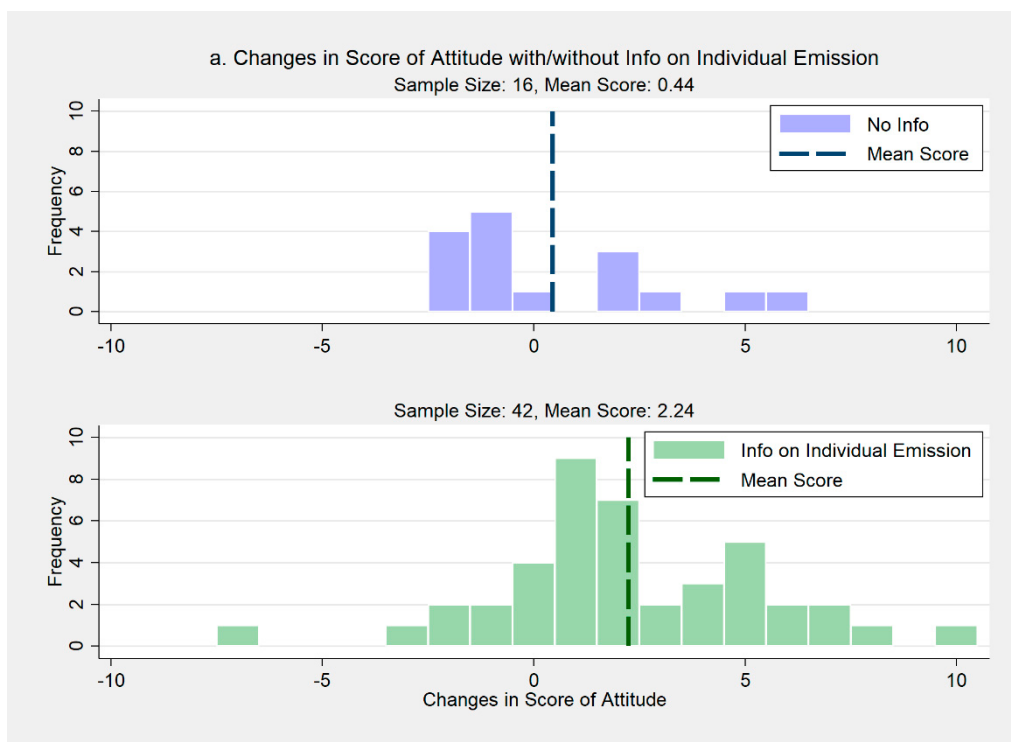


Figure 1. Cont.

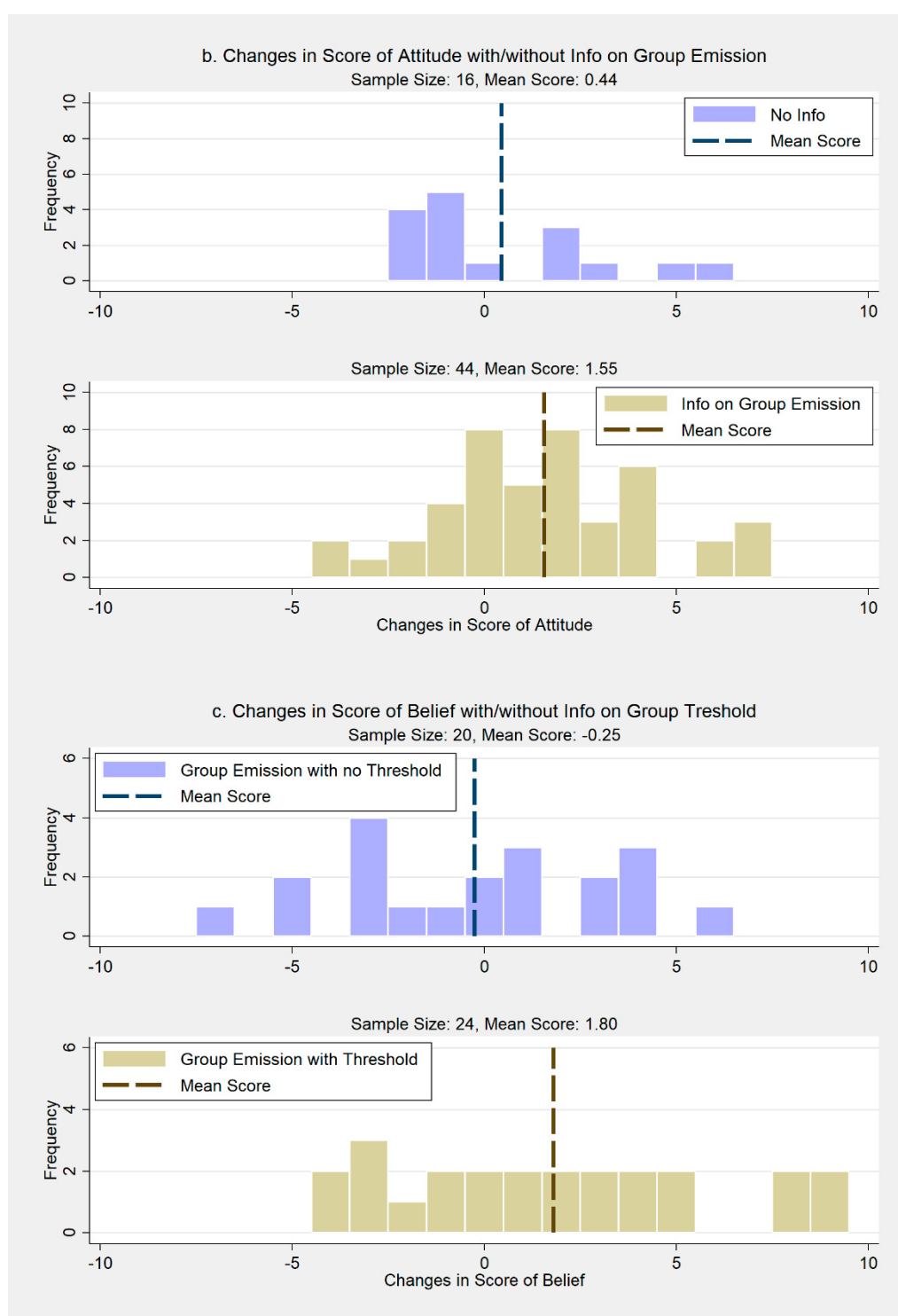


Figure 1. Cont.

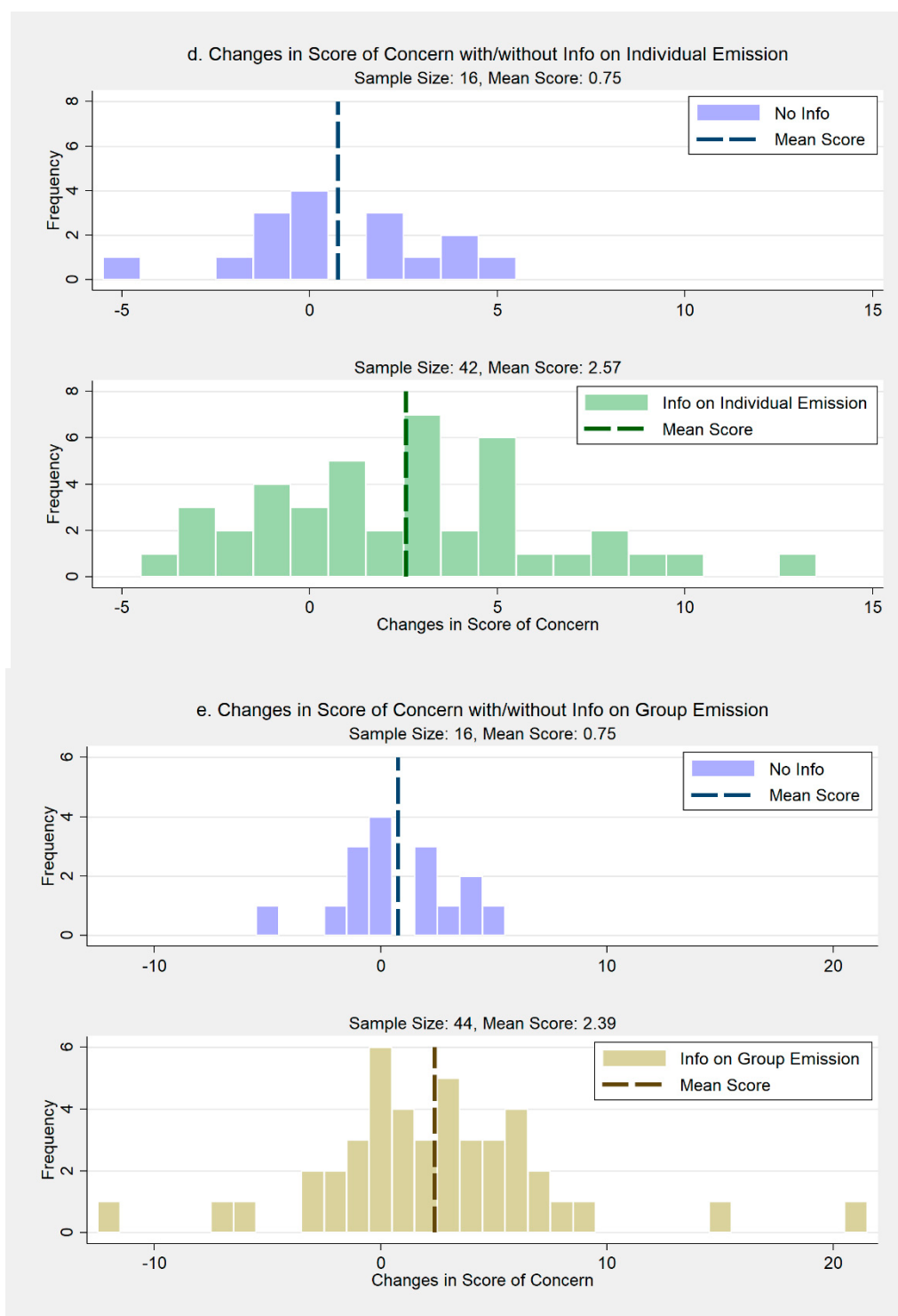


Figure 1. Statistically significant differences between groups in changes of scores. Statistically significant differences between groups in changes of scores (continued). Note: ***, **, and * represent a 1%, 5%, and 10% significance, respectively. Each test evaluates the difference in changes of respondents' scores from pre-survey to post-survey between groups with different treatments. (a) Mann–Whitney U test; One-sided test (No Info < Info on Individual Emission); z -value = -2.21 ***; $p < 0.01$. (b) Mann–Whitney U test; One-sided test (No Info < Info on Group Emission); z -value = -1.68 **; $p < 0.05$. (c) Mann–Whitney U test; One-sided test (No Info < Info on Group Threshold); z -value = -1.46 *; $p < 0.10$. (d) Mann–Whitney U test; One-sided test (No Info < Info on Individual Emission); z -value = -1.62 *; $p < 0.10$. (e) Mann–Whitney U test; One-sided test (No Info < Info on Group Emission); z -value = -1.41 *; $p < 0.10$.

Figure 1 shows the results of statistical tests on the difference in average values of change in the aggregate score of environmental friendliness. The average value of changes in the score of attitude category for subjects having information about individual emissions is larger than that for subjects not having any information about their emissions, with a 1% statistical significance (Figure 1a). The average value of changes in the score of attitude category for subjects being provided with information about group emissions is larger than that for subjects not having any information about their emissions, with a 5% statistical significance (Figure 1b). The average value of changes in the score of belief category for subjects who have information about the threshold value in addition to information about group emissions is larger than that for subjects who do not have information about the threshold value, with a 10% statistical significance (Figure 1c). The average value of changes in the score of concern category for subjects having information about individual emissions is larger than that for subjects not having any information about their emissions, with a 10% statistical significance (Figure 1d). The average value of changes in the score of concern category for subjects who are provided with information about group emissions is larger than that for subjects who are not provided with any information about their emissions, with a 10% statistical significance (Figure 1e).

Table 3 shows the results of the regressions of the ordered logit model that include statistically significant estimated parameters in the category of values (VAL). Provision of information about individual emissions improves environmental friendliness in question VAL-3, which asks how much the participant agrees with the statement “all countries including developed and developing ones should equally make efforts to mitigate climate change”. Provision of information about group emissions improves environmental friendliness in question VAL-8. Provision of information about the threshold value in addition to information about individual or group emissions decreases the degree of environmental friendliness in question VAL-6, which asks how much the participant agrees with the statement “firms should aim to solve environmental issues”. The opportunity of communication positively affects environmental friendliness in question VAL-8, which asks how much the participant agrees with the statement “you should be responsible for nature, considering the impact of what you are doing on nature and the environment”. In addition to those experimental treatments above, some socio-economic factors also affect changes in the degree of environmental friendliness due to the participation in the experiment. Individuals majoring in economics show decreased environmental friendliness in question VAL-3 and improve it in question VAL-9, which asks how much they agree with the statement “extinction of a species is inevitable”. An increase in monthly income enhances environmental friendliness in question VAL-5, which asks how much the participant agrees with the statement “Governments should aim to solve environmental issues.” The experience of learning about environmental studies also augments environmental friendliness in question VAL-5. It should be noted that the impacts of these socio-economic factors, not the experimental treatments, stimulated environmental friendliness due to the participation in the experiment. For example, people with higher income tended to have higher pro-environmental values in question VAL-5, probably because the experiment provided the impetus for promoting their pro-environmental consideration.

Table 3. Estimation results of regressions in the category of values (VAL).

	VAL-3	VAL-5	VAL-6	VAL-8	VAL-9
<i>individual emissions</i>	1.082 * (0.640)	0.567 (0.737)	−0.624 (0.734)	−0.107 (0.633)	0.0188 (0.625)
<i>group emissions</i>	0.572 (0.650)	−0.210 (0.756)	−0.253 (0.721)	1.105 * (0.654)	−0.457 (0.650)
<i>individual emissions X individual threshold</i>	−0.619 (0.584)	−1.147 (0.699)	−1.334 * (0.702)	−0.131 (0.576)	−0.133 (0.623)

Table 3. Cont.

	VAL-3	VAL-5	VAL-6	VAL-8	VAL-9
<i>group emissions</i>	−0.170	0.0514	−1.241 *	−0.132	0.668
<i>X group threshold</i>	(0.589)	(0.697)	(0.694)	(0.584)	(0.620)
<i>communication</i>	−0.195	−0.322	0.523	0.861 **	0.176
	(0.379)	(0.449)	(0.439)	(0.386)	(0.390)
<i>female</i>	0.485	0.365	0.185	−0.554	−0.442
	(0.411)	(0.468)	(0.448)	(0.394)	(0.407)
<i>economics</i>	−1.115 **	−0.632	−0.443	−0.350	1.015 *
	(0.546)	(0.625)	(0.596)	(0.496)	(0.532)
<i>monthly income</i>	0.0272	0.0404 *	−0.0320	0.0327	−0.0226
	(0.0196)	(0.0226)	(0.0267)	(0.0202)	(0.0205)
<i>environmental study</i>	0.173	1.257 **	0.251	−0.160	0.143
	(0.457)	(0.541)	(0.510)	(0.444)	(0.469)
Observations	102	102	102	102	102
Pseudo R-squared	0.0273	0.0640	0.0702	0.0690	0.0253
Log-likelihood	−140.1	−82.18	−92.22	−126.8	−126.5

Note: Standard errors in parentheses. **, and * represent a 5%, and 10% significance, respectively.

Table 4 shows the results of the regressions of the ordered logit model that include statistically significant estimated parameters in the category of beliefs (BEL). Provision of information about individual emissions improves environmental friendliness in question BEL-2 (how much the participant agrees with the statement “human beings can change natural environments, but they cannot perfectly control them”), BEL-3, and BEL-10 (how much they agree with the statement “my action affects neighbors’ and friends’ happiness”). Provision of information about group emissions enhances environmental friendliness in question BEL-3. Provision of information about the threshold value in addition to information about individual emissions increases the degree of environmental friendliness in question BEL-6, but it decreases the degree of environmental friendliness in question BEL-9, which asks how much the participant agrees with the statement “resilience of nature is strong enough to endure environmental burdens generated by human economic activities”. Provision of information about the threshold value in addition to information about group emissions increases the degree of environmental friendliness in questions BEL-2 and BEL-10. The opportunity of communication positively affects environmental friendliness in question BEL-3 (how much the participant agrees with the statement “rules are beneficial to everyone”) and BEL-6 (how much they agree with the statement “climate change is caused by CO₂ emissions due to human economic activities”). In addition, some socio-economic factors acted on environmental friendliness. Compared to male participants, female participants show improved environmental friendliness in question BEL-7, which asks how much they agree with the statement “when human beings change nature, they often face dreadful outcomes”. Participants who major in economics show decreased environmental friendliness in questions BEL-6, BEL-7, and BEL-10. An increase in monthly income enhances environmental friendliness in questions BEL-3 and BEL-6. Having learned about environmental studies lowers environmentally friendliness in question BEL-8, which asks how much the participant agrees with the statement “technological innovation can solve environmental issues”.

Table 4. Estimation results of regressions in the category of beliefs (BEL).

	BEL-2	BEL-3	BEL-6	BEL-7	BEL-8	BEL-9	BEL-10
<i>individual emissions</i>	1.863 **	1.287 *	−1.047	−0.376	−0.474	0.642	1.532 **
	(0.763)	(0.662)	(0.703)	(0.617)	(0.614)	(0.629)	(0.631)
<i>group emissions</i>	0.845	1.636 **	−0.384	−0.381	−0.248	−0.223	−0.450
	(0.725)	(0.658)	(0.674)	(0.636)	(0.582)	(0.624)	(0.662)

Table 4. Cont.

	BEL-2	BEL-3	BEL-6	BEL-7	BEL-8	BEL-9	BEL-10
<i>individual emissions</i>	−0.686	−0.367	1.125 *	−0.119	0.384	−1.537 **	0.109
<i>X individual threshold</i>	(0.720)	(0.594)	(0.640)	(0.569)	(0.595)	(0.621)	(0.582)
<i>group emissions</i>	1.508 **	−0.283	0.763	0.104	0.382	−0.383	1.348 **
<i>X group threshold</i>	(0.722)	(0.572)	(0.610)	(0.582)	(0.547)	(0.586)	(0.639)
<i>communication</i>	0.0141	0.692 *	0.799 *	−0.269	0.0384	−0.0782	−0.236
	(0.434)	(0.383)	(0.408)	(0.376)	(0.366)	(0.380)	(0.384)
<i>female</i>	0.00476	−0.202	0.158	0.989 **	−0.251	0.00183	0.521
	(0.459)	(0.394)	(0.423)	(0.402)	(0.387)	(0.401)	(0.402)
<i>economics</i>	−0.371	−0.787	−0.946 *	−0.947 *	−0.0983	−0.0830	−1.025 *
	(0.585)	(0.516)	(0.559)	(0.545)	(0.504)	(0.524)	(0.553)
<i>monthly income</i>	0.0229	0.0425 **	0.0367 *	−0.00365	0.0172	−0.0245	0.0115
	(0.0254)	(0.0202)	(0.0213)	(0.0207)	(0.0219)	(0.0206)	(0.0201)
<i>environmental study</i>	0.275	−0.353	−0.104	0.667	−1.066 **	−0.301	0.318
	(0.537)	(0.445)	(0.472)	(0.473)	(0.445)	(0.455)	(0.449)
Observations	102	102	102	102	102	102	102
Pseudo R-squared	0.0675	0.0607	0.0650	0.0360	0.0278	0.0396	0.0669
Log-likelihood	−93.74	−137	−110.9	−138.7	−145.5	−124.4	−129.9

Note: Standard errors in parentheses. **, and * represent a 5%, and 10% significance, respectively.

Table 5 shows the results of the regressions of the ordered logit model that include statistically significant estimated parameters in the category of controllability (CTL). Provision of information about individual and group emissions worsens environmental friendliness in question CTL-9, which asks how much the participant agrees with the statement “it is almost impossible to reduce the amount of emissions of greenhouse gases, considering the current economic activities”. Provision of information about group emissions improves environmental friendliness in question CTL-3, which asks how much they agree with the statement “changes in your lifestyle could solve climate change issues”. It decreases the degree of environmental friendliness in question CTL-6, which asks how much the participant agrees with the statement “it is unlikely to conserve biodiversity because of uncertainty in nature”. Furthermore, some socio-economic factors influence environmental friendliness. Compared to male participants, female participants show enhanced environmental friendliness in questions CTL-7 (measuring how much they agree with the statement “it is too costly to address environmental issues”), CTL-8 (how much they agree with the statement “refusing plastic bags is not enough to contribute to solving global environmental issues”), and CTL-9. Those who major in economics show worsened environmental friendliness in question CTL-7. An increase in monthly income improves environmental friendliness in question CTL-1 (measuring how much the participant agrees with the statement “you can reduce the amount of electricity consumption, being careful about it”) and CTL-4 (how much they agree with the statement “cooperative actions could solve climate change issues”), but lowers it in question CTL-6.

Table 5. Estimation results of regressions in the category of controllability (CTL).

	CTL-1	CTL-3	CTL-4	CTL-6	CTL-7	CTL-8	CTL-9
<i>individual emissions</i>	0.391	0.884	0.103	−0.449	0.805	−0.269	−1.077 *
	(0.715)	(0.624)	(0.613)	(0.625)	(0.620)	(0.642)	(0.618)
<i>group emissions</i>	−0.539	1.095 *	0.122	−1.296 **	−0.223	0.343	−1.160 *
	(0.704)	(0.637)	(0.627)	(0.639)	(0.628)	(0.661)	(0.630)
<i>individual emissions</i>	0.000582	−0.598	−0.651	−0.688	−0.664	0.374	0.426
<i>X individual threshold</i>	(0.646)	(0.596)	(0.555)	(0.568)	(0.574)	(0.570)	(0.572)
<i>group emissions</i>	0.951	−0.149	−0.0122	0.918	−0.423	−0.0380	−0.368
<i>X group threshold</i>	(0.665)	(0.592)	(0.569)	(0.570)	(0.604)	(0.608)	(0.574)

Table 5. Cont.

	CTL-1	CTL-3	CTL-4	CTL-6	CTL-7	CTL-8	CTL-9
<i>communication</i>	0.700 (0.435)	0.382 (0.382)	−0.412 (0.366)	−0.127 (0.369)	−0.290 (0.378)	0.141 (0.385)	−0.173 (0.374)
<i>female</i>	0.381 (0.449)	−0.286 (0.393)	0.476 (0.384)	−0.140 (0.388)	0.929 ** (0.399)	0.831 ** (0.409)	0.795 ** (0.392)
<i>economics</i>	−0.124 (0.584)	−0.447 (0.556)	−0.651 (0.541)	0.471 (0.480)	−1.497 *** (0.578)	−0.399 (0.562)	0.116 (0.504)
<i>monthly income</i>	0.0389 * (0.0219)	0.0259 (0.0202)	0.0348 * (0.0193)	−0.0385 * (0.0212)	−0.00683 (0.0216)	−0.0252 (0.0200)	−0.00257 (0.0205)
<i>environmental study</i>	−0.171 (0.509)	0.350 (0.475)	0.137 (0.437)	0.0106 (0.426)	0.607 (0.470)	−0.237 (0.460)	−0.295 (0.453)
Observations	102	102	102	102	102	102	102
Pseudo R-squared	0.0489	0.0284	0.0261	0.0311	0.0578	0.0245	0.0415
Log-likelihood	−97.13	−137.4	−151.9	−155.1	−143.5	−146.3	−152.7

Note: Standard errors in parentheses. ***, **, and * represent a 1%, 5%, and 10% significance, respectively.

Table 6 shows the results of the regressions of the ordered logit model that include statistically significant estimated parameters in the category of concern (CON). Provision of information about group emissions enhances environmental friendliness in question CON-5, which asks how much the participant is concerned about “the amount of plastic rubbish (e.g., plastic bottles)”. Provision of information about the threshold value in addition to information about individual emissions increases the degree of environmental friendliness in question CON-7, which asks how much they are interested in “new technologies to reduce the amount of CO₂ emissions and the development of such technologies.” On the other hand, provision of information about the threshold value in addition to information about group emissions lowers the degree of environmental friendliness in question CON-4, which asks how much the participant is interested in “renewable energy”. In addition, some socio-economic factors influence changes in the degree of environmental friendliness because of the participation in the experiment. Compared with male participants, female participants show improved environmental friendliness in question CON-1 (asking how much they are interested in “services and goods that generate as small an amount of CO₂ emissions as possible”) and CON-3 (asking how much they are interested in “electric, hydrogen, and hybrid vehicles”). However, female participants show a decreased degree of environmental friendliness in question CON-2, which asks how much they are interested in “the amount of my electricity consumption”. Participants majoring in economics show enhanced environmental friendliness in question CON-2, as well. The experience of learning about environmental studies augments environmental friendliness in question CON-7.

Table 6. Estimation results of regressions in the category of concern (CON).

	CON-1	CON-2	CON-3	CON-4	CON-5	CON-7
<i>individual emissions</i>	0.718 (0.623)	0.357 (0.612)	0.544 (0.722)	0.649 (0.666)	0.874 (0.617)	−0.931 (0.670)
<i>group emissions</i>	0.619 (0.645)	0.216 (0.623)	1.125 (0.741)	0.896 (0.683)	1.134 * (0.630)	−0.627 (0.687)
<i>individual emissions</i> X <i>individual threshold</i>	−0.0510 (0.573)	−0.0937 (0.574)	0.260 (0.620)	−0.185 (0.617)	0.538 (0.569)	1.121 * (0.666)
<i>group emissions</i> X <i>group threshold</i>	0.144 (0.618)	−0.318 (0.581)	−0.817 (0.625)	−1.255 ** (0.622)	−0.294 (0.582)	−0.584 (0.631)
<i>communication</i>	0.170 (0.387)	0.469 (0.380)	0.464 (0.413)	−0.0872 (0.395)	−0.343 (0.369)	0.248 (0.406)
<i>female</i>	0.845 ** (0.409)	−0.731 * (0.392)	0.735 * (0.435)	−0.156 (0.421)	−0.378 (0.382)	0.454 (0.426)

Table 6. Cont.

	CON-1	CON-2	CON-3	CON-4	CON-5	CON-7
<i>economics</i>	−0.123 (0.529)	1.723 *** (0.602)	−0.0678 (0.569)	0.466 (0.556)	0.715 (0.506)	−0.755 (0.561)
<i>monthly income</i>	0.0281 (0.0195)	−0.0122 (0.0232)	0.0137 (0.0228)	0.0247 (0.0240)	−0.00994 (0.0224)	−0.00992 (0.0211)
<i>environmental study</i>	0.0580 (0.460)	−0.0718 (0.454)	0.217 (0.498)	−0.135 (0.475)	−0.155 (0.457)	0.986 ** (0.485)
Observations	102	102	102	102	102	102
Pseudo R-squared	0.0318	0.0431	0.0365	0.0312	0.0334	0.0571
Log-likelihood	−123.8	−136.5	−107.3	−113.2	−152.9	−111.3

Note: Standard errors in parentheses. ***, **, and * represent a 1%, 5%, and 10% significance, respectively.

Table 7 shows the results of the regressions of the ordered logit model that include statistically significant estimated parameters in the category of attitude (ATT). Provision of information about individual emissions has a positive impact on environmental friendliness in question ATT-3 (how similar the following statement is to their attitude: “I disapprove of government’s inaction on environmental issues”), ATT-7 (how similar the following statement is to their attitude: “it is inevitable that typhoons often come”), and ATT-8 (how similar the following statement is to their attitude: “I feel sad, seeing the Earth polluted by human activities”). Provision of information about group emissions improves environmental friendliness in questions ATT-7 and ATT-8. It, however, lowers the degree of environmental friendliness in question ATT-2, which asks how similar the following statement is to the participant’s attitude: “I do not want the temperature in summer to rise more”. Adding information about the threshold value to information about individual emissions worsens environmental friendliness in questions ATT-7 and ATT-8. Including the threshold value in information about group emissions enhances environmental friendliness in questions ATT-2 and ATT-10 (how similar the following statement is to their attitude: “I am willing to change my lifestyle for environmental conservation and preservation”). Compared to male participants, female participants’ degree of environmental friendliness decreases in question ATT-4 (how similar the following statement is to their attitude: “I am sad about a decrease in beaches due to sea-level rise”). For those who major in economics, the degree of environmental friendliness increases in question ATT-4 and decreases in question ATT-8. An increase in monthly income enhances environmental friendliness in question ATT-2.

Table 7. Estimation results of regressions in the category of attitude (ATT).

	ATT-2	ATT-3	ATT-4	ATT-7	ATT-8	ATT-10
<i>individual emissions</i>	0.00187 (1.072)	1.316 ** (0.653)	0.460 (0.623)	1.529 ** (0.698)	2.624 *** (0.716)	−0.170 (0.656)
<i>group emissions</i>	−2.391 ** (1.071)	0.539 (0.641)	−0.312 (0.627)	1.516 ** (0.704)	1.774 ** (0.711)	−0.0778 (0.681)
<i>individual emissions</i>	−1.006 (1.039)	−0.129 (0.607)	−0.789 (0.577)	−1.762 *** (0.682)	−1.201 * (0.614)	0.484 (0.615)
<i>X individual threshold</i>	1.922 ** (0.970)	0.336 (0.605)	0.527 (0.594)	−0.786 (0.620)	0.284 (0.619)	1.297 ** (0.631)
<i>X group threshold</i>	−0.00584 (0.599)	0.439 (0.391)	−0.437 (0.380)	−0.249 (0.405)	−0.336 (0.397)	0.136 (0.395)
<i>female</i>	0.0622 (0.624)	−0.278 (0.402)	−0.740 * (0.399)	−0.441 (0.426)	0.398 (0.421)	−0.245 (0.413)
<i>economics</i>	0.0880 (0.811)	0.801 (0.548)	1.011 * (0.526)	−0.248 (0.542)	−1.419 *** (0.549)	0.475 (0.527)
<i>monthly income</i>	0.0545 * (0.0309)	0.00357 (0.0208)	0.0206 (0.0199)	−0.0179 (0.0229)	−0.00933 (0.0245)	−0.00292 (0.0225)

Table 7. Cont.

	ATT-2	ATT-3	ATT-4	ATT-7	ATT-8	ATT-10
<i>environmental study</i>	−0.180 (0.730)	0.402 (0.462)	−0.711 (0.454)	−0.436 (0.516)	0.780 (0.486)	0.00852 (0.475)
Observations	102	102	102	102	102	102
Pseudo R-squared	0.101	0.0415	0.0442	0.0671	0.0940	0.0335
Log-likelihood	−51.97	−121.3	−137.3	−106.3	−106.8	−117.4

Note: Standard errors in parentheses. ***, **, and * represent a 1%, 5%, and 10% significance respectively.

Table 8 shows the results of the regressions of the ordered logit model that include statistically significant estimated parameters in the category of intention (INT). Provision of information about individual emissions enhances environmental friendliness in question INT-4, which asks how similar the following statement is to the participant's attitude: "I want to buy products and services produced by environmentally friendly firms." Provision of a communication opportunity lowers the degree of environmental friendliness in question INT-10, which asks how similar the following statement is to their attitude: "I will meet the standard of emissions when it is set." In addition, some socio-economic factors influence changes in the degree of environmental friendliness after participation in the experiment. Compared to male participants, female participants show an improved environmental friendliness in question INT-4. Participants majoring in economics show a reduced degree of environmental friendliness in question INT-10. On the other hand, the experience of learning about environmental studies improves environmental friendliness in question INT-10. An increase in monthly income enhances environmental friendliness in questions INT-5 (how similar the following statement is to the participant's attitude: "I am going to change my lifestyle for environmental preservation and conservation"), INT-6 (how similar the following statement is to their attitude: "I will avoid using automobiles and airplanes if possible"), and INT-9 (how similar the following statement is to their attitude: "I am willing to donate my daily wage once a year for supporting environmental conservation").

Table 8. Estimation results of regressions in the category of intention (INT).

	INT-4	INT-5	INT-6	INT-9	INT-10
<i>individual emissions</i>	1.527 ** (0.667)	−0.173 (0.673)	−0.162 (0.624)	0.417 (0.626)	0.546 (0.640)
<i>group emissions</i>	0.668 (0.685)	0.671 (0.651)	−0.450 (0.661)	−0.0193 (0.683)	−0.416 (0.646)
<i>individual emissions</i> <i>X individual threshold</i>	−0.767 (0.577)	0.488 (0.639)	−0.367 (0.543)	−0.310 (0.592)	−0.660 (0.601)
<i>group emissions</i> <i>X group threshold</i>	0.306 (0.623)	−0.219 (0.588)	0.694 (0.595)	−0.655 (0.633)	−0.705 (0.585)
<i>communication</i>	−0.0626 (0.391)	0.537 (0.399)	−0.316 (0.373)	−0.503 (0.392)	−0.813 ** (0.396)
<i>female</i>	0.912 ** (0.422)	−0.109 (0.415)	−0.217 (0.389)	0.437 (0.409)	0.530 (0.407)
<i>economics</i>	0.632 (0.561)	−0.384 (0.510)	−0.565 (0.530)	0.238 (0.518)	−1.182 ** (0.553)
<i>monthly income</i>	0.0180 (0.0207)	0.0460 ** (0.0201)	0.0547 ** (0.0241)	0.0562 ** (0.0228)	−0.00366 (0.0214)
<i>environmental study</i>	0.498 (0.471)	0.224 (0.466)	−0.271 (0.442)	−0.0286 (0.481)	1.142 ** (0.474)
Observations	102	102	102	102	102
Pseudo R-squared	0.0558	0.0396	0.0346	0.0548	0.0711
Log-likelihood	−127.6	−114.3	−146	−113	−127.5

Note: Standard errors in parentheses. **, and * represent a 5%, and 10% significance, respectively.

Table 9 shows the results of the regressions of the ordered logit model that include statistically significant estimated parameters in the category of behavior (BEH). Provision of information about individual emissions enhances environmental friendliness in question BEH-6, which asks how similar the following statement is to the participant's behavior: "I use public transportation in urban areas". Provision of information about group emissions lowers the degree of environmental friendliness in question BEH-1, which asks how similar the following statement is to their behavior: "I move by bicycle and/or on foot as frequently as possible". Provision of information about the threshold value in addition to information about individual emissions decreases the degree of environmental friendliness in question BEH-6. Provision of information about the threshold value in addition to information about group emissions increases the degree of environmental friendliness in question BEH-1 and decreases it in question BEH-3, which asks how similar the following statement is to the participant's behavior: "I do not buy beverages in a plastic bottle". Provision of a communication opportunity improves environmental friendliness in question BEH-1. However, it reduces the degree of environmental friendliness in questions BEH-2 (how similar the following statement is to their behavior: "I buy goods that have low food mileage"), BEH-3, BEH-6, and BEH-7 (how similar the following statement is to their behavior: "I point out other's environmentally unfriendly behavior"). In addition, some socio-economic factors have an impact on changes in the degree of environmental friendliness due to the participation in the experiment. Female participants show worsened environmental friendliness in question BEH-2. Those who major in economics improve their environmental friendliness in question BEH-10, which asks how similar the following statement is to their behavior: "I get plastic and/or paper bags when I go shopping". An increase in monthly income enhances environmental friendliness in question BEH-1 and lowers it in question BEH-10. The experience of studying environmental subjects elevates the degree of environmental friendliness in question BEH-2 and BEH-6. However, it reduces it in question BEH-5, which asks how similar the following statement is to their behavior: "I avoid buying plastic products".

Table 9. Estimation results of regressions in the category of behavior (BEH).

	BEH-1	BEH-2	BEH-3	BEH-5	BEH-6	BEH-7	BEH-10
<i>individual emissions</i>	−0.684 (0.661)	0.376 (0.672)	0.174 (0.737)	−0.0643 (0.630)	2.201 ** (0.870)	0.463 (0.648)	0.285 (0.628)
<i>group emissions</i>	−1.705 ** (0.710)	0.168 (0.654)	0.573 (0.744)	0.525 (0.652)	0.959 (0.804)	0.709 (0.624)	0.957 (0.632)
<i>individual emissions</i>	−0.169 (0.652)	−1.063 (0.651)	0.771 (0.666)	0.251 (0.605)	−1.635 ** (0.801)	−0.499 (0.603)	0.185 (0.598)
<i>X individual threshold</i>							
<i>group emissions</i>	1.295 * (0.668)	−0.977 (0.623)	−0.258 (0.673)	0.270 (0.589)	−0.816 (0.719)	−0.743 (0.592)	−0.852 (0.588)
<i>X group threshold</i>	0.793 * (0.425)	−0.737 * (0.415)	−0.902 ** (0.453)	−0.0517 (0.385)	−0.954 * (0.499)	−0.672 * (0.391)	0.00289 (0.382)
<i>communication</i>							
<i>female</i>	−0.0329 (0.438)	−0.762 * (0.429)	0.533 (0.459)	0.550 (0.407)	−0.581 (0.507)	−0.188 (0.396)	−0.204 (0.395)
<i>economics</i>	−0.0943 (0.538)	0.106 (0.561)	−0.00320 (0.580)	−0.403 (0.549)	−0.983 (0.683)	−0.283 (0.563)	0.896 * (0.514)
<i>monthly income</i>	0.0467 ** (0.0203)	0.0149 (0.0199)	−0.00921 (0.0261)	0.0278 (0.0232)	−0.0259 (0.0238)	0.00851 (0.0214)	−0.0682 *** (0.0227)
<i>environmental study</i>	0.338 (0.519)	1.002 ** (0.489)	−0.107 (0.570)	−1.202 ** (0.496)	1.075 * (0.585)	0.366 (0.469)	0.450 (0.477)
Observations	102	102	102	102	102	102	102
Pseudo R-squared	0.0647	0.0588	0.0382	0.0454	0.111	0.0221	0.0523
Log-likelihood	−116.6	−120.8	−87.79	−126.9	−77.23	−137.9	−144.7

Note: Standard errors in parentheses. ***, **, and * represent a 1%, 5%, and 10% significance, respectively.

4. Discussion

4.1. Importance of Information about Individual CO₂ Emissions

One of the interesting results is that information about individual CO₂ emissions could enhance individual environmental friendliness in the aggregate score of measures of attitude (Figure 1a) and concern (Figure 1d), and in some questions of values (Table 3), beliefs (Table 4), attitude (Table 7), intention (Table 8), and behavior (Table 9). This implies that an individual can be motivated to take pro-environmental actions if he/she obtains information about the environmental burdens he/she imposes. For example, many individuals might be interested in making contributions to the reduction of CO₂ emissions. However, they might not know how to do so without relevant information about their current level of individual CO₂ emissions.

In many cases, an individual is able to reduce their CO₂ emissions by changing their patterns of consumption. Changes in individual behavior also alter the processes of industrial production to be done in a more environmentally friendly manner. However, information about the emissions related to the consumption of commodities is often unavailable. If every individual had access to such information, they could choose to use a lower carbon commodity among substitutes. Governments also need to appropriately incentivize producers to provide information to consumers about the amount of CO₂ emissions that occurred in the production process of a product, because carbon-labelling might enable individuals to make eco-friendly purchases [52–54]. The carbon footprint of commodities should be evaluated and available to every individual, ideally based on the life cycle assessment of the commodities.

We should note that information about individual emissions negatively affects individual environmental friendliness only in question CTL-9 (how much the participant agrees with the statement: “it is almost impossible to reduce the amount of emissions of greenhouse gases, considering the current economic activities”) in the category of controllability (Table 5). Understanding how much CO₂ an individual emits may make him/her feel that it is too difficult to sufficiently reduce these emissions, although people need to know how much CO₂ they emit and what activity is responsible for most of the issues related to climate change in order to take specific actions to reduce their CO₂ emissions.

Every individual might be latently willing to take action to reduce CO₂ emissions. However, people generally tend to believe that organizations, such as firms, municipalities, central governments, and international organizations are to blame for climate change and have the responsibility to alleviate it, because an individual’s potential contribution is small compared to the size of the problem. This is because individuals might think that it is impossible to resolve the problem of climate change in question CTL-9 from the individual point of view. They may rely on governments and firms for solutions. Although school climate strikes and movements to spur governmental actions on climate change issues are now common, every individual needs to change his/her behavior to alleviate climate change problems, because the aggregate changes in individual behavior could be impactful. In the polycentric system, both individual and organizational actions on climate change are required to resolve the issue.

On the other hand, the provision of information about group CO₂ emissions can have positive or negative impacts on individual environmental friendliness (Tables 3–9), although positive impacts were observed in the aggregate score of measure of attitude (Figure 1b) and concern (Figure 1e). This depends on the questions. Even if people are provided with information about group emissions, its positive effects on changes in pro-environmental motivation are not necessarily obtained. We should note that information about group emissions lowers individual environmental friendliness in the category of behavior, although information about individual emissions enhances it in the same category (Table 9). It is not necessarily effective to provide information about group emissions, but information about individual emissions seems more important for a positive behavior change.

4.2. Effects of Threshold Value on Individual Environmental Friendliness

We obtain complicated results about the effects of the threshold value on changes in individual environmental friendliness. In some cases, the provision of thresholds affects participants' values, beliefs, concern, attitude, and behavior in both positive and negative directions (Tables 3, 4, 6, 7 and 9). What we need to focus on is that the addition of information about the threshold value sometimes lowers individual environmental friendliness, while providing information about individual emissions positively affects it in terms of questions ATT-7 (how similar the following statement is to the participant's attitude: "it is inevitable that typhoons often come"), ATT-8 (how similar the following statement is to their attitude: "I feel sad, seeing the Earth polluted by human activities"), and BEH-6 (how similar the following statement is to their behavior: "I use public transportation in urban areas"). This means that participants tend to feel that it is too difficult to reduce the amount of CO₂ emissions sufficiently when they know the ratio of the emission amount relative to the standard. In many cases, the actual emission amount exceeded the threshold stated in the Paris Agreement. For this reason, people should not be informed of the threshold if quick changes in individual behavior are needed. We should be cautious when we add information about the threshold value to information about individual emissions, as this may offset the positive effect of information about individual emissions on individual environmental friendliness in some cases.

Some studies have reported that an individual increases the extent of their pro-environmental behavior if he/she is given information about the relative size of their environmental burden within a group (e.g., an individual's relative proportion of the entire electricity consumption), as this information enables him/her to compare their value with that of others [20,22–25]. In our study, we provided threshold values instead of a relative value, which enabled participants to compare their CO₂ emission with the Paris Agreement standard. Thus, our results are distinct from those of previous studies in that changes in pro-environmental behavior depend on the relationship between the amount of CO₂ emissions and the threshold value. We believe that the standard, based on the Paris Agreement, is more significant as a criterion for individual behavior than relative values within a group. This is because the amount of individual emissions that is smaller within a group may still exceed the standard provided in the Paris Agreement. In this respect, our results are more meaningful, because they illustrate that individuals must urgently abide by the standard in order to solve climate change issues effectively.

4.3. Impact of Communication on Environmental Friendliness

The provision of a communication opportunity might be able to improve environmental friendliness in the category of values and beliefs (Tables 3 and 4). Considering the questions in which communication has a positive effect with statistical significance (VAL-8: how much the participant agrees with the statement: "you should be responsible for nature, considering the impact of what you do on nature and the environment", BEL-3: how much they agree with the statement "rules are beneficial to everyone", and BEL-6: how much they agree with the statement "climate change is caused by CO₂ emissions due to human economic activities"), subjects could gain a correct understanding of some aspects of climate change issues through communication. As a result, they might change their recognition of the current state related to these problems.

However, it decreases the degree of environmental friendliness in the category of intention and behavior, except for one question (Tables 8 and 9). Through communication, subjects may have clarified what they can do and what they cannot do to alleviate the issues of climate change. Based on their current lifestyles, they may have learned that they have no choice other than accepting what they currently do and that they cannot easily change their current behavior. These results tell us that we need to consider how and what we should discuss during a communication opportunity in order to change individuals' behavior to be more in line with the solutions for climate change problems.

4.4. Income Effects on Environmental Friendliness

The results of the regression analysis show that environmental friendliness, measured in 10 questions addressing each category of values, beliefs, controllability, attitude, intention, and behavior, improves more significantly after participating in the experiment and as monthly income becomes larger, except for two questions (Tables 3–5 and 7–9). This implies that people with a higher income would be more motivated to change their behavior in a pro-environmental manner if they reviewed their current environmental friendliness and lifestyle. People with a higher income can also more easily improve their intentions, because a large monthly income expands their range of choices in terms of pro-environmental behavior (Table 8). Obviously, it is possible for people with a lower income to reduce their living costs by making their behavior environmentally friendly as well. For example, the cost of walking is cheaper than that of using a car. However, it is often the case that such low-cost options are inconvenient and provide disutility. While their income is not sufficiently high, people tend to focus on their own welfare, which is closely linked to consumption. As their income increases, people may be more altruistic and inclined to form pro-environmental beliefs, focusing on the relationships between human activities and the environment. In addition, people with a high income may have grown in a rich family with wider options such as education opportunities and life/travel experiences. Thus, they are inclined to have more ideas and options to change their behavior in a pro-environmental manner.

As mentioned above, an increase in monthly income lowers environmental friendliness due to the participation in the experiment in questions CTL-6 (how much the participant agrees with the statement “it is unlikely to conserve biodiversity because of uncertainty in nature”) and BEH-10 (how similar the following statement is to their behavior: “I get plastic or/and paper bags when I go shopping”). These two exceptions have not been well explained up to now. This finding needs to be further researched, including not only university students, but also the general public as experimental subjects.

4.5. Other Significant Findings

The ordered logit regression analysis reveals five additional findings (Tables 3–9). First, economics students tend to give low priority to environmental consideration in seven questions, while they increase their environmental friendliness in four questions. This may be because economics students are more self-interested and sensitive to economic profits [55–57].

Second, female participants enhance their environmental friendliness because of the participation in the experiment in seven questions, while they lower it in three questions. As compared with male participants, female participants tend to consider environmental aspects more important than other socio-economic aspects. This coincides with the results of similar studies [58–60].

Third, learning about environmental studies improves environmental friendliness after the experiment in five questions, while it reduces the degree of environmental friendliness in two questions. On the whole, studying environmental subjects seems to be effective for enhancing pro-environmental motivations. This may depend on the contents of environmental studies.

5. Conclusions

We carried out an experiment with surveys to detect factors that can change the environmental friendliness of individuals in the context of climate change issues in terms of values, beliefs, controllability, concern, attitude, intention, and behavior. Then, we analyze the data obtained from the experiment by using the statistical tests and the ordered logit model. The results of the analysis show that information about individual CO₂ emissions might mostly be able to enhance individual environmental friendliness in terms of values, beliefs, concern, attitude, intention, and behavior, even though the time scale of this experiment was short term. Based on these results, providing relevant information about

individual CO₂ emissions may be able to contribute to mitigating climate change issues. In other words, individuals would not change their behavior to reduce CO₂ emissions without relevant information about their individual emissions, even though they may be motivated to do so. However, the provision of information about group CO₂ emissions has positive or negative impacts on individual environmental friendliness. It positively affects pro-environmental attitude and concern.

On the other hand, we obtain complex results about the provision of information regarding the threshold value. In some cases, we observe a positive impact of it on environmental friendliness, but in other cases, a negative impact is observed. The addition of information about the threshold value lowers individual environmental friendliness while providing information about individual emissions positively affects it in terms of some questions related to global environmental issues: how similar the following statement is to the participant's attitude: "it is inevitable that typhoons often come" (ATT-7); how similar the following statement is to their attitude: "I feel sad, seeing the earth polluted by human activities" (ATT-8); and how similar the following statement is to their behavior: "I use public transportation in urban areas" (BEH-6). The big gap between the current emission amount and the threshold might make subjects feel that it is too difficult to reduce the amount of CO₂ emissions to a substantial extent. We believe that information about the comparison between our current emissions and the threshold is crucial, and thus, we need to avoid providing such a negative mental effect while showing information about the threshold.

Furthermore, we have obtained some other findings. Communication opportunities may be able to improve environmental friendliness in terms of values and beliefs, while they lower it in the category of intention and behavior. Environmental friendliness in values, beliefs, controllability, attitude, intention, and behavior improves in the experiment as income level increases. Economics students tend to place less importance on environmental consideration. Female participants are likely to give a high priority to environmental friendliness, compared to male ones. Learning about environmental studies is inclined to enhance environmental friendliness.

Based on the main results of this study, it is urgently necessary to devise policies that enable every individual to access information about their carbon footprint (i.e., carbon footprint labelling), at least in their usual life. Every individual should obtain information about his/her daily and/or monthly carbon footprint based on the life cycle assessment and the impacts of his/her efforts to change specific actions regarding CO₂ emission reduction. Most people are currently addicted to smart phones, and thus it may be a promising idea to pre-install some software programs to automatically calculate and record carbon footprint in smart phones. If people glanced at the data of their own carbon footprint as compared to the threshold value whenever they used a smart phone, they might change their behavior in a more sustainable manner. Another practical option is to set up meters of monthly carbon footprint in many places in each municipality, like thermometers erected at corners of roads. They show a monthly carbon footprint that is clearly compared to the threshold value at the same time. They may work like information about the amount of group emissions.

In our current world, we have been managing CO₂ emissions through macro-entities such as countries, municipalities, and firms, but we have not currently accomplished the necessary reduction of CO₂ emissions to be in the target zone. This is because we cannot attribute the aggregate emission amount to every individual as a crucial constituent member in a macro-entity. It is necessary to consider behavior changes of all the stakeholders in the polycentric system in terms of a CO₂ emission target. We can manage only macro-entities if we do not consider the clear responsibility of every individual or motivate them to reduce their emissions. Under this condition, we have no effective measure, because the total amount of emissions of micro-entities is too large to ignore. Every individual should be practically responsible in order to make the polycentric governance work well. Improvement of individual behavior would positively affect changes in the

other stakeholders' actions, as well. The interactions between them would lead to the target reduction of CO₂ emissions.

Several limitations of this study should be considered in future research. First, we need to expand the experiment so that the results are more generalizable to other locales. In the current study, the sample size and participants' diversity are limited, although some studies taking an experimental approach are similar to ours in terms of sample size and subjects' diversity [61–63]. However, we should note that the experiment in this paper treated students in a university in Japan. They might make more collective decisions in comparison with European and American people and be more pro-environmental as compared with people in low-income countries. Second, the long-term effects of the intervention should be observed. In the current study, only short-term effects were analyzed, and it is unclear how long the effects observed in this study remain. We need to conduct a follow-up study after the initial experiment in order to investigate whether long-term changes occur in environmental friendliness in terms of the seven categories. Furthermore, we want to analyze the impact of the frequency of experimental treatments over a certain period of time on changes in environmental friendliness. This should also be carried out in a long-term study. Third, the impacts of the treatments provided in the experiment were measured via questionnaires, which were based on subjective evaluations, even regarding behavior. In addition to psychological changes based on subjective assessments, we need to capture real behavioral changes that can be objectively measured. Fourth, we cannot measure or observe to what extent subjects understand information about their CO₂ emissions in this experiment. Variation in the level of understanding may make differences in changes of their environmental friendliness. An explanatory variable of educational background is included in the ordered logit model as a proxy to partly measure the level of understanding. On the other hand, we think that people would be motivated to change their behavior in a more pro-environmental manner if they perceived a connotative message in the data of their own emissions and noticed the gap between their personal emissions and the threshold value. Fifth, the mechanisms for enhancing the environmental friendliness of every individual need to be linked to macro governmental policies to tackle issues of climate change. We need both individual and collective pro-environmental actions in polycentric systems to find effective solutions. Responsibility should not be imposed only on governments but also on every individual. We need to specify how we can, or should, inspire their responsibility with relevant information about their CO₂ emissions. Sixth, we need to develop specific methods to provide every individual with information about their personal CO₂ emissions, considering the results we have obtained in this study. This is obviously a future research topic in the sustainability field.

Finally, we need to find factors that will have changed people's non-sustainable repeated behavior and lasting routines in their daily life for dealing with climate change problems in the future research. Certainly, individuals have the incentive to freeride other people's pro-environmental behavior [6], but they merely repeat their usual activities as their lifestyles without intention of freeriding in most cases. Unless we can change our unsustainable continued behavior in our daily life, we will be confronted with calamities due to climate change sooner or later.

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Appendix A

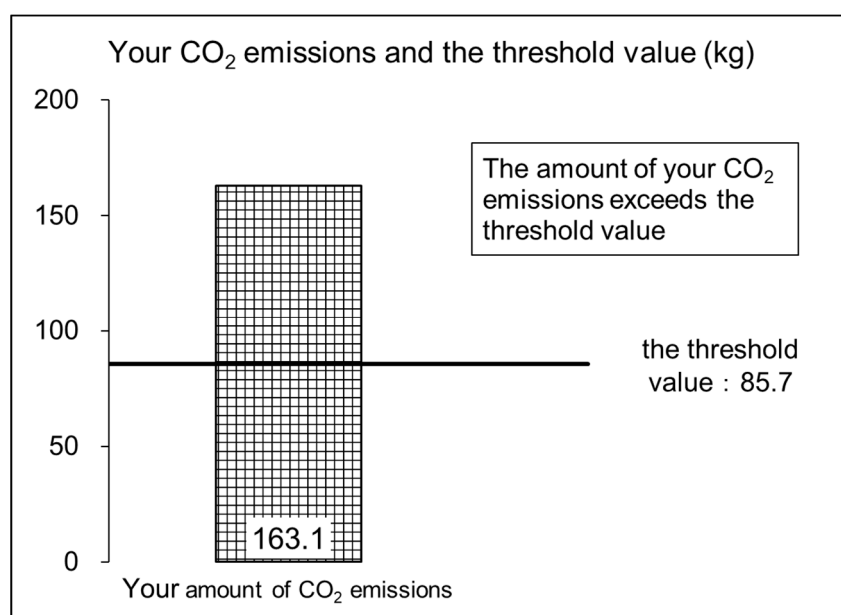


Figure A1. A sample feedback sheet. Feedback sheets were provided in Japanese. Participant's CO₂ emissions with the threshold are provided.

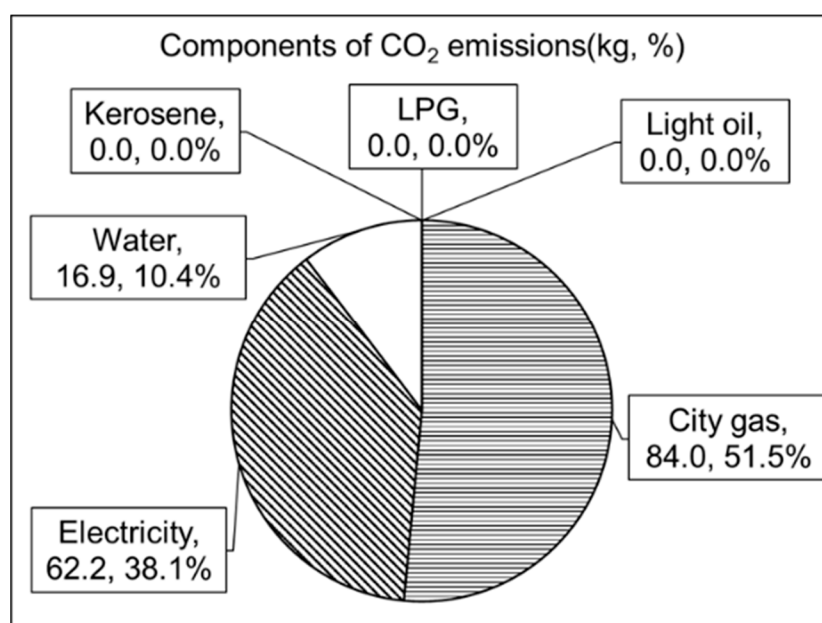


Figure A2. A sample feedback sheet. Feedback sheets were provided in Japanese. Proportions of CO₂ emissions in categories are provided.

Table A1. Questions in Values.

	Questions	Reference
VAL-1	All living organisms on earth have rights as equally as human beings have. (地球上のすべての生物は人間と同等の利を持っている)	[29,45]
VAL-2	Human beings need to address environmental issues (e.g., climate change) for future generations. (世代のために、候動問題などの環境問題解決に取り組む必要がある)	-
VAL-3	All countries including developed and developing ones should equally make efforts to mitigate climate change. (先進・展途上を問わず、全ての国が候動問題減の努力を等しく行うべきである)	-
VAL-4	Everyone should obey rules such as international agreements, treaties, laws, and regulations. (際合意・条約・法律・規制などのルルは守るべきである)	-
VAL-5	Governments should aim to solve environmental issues. (政府は環境問題解決に取り組むべきである)	-
VAL-6	Firms should aim to solve environmental issues. (企業は環境問題解決に取り組むべきである)	-
VAL-7	Human beings have the right to fully use natural resources and the environment. (人間には、天然資源・自然環境を好きなだけ利活用する利がある)	[29,43]
VAL-8	You should be responsible for nature, considering the impact of what you are doing on nature and the environment. (環境に影響をえる行を含め、自分が行うことはすべて、自然にして責任を負わなければならない)	[45]
VAL-9	Extinction of a species is inevitable. (絶滅する生物種がいても仕方ない)	[19]
VAL-10	Lifestyles should be changed for solving climate change issues. (候動問題を解決するためには自分たちのライフスタイルをえなければならない)	-
Response alternatives	1: agree, 2: slightly agree, 3: neither agree nor disagree, 4: slightly disagree, 5: disagree	

Note: All the questions above were translated from Japanese. The questions were given to subjects in Japanese. The sentence in parentheses is the original Japanese question.

Table A2. Questions in Belief.

	Questions	Reference
BEL-1	Environmentalists exaggerate environmental issues to justify their activities. (環境活動家は自らの活動を正化するために環境問題を大きめに語っている)	-
BEL-2	Human beings can change natural environments, but they cannot perfectly control them. (人間は自然環境をえる能力を持っているが、思い通りに自然をコントロールすることはできない)	-
BEL-3	Rules are beneficial to everyone. (ルルは全てのの人に恩をえるものだ)	[49]
BEL-4	Conditions of the environment on earth improve without any help. (何も手を打たなくても、地球環境全の態は改善する)	-

Table A2. Cont.

	Questions	Reference
BEL-5	Human populations and the level of human economic activity are approaching the limit above which human beings cannot live on earth. (人口や活動水準は、人間が地球に住める限界レベルに近づいている)	[43]
BEL-6	Climate change is caused by CO ₂ emissions due to human economic activities. (人間の活動によって排出された二酸化炭素が候動の原因である)	-
BEL-7	When human beings change nature, they often face dreadful outcomes. (人間が自然に手を加えると、しばしば悲な結果となる)	[43]
BEL-8	Technological innovation can solve environmental issues. (技術革新によって環境問題は解決するはずだ)	-
BEL-9	Resilience of nature is strong enough to endure environmental burdens generated by human economic activities. (自然界の回復力は、わたしたちの活動が生み出す環境負荷にできるほど十分)	[43]
BEL-10	My action affects neighbors' and friends' happiness. (私の行動は、周の人や知人の幸福度に影響をえる)	[49]
Response alternatives	1: agree, 2: slightly agree, 3: neither agree nor disagree, 4: slightly disagree, 5: disagree	

Note: All the questions above were translated from Japanese. The questions were given to subjects in Japanese. The sentence in parentheses is the original Japanese question.

Table A3. Questions in Controllability.

	Questions	Reference
CTL-1	You can reduce the amount of electricity consumption, being careful about it. (自分の心がけ次第で、電使用量を減らすことができる)	-
CTL-2	My actions do not affect solutions of environmental issues that happen at the place far away from my place. (私の行動が地球の遠く離れたどこかの環境問題解決に影響をえることはないと思う)	[29]
CTL-3	Changes in your lifestyle could solve climate change issues. (自分たちがライフスタイルをえれば、候動問題の解決に貢献できる)	-
CTL-4	Cooperative actions could solve climate change issues. (みんなが協力すれば、候動問題は解決に向かう)	-
CTL-5	It will be difficult to get others' cooperation even if you take pro-environmental actions. (自分一人が環境配慮的行動を取っても、多くの人に協力してもらうことは難しい)	-
CTL-6	It is unlikely to conserve biodiversity because of uncertainty in nature. (自然では予測できないことが起きるので、生物多性を保全できる可能性は低い)	-
CTL-7	It is too costly to address environmental issues. (環境問題の解決にはお金がかかりすぎるので、際には取り組むことができない)	-
CTL-8	Refusing plastic bags is not enough to contribute to solving global environmental issues. (レジ袋をもらわないくらいでは、地球環境問題の解決に貢献できないと思う)	-

Table A3. Cont.

	Questions	Reference
CTL-9	It is almost impossible to reduce the amount of emissions of greenhouse gases, considering the current economic activities. (現在の活動を考えると、温室効果ガスの排出削減はほとんどできないと思う)	-
CTL-10	An individual can do nothing to solve global environmental issues. (グローバル環境問題解決にして個人で取り組めることはないと思う)	-
Response alternatives	1: agree, 2: slightly agree, 3: neither agree nor disagree, 4: slightly disagree, 5: disagree	

Note: All the questions above were translated from Japanese. The questions were given to subjects in Japanese. The sentence in parentheses is the original Japanese question.

Table A4. Questions in Concern.

	Questions	Reference
CON-1	(... ..) services and goods that generate as small amount of CO ₂ emissions as possible. (CO ₂ をできるだけ排出しないサービス・商品)	-
CON-2	(... ..) the amount of my electricity consumption. (消費電力)	-
CON-3	(... ..) electric, hydrogen, and hybrid vehicles. (電気自動車・水素自動車・ハイブリッド車)	-
CON-4	(... ..) renewable energy. (再生可能エネルギー)	-
CON-5	(... ..) the amount of plastic rubbish (e.g., plastic bottles). (プラスチック(ペットボトルを含む)ごみの量)	-
CON-6	(... ..) risk of landslides and floods caused by a storm or/and a blizzard. (暴風雨・暴風雪による土砂災害・水害リスク)	-
CON-7	(... ..) new technologies to reduce the amount of CO ₂ emissions and the development of such technologies. (新しい二酸化炭素排出削減の技術・その技術の開)	-
CON-8	(... ..) governmental actions on climate change issues. (政府の気候変動問題解決に向けた取り組み)	-
CON-9	(... ..) environmental issues caused by CO ₂ emissions: such as Antarctic ice loss, degradation of coral reefs, biodiversity loss, sea level rise, oceanic acidification, and heatwave. (二酸化炭素排出を原因とする環境問題(南極の氷の減少・サンゴ礁の劣化・生物多性の損失・海面上昇・海洋酸性化・熱波など))	-
CON-10	(... ..) the amount of my gas consumption. (ガスの使用量)	-
Response Alternatives	1: I am interested in, 2: I am slightly interested in, 3: I am neither interested in nor not interested in, 4: I am little interested in, 5: I am not interested in	

Note: All the questions above were translated from Japanese. The questions were given to subjects in Japanese. The sentence in parentheses is the original Japanese question.

Table A5. Questions in Attitude.

	Questions	Reference
ATT-1	I sometimes consider the causes and effects of issues that human beings have faced. (私は人類の直面する問題の原因やその影響について考えることがある)	[49]
ATT-2	I do not want the temperature in summer to rise more. (これ以上夏場のが上昇したら困る)	-
ATT-3	I disapprove of government's inaction on environmental issues. (政府が環境問題にしていないと、腹立たしい)	[44]
ATT-4	I am sad about a decrease in beaches due to sea level rise. (海面上昇によって浜が減ると悲しい)	-
ATT-5	I like spending time in nature. (自然とれ合うのが好きだ)	-
ATT-6	I feel sad when I see trees cut down. (伐採された森林を見ると悲しくなる)	[47]
ATT-7	It is inevitable that typhoons often come. (台風がたくさんるのは仕方ない)	-
ATT-8	I feel sad, seeing the Earth polluted by human activities. (我の活動によって地球が汚染されていると思うと、悲しい)	-
ATT-9	I have affinity with variety of animals and plants. (多な動植物にし親近感をえる)	[48]
ATT-10	I am willing to change my lifestyle for environmental conservation and preservation. (環境保全・環境保護のためなら、自らのライフスタイルをえてもよい)	-
Response alternatives	1: similar to my idea, 2: slightly similar to my idea, 3: neither similar nor different 4: slightly different, 5: different	

Note: All the questions above were translated from Japanese. The questions were given to subjects in Japanese. The sentence in parentheses is the original Japanese question.

Table A6. Questions in Intention.

	Questions	Reference
INT-1	I want to share the necessity of pro-environmental behavior with my family and friends. (環境配慮行動の必要性について、家族や友人と共有したい)	[46]
INT-2	I will make efforts in order not to consume fossil fuels in near future. (近い、化石燃料を使わないように努力するつもりだ)	-
INT-3	I want to preserve and conserve nature for future generations. (世代のために環境保全・環境保護を行いたい)	-
INT-4	I want to buy products and services produced by environmentally friendly firms. (環境配慮行動を取っている企業の製品・サービスを購入したい)	-
INT-5	I am going to change my lifestyle for environmental preservation and conservation. (環境保全・環境保護のために、自らのライフスタイルをえていくつもりだ)	-
INT-6	I will avoid using automobiles and airplanes if possible. (できるだけ自動車や飛行機を利用しないつもりだ)	[44]
INT-7	I want to avoid producing rubbish as much as possible. (できるだけごみを出したくない)	-
INT-8	I want to participate in an environmental organization. (環境保全・保護活動に所・加したい)	-

Table A6. Cont.

	Questions	Reference
INT-9	I am willing to donate my daily wage once a year for supporting environmental conservation. (環境保全・保護運動を支援するために、年に1回、1日分の入を寄付してもよい)	[44]
INT-10	I will meet the standard of emissions when it is set. (排出基準が設定されたら、その排出基準を守るつもりだ)	-
Response alternatives	1: similar to my idea, 2: slightly similar to my idea, 3: neither similar nor different, 4: slightly different, 5: different	

Note: All the questions above were translated from Japanese. The questions were given to subjects in Japanese. The sentence in parentheses is the original Japanese question.

Table A7. Questions in Behavior.

	Questions	Reference
BEH-1	I move by bicycle or/and on foot as frequently as possible. (できるだけ自転車・徒で移動する)	[44]
BEH-2	I buy goods that have low food mileage. (商品を購入する際、フードマイレージの低い商品を購入する)	[44]
BEH-3	I do not buy beverages in a plastic bottle. (ペットボトル料は購入しない)	-
BEH-4	I use a heater in winter because I do not want to wear winter clothes in a room. (冬場、部屋で防寒着を着なくてむように暖房をつける)	[46]
BEH-5	I avoid buying plastic products. (プラスチック製品の購入を避ける)	-
BEH-6	I use public transportation in urban areas. (都市部では、公共交通を利用する)	[46]
BEH-7	I point out other's environmentally unfriendly behavior. (他人の非環境配慮的行動を指摘する)	[46,47]
BEH-8	I avoid producing rubbish as much as possible. (できるだけごみを出さない)	[49]
BEH-9	I turn off lights when I leave a room. (部屋を出るとき、電を消している)	[49]
BEH-10	I get plastic or/and paper bags when I go shopping. (買い物の際、ビニル袋・紙袋をもらう)	-
Response alternatives	1: similar to my behavior, 2: slightly similar to my behavior, 3: neither similar nor different, 4: slightly different, 5: different	

Note: All the questions above were translated from Japanese. The questions were given to subjects in Japanese. The sentence in parentheses is the original Japanese question.

Table A8. List of independent variables with key statistics.

Independent Variables	Definition	Mean	S.D.
<i>individual emissions</i>	Dummy variable (=1 if information on the amount of individual emissions was provided)	0.41	0.49
<i>group emissions</i>	Dummy variable (=1 if information on the amount of group emissions was provided)	0.43	0.50
<i>individual threshold</i>	Dummy variable (=1 if information on the individual threshold of the emissions was provided)	0.21	0.41

Table A8. Cont.

Independent Variables	Definition	Mean	S.D.
group threshold	Dummy variable (=1 if information on the group threshold of the emissions was provided)	0.24	0.43
communication	Dummy variable (=1 if participant had an opportunity of communication)	0.49	0.50
female	Dummy variable (=1 for female)	0.43	0.50
environmental study	Dummy variable (=1 if participant takes a class of environment)	0.23	0.42
economics	Dummy variable (=1 if participant majors economics)	0.82	0.38
monthly income	2.5: if monthly income is 0–50,000 yen	8.87	8.85
	7.5: 50,000–100,000 yen		
	12.5: 100,000–150,000 yen		
	17.5: 150,000–200,000 yen		
	27.5: 250,000–300,000 yen		
	52.5: more than 500,000 yen		

Note: The number of observations is 102 for all independent variables.

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