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Hideki Yamashita Shinsuke Kyoi Koichiro Mori

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The Institute for Economic and Business Research
Faculty of Economics
SHIGA UNIVERSITY

1-1-1 BANBA, HIKONE,
SHIGA 522-8522, JAPAN

Stimulus to change every individual for reducing CO_2 emissions: A survey experiment

Hideki Yamashita [a], Shinsuke Kyoi [b,c], and Koichiro Mori [d,e]

a. The Institute for Economic and Business Research Shiga University, Shiga University, Japan
email: h.soc0829@gmail.com
b. Graduate School of Agriculture, Kyoto University, Japan
email: kyoi.shinsuke.58c@st.kyoto-u.ac.jp
c. The Institute for Economic and Business Research Shiga University, Shiga University, Japan
d. Faculty of Economics, Shiga University, Japan
email: ko-mori@biwako.shiga-u.ac.jp
e. Institute of Industrial Science, the University of Tokyo, Japan
email: kmori@iis.u-tokyo.ac.jp

Abstract

It is crucial to change the behaviour of individuals to reduce CO_2 emissions. The goal of this study was to conduct a survey experiment to identify factors that can change the environmental friendliness of individuals in terms of values, belief, concern, controllability, attitude, intention, and behaviour and to use the data to test the hypothesis that providing information about the amount of CO_2 emissions attributable to an individual motivates him/her to reduce that amount. The subjects were 102 students at Shiga University in Japan. They were provided with communication opportunities, information about individual or group CO_2 emissions, and information about a threshold value provided in the Paris Agreement. The results of this study indicate that knowing the amount of one's CO_2 emissions can improve that person's environmental friendliness in terms of concern, attitude, intention, and behaviour. Therefore, such information should be provided to every individual (i.e., consumer) to reduce CO_2 emissions.

Introduction

Climate change due to emissions of greenhouse gases such as CO_2 is damaging natural and human systems on Earth [1]. The data for global land and ocean surface averaged temperature shows a warming of 0.85°C from 1880 to 2012 [1], 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 CO_2 (398.5 ppm) has already exceeded a planetary boundary (350 ppm) [3,4]. We need to reduce CO_2 emissions by a minimum of 33% by 2055 so that our emissions stay below the high-risk zone (550 ppm) in 2100 [5].

Climate change is an example of the tragedy of the commons [6] because the use of atmospheric sinks for greenhouse gases is non-rival and non-excludable [7]. Under the tragedy of the commons, freeriding pays from a viewpoint of each economic entity.

Multiple governing authorities working as a part of polycentric governance are likely to be effective at solving climate change problems on different scales [8–10]. 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 [8]. 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 a key player. In the context of CO_2 emissions, however, individuals generally do not know how much CO_2 they emit, nor do they have a standard for comparison that they can use to try to decrease their emissions. In contrast, organisations such as firms and governments have several measures they can use to evaluate their performance in terms of CO_2 emissions and other environmental burdens [11–14].

Therefore, we propose that providing every individual with information about his/her individual CO_2 emissions would encourage citizens to reduce emissions and to behave in a more environmentally friendly manner. Although school climate strikes are gaining momentum, they are based on the assumption that organisations, not individuals, are to blame for CO_2 emissions. However, although the amount of CO_2 emitted by an individual is trivial, the aggregate amount of household CO_2 emissions is too large to ignore. We believe that a household can be motivated to reduce its CO_2 emissions if its members are informed about how changes in household behaviour can have the desired effect [15,16]. This also would make parties who refuse to accept the need for CO_2 reduction (i.e., veto players) agree with climate mitigation, which is important for success of polycentric systems [17].

In this study, we conducted a survey experiment to identify factors that can change individual environmental friendliness in the psychological categories of values, belief, concern, controllability, attitude, intention, and behaviour in order to motivate an individual to reduce his/her CO_2 emissions. We used the survey results to test the hypothesis that providing information about the amount of CO_2 emissions attributable to an individual motivates him/her to reduce that amount.

Methods

Subjects

One hundred and two students majoring in either economics or data science at Shiga University, a national university in Japan, participated in this study, which was conducted in Japanese. To solicit participation, we advertised by putting up posters on campus and sending out emails. We set the sample size to at least 10 respondents in each of the 10 treatment groups. 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 this experiment. Similar experiments targeting university students have been conducted in the past [18–22]. The discrepancy in responses between students and relevant professionals is not large [23].

Experimental design

In this experiments, the 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. They answered questions about their monthly consumption of electricity (kWh), water (m^3), city gas (m^3), 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 CO_2 emissions based on the CO_2 emission factor for each energy source (obtained from the Japanese Ministry of the Environment [24] and the Japan Sanitary Equipment Industry Association [25]) as follows: 0.496 (kg CO_2/kWh) for electricity; 0.54 (kg CO_2/m^3) for water; 2.23 (kg CO_2/m^3) for city gas; 3.00 (kg CO_2/kg) for LPG; 2.58 (kg CO_2/ℓ) for diesel; and 2.49 (kg CO_2/ℓ) for kerosene. 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 particular question after we cut both upper and lower 10% figures to decrease the effects of outliers.

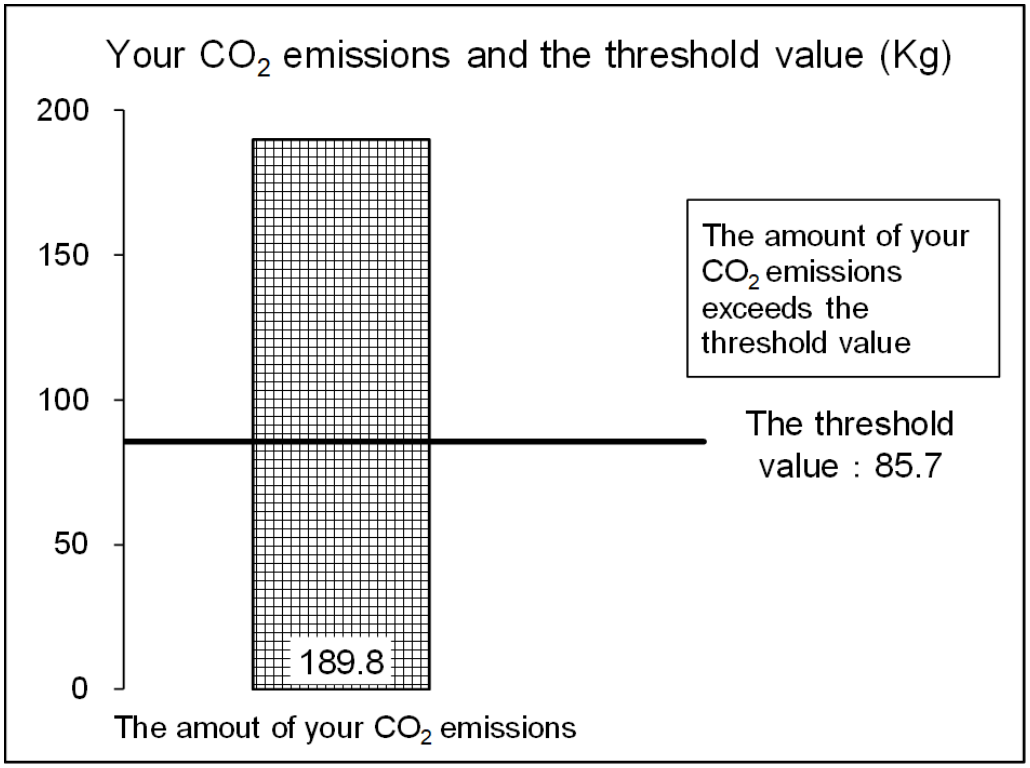
Pre-survey: To measure psychological factors that lead to behaviour and actual pro-environmental behaviour, we administered a pre-survey consisting of 70 questions to each subject on 20–22 January 2020. We asked 10 questions in each of the following seven categories that are commonly used in studies of environmental psychology and behaviour [26–30]: values (sense of values), belief, controllability, concern, attitude, intention, and behaviour. The original questions and categories were based on previous research in the different contexts [31-38], but they were modified, customised, and adapted to the current context of Japanese society. Answers to each question were provided based on a five-point Likert scale.

Table 1. Experimental Settings for 10 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	✓		✓	✓

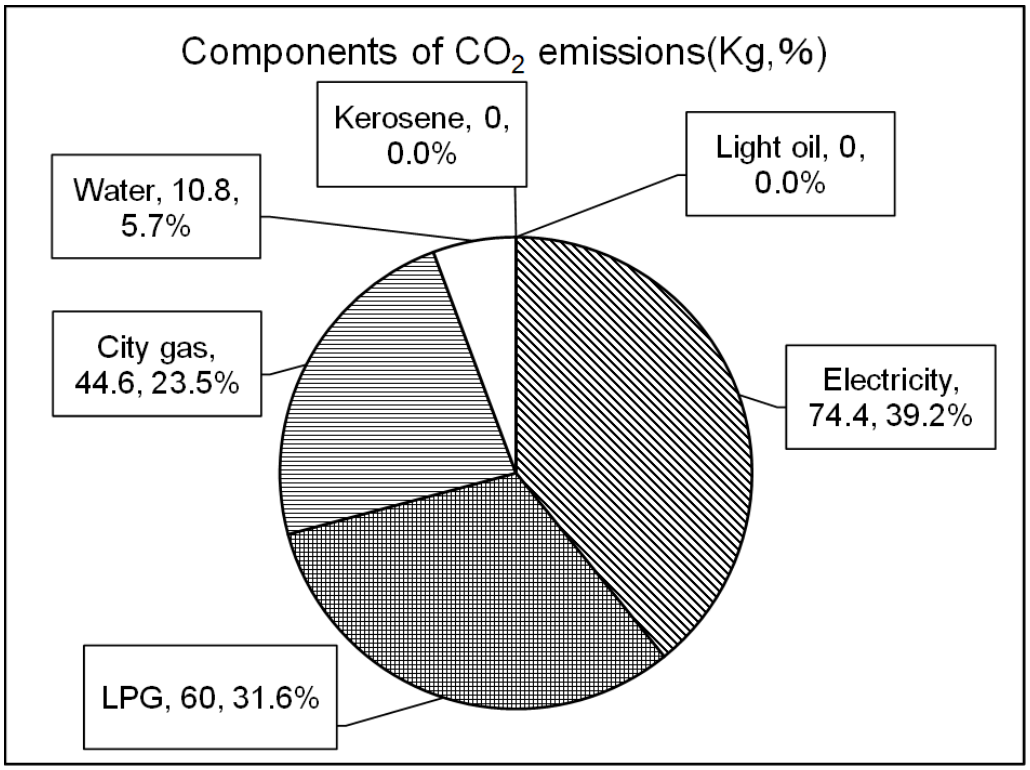
Treatment: For the treatment stage of the experiment, the 102 participants were randomly divided into 10 groups with different treatments (Table 1). One of the treatments in the experiment was provision of information about the threshold value. We used 85.7 kg per person per month as the value of the threshold based on the following information. The target amount of CO_2 emissions in the household sector is 0.601 times smaller than the amount of CO_2 emissions in 2013 according to the draft of Nationally Determined Contributions of Japan in the Paris Agreement [39]. We calculated the amount of monthly CO_2 emissions for each energy source of the Japanese household sector in 2013 using the data provided by the Greenhouse Gas Inventory Office of Japan. We then multiplied the aggregate amount by 0.601 to obtain 85.7 kg. We multiplied the figure, 85.7 kg, by the number of subjects in a group to obtain the group threshold. 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) CO_2 emissions with it. The threshold value indicates the amount of CO_2 emissions that we must not exceed. Thus, you can simply compare between them. If the amount of your (or your group’s) CO_2 emissions exceeds the threshold value, it is considered unsustainable.” Figure 1 shows a sample feedback sheet with information about the amount of CO_2 emissions per month with the threshold value. Subjects also received the information about its component percentages (Figure 2).

Figure 1. A sample feedback sheet (your CO_2 emissions with the threshold)



Note. Feedback sheets are provided in Japanese.

Figure 2. A sample feedback sheet (proportions of CO_2 emissions in categories)



Note. Feedback sheets are provided in Japanese.

Members of group 1 (the control group) had no opportunity for communication and were given no information about their level of CO_2 emissions or the related threshold value. Participants in some groups had the opportunity to communicate with each other for 25 minutes to discuss potential measures for reducing their CO_2 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 CO_2 emissions and were given information about their individual CO_2 emission levels and the CO_2 emission threshold. The participants were able to compare their emission levels with the threshold value and determine if their amount was above (*above threshold*) or below (*below threshold*) the threshold.

Post-survey: In the last step of the experiment, each subject completed the post-survey on 27–29 January 2020 (1 week after participating in the treatment phase of the experiment). The post-survey contained the pre-survey questions but in a different order. Every subject received 2000 Japanese Yen as a reward for completing all steps of the experiment.

Data analysis

We calculated each participant's environmental friendliness scores in the seven categories of psychological factors and behaviour obtained from the pre- and post-surveys. The 5-point Likert scale values were sorted in descending order for each question, with higher values indicating greater environmentally friendliness. We then calculated the change in score from the pre-survey to the post-survey in the seven categories for each participant.

We then used Welch's t-test to investigate whether differences between treatment groups were statistically significant for the seven categories. We also performed multi-variate regression analysis for the seven categories. In the regressions, the dependent variable was the change in score, and the independent variables were the conditions of the treatments and other socio-economic characteristics (Table 2).

Table 2. List of independent variables with key statistics

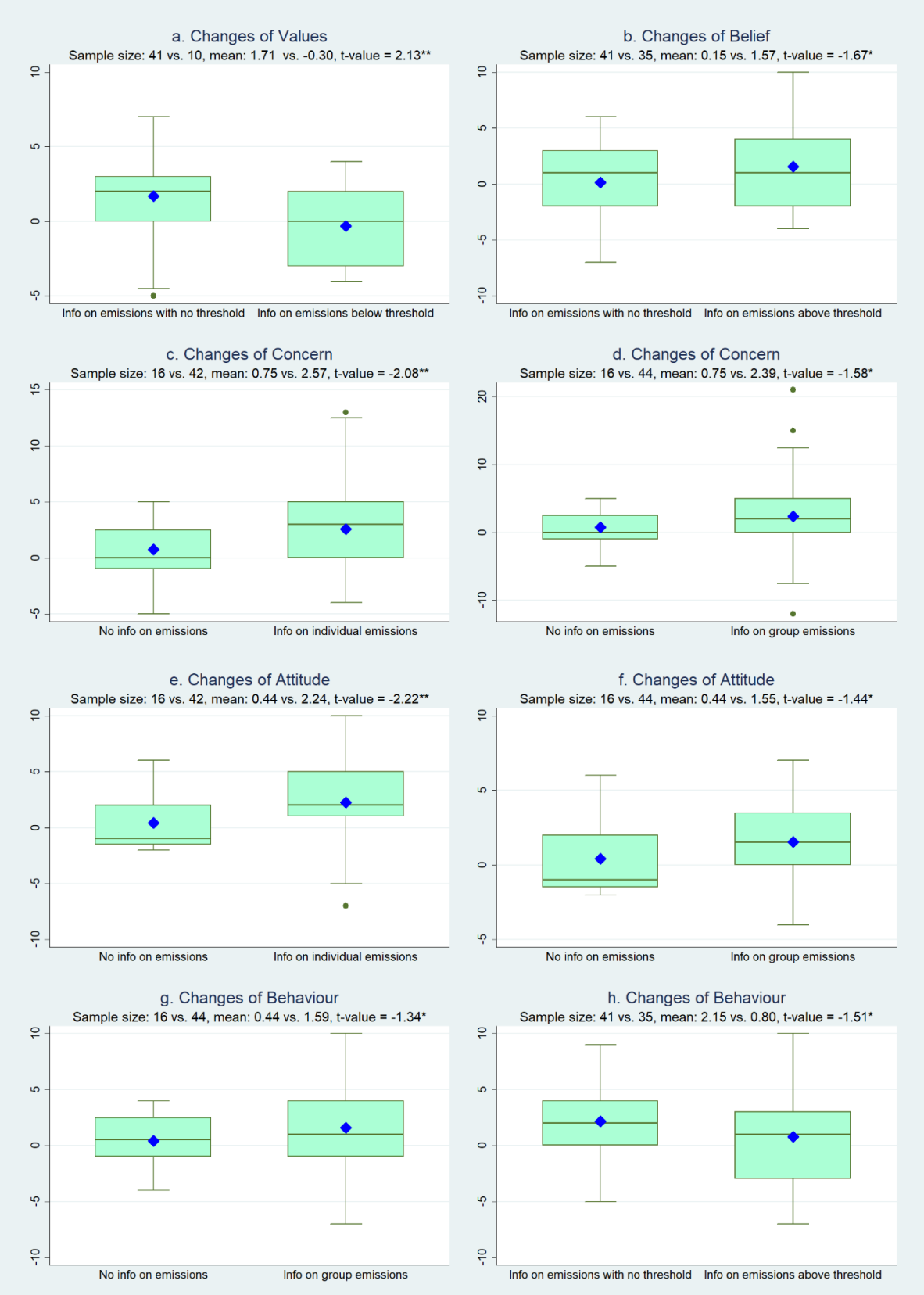
Independent Variables	Definition	Mean	S.D.
communication	Dummy variable (=1 if participant had an opportunity of communication)	0.49	0.50
individual emissions	Dummy variable (=1 if the information on the amount of individual emissions was provided)	0.41	0.49
group emissions	Dummy variable (=1 if the information on the amount of group emissions was provided)	0.43	0.50
threshold	Dummy variable (=1 if the information on the threshold of the emissions was provided)	0.44	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 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	8.87	8.85

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

Results

Figure 3 shows statistically significant differences between treatment groups in terms of changes in respondents' scores of environmental friendliness from pre-survey to post-survey in the categories of psychological factors and behaviour. We identified eight significant differences out of 42 tests. Figure 3 shows four main results. First, changes of values scores differed between the *info on emissions with no threshold* and *info on emissions below threshold* groups. The *info on emissions below threshold* group became less environmentally friendly, whereas the *info on emissions with no threshold* group became more environmentally friendly. Second, the *info on emissions above threshold* group became more environmentally friendly in belief than the *info on emissions with no threshold* group. For behaviour, the *info on emissions with no threshold* group became more pro-environment than the *info on emissions above threshold* group. Third, for concern and attitude, the *info on individual emissions* group became more environmentally friendly than the *no info on emissions* group. Fourth, the *info on group emissions* group became more environmentally friendly than the *no info on emissions* group for concern, attitude, and behaviour.

Figure 3. Statistically Significant Differences between Groups in Changes of Scores



Note: ** and * represent 95% and 90% significance respectively. Each t-test evaluates the difference in changes of respondents' scores from pre-survey to post-survey between groups with different treatments. Each point in a boxplot represents a mean value. Mean values show average changes of respondents scores from pre-survey to post-survey in the groups. The higher a mean value is, the more improvement in environmental friendliness it indicates.

Table 3. Estimation Results of Regressions

	Values	Belief	Controllability	Concern	Attitude	Intention	Behaviour
Independent Variables	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.
communication	0.36 (0.58)	0.13 (0.63)	-1.15 (0.87)	0.39 (0.91)	-0.25 (0.59)	-0.33 (0.84)	-0.76 (0.71)
individual emissions	0.97 (0.87)	0.69 (0.83)	0.28 (1.04)	1.75 (1.10)	2.18** (0.87)	2.00* (1.19)	1.56* (0.93)
group emissions	0.60 (0.90)	0.29 (0.92)	-0.61 (1.07)	2.22 (1.36)	1.14 (0.82)	1.19 (1.17)	1.96** (0.92)
threshold	-2.47** (1.07)	-0.52 (1.10)	-1.42 (1.21)	0.85 (1.34)	-1.48 (1.38)	-1.76 (1.33)	-0.43 (1.57)
above threshold	2.08* (1.17)	1.89 (1.20)	1.59 (1.46)	-1.98 (1.41)	1.34 (1.44)	1.35 (1.30)	-0.99 (1.65)
female	0.16 (0.64)	0.74 (0.64)	2.06** (0.85)	0.43 (0.85)	-0.50 (0.62)	0.84 (0.87)	0.01 (0.76)
environmental study	1.17 (0.75)	-0.14 (0.79)	-0.02 (1.14)	0.09 (0.87)	-0.00 (0.67)	0.95 (0.99)	0.47 (1.00)
economics	-0.70 (0.74)	-3.13*** (0.96)	-1.56 (1.36)	1.25 (1.34)	0.19 (0.89)	-0.42 (1.17)	0.01 (1.05)
monthly income	0.02 (0.03)	0.06 (0.04)	0.00 (0.04)	0.00 (0.05)	0.03 (0.03)	0.10** (0.04)	-0.03 (0.04)
constant	0.95 (1.06)	1.43 (1.21)	1.58 (1.17)	-0.61 (1.55)	0.35 (1.17)	0.13 (1.17)	0.93 (1.01)
R-squared	0.08	0.18	0.08	0.06	0.07	0.07	0.06

Note: The number of observations is 102 for all models. ***, **, and * represent 99%, 95%, and 90% significance. The heteroskedasticity robust standard errors are reported in parentheses. Dependent variables are the changes in individual participant's scores of environmental friendliness from pre-survey to post-survey in each category. See Table 2 about the definitions of independent variables.

Table 3 shows the results of multi-variate regressions for the seven categories. Provision of the information about *individual emissions* significantly and positively affected changes in environmental friendliness in terms of attitude, intention, and behaviour. The information on *group emissions* also significantly enhanced environmental friendliness in behaviour. Provision of *threshold* decreased environmental friendliness in values. The condition of *above threshold* increased environmental friendliness in values. Female subjects became more pro-environment than male participants in controllability, and people majoring in *economics* became less so in belief. The term *monthly income* had a positive impact on environmental friendliness in intention.

Discussion

The most interesting result of this study was that information about individual CO_2 emissions could enhance individual environmental friendliness in terms of concern (Figure 3), attitude, intention, and behaviour (Table 3). 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. In other words, many individuals might be interested in making contributions to the reduction of CO_2 emissions. However, they might not know how to do so without relevant information about their current level of individual CO_2 emissions. Thus, people need to know how much CO_2 they emit and what activity is responsible for the majority of it in order to take specific actions to reduce their CO_2 emissions.

In many cases, individuals are able to reduce CO_2 emissions by changing patterns of consumption. However, information about the emissions that is related to consumption of commodities is often unavailable. If every individual had such information, they could choose to use a lower carbon commodity among substitutes. Governments also need to appropriately incentivise producers to provide information to consumers about the amount of CO_2 emissions that occurred in the production process of a product, because carbon-labelling might enable individuals to make eco-friendly purchases [40–42]. The carbon footprint of commodities should be evaluated and available to every individual, ideally based on the life cycle assessment of the commodities.

Furthermore, every individual might be latently willing to take actions to reduce CO_2 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. Although school climate strikes and movements to spur governmental actions on climate change issues are now common, every individual needs to change his/her behaviour to alleviate climate change problems because the aggregate changes in individual behaviour could be impactful. In the polycentric system, both individual and organizational actions on climate change are required to resolve the issue.

Our results also showed that providing information about individual emissions had no impact on values, belief, and controllability (Figure 3, Table 3). These three factors are difficult to change because they are deeply rooted in long-term mental action. However, in some cases the provision of thresholds affected participants' values, belief, and behaviour in both positive and negative directions (Figure 3, Table 3). Participants became less environmentally friendly in terms of values when the amount of the emissions fell below the threshold, and their behaviour became less environmentally friendly when the level exceeded the threshold. On the other hand, subjects became more environmentally friendly in terms of values and belief when the amount of the emissions exceeded the standard. This means that the participants tended to feel that it was too difficult to reduce the amount of CO_2 emissions sufficiently when they knew the ratio of the amount of emissions relative to the standard. In many cases, the actual amount of emissions exceeded the threshold given in the Paris Agreement. For this reason, people should not be informed of the threshold if quick changes in individual behaviour are needed. Overall, however, our results suggest that improvement in environmental friendliness in terms of values and belief will cause pro-environmental actions in the long term [26]. If this scenario is true, we should provide information about the threshold.

Some studies have reported that an individual increases the extent of pro-environmental behaviour if he/she is given information about the relative size of environmental burden within a group (e.g., an individual's relative proportion out of the whole electricity consumption), as this information enables him/her to compare his/her value with that of others [43-47]. In our study, we provided the standard value (threshold) instead of a relative value, which enabled participants to compare their amount of CO_2 emissions with the threshold value. Thus, our results are distinct from those of previous studies in that changes in pro-environmental behaviour depended on the relationship between the amount of CO_2 emissions and the threshold value. We believe that the standard based on the Paris Agreement is more significant as a criterion for individual behaviour than relative values. This is because a smaller amount of individual emissions may still exceed the standard given 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.

Multivariate regression analysis revealed five additional findings (Table 3). First, unlike information about individual emissions, information about group emissions did not improve individual environmental friendliness in terms of attitude and intention. An individual can be motivated to take pro-environmental actions based on information about group emissions, but this positive effect on individual behaviour may not be as large as that induced by information about individual emissions because group data had no effect on attitude and intention. Second, economics students tended to give low priority to environmental consideration in terms of belief. This may be because economics students are more self-interested and sensitive to economic profits [48–50]. Third, female participants tended to think that people can control the environment in an environmentally friendly manner, which coincided with results of similar

studies [51–53]. Fourth, communication among participants about possible measures to reduce individual CO_2 emissions did not change environmental friendliness in terms of any of the seven categories. The ability to discuss and communicate during the experiment was a short-term and temporary factor, and it may be necessary to continue this type of communication over a certain period of time to make it effective. Fifth, whether or not an individual studied environmental issues had no effect on the results. The last two points suggest that knowledge and its dissemination are not necessarily effective for solving issues of climate change.

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 were limited. Second, the duration of the experiment should be extended. For example, we need to conduct a follow-up study 1 year after the initial experiment to investigate long-term changes in environmental friendliness in terms of the seven categories. In the current study, only short-term effects were analysed, and only subjective changes in behaviour were obtained directly from respondents in the short-term surveys. Objective changes should be measured and observed in a future long-term study. Third, the mechanisms for enhancing 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 a solution. Responsibility should not be imposed only on governments but also on every individual.

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Author Contributions

Original idea, H.Y.; conceptualization, H.Y. and K.M.; methodology, H.Y., S.K., and K.M.; experiment & data collection, H.Y., S.K., and K.M.; data analysis, S.K. and H.Y.; writing—Original draft preparation, S.K., H.Y., and K.M.; writing—Review and editing, K.M.; project administration, K.M.; funding acquisition, K.M.

Competing Interests

The authors declare no competing interests.