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Is climate change induced by humans? The impact of the gap in perceptions on cooperation

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Abstract

Climate change is a serious problem that requires people's cooperation to solve, and it has been reported that there have been gaps in perceptions about the cause. However, little is known about what makes people perceive that climate change is human-induced, nature-induced or induced by some other factor and the linkage between perception and cooperation. We analyze the determinants of human-induced perception and the impact of the gap in perceptions on cooperative behaviors toward climate change by conducting a survey experiment with a climate donation game with 400 Japanese subjects. First, the analysis identifies the importance of people's scientific literacy in explaining the perception gaps in that those with high scientific literacy tend to have the perception of human-induced climate change. Second, people are identified as being cooperative toward climate change, as they have a prosocial value orientation, high scientific literacy and the perception of human-induced climate change, demonstrating two important roles of scientific literacy as not only a direct determinant but also an indirect one, through a mediator of people's perceptions. Overall, the results suggest that scientific literacy shall be a key to enhancing cooperation toward climate change by promoting the perception of human-induced climate change.

Keywords: Human-induced climate change; scientific literacy; climate donation game

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Nomenclature

CDG Climate donation game

GCF Green climate fund

JPY Japanese yen

NISTEP National Institute of Science and Technology Policy of Japan

SEM Structural equation modeling

SVO Social value orientation

WTP Willingness to pay

1 Introduction

Climate change is a serious problem that requires people's cooperation to solve (Pacheco et al., 2014, Bang et al., 2015). Unfortunately, people around the world seem to have failed in cooperating and coordinating their efforts on this issue, although humans are known as unusually cooperative species compared with other species (Boyd and Richerson, 2009, Tattersall, 2011). There have been several types of research to analyze how people become cooperative regarding climate change. These studies establish that correct perception and/or knowledge of climate change are positively associated with cooperative attitudes, whereas a wide variety of gaps in such perceptions exist (Rand et al., 2009, Tobler et al., 2011, Fischer and Charnley, 2012, Islam et al., 2016). Despite its importance, few studies have examined how such gaps in perception are related to knowledge and to other factors and how the relationship influences cooperative behaviors. Given this state of affairs, this research addresses people's perception gaps with a focus on the cause of climate change, knowledge, and cooperative behaviors within a single framework.

Past studies have examined people's perceptions of the cause of climate change (Bray, 2010, Cook et al., 2013, Carlton et al., 2015). By and large, there are two ideas about the cause of climate change. One is that climate change is human-induced, in that climate change can be considered to be caused by human activities, such as burning fossil fuels, cutting down forests and farming livestock (Karl and Trenberth, 2003, Koneswaran and Nierenberg, 2008, Doran and Zimmerman, 2009, Solomon et al., 2009, Bechtel and Scheve, 2013, Höök and Tang, 2013). The other idea is that climate change is nature-induced, in that climate change can be considered a part of natural climate cycles. It will continue to be so, being exemplified by many events in the Earth's history, such as changes in solar output, Earth's orbit and volcanic eruptions (Karl and Trenberth, 2003, Solomon et al., 2009, Council et al., 2011). A group of former studies show that scientists have largely accepted the idea of human-induced climate change (Karl and Trenberth, 2003, Hegerl et al., 2007, Anderegg et al., 2010, Council et al., 2011, Lehtonen et al., 2019). Leiserowitz et al. (2010) report that approximately 97 % of publications by climate scientists advocate human-induced climate change, while only half of the American public believe in human-induced climate change (Doran and Zimmerman, 2009, Anderegg et al., 2010, Carlton et al., 2015).

Shealy et al. (2016) and Shealy (2018) find that civil engineering students in America who do not believe in human-induced climate change are less likely or never desire to take jobs associated with addressing climate change in their careers. Saleh Safi et al. (2012) examine the relationships among the vulnerability, beliefs and risk perception of human-induced climate change in rural Nevada. They report that climate-change-specific beliefs, particularly whether people believe in the human-induced causes of climate change and/or whether they connect the locally observed impacts to climate change, are the most prominent determinants of risk perception. The idea of human-induced climate change remains a public controversy despite the consensus among climate scientists (Bray, 2010, Cook et al., 2013, Tol, 2014, Carlton et al., 2015). Aside from this controversy, it is likely that the actual perception and attitudes toward climate change will be affected by the extent to which people believe in human-induced climate change.

Some researchers implement surveys on people's perceptions and their cooperative attitudes toward climate problems proxied by their willingness to pay (WTP) (O'Connor et al., 1999, Akter and Bennett, 2011, Brechin and Bhandari, 2011, Islam et al., 2016). Brechin and Bhandari (2011) confirm that people in some countries remain more concerned about general environmental problems than global climate change through comparative national studies on the public perception of climate change and its WTP. O'Connor et al. (1999) examine the relationship between people's risk perceptions and their WTP for climate problems, reporting that an environmental belief is a strong predictor of behavioral intentions for voluntary actions. Akter and Bennett (2011) examine Australian households' perceptions of climate change and their preferences for mitigation action, finding that people's willingness to take actions against climate problems at national and household levels is influenced by their level of mass media exposure. Moreover, Islam et al. (2016) examine the relationship between climatic perception and flood mitigation cooperation, suggesting that accurate climatic perception is key to increasing people's cooperation in managing climate change.

These studies have demonstrated that people's perception influences their cooperative attitudes toward climate change. However, few works have addressed people's perceptions of the cause of climate change along with their cooperative behaviors. Specifically, little is known about what makes people perceive that climate change is human-induced, nature-induced or induced by another factor and the linkage between their perception and cooperative behaviors. To examine these issues, we empirically analyze the determinants of people's perception of human-induced climate change and the linkage to their cooperation toward climate change by conducting a survey experiment with a climate donation game (CDG) with 400 Japanese subjects. In this survey, we measure and collect people's scientific literacy, social preferences and actual cooperation toward climate change by the use of the CDG in addition to sociodemographic information. Social psychologists and economists argue that scientific literacy and social preferences can be keys to influencing people's cooperative attitudes toward natural disasters and other social events (Van Lange et al., 2007, Bogaert et al., 2008, Nakagawa, 2016, Mischkowski and Glöckner, 2016, Shahrier et al., 2016, Timilsina et al., 2019). With these data, our research addresses the following two open questions. (1) What are the determinants of the human-induced perception of the cause of climate change? (2) How does the gap in perceptions of the cause of climate change, along with scientific literacy and social preferences, affect people's cooperative behaviors?

2 Materials and methods

The online survey experiment is conducted with 400 subjects in a web-based research organization, Cross Marketing Inc. Subjects' mean age is 49.61 years, with the standard deviation $= 17.32$ ranging between 20 and 89 years. The area the survey covers is divided into urban and nonurban areas according to the population density of 500 people km^{-2}. If the population density in the residence area where a subject lives is above or equal to 500 people km^{-2}, then it is urban; otherwise, it is nonurban. This survey collects a sample of 200 subjects in each of the urban and nonurban areas with information about (i) sociodemographic factors, such as age, gender, marital status, occupation, educational background, family characteristics and household income, (ii) perceptions on the cause of climate change, (iii) scientific literacy, (iv) cooperation for climate change and (v) social value orientation (as a proxy for social preferences).

[Figure 1 about here.]

Subjects are asked which perception they have concerning the cause of climate change: human-induced, nature-induced or induced by some other factor. Subjects read the explanatory notes 1 and 2, each of which corresponds to the description of "human-induced climate change" and "nature-induced climate change" associated with figures 1(a) and 1(b), respectively. After subjects understand these explanations, they are asked to choose one option that is the closest to their current perception among the five options. (1) "I choose the explanatory note of 1 of human-induced climate change," (2) "I choose the explanatory note of 2 of nature-induced climate change," (3) "Explanatory notes 1 and 2 are somewhat persuasive, but I cannot choose which one to support," (4) "None of explanatory notes 1 and 2 are persuasive" and (5) "I cannot judge it because I do not or cannot understand the explanation."

Explanatory note 1: Some studies on climate change suggest that the greenhouse gases and carbon dioxide released by human production activities are changing the patterns and cycles of climate around the world, as described in figure 1(a). Currently, the challenges posed by climate change are well recognized. The greenhouse gases and carbon dioxide released from various human activities have an adverse effect on societies.

Explanatory note 2: Human impacts on climate change may neither be significant nor relevant. In the long term of thousands or tens of thousands of years, it is said that the pattern and cycles of the climate are changing naturally, as demonstrated in figure 1(b). Some studies suggest that the cause of climate change cannot be verified as being human-induced, claiming that human-induced climate change is exaggerated too much. It is appropriate to understand that climate change is a part of natural cycles in the long-term dynamics of the earth.

Scientific literacy is measured by the NISTEP scientific literacy scale adopted from a national questionnaire survey about people's attitudes toward general science and technology (NISTEP, 2001). The National Institute of Science and Technology Policy of Japan (NISTEP) has organized a scale consisting of 15 questions regarding general scientific knowledge and literacy, and it has been employed in some recent field studies (Nakagawa, 2016, Jingchao et al., 2018). A subject is asked to answer "true," "false" or "no idea" for each question, where either "true" or "false" is usually set to be a correct answer. When she chooses a correct answer for a question, she scores 1, and otherwise, she scores 0. The answer "no idea" for each question is counted as 0. The scale is defined as the number of questions for which a subject answers correctly, ranging from 0 to 15.

Questions 1-13 pose scientific propositions such as (1) "the center of the Earth is very hot," (2) "all radioactivity is humanmade," (3) "the oxygen we breathe comes from plants," (4) "it is the father's gene that decides whether the baby is a boy or a girl" and so on, each of which shall be answered by choosing "true," "false" or "no idea." Questions 14 and 15 are posed in a different manner. Question 14 is posed as "which travels faster, light or sound?" Each subject is asked to choose one of four answers: "light," "sound," "the speeds are nearly the same" and "I have no idea." Question 15 comprises two subquestions, where the first subquestion is "does the Earth go around the sun, or does the sun go around the Earth?" When a subject answers correctly in the first subquestion, the next subquestion is posed as "if the Earth goes around the Sun, how long does it take?" The NISTEP scientific scale is established as a reliable measurement to influence people's behaviors and cooperative attitudes in disaster management and energy issues (Nakagawa, 2016, Jingchao et al., 2018).

We institute a climate donation game (CDG) to approximate the degree of people's cooperation toward climate change. This game is considered a variant of a dictator game in a two-player setting, where one person (the other person) is assigned to be a dictator (a receiver), and the dictator can decide how to split a fixed amount of money between herself and the receiver (see, e.g., Bolton et al., 1998, Engel, 2011). In most cases, a dictator and a receiver play the game under an anonymous setting so that each player never knows the identity of the other. The CDG is distinct from a typical dictator game in two ways. First, each subject becomes a dictator, knowing who is a receiver. Second, the receiver is not a human but a well-known organization called the "Green Climate Fund" (GCF) in Japan that runs a series of nonprofit activities to fight against climate change.

In the CDG, each subject is given 1000 JPY as an initial endowment and asked to distribute the money between herself and GCF as she wishes. If she takes everything (nothing) for herself, then the money donated to GCF is 0 JPY (1000 JPY). If she takes 400 JPY for herself, then the money donated to GCF is 600 JPY. When we instruct subjects about the CDG, we are cautious about stating "how to split between yourself and GCF is totally up to you, and nobody can know how you split because everything is recorded by an ID, not by your name." Economists use the amount of money the dictator gives to the receiver in dictator games as a good proxy of altruism, i.e., how much one person cares about the generally unknown other (Diekmann, 2004, Bekkers, 2007, List, 2007, Andreoni et al., 2017). In a similar fashion, we consider that the amount of money the dictator gives to GCF is a good proxy for how much one person cares about climate change, wanting to cooperate for its solution.

We use social value orientations (SVOs) in the triple-dominance game developed by Van Lange et al. (1997, 2007) to characterize subjects' social preferences. It is known to be reliable and to reflect a stable personality trait of how people evaluate interdependent outcomes for themselves and others in social environments (Van Lange et al., 1997). This method categorizes individual value orientations into four types—"competitive," "individualistic," "prosocial", and "unidentified"—depending on their choices in the questions. In one question, a subject chooses one option among three options, option (1): you get 480, and the other gets 80, option (2): you get 480, and the other gets 480, and option (3): you get 540, and the other gets 280. In this example, option (1) represents a competitive orientation that maximizes the point gap between herself and the other ($480 - 80 = 400$). Option (2) is a prosocial orientation that maximizes the joint outcome ($480 + 480 = 960$). Option (3) is an individualistic orientation that maximizes her own outcome of 540, being indifferent to the outcome of the other. This SVO game contains nine questions, each of which consists of three options for herself and the other. In each question, one option among them corresponds to one of the following orientations, i.e., "competitive," "individualistic" and "prosocial." Each subject is asked to choose one option as the most preferred in each item, finally generating nine choices of options. Each subject is classified as prosocial (individualistic or competitive) if she makes six or more choices of options with that orientation. Otherwise, she is categorized as "unidentified."

Our survey experiments have been conducted with real monetary payments in CDG and SVO games. These are made for motivating subjects to seriously participate in the survey experiment, considering their opportunity costs of time and their true revelation of social preferences and cooperative behaviors toward climate change, and one session took 40 to 60 minutes for each subject. In the CDG, subjects are informed that the amount of money they keep is theirs (subjects obtain 438 JPY $\approx$ 3.98 USD on average in the CDG). In SVO games, subjects are informed that we randomly match two subjects as a pair, and the more experimental points one subject gets from her own and partner's nine choices of options, the more real money she will earn with some exchange rate (20 points are converted to 1 JPY) (subjects obtain 226 JPY $\approx$ 2.05 USD on average in SVO games). In total, subjects are paid on average 769 JPY from the two games and surveys with a fixed participation fee of 105 JPY.

3 Results and discussion

Tables 1 and 2 present the definitions of all variables used in the analysis and the summary statistics of the variables for urban, nonurban and overall areas. The percentages of female subjects are similar in urban and nonurban areas (38 % and 36 %, respectively). Subjects in urban and nonurban areas possess a high school diploma as the median of education. The median household income in urban areas is 1 million JPY higher than that in nonurban areas. With respect to occupations, only 2 % of the subjects in nonurban areas are employed in agriculture, while all subjects in urban areas report that they are salaried workers, such as company owners, office workers and civil servants.[1] This implies that Japanese people depend on industries other than agriculture, even in nonurban areas. The statistics of the sociodemographic information in table 2 are in accordance with our expectation; that is, subjects in urban areas have higher education and household income than those in nonurban areas. Additionally, in Japan, there exists a difference between urban and nonurban areas with respect to basic sociodemographic factors; however, the difference is not so large.

[Table 1 about here.]

We report the summary statistics of subjects' SVOs, focusing on the percentages of prosocial subjects in urban, nonurban, and overall areas (see the "SVO (prosocial)" row in table 2). While 58 %

[1] In nonurban areas, 173 out of 200 subjects report that they receive a regular salary in the same way as urban subjects.

of subjects overall are prosocial, 56 % (60 %) of urban (rural) subjects are prosocial. This result is in sharp contrast to those of similar studies in developing nations showing that the percentages of prosocial subjects between urban and rural areas are quite different, and the percentage of prosocial subjects in rural areas is higher than that in urban areas (Shahrier et al., 2016, 2017, Timilsina et al., 2017, 2019).[2] Our result can be interpreted as indicating that the degree of prosociality among people is not different between urban and nonurban areas in Japan compared to other developing countries.

[Table 2 about here.]

Table 2 shows the summary statistics of subjects' scientific literacy in urban, nonurban and overall areas. We compute the Cronbach's alpha of this scale to be 0.76, illustrating that the scientific literacy scale possesses acceptable internal consistency in our sample. The median score of scientific literacy is 9 points in both urban and nonurban areas, while the average scores of scientific literacy are 8.53 and 8.24 points, respectively. This implies that scientific literacy between urban and nonurban subjects is not much different; however, scientific literacy in urban subjects is slightly higher than that in nonurban subjects. This result is in line with the expectation because education levels are almost the same between the two areas. With respect to people's perception of the causes of climate change (see the "Perception of climate change" row in table 2), 30 % (33 %) of urban (nonurban) subjects answer that climate change is caused by human-induced factors. Conversely, 12 % (14 %) of urban (nonurban) subjects answer that climate change is caused by nature-induced factors, implying that, interestingly, 59 % (53 %) of urban (nonurban) subjects answer that the cause of climate change cannot be judged to be human-induced or nature-induced. Regarding the results of the climate donation game (CDG) (see the last row of "Donation" in table 2), the donation (JPY) by urban subjects (mean $=$ 455.53, median $= 500$) is generally higher than that by nonurban subjects (mean $= 419.90$, median $=$ 400), while the overall average donation is 437.71 (median $= 500$).

[Table 3 about here.]

[2]As mentioned earlier, Japanese people depend on some industries other than agriculture, even in nonurban areas, receiving a regular salary for office work. This may be one of the reasons why the difference in prosociality between urban and nonurban areas is not found in our study.

Table 3 demonstrates that there is some relationship between subjects' perceptions of the causes of climate change and their donations (JPY) to climate change. With respect to those with the perception of human-induced climate change, the average (median) donations are 590.25 (500) by urban subjects and 525.00 (500) by nonurban subjects, respectively, as shown in the "Human-induced" row of table 3. With respect to those with the perception of nature-induced climate change, the average (median) donations are 535.22 (500) by urban subjects and 272.50 (100.00) by nonurban subjects. Finally, with respect to those with "Other," the average (median) donations are 370.78 (300) by urban subjects and 393.39 (300.00) by nonurban subjects. Overall, it appears that subjects who perceive climate change as being human-induced tend to donate more to the prevention of climate change than those who perceive climate change to be nature-induced or induced by another factor, irrespective of urban and nonurban areas. We can also confirm the same tendency from the "Overall" column of table 3, depending on whether subjects perceive human-induced climate change.

[Figure 2 about here.]

Figure 2 shows a series of boxplots to represent whether there is a distributional difference of donations among those with perceptions of human-induced, nature-induced, and other climate change. Figures 2(a) and 2(b) present that the distribution of donations by subjects with the perception of human-induced climate change is in higher positions than those by subjects with the perception of nature-induced and other climate change. Moreover, figure 2(c) shows that there is little difference between those with the perception of nature-induced and those with the perception of other climate change. To statistically check whether the distribution of donations differs by subjects' perceptions on the cause of climate change, we run Mann-Whitney tests with the following three pairs of donations by those with different perceptions: (a) human-induced *vs.* nature-induced, (b) human-induced *vs.* other, (c) nature-induced *vs.* other and (d) nature-induced+other *vs.* human-induced.[3] For each pair, a null hypothesis is that the distribution of donations by those with one perception is the same as that by those with the other perception. The Mann-Whitney tests show that pairs (a), (b) and (d) statistically reject the null hypotheses ($Z = -2.667, p < 0.01$, $Z = -4.106, p < 0.01$ and $Z = 4.31, p < 0.01$),

[3]For pair (d), we have combined the observations of donations from "nature-induced" and "other" climate changes as "nature-induced + other. "

while pair (c) does not ($Z = 0.946, p = -0.068$). This implies that whether subjects have human-induced perceptions can truly matter in determining their cooperative behaviors regarding climate change.

Given the qualitative statistical results associated with perceptions and cooperation, we now seek to quantitatively characterize what makes one person possess the perception of human-induced climate change. To this end, we run the logit regression by taking the perception of climate change as a dependent variable (human-induced $= 1$, and 0 otherwise) and scientific literacy, prosociality and basic sociodemographic factors as independent variables (see table 1 for the definitions of the variables). The logit regressions assume a logit form of the following distribution function:

$$\text{Prob}(y_i = 1) = \frac{\exp(X_i\beta)}{1 + \exp(X_i\beta)} \tag{1}$$

where y_i is a binary dependent variable, X_i is a vector of independent variables, and β is a vector of unknown parameters. With this distributional assumption, the maximum likelihood methods estimate the unknown parameters of β, enabling the identification of the marginal probability of one person possessing the perception of human-induced climate change when the independent variable increases by one unit (holding other independent variables fixed). Therefore, the estimation of the logit regression answers the open question (1) posed in the introduction: "What are the determinants of the human-induced perception on the cause of climate change?"

Table 4 reports the marginal probabilities and the respective standard errors of the independent variables on the perception of human-induced climate change along with the statistical significance. Model 1 of table 4 contains only scientific literacy as an independent variable, and next, we gradually add age, gender, prosociality and other factors as independent variables in models 2 to 4, building upon model 1. We first find that scientific literacy is statistically significant, with a positive sign at the 1 % level in a robust manner, irrespective of the models. The estimated marginal probabilities of scientific literacy on the perception of human-induced climate change range between 4.4 % and 3.9 % in models 1 to 4, implying that a subject is likely to have the perception of human-induced climate change by 4.4 %$\sim$3.9 % when her scientific literacy increases by one point.

Second, the age and gender dummy exhibit 1 % and 5 % statistical significance with positive signs in every model, respectively, while SVO is statistically significant only at the 10 % level, with positive signs in models 3 and 4. For instance, in model 4, a subject is likely to have the perception of human-induced climate change by 0.3 % (8.3 %) when their age (gender) increases by one year (is female). Similarly, a subject tends to have the perception of human-induced climate change by 6.6 % when their SVO is prosocial. The other independent variables, such as marital status, education, household income, area dummy and family type, are identified to be statistically insignificant, as shown in model 4 of table 4. We have confirmed that the aforementioned main results qualitatively remain the same after trying various specifications of the models other than models 1 to 4, such as including age squared or interaction terms among the variables. Overall, scientific literacy, age, gender and prosociality are established as the main determinants that are statistically and practically significant of the likelihood for a subject having the perception of human-induced climate change.

[Table 4 about here.]

We now seek to identify the determinants of people's cooperative behaviors toward the prevention of climate change by estimating the marginal effect of an independent variable on a donation in the CDG. To this end, tobit regression is applied because it is established to be appropriate when a considerable portion of observations for a dependent variable is found to be zero in the sample, and our donation data include 106 zero observations in a sample size of 400 (Wooldridge, 2010, 2016). In the regression, the donation to the prevention of climate change in the CDG is taken as a dependent variable, whereas the perceptions of climate change, scientific literacy, prosociality, and basic sociodemographic factors are taken as independent variables (see table 1 for the definitions of the variables). A specification of tobit regressions is given as

$$y_i^* = \beta_0 + X_i\beta_1 + S_i\beta_2 + P_i\beta_3 + O_i\beta_4 + \varepsilon_i \tag{2}$$

where subscript i represents a subject ID from 0 to 400, y_i^* is a latent dependent variable of donations in CDG satisfying $y_i = \max(0, y_i^*)$, y_i is an observed actual donation, X_i is a dummy variable of the perception of human-induced climate change, S_i is a scientific literacy scale, P_i is a dummy variable of prosociality, and O_i is a vector of sociodemographic variables at individual and household levels such as age, gender, marital status, household income, education and housing areas. The β_0 is an intercept, β_js for $j = 1, \ldots, 4$ are the unknown parameters associated with X_i, S_i, P_i, O_i to be estimated, and ε_i is a normally distributed error term.

While the latent variable y_i^* is assumed to be normally distributed, the observed donation y_i does not follow the same assumptions. y_i is assumed to be equal to y_i^* when $y_i^* > 0$; otherwise, $y_i = 0$. With the distributional assumptions for the actual donations in CDG and the associated latent variable, a tobit regression identifies the estimates of β_0, β_1, β_2, β_3 and β_4 via the maximum likelihood method, enabling us to calculate a marginal effect of an independent variable on the donation in the CDG. Specifically, the marginal effect is interpreted to be a change in the donation when one independent variable increases by one unit while holding other variables fixed. Therefore, the estimation of the tobit regression for the marginal effects associated with β_js should be able to answer the open question (2) posed in the introduction: "How does the perception gap on the cause of climate change along with scientific literacy and social preferences affect people's cooperative behaviors?"

Table 5 reports the marginal effects and their respective standard errors of independent variables on subjects' donations by the CDG along with the statistical significance. Model 1 of table 5 contains only the perception of human-induced climate change as an independent variable, and next, we gradually add scientific literacy, prosociality, age and other factors as independent variables in models 2 to 4, building upon model 1. We first find that the perception of human-induced climate change is statistically significant, with a positive sign at the 1 % level in a robust manner, irrespective of the models. The estimated marginal effects of the perception of human-induced climate change on their donations range between 235.016 JPY and 136.400 JPY in models 1 to 4, implying that a subject with the perception of human-induced climate change is likely to make more donations by 235.016 JPY $\sim$ 136.400 JPY than that with other perceptions.

Second, scientific literacy has a positive effect on donations at the 1 % significance level in models 2 and 3 but at the 10 % significance level in model 4. The estimated marginal effects of scientific literacy in models 2 to 4 suggest that a subject is likely to increase her donation by 24.101 JPY $\sim$

13.506 JPY when her scientific literacy increases by one point. The prosociality also exhibits 5 % statistical significance with a positive sign in models 3 and 4, implying that a subject with prosocial orientation tends to make more donations by 102.215 JPY $\sim$ 104.477 JPY than that with other orientations. Similarly, in model 4, a subject is likely to make more donations by 4.935 JPY (93.457 JPY) when her age (marriage) increases by one year (is experienced). The other independent variables, such as the gender dummy, household income, education and area dummy, are identified to be statistically insignificant, as shown in model 4 of table 5. Here, we have again confirmed that the main results in the tobit regressions qualitatively remain the same, irrespective of the various specifications of models other than models 1 to 4, such as including additional terms among the variables. Overall, the perception of human-induced climate change, scientific literacy, prosociality and age are established as the main determinants that are statistically and practically significant in cooperation with the prevention of climate change.

[Table 5 about here.]

Based on the aforementioned results, there appear to exist some "path" relationships in the following three pairs: (1) scientific literacy $\rightarrow$ the perception of human-induced climate change, (2) scientific literacy $\rightarrow$ donations in the CDG and (3) the perception of human-induced climate change $\rightarrow$ donations in the CDG. Examining the existence of the three paths is interpreted to test that the perception of human-induced climate change is a mediator between donations in the CDG and scientific literacy as graphically conceptualized in figure 3.[4] To statistically address whether the perception of human-induced climate change is a mediator or not, structural equation modeling (SEM) is employed by checking the paths among the three variables together with the direct and indirect effects of scientific literacy, following the procedures in Gunzler et al. (2013, 2014) and Venturini and Mehmetoglu (2019). The SEM analysis computes a beta weight as a standard coefficient, β, along with the associated statistical significance for each path. This analysis enables us to establish that scientific literacy and perception of human-induced climate change are important determinants for people's coopera-

[4]Mediation is established as a concept to describe a causal chain in which the first variable, X, (scientific literacy), affects a second variable, M, (the perception of human-induced climate change) that affects a third variable of the outcome, Y, (donations in the CDG), where the second variable is called a "mediator" (Baron and Kenny, 1986, Newsom, 2018).

tion through not only their direct but also indirect effects, which is another robustness check for the regression results.

We first analyze the two direct effects from scientific literacy to donations in the CDG (path A in figure 3) and from the perception of human-induced climate change to donations in CDG (path C in figure 3) by SEM analysis. The results successfully show the existence of the path A with ($\beta = 0.144, p < 0.001$) and that of path C ($\beta = 0.165, p < 0.001$), meaning that both the perception of human-induced climate change and scientific literacy have direct effects on donations in the CDG. Next, we analyze the direct effect from scientific literacy to the perception of human-induced climate change (path B in figure 3) and an indirect effect from scientific literacy to donations via the perceptions of human-induced climate change (path $\bar{C}$ in figure 3). The SEM analysis demonstrates the significance of path B ($\beta = 0.275, p < 0.001$) as well as path $\bar{C}$ ($\beta = 0.045, p < 0.01$). Overall, the SEM analysis establishes that scientific literacy and the perception of human-induced climate change directly and indirectly affect donations in the CDG, where the perception of human-induced climate change is a mediator between scientific literacy and donations.

[Figure 3 about here.]

We are now ready to summarize the answers to the two open questions posed at the end of the introduction section based on our statistical analyses. The first question is "what are the determinants of the human-induced perception of the cause of climate change?" Our answer to the question is that scientific literacy, age, gender and prosociality are the main determinants regarding whether people possess the perception of human-induced climate change. In particular, scientific literacy is of utmost importance due to the magnitude and significance of the regression and SEM analyses. The second question is "how does the gap in perceptions on the cause of climate change along with social preferences and scientific literacy affect people's cooperative behaviors?" Our answer to the question is that the perception of human-induced climate change, scientific literacy, prosociality and age positively affect people's cooperative behaviors toward climate change, demonstrating the importance of possessing the perception of human-induced climate change and high scientific literacy for cooperation with climate change.

Some of the literature has reported that prosociality, age and gender matter for people's perception and behaviors toward climate change, which is in line with our findings (Bord and O'Connor, 1997, O'Connor et al., 1999, Meyer and Liebe, 2010, Gatersleben et al., 2014, Kline et al., 2018, MacManus, 2018). Specifically, the literature shows that people are likely to possess correct perceptions and to cooperate for climate change as they are prosocial, aged and female. Here, a majority of people agree that age and gender shall be considered almost impractical to change, while some may wonder whether or not social preferences of prosociality change over time. The literature appears to reach a consensus that people's social preferences remain the same once they are fixed in their young ages. Brosig-Koch et al. (2011) studied people's cooperation between East and West Germany 20 years after reunification by performing a solidarity game, demonstrating that their social preferences had remained unchanged over 20 years. Thus, prosociality, age and gender are considered exogenous and impossible to change by policy interventions or education in the short run.

American Association for the Advancement of Science (2016) and Wigginton et al. (2016) report that further urbanization will have taken place and 65 % $\sim$ 75 % of the world population are predicted to concentrate in urban cities in Asia and Africa. Although technology and education will be making progress along with such urbanization processes in the world, there remains an important question of how people's perception and cooperative behaviors toward climate change evolve over time. The literature claims that people tend to be proself, individualistic, and less cooperative with social problems when societies transition from rural to urban (Schwartz, 2007, Shahrier et al., 2016, Timilsina et al., 2017, 2019).[5] If this is the case, our results suggest that people are unlikely to have the perception of human-induced climate change, being less cooperative with climate change and having negative impacts on future generations.

Scientific literacy is known to be increased by education or cultural learning at any age, while urban city life is reported to detach people from having hands-on experience, knowledge and learning about nature (NISTEP, 2001, Nakagawa, 2016, Jingchao et al., 2018). Given the findings in our

[5] In our study, prosociality does not differ between urban and nonurban Japanese people. We conjecture that this may be due to the fact that Japanese nonurban life is urbanized and depends on industries other than agriculture in comparison with developing countries, as demonstrated by our data. For example, Shahrier et al. (2016, 2017), Timilsina et al. (2017) and Timilsina et al. (2019) study people between urban and rural areas that are quite different from one another with respect to industries and practices.

research, how to enhance scientific literacy shall be a key for giving positive influences on not only the perceptions of human-induced climate change but also actual cooperative behaviors, especially when societies are further urbanized. Akter and Bennett (2011) and Sun and Han (2018) present that people are likely to have risk perception and willingness to take actions toward climate change when they are educated or exposed to mass media. While the results are quite plausible, they can be reinterpreted. We conjecture that scientific literacy works as a substitute or complement of hands-on experience, mass-media exposure, education, knowledge and learning about nature even in urbanization processes. In this sense, scientific literacy may be more important than years of schooling for linking people with the perception of human-induced climate change and cooperative behaviors. Thus, it is vital for climate scientists to prepare and explain some evidence, facts and the associated programs for not only enhancing people's scientific literacy but also convincing people to recognize that climate change is genuinely human-induced, as argued in Lehtonen et al. (2019).

4 Conclusions

This research has explored the determinants of the perception of human-induced climate change and the impact of the perception gaps on cooperative behaviors toward climate change by conducting a survey experiment with a climate donation game for 400 Japanese subjects. The results suggest two main findings. First, the analysis finds the importance of people's scientific literacy to explain the perception gaps in that those with high scientific literacy tend to have the perception of human-induced climate change. Second, people are identified as cooperative toward climate change, as they have prosocial value orientation, high scientific literacy and the perception of human-induced climate change, demonstrating that scientific literacy plays two important roles as not only a direct determinant but also an indirect determinant through a mediator of people's perceptions of human-induced climate change. The results imply that the enhancement of scientific literacy among people shall be a key for giving positive influences on not only the perceptions of human-induced climate change but also actual cooperative behaviors to climate change.

We note some limitations of our study and directions for future research. Our survey experiment was conducted in one country (Japan), which is culturally homogeneous and relatively urbanized, even in nonurban areas, compared to the rest of the world. To generalize our findings, the same types of empirical studies should be conducted in other countries, especially developing countries that are in contrast with Japan in several aspects and are more vulnerable to climate change than developed countries. In addition, our findings are established only by empirical and quantitative research methods. Future research should employ a qualitative approach, such as individual interviews, to clarify the detailed processes of how a personal perception of human-induced climate change actually "influences" her cooperative behaviors, as suggested in Corbin and Strauss (2014), contributing to further policy implications. These caveats notwithstanding, we believe that this study is the first step toward understanding the importance of having the perception of human-induced climate change along with the associated determinants, hoping that further studies will ensue for further identification of how to enhance cooperation toward climate change for its resolution.

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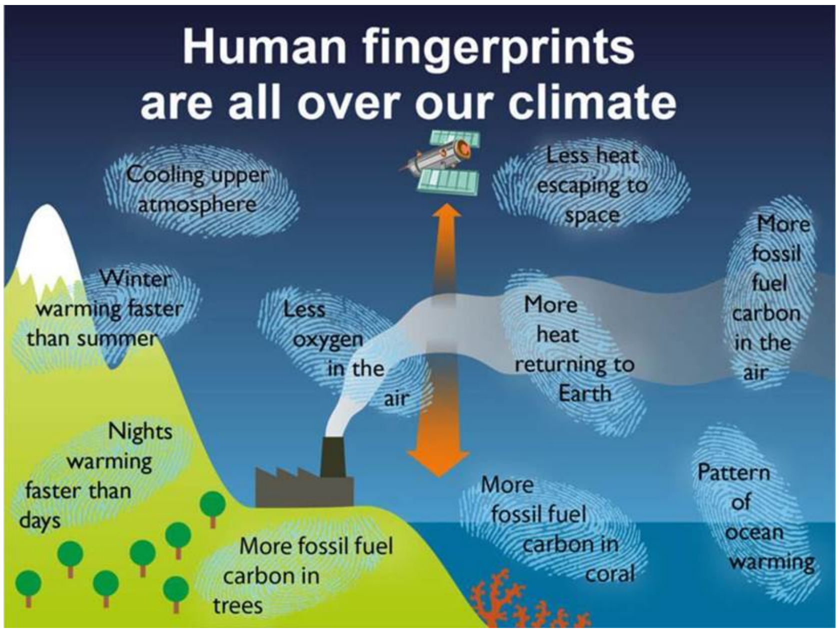
Figure 1: Graphical explanations for human-induced and nature-induced climate change

(a) Human-induced climate change



(b) Nature-induced climate change

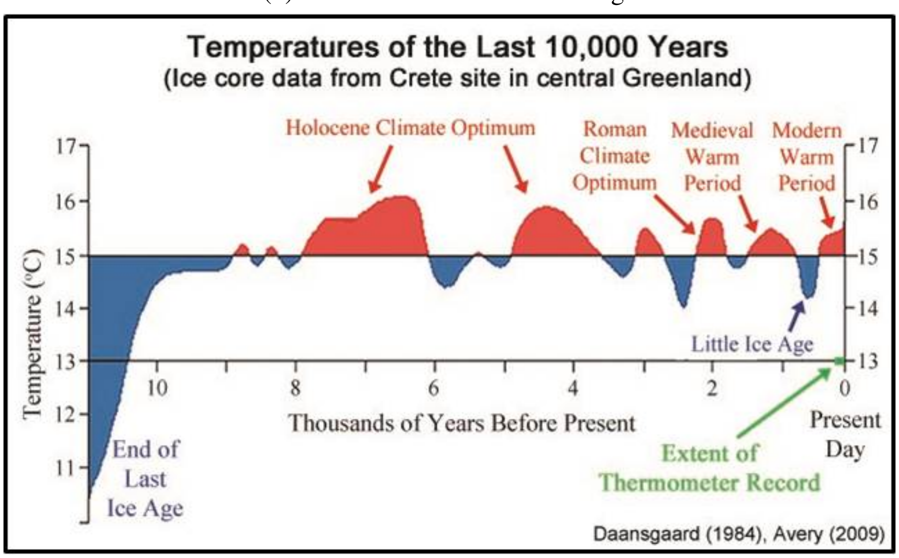


Figure 2: Boxplots of donations among human-induced, nature-induced and other climate change

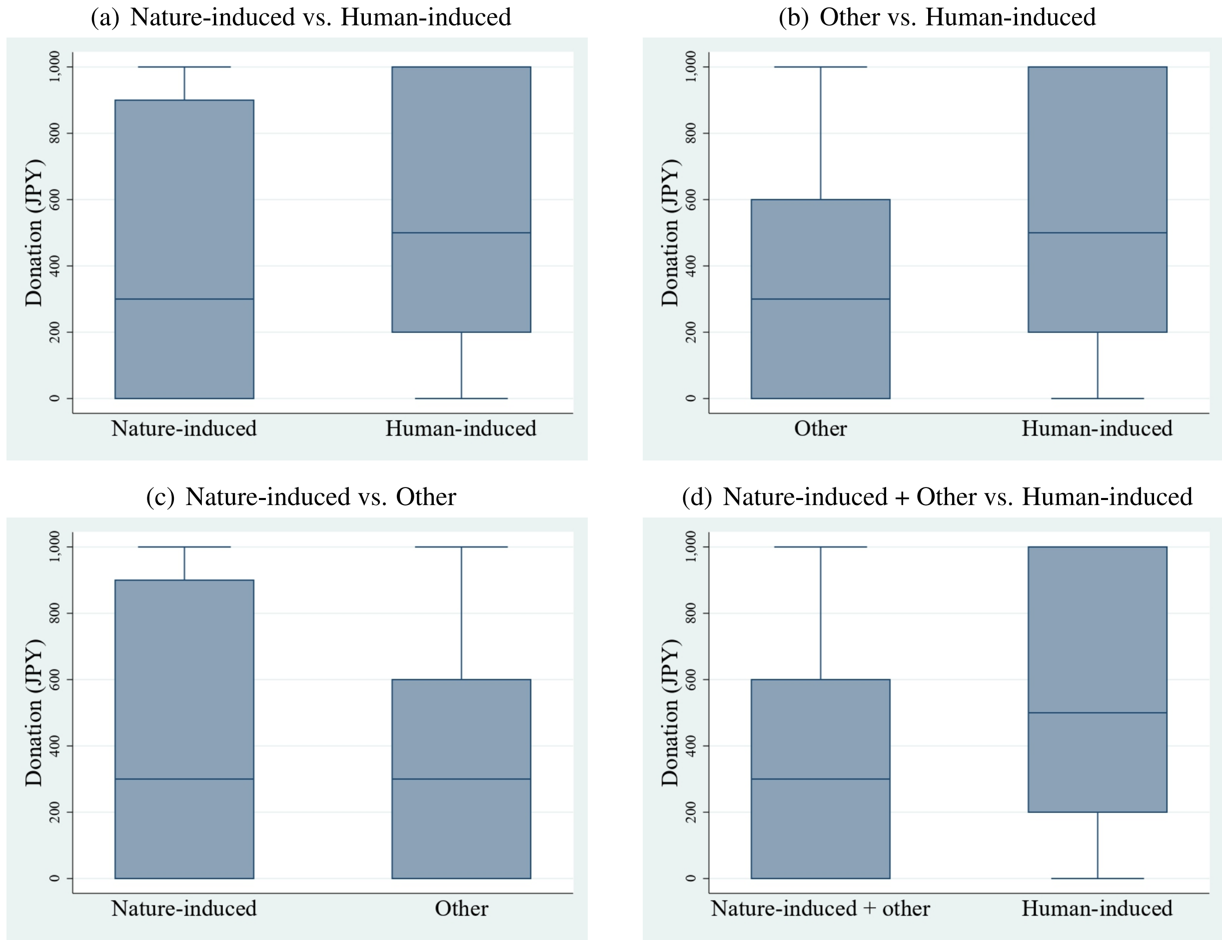


Figure 3: The mediating effects among scientific literacy, people's perceptions and donations

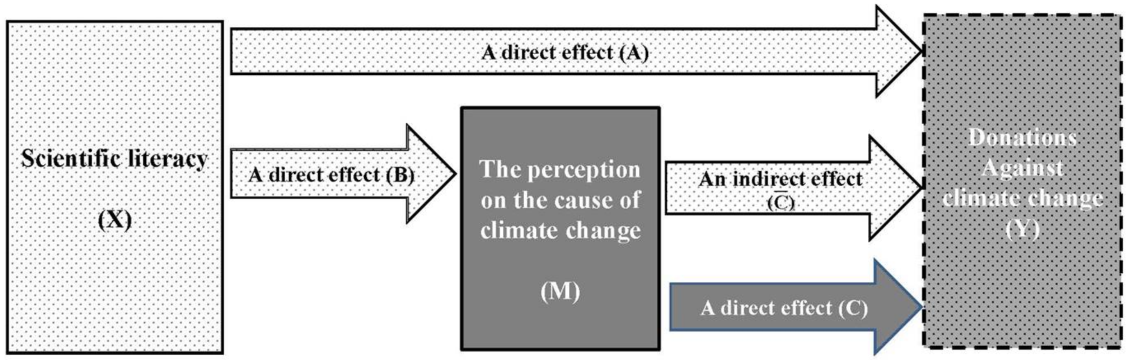


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Table 1: Variable definitions

Variables	Definitions
Area	Area is a dummy variable that takes 1 when the area is urban and 0 otherwise.
Age	Age is defined as years of age.
Gender	Gender is a dummy variable that takes 1 when the subject is female, and 0 otherwise.
Education	Education is an ordered categorical variable of $0, 1, 2, 3$ and 4 where no scholastic education, junior high school, high school, undergraduate, graduate and higher education are coded as $0, 1, 2, 3$ and 4, respectively.
Household income	Household income per year in JPY. Categorical variable of 0 to 12 with an interval of 1 M, However, 11 presents as earning 10 M $<$ 15 M, and 12 represents as earning more than 15 M per year.
Marital status	Marital status is a dummy variable with categorical variables of 0 and 1 where marital status experienced, marital status nonexperienced are coded as 0 and 1, respectively.
Family type	Family type is the categorical variable of 0 and 1 where family type, nuclear family or extended family, are coded as 0 and 1, respectively.
Occupation/agriculture	Occupation/agriculture is defined as 1 if the respondent engages in agriculture or is employed.
SVO	The "SVO" represents a dummy variable taking 1 when the subject is prosocial and 0 otherwise, based on SVO games.
Scientific literacy	This scale is defined as the number of questions for which subjects provided correct answers. The theoretical range is from 0 to 15.
Perceptions	Perception of the cause of climate change is categorized as human-induced climate change, nature-induced climate change or climate change induced by another factor (cannot say and no idea).
Human-induced	Perception of human-induced climate change represents a dummy variable taking 1 when the subject chooses human-induced and 0 otherwise (nature-induced, cannot say, and no idea).
Donation	Donation is defined as a donation payment (range is between 0 and 1000 JPY)

Table 2: Summary statistics of the variables

	Urban areas				Nonurban areas				Overall			
	Mean (Median)	SD[1]	Min	Max	Mean (Median)	SD	Min	Max	Mean (Median)	SD	Min	Max
Age	49.4 (47)	17.72	20	89	49.82 (49)	16.96	21	86	49.61 (48)	16.32	20	89
Gender (female)	0.38 (0)	0.49	0	1	0.36 (0)	0.48	0	1	0.37 (0)	0.48	0	1
Education	2.71 (3)	0.70	0	4	2.54 (3)	0.67	1	4	2.65 (3)	0.69	0	4
Household income	6.21 (6)	3.1	0	12	5.52 (5)	2.97	0	12	5.86 (5)	3.05	0	12
Marital status (experienced)	0.69 (1)	0.47	0	1	0.66 (1)	0.48	0	1	0.67 (1)	0.47	0	1
Family type (nuclear family)	0.1 (0)	0.3	0	1	0.12 (0)	0.33	0	2	0.11 (0)	0.31	0	1
Occupation (agriculture)	0 (0)	0	0	0	0.02 (0)	0.12	0	1	0.01 (0)	0.12	0	1
SVO (prosocial)	0.56 (1)	0.50	0	1	0.60 (1)	0.49	0	1	0.58 (1)	0.49	0	1
Scientific literacy	8.53 (9)	3.36	0	14	8.24 (9)	2.95	0	14	8.39 (9)	3.16	0	14
Perception of climate change												
Human-induced	0.3 (0)	0.46	0	1	0.33 (0)	0.47	0	1	0.32 (0)	0.47	0	1
Nature-induced	0.12 (0)	0.32	0	1	0.14 (0)	0.35	0	1	0.13 (0)	0.33	0	1
Other	0.59 (0)	0.49	0	1	0.53 (1)	0.5	0	1	0.56 (1)	0.50	0	1
Donation	455.53 (500)	403.88	0	1000	419.90 (400)	381.09	0	1000	437.71 (500)	392.56	0	1000
Subjects	n = 200				n = 200				n = 400			

[1] SD stands for standard deviation.

Table 3: Donations and subjects' perception of the cause of climate change across urban, nonurban and overall areas

Perception	Urban areas					Nonurban areas					Overall				
	n	Mean (Median)	SD[1]	Min	Max	n	Mean (Median)	SD	Min	Max	n	Mean (Median)	SD	Min	Max
Human-induced	60	590.25 (500)	386.23	0	1000	66	525 (500)	365.88	0	1000	126	556.07 (500)	375.62	0	1000
Nature-induced	23	535.22 (500)	444.23	0	1000	28	272.50 (100)	326.7	0	1000	51	390.98 (300)	402.36	0	1000
Other	117	370.78 (300)	385.55	0	1000	106	393.39 (300)	389.2	0	1000	223	381.52 (300)	386.58	0	1000
Subjects	n = 200					n = 200					n = 400				

[1] SD stands for standard deviation.
[2] Proself includes individualists and competitors.

Table 4: Marginal probability of independent variables in logistic regression for the perception of human-induced climate change

Variable	Marginal probability			
	Model 1	Model 2	Model 3	Model 4
Scientific literacy	0.044***	0.039***	0.039***	0.040***
	(0.007)	(0.008)	(0.008)	(0.008)
Age		0.004***	0.004***	0.003**
		(0.001)	(0.001)	(0.001)
Gender dummy (female = 1, male = 0)		0.096**	0.100**	0.083**
		(0.045)	(0.045)	(0.046)
SVO (prosocial = 1, otherwise = 0)			0.069*	0.066*
			(0.049)	(0.045)
Marital status (experienced = 1, nonexperienced = 0)				0.069
				(0.059)
Education				–0.040
				(0.045)
Household income				0.007
				(0.008)
Area dummy (urban = 1, nonurban = 0)				–0.045
				(0.234)
Family type (nuclear family = 1, extended family = 0)				–0.004
				(0.070)

[1] *** significant at the 1 % level, ** significant at the 5 % level, and * significant at the 10 % level

[2] The age squared variable is not added to these models because we judge this variable as less important by a predicted probability logistic regression.

Table 5: Marginal effects of independent variables in the tobit regression for donations to the prevention of climate change

Variable	Marginal effect			
	Model 1	Model 2	Model 3	Model 4
Perception (Human-induced = 1, Otherwise = 0)	235.016***	190.834***	183.948***	136.4***
	(54.566)	(56.004)	(55.835)	(55.317)
Scientific literacy		24.101***	22.996***	13.506*
		(8.490)	(8.477)	(8.881)
SVO (prosocial = 1, otherwise = 0)			102.251**	104.477**
			(51.441)	(50.191)
Age				4.935***
				(1.696)
Gender dummy (female = 1, male =0)				67.191
				(64.313)
Marital status (experienced = 1, nonexperienced = 0)				93.457*
				(64.313)
Household income				6.037
				(8.611)
Education				−27.055
				(3.912)
Area dummy (urban = 1, nonurban = 0)				49.880
				(49.651)

*** significant at the 1 % level, ** significant at the 5 % level, and * significant at the 10 % level