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TIME DISCOUNTING, AMBIGUITY AVERSION, AND PREFERENCES FOR FUTURE ENVIRONMENTAL POLICIES: EVIDENCE FROM DISCRETE CHOICE EXPERIMENTS

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Time discounting, ambiguity aversion, and preferences for future environmental policies: Evidence from discrete choice experiments*

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Abstract

Designing efficient environmental policies requires knowledge about households' preference parameters for their intertemporal decisions. By conducting an original Internet-based survey using Japanese participants (n=2,906) and a follow-up survey (n=1,407), we examine how people evaluate pro-environmental policies depending on their individual attributes. The discount rates for environmental outcomes are estimated by using a discrete choice experiment. We show that participants' discount rates in environmental policy choices are on average negative and future-biased. Those who are more ambiguity-averse and patient for money concerns, and anticipate more rapid increases in future temperatures are more willing to incur present-day tax burdens to ensure future environmental improvements. These results are highly robust against alternative estimation models and stable when using the follow-up survey data obtained 21 months later.

JEL Classification Numbers: D91; Q51

Keywords: Time discounting; Ambiguity aversion; Environmental policy; Random utility model; Discrete choice analysis

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1 Introduction

In the face of rapid climate change and global warming, a consensus seems to have been reached that governments must adopt policies to preserve the environment. These environmental policies have an aspect of intertemporal choice for taxpayers, who stand to gain future environmental improvements at the cost of a present-day tax burden. Hence, designing efficient environmental policies inevitably requires knowledge about households' preference parameters related to their intertemporal decisions.

This study examines how people evaluate the future environment. In particular, we investigate how the imputed time preference over the future environment is associated with individual attributes that affect the intertemporal tradeoffs in people's environmental decision-making. The attributes on which we focus are (i) the time preferences in the domain of monetary/financial outcomes, (ii) attitudes toward risk and ambiguity, (iii) subjective views on pro-environmental activities, and (iv) the anticipation of future environmental deterioration. As discussed in the literature (e.g., Hardisty and Weber, 2009; Richards and Green, 2015), it is important both for researchers and policy makers to know whether the features of the time preferences in the environment domain are well captured by those in the monetary domain (point (i)), which are usually taken into account when formulating environmental policies. For point (ii), as the future conditions of the environment are not deterministic, but risky and/or ambiguous (Fox and Tversky, 1995; Eismont and Welsch, 1996), the intertemporal tradeoffs in environment-related decision-making could depend on the degrees of risk and ambiguity aversion. Finally, subjective views and the anticipation of future environmental deterioration (points (iii) and (iv)) may affect preferences for pro-environmental policies with delayed effects. In particular, those who anticipate the environment becoming rapidly scarcer in the future will prefer environmental policies that take effects with longer delays.

Methodologically, we conduct an original Internet-based survey using Japanese participants (n=2,906) and a follow-up survey (n=1,407), where the cohort profile mirrors that of the national statistics. With those data, we estimate the discount rates for environmental outcomes by using a discrete choice experiment approach a la Viscusi et al. (2008) and Meyer (2013) as well as elicit other preference parameters such as the discount rates for monetary outcomes and degrees of risk and ambiguity aversion by using choice-titration procedures (Scholten and Read, 2006; Rodzon et al., 2011).

Our main findings can be summarized as follows. First, in contrast to the findings in the economics literature, participants' discount rates in environmental policy choices are on average negative and future-biased: they ceteris paribus prefer delayed environmental improvements to immediate ones. This is the case irrespective of the fact that the same participants do discount future monetary outcomes at normal positive rates, preferring present rewards to future ones.

Second, the time preferences in the environment domain are shown to be positively correlated with the time preferences in the monetary domain: those who value the future environment more highly tend to be more patient in terms of monetary outcomes and hence of standard consumption goods. This finding implies that differences in individual discount rates in the monetary domain partially explain those in pro-environmental attitudes. However, from our first finding, it is not straightforwardly justifiable, unlike what Hardisty and Weber (2009) stress, to apply discount rates in the monetary domain to environment-related policy. For example, although people prefer a present money amount to the same amount in the future because of positive discount rates, they are willing to pay present-day tax payments for future environmental improvements with negative discount rates. Policymakers can thus exploit this patient nature of taxpayers in the environmental domain when designing pro-environmental policies.

Third, ambiguity aversion plays a significant role in generating participants' preferences for future environmental policies: a more ambiguity-averse participant is more patient in waiting for future environmental improvements. By contrast, his or her risk aversion does not affect his or her patience in waiting for future environmental improvements. These findings are consistent with the fact that the true probability distributions of future environmental conditions are usually unknown to policymakers and consumers (Fox and Tversky, 1995).

These findings are highly robust against alternative estimation models (e.g., mixed logit models) and stable in another dataset taken from our follow-up survey conducted a year later. Furthermore, the follow-up survey detects our fourth finding: people who anticipate more rapid increases in future temperatures can wait for future environmental improvements more patiently. A policy implication follows from this: people would take a greater tax burden today for a pro-environmental policy with a long delay, even though they have positive time preferences for monetary concerns, if the policy reduces future environmental uncertainty and contributes to mitigating rising temperatures.

Our study is closely related to Viscusi et al. (2008) and Meyer (2013), both of which conduct discrete choice experiments by using Internet surveys to elicit time preferences in environment-related decision-making. Viscusi et al. (2008) develop a novel estimation method with which to elicit discount rates, detecting positive and present-biased time preferences for environmental policy choices. However, they do not examine how these estimated time preferences are associated with other individual preferences such as discount rates for monetary and ambiguity concerns or the anticipation of future environmental improvements. By following their method that allows us to elicit the environment-concerning time preferences directly from the utility parameters, we show that our Japanese participants exhibit negative and future-biased time preferences in contrast to the findings in Viscusi et al. (2008).

By conducting a discrete choice experiment for residents in the Minnesota River basin, Meyer (2013) estimates both exponential and hyperbolic discounting models. Although he concludes that the data are indicative of exponential discounting (p. 56, Meyer, 2013), his analysis shows that the quasi-hyperbolic discounting model exhibits the best model fit in terms of the simulated log likelihood value among alternative models and that the point estimate of the present-biased discount parameter (β) is greater than one (1.27); in other words, time preferences are future-biased. Our study shows that our participants' choices are consistent with this finding.

Hardisty and Weber (2009) and Richards and Green (2015) conduct lab experiments to examine the differences in discounting for financial and environmental outcomes. Hardisty and Weber (2009) report similar discounting in the two domains, whereas Richards and Green (2015) detect significantly lower discount rates for environmental concerns than those for financial concerns. Our study supports the latter finding, although our results are also consistent with Hardisty and Weber (2009) in that the elicited discount rates for environmental concerns are positively associated with those for monetary concerns. Furthermore, we examine the relationship between the time preferences for environmental concerns and the other parameters mentioned above.

The remainder of this paper is organized as follows. Section 2 describes the data collected. Section 3 presents the empirical model and econometric method used for the estimation. Section 4 reports the estimation results and discusses their implications. Section 5 checks the robustness of our results by using a mixed logit model. Section 6 concludes.

2 Data

Our empirical research is based on our original nationwide Internet survey, the Internet Survey on Environments and Behavior (ISEB 2014, hereafter), conducted between March 12 and 18, 2014, and its follow-up survey (ISEBf 2015, hereafter), conducted on December 4–10, 2015. Nikkei Research, a representative Japanese private research company, conducted the ISEB 2014 and the ISEBf 2015, based on questionnaires that we originally prepared. For the ISEB 2014, the participants were 2906 Japanese people between the ages of 20 and 65, who had been enrolled in the Nikkei Research Access Panel, composed of roughly 155,000 registrants. Cash vouchers of JPY 500 are given as incentives by lottery to participants. The sample was selected by stratified random sampling such that the age and sex distribution was as close as possible to that of the Japanese census. Table 1 presents the characteristics of the participants.

Insert Table 1.

As detailed in the next subsection, we included various questions in the ISEB 2014 to elicit information about participants' (i) preferences for future environmental policies, (ii) attitudes toward the environment, (iii) preferences for time discounting and risk/ambiguity aversion on monetary outcomes, and (iv) demographic and socioeconomic attributes. In particular, following Viscusi et al. (2008), we designed hypothetical discrete choice questions for environmental policy choices to examine participants' preferences for environmental policies.

The ISEBf 2015 was conducted to check the stability of the elicited parameters and examine how participants' time preferences for the environment revealed from the choice questions were related to their anticipation of future environmental deterioration. Detailed information on the follow-up survey is provided in Section 6.

2.1 Preferences for pro-environmental policies

By using data from the ISEB 2014 and ISEBf 2015, we apply a random utility model a la McFadden (1974) to elicit participants' time preferences for environmental improvements that take effect with certain delays. Discrete choice analysis has been widely used in environmental economics to value environmental amenities or changes in environmental quality and natural resources (e.g., Adamowicz et al., 1994).

Discrete choice analysis requires participants to rank different policies with varying combinations of attribute levels. In our hypothetical questions, we specify alternative environmental policies characterized by three attributes: (i) the expected rates of reduction in environmental risk and pollution (5%, 10%, 15%, 20%, or 30%); (ii) annual costs in terms of tax payments per household (JPY 3,100, JPY 3,600, JPY 4,100, JPY 4,600, or JPY 5,100); and (iii) the delay before the environmental improvement takes effect (zero (immediate effectuation), 6 months, 1 year, 2 years, or 3 Years). As each of the three attributes above take five possible values, there are 125 ($= 5 \times 5 \times 5$) potential variations of these alternatives. An orthogonal design (Orthoplan in SPSS, 2014) is used to pick up 25 out of the 125 variations to make a vector of the alternatives. We repeat this procedure three times to form the three-situation choice task used in the survey.

Fig. 1 presents a typical choice problem in the ISEB 2014 and ISEBf 2015, where a participant is told to choose the most preferable policy from three alternatives (A to C). Each participant replies to six such problems with different alternative policies generated by the orthogonal design procedure. Five sets of different six choice problems are randomly assigned to participants. Overall, we collect data on 17,436 decisions among the three policies.

Insert Fig. 1.

2.2 Individual characteristics

In addition to questions about policies for environmental improvements, participants are asked various questions about their pro-environmental attitudes, money-based preferences for time, risk, and ambiguity, as well as economic, demographic, and social attributes such as sex, age, family, education, and income.

2.2.1 Environment-related behaviors

To examine the associations between participants' imputed environmental time preferences and their actual environment-related attitudes and activities, we ask them 10 questions, Q1–Q10, on environment-related behaviors in everyday life, as shown in Appendix A. Participants are asked to reply to each by using a five-point scale from 1 (not at all, not the case) to 5 (applied perfectly). Q1 asks whether a respondent participates in outdoor activities such as hiking, climbing, and fishing. We construct a binary indicator for active participation in outdoor activities, which equals one if the chosen number is greater than 4 and zero otherwise. Q2–Q10 ask how pro-environmental a participant's attitude is. The raw scores for each question are converted into standardized values with a mean of zero and a standard deviation of one. The standardized scores of Q2–Q10 are then averaged to form a composite score for each participant to quantify his or her pro-environmental attitude.

2.2.2 Money-based discount rates

To explore the nature of the money-based discount rates of participants, our questionnaire contains two questions, Q18 and Q19, which consist of three sequential binary choices between small rewards today and larger rewards a month later as well as between small rewards a year later and larger rewards 13 months later, respectively. As detailed in Appendix B, in Q18, participants are first asked to reply to Q-18-1 by choosing between two alternatives: (A) receiving JPY 10,000 today or (B) receiving JPY 10,800 one month later. For Q-18-2, respondents choose between (A) receiving JPY 10,000 today or (B) receiving JPY 13,000 later. For Q-18-3, the choice is between(A) receiving JPY 10,000 today or (B) receiving JPY 10,150 later. In this way, Q18 classifies participants through the sequential three choices into eight classes according to the degree of impatience for immediate intertemporal decisions. Similarly, the three sequential questions of Q19 ask participants to choose between (A) receiving JPY 10,000 one year later or (B) receiving a larger amount of money one year and one month later, thereby classifying them into eight classes according to impatience for long-term intertemporal decisions. By assuming that the participant's money-based discount factor obeys the quasi-hyperbolic discount model (the β-δ model, Laibson, 1997), we elicit from the choices in Q18 and Q19 the parameters of the present bias (β) and the long-run discount factor (δ) for money.[1] The imputed parameters for discounting are used to detect associations with the corresponding discount factors with respect to environmental policies.

2.2.3 Risk aversion and ambiguity aversion

As the state of the future environment is uncertain, preferences for environmental policies are expected to depend on participants' aversive attitudes toward the risk and/or ambiguity of future events. We measure participants' degrees of money-based risk and ambiguity aversion by including two questions, Q20 and Q21, in our questionnaire, each composed of three sequential choices as in Q18 and Q19. As detailed in Appendix C, these questions ask each participant whether he or she would rather participate in a lottery that offers a prize of JPY 10,000 for picking a winning ball from an urn or receive a smaller certain amount of money. In Q20, participants know that the urn contains 10 winning balls and 10 losing balls, whereas in Q21, the composition of the urn is not known. From the responses to Q20, we can stratify participants into eight classes according to their degree of risk aversion. In the same way, form the responses to Q21, participants are classified into eight groups. If a participant is ambiguity-averse, he or she will participate in the lottery with smaller rewards in Q20 than he or she would in Q21. By taking the difference between the class numbers of Q20 and Q21, we can classify participants into 15 categories according to their degree of ambiguity aversion.

3 Estimation of the discount rates for environmental outcomes

3.1 Random utility model

To analyze the data derived from our discrete choice experiments, we adopt the random utility model developed by Viscusi et al. (2008). Following these authors, we assume that the utility of environmental improvements is composed of three attributes: the cost of the environmental improvements c , the effect of the improvements e, and the time delay required before the improvements t. Formally, we specify the utility of alternative policy option i in choice set k for participant n, u_{ikn}, as follows:

$$u_{ikn} = \alpha c_{ikn} + \lambda e_{ikn} + \gamma t_{ikn} + \theta e_{ikn} t_{ikn} + \varepsilon_{ikn}, \tag{1}$$

[1] When eliciting money-based discount factors, we assume a linear utility function for simplicity. This may cause a bias in their estimates (Andersen et al., 2008). However, as we shall show later, discount factors for environmental concerns have no association with the degree of risk aversion and, hence, with the concavity of the utility function. Therefore, the linearity assumption for the money-based discount factors does not affect our result below that discount factors for environmental concerns are associated with those for money.

where α, λ, and γ denote the marginal utilities associated with the cost, effect, and time delay and ε_{ikn} is the random error term. The interaction term $\theta e_{ikn} t_{ikn}$ is added on the right-hand side to capture how participants discount future environmental improvements. Given the random utility specification, the probability of participant n choosing alternative i from choice set k, p_{ikn}, is determined by

$$\begin{aligned} p_{ikn} &= \text{Prob}(\alpha c_{ikn} + \lambda e_{ikn} + \gamma t_{ikn} + \theta e_{ikn} t_{ikn} + \varepsilon_{ikn} \\ &\qquad > \alpha c_{jkn} + \lambda e_{jkn} + \gamma t_{jkn} + \theta e_{jkn} t_{ikn} + \varepsilon_{jkn}), \text{ for all } j \neq i. \end{aligned} \tag{2}$$

3.2 Conditional logit estimates

We first estimate the parameters of the random utility model by using a conditional logit framework. Recall that the time delay variable t_{ikn} can take five values: 0, 6, 12, 24, and 36 months (denoted 0, 1, 2, 4, and 6, respectively). By letting $Delay1$, $Delay2$, $Delay4$, and $Delay6$ denote dummy variables that equal one if the time delay before the improvement in policy i is 6, 12, 24, and 36 months, respectively, and zero otherwise, we rewrite Eq. (1) by replacing the time delay variable in the interaction term with the four dummy variables as follows:

$$\begin{aligned} u_{ikn} &= \alpha c_{ikn} + \lambda e_{ikn} + \gamma t_{ikn} \\ &\quad + \xi_1 e_{ikn} Delay1 + \xi_2 e_{ikn} Delay2 + \xi_4 e_{ikn} Delay4 + \xi_6 e_{ikn} Delay6 + \varepsilon_{ikn}. \end{aligned} \tag{3}$$

From the estimated coefficients of Eq. (3), we calculate the discount factors for environmental improvements. Since these discount factors are defined as the marginal utility of future environmental improvements divided by the marginal utility of present environmental improvements, the semi-annual discount factor for the m month delayed environmental improvements $\tilde{\delta}_m$ is given by

$$\tilde{\delta}_m = \left(1 + \frac{\xi_{\frac{m}{6}}}{\lambda}\right)^{\frac{6}{m}}, \text{ for } m = 6, 12, 24, 36. \tag{4}$$

Further, we interpret the discount factors in the quasi-hyperbolic ($\beta\delta$) model proposed by Laibson (1997) instead of the exponential function model. In the $\beta\delta$ model, the present bias parameter β and long-run discount factor δ satisfy, respectively,

$$\begin{aligned} \tilde{\delta}_6 &= \beta\delta, \\ \tilde{\delta}_{12}^2 &= \beta\delta^2, \\ \tilde{\delta}_{24}^4 &= \beta\delta^4, \\ \tilde{\delta}_{36}^6 &= \beta\delta^6. \end{aligned}$$

Therefore, β and δ for a certain period of time, such as from now to m months later, are calculated by the following equations:

$$\delta_m = \left(\frac{\tilde{\delta}_m^{\frac{m}{6}}}{\tilde{\delta}_6} \right)^{\frac{1}{\frac{m}{6}-1}}, \tag{5}$$

$$\beta_m = \frac{\tilde{\delta}_6}{\delta_m}, \text{ for } m = 12, 24, 36. \tag{6}$$

We also investigate the influence of individual characteristics on environmental time discounting. To do so, we rewrite Eq. (3) by incorporating individual attributes into the interaction terms in the equation as follows:

$$\begin{aligned} u_{ikn} &= \alpha c_{ikn} + \lambda e_{ikn} + \gamma t_{ikn} + (\xi_1 + \boldsymbol{\zeta}_1' \mathbf{x}_n) e_{ikn} Delay1 \\ &\quad + (\xi_2 + \boldsymbol{\zeta}_2' \mathbf{x}_n) e_{ikn} Delay2 + (\xi_4 + \boldsymbol{\zeta}_4' \mathbf{x}_n) e_{ikn} Delay4 \\ &\quad + (\xi_6 + \boldsymbol{\zeta}_6' \mathbf{x}_n) e_{ikn} Delay6 + \varepsilon_{ikn}, \end{aligned} \tag{7}$$

where $\mathbf{x}_n$ is a vector of the individual characteristics such as participants' demographic and preference attributes listed in Table 1.

4 Results

4.1 Time discounting and future bias revealed from preferences for environmental policies

The first column of Table 2 summarizes the estimation results of the conditional logit model (3). Rows (1)–(3) of the first column show that a lower cost, a higher improvement effect, and a shorter delay of the environmental policy lead to higher utility, which is intuitively understandable. Our novel finding here is that, as the last four rows of the table indicate, the marginal utilities of the improvement effect are greater for delayed ones: our participants prefer delayed environmental improvements to immediate environmental improvements.

Insert Table 2.

More explicitly, by using the estimates of the interaction effects, we can obtain from Eq. (4) the imputed discount factors for the environmental improvements. The second column of Panel A of Table 3 shows the results, indicating that the imputed discount factors are greater than unity with a decreasing trend over the examined time period of delay. For example, the point estimate of δ_m for 0–0.5 year is 1.36, which is higher than that for 0–3 years, 1.07. The associated 95% confidence intervals indicate that all the point estimates for δ_m are greater than unity.

Insert Table 3.

Based on the $\beta\delta$ specification, we compute the associated long-run discount factor δ and present bias parameter β by using Eqs. (5) and (6). The fourth and fifth columns of Panel A of Table 3 show that both the parameters are greater than unity. In particular, for any horizon, the point estimates of the environmental beta are larger than 1.3. These results imply that participants' time preferences with respect to environmental improvements are on average negative and future-biased. Although the results seem to contradict the existing empirical evidence that time preferences are positive and present-biased (e.g., Viscusi et al., 2008), our participants consistently display positive and present-biased time preferences for monetary rewards, as shown in Table 1. The negative and future-biased time preferences, revealed in Panel A of Table 3, might thus be considered to be specific to environmental concerns in our experiments. Even for those impatient and present-biased for monetary rewards, negative and future-biased time preferences are detected during intertemporal decisions on environmental improvements. Furthermore, we show in the next section that the imputed time preferences for environmental concerns are positively associated with those for monetary concerns.

4.2 Individual attributes and environmental time discounting

This subsection presents the estimation results of Eq. (7). To examine the association between the individual attributes and environmental time discounting, we focus on how the interactions between environmental improvements and each delay dummy correlate with the individual preferences and other characteristics. A positive (negative) correlation between them implies that environmental discount factor δ_m positively (negatively) depends on the attribute variable.

Two findings in Table 4 are noteworthy. First, as can be seen from rows (5), (13), (21), and (29) of the table, the interaction between environmental improvements and each delay dummy has a significantly positive correlation with the pecuniary discount factor, where for different delay periods, the estimated coefficients are stable in magnitude (0.032–0.036) and significance level (p-values < 0.05). This finding indicates that participants more patient in waiting for future monetary rewards wait for future environmental improvements more patiently. Thus, the discount rates for monetary outcomes, which economics researchers usually estimate as a proxy of the degree of impatience, would indeed be at least partially useful in environmental issues.

Insert Table 4.

Second, all the interactions between delayed environmental improvements and ambiguity aversion are significantly positive (see rows (7), (15), (23), and (31) of Table 4), whereas those between delayed environmental improvements and risk aversion are all insignificant (see rows (6), (14), (22), and (30) of Table 4). Thus, the level of the discount factor for environmental concerns is positively correlated with the degree of ambiguity aversion, but not associated with risk aversion: a more ambiguity-averse person is more patient in waiting for future environmental improvements. This result is reasonable if more distant future environmental improvements are more ambiguous in the Knightian sense. In other words, as its probability distribution is unknown, participants prefer future environmental improvements that can compensate for the greater ambiguity.[2]

Table 4 also shows the associations between the environmental discount factors and other individual attributes. First, as seen from rows (8), (16), (24), and (31), the discount factor for environmental concerns is significantly higher for university graduates than for non-graduates. Second, respondents who more frequently participate in outdoor activities are less patient in waiting for future environmental improvements (see row (9) of Table 4). This tendency is consistent with the finding in Viscusi et al. (2008) that recreational users of water bodies tend to evaluate immediate water improvements highly. Third, on the contrary, rows (10) and (18) show that the interactions of delayed environmental improvements and pro-environmental attitudes are significantly positive, which indicates that participants with stronger pro-environmental attitudes are more patient in waiting for future environmental improvements.

5 Mixed logit estimation

To check the robustness of our results, we re-estimate the random utility model (3) by using a mixed logit specification, which allows for heterogeneous utility parameters for individual participants (α_n, γ_n, ξ_{1n}, ..., ξ_{6n}). Formally, we estimate

$$\begin{aligned} u_{ikn} &= \alpha_n c_{ikn} + \lambda e_{ikn} + \gamma_n t_{ikn} + \xi_{1n} e_{ikn} Delay1 \\ &\quad + \xi_{2n} e_{ikn} Delay2 + \xi_{4n} e_{ikn} Delay4 + \xi_{6n} e_{ikn} Delay6 + \varepsilon_{ikn}, \end{aligned} \tag{8}$$

instead of Eq. (3).

The last column of Table 2 summarizes the estimation results for Eq. (8), in a comparable way to the conditional logit case (the first column of Table 2). The estimates and standard errors of the utility parameters here represent the mean magnitudes of the heterogeneous parameters and extent of the variation in the sample, respectively. The estimated coefficients are similar in signs and significance levels to those in the case of the conditional logit model: participants prefer environmental policies that are less costly, more effective, and less delayed (rows (1)–(3) of the last column); they also prefer environmental policies with delayed effects to those taking

[2] In the theoretical literature, how ambiguity aversion affects the optimal timing of environmental policies is controversial (e.g., Asano and Shibata, 2014). However, no research considers the case that environmental ambiguity is delay-dependent.

effect immediately (rows (4)–(7)). As in the conditional logit results, again, all the estimates are significant at the 1% level.

By substituting the estimated individual participants' utility parameters into Eq. (4), we can calculate their discount factors. To check the robustness of the correlations between the discount factor for future environmental improvements and each individual attribute, we regress the estimated individuals' discount factors on their individual attributes by adopting the following ordinary least squares (OLS) model:

$$\tilde{\delta}_{mn} = \boldsymbol{\zeta}'\mathbf{x}_n + \varepsilon_n. \tag{9}$$

Panel A of Table 5 summarizes the results for the environmental discount factors in the shortest horizon $\tilde{\delta}_{36n}$ (the 0–3 years setting).[3] The table indicates that, with minor exceptions, the estimated associations between the environmental discount factors and individual attributes are highly consistent with those in Table 4. In particular, as in the conditional logit estimation, the environmental discount factor for either horizon is positively associated with the pecuniary discount factor and ambiguity aversion at the 1% level and has no significant association with risk aversion.

Insert Table 5.

6 Follow-up survey

Section 4 showed that respondents were on average willing to incur higher costs for environmental policies with longer delays. In other words, our subjects have negative discount rates for future environmental goods. After making these findings, we conducted an Internet-based follow-up survey using the participants in the first survey for two purposes. First, we check the stability of the elicited preference parameters. In particular, since our finding of a negative discount rate for the environment is novel in the literature, checking if the finding is robust is important for the validity of our study. Second, we address a mechanism that may account for the negative discount rate: we hypothesize that respondents' future preferences for environmental policy choices are related to their expectations of future environmental deterioration. Specifically, people who anticipate more rapid deterioration in the natural environment prefer policies with more delayed pro-environmental effects because of consumption smoothing.

For these purposes, the follow-up survey was constructed in two sections: (i) three consecutive questions (AQ1–AQ3) asking participants about their views on future changes in the global envi-

[3] When estimating the environmental discount factor for the 0–0.5 year setting, the environmental discount factor for the 0.5–3 year setting is added to the list of control variables to control for the possible cofounding effect. The results do not change substantially even when we exclude it from the controls.

ronment (to be shown Figs. 3–5 below) and (ii) discrete choice questions on environmental policy choices as in the first survey. Regarding the discrete choice questions on environmental policy, we distributed the same five sets of questions as in the first survey randomly to participants, unconditional on the sets of questions they responded to in the first survey. The follow-up survey was again conducted by Nikkei Research, Inc. and run from December 4–10, 2015. The total number of respondents was 1407 (response rate 48.4%).

6.1 Stability of the elicited discount rates for the future environment

We first check the stability of the elicited discount factors for environmental improvements between the two surveys, which were 21 months apart. By using the data derived from the follow-up survey, we re-estimate Eq. (3). Panel B of Table 3 shows the imputed discount factors on the future environment from the follow-up survey data. They reveal the same tendencies as those in the first survey. Most importantly, the re-elicited discount factors retain the same novel features of negative discount rates and future bias reported in the first survey. We also show that the values of these imputed discount factors, δ and β, do not differ significantly from those in the first study. Hence, we conclude that the results of our discrete choice experiments are robust. By using the follow-up survey data, we further re-elicit individual participants' discount factors for the environment in the same way as in Section 5. 2 shows the jitter scatterplots of individual participants' environmental discount factors estimated from the first survey data compared with the follow-up survey data. Both for the shortest horizon (0–0.5 year) and for the longest horizon (0–3 years), we find significantly positive correlations between the discount factors elicited in the two surveys ($\rho = 0.3342$, p-value < 0.0001 for the 0–0.5 year setting and $\rho = 0.3122$, p-value < 0.0001 for the 0–3 years setting).[4]

Insert Fig. 2.

6.2 Mechanism of negative time discounting for the future environment

To test our hypothesis that respondents who expect faster environmental deterioration prefer to defer environmental improvements to the far future for consumption smoothing, we use the data on respondents' views about future environmental changes. The three questions, AQ1–AQ3, are shown below. Each of these subjective evaluations is additionally incorporated into Eq. (9) to see if our hypothesis is supported.

[4]We also estimate the same regression models as in Table 5 for individual respondents' environmental discount factors estimated from the first survey data, but with the inclusion of the imputed environmental discount factors from the follow-up survey data on the right-hand side. The coefficients of the imputed discount factors from the follow-up survey data are significantly positive in both horizons (not tabulated). The signs and significance levels of the other coefficients are also similar to those in Table 5.

Insert Figs. 3–5.

From AQ1, we find that the higher people expect future global temperatures to be, the more they want to postpone future environmental improvements. The regression results are shown in Table 6 for some specifications. This finding supports our hypothesis (see row (8) in Table 6).

Insert Table 6.

Regarding the variables on natural resource depletion (AQ2) and CO2 (AQ3), however, we did not find stable supporting results for our hypothesis. In some regressions, the R^2 values are smaller than those taken from the regression with the global warming variable, while the signs of the coefficients of the expectation of future environmental improvements are not as expected (results available upon request).

We speculate that we did not obtain consistent results since our subjects are more concerned about global temperatures than the increase in CO2 or decrease in natural resources: governments globally seem to be well aware of the need to reduce CO2 emissions and ensure the eco-friendly use of natural resources, while abnormal weather such as heat and drought is conspicuous in the media.

To summarize the results from the follow-up survey, negative and future-biased time discounting for the future environment is robust for our sample of Japanese subjects. We find partly supporting evidence that this is due to the motivation of consumption smoothing under the anticipated increased scarcity of future environmental resources. Another possible mechanism from a theoretical viewpoint is the increasing-returns-to-scale nature of environmental goods, which is left unanswered in our study.

7 Conclusions

In this study, we showed that negative time preferences are detected in environmental policy choices: participants prefer delayed environmental improvements to immediate ones. This future-biased preference for environment choices is stronger for participants who are more patient for monetary concerns; have stronger preferences for ambiguity aversion; and anticipate a steeper upward trend in future temperatures. The presented findings are highly robust against alternative estimation models and compared with data derived from a follow-up survey conducted 21 months later.

A policy implication follows from the results: even if people have positive time preferences for monetary concerns, they are willing to incur present-day tax burdens to improve the future environment, particularly when this reduces environmental uncertainty and contributes to mitigating rising temperatures. Our findings are partly consistent with the findings of Richards and Green (2015), who show significantly lower discount rates for environmental concerns than those for financial concerns. However, our findings are in contrast to those of Viscusi et al. (2008) where time preferences are positive and present-biased. A possible clue for these contrasting findings can be found in the study of Richards and Green (2015).

Richards and Green (2015) distinguish not only between short-horizon environmental goods and long-horizon environmental goods but also between private-benefit environmental goods and public-benefit environmental goods. These distinctions enable them to find that discount rates for long-horizon environmental goods with a public benefit are significantly lower than for short-horizon environmental goods with a private benefit. Their finding may be useful in understanding why our results differ from those of Viscusi et al. (2008). Concerning the settings of the environmental policy choice questions, there are several important differences between our study and that of Viscusi et al. (2008). For instance, Viscusi et al. (2008) administer hypothetical environmental policy choices with respect to improvements in the water quality of lakes and rivers. These improvements are hypothesized to persist for five years. On the contrary, in our environmental policy choice questions, the environmental improvements are defined as a reduction in environmental pollution and the risk of natural disaster, which are associated more strongly with a public benefit than improvements in the water quality of lakes and rivers.[5] In addition, our questions state that after a policy takes effect, it continues for 10 years, far longer than the setting of Viscusi et al. (2008). The differences in these settings may partially explain the contrasting results.[6]

[5] In the experiments of Richards and Green (2015), improvements to park space and greenhouse gas abatement are used as examples of short-horizon environmental goods with a private benefit and long-horizon environmental goods with a public benefit, respectively.

[6] In Richards and Green (2015), investments in greenhouse gas abatement are discounted at a near-zero (0.005%) rate.

Appendix A Q1–Q10

Please select the appropriate number to indicate the extent to which each of the following 10 statements represents you. Read each statement carefully and then click the appropriate number rated on a five-point scale from 1 (not at all, not the case) to 5 (applies perfectly) as it relates to you. Choose the number that most closely matches your answer.

Q1. I often spend time on outdoor activities such as hiking, climbing, and fishing.

Q2. I don't know precisely what my monthly electricity costs are.

Q3. I always bring my own reusable cup or a water bottle when I go somewhere. I avoid disposable cups.

Q4. In the supermarket, I take a shopping bag with me instead of using disposable plastic bags.

Q5. I am not willing to dispose waste properly at home, that is to separate waste according to the rules in my local community.

Q6. I often participate in environmental conservation activities such as cleaning areas of arid land, cleaning beaches or waterways, or protecting rare animals, such as the Crested Ibis (Toki) Restoration Program.

Q7. I choose an energy-saving type when I purchase electrical appliances such as an air-conditioner or a refrigerator.

Q8. I don't think of habitat conservation as a cause close to me.

Q9. I buy refillable shampoo and detergent bottles.

Q10. I prefer environmentally friendly products for my daily needs.

Appendix B Q18

Insert Fig. A1.

Appendix C Q20

Insert Fig. A2.

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Table 1: Descriptive statistics

Variable	Obs.	Mean	Std. dev.	Min	Max
Participation in Outdoor Activities	2906	0.2646	0.4412	0.0000	1.0000
Pro-environmental Attitude	2906	0.0000	0.5221	-2.1861	1.4595
Male	2906	0.4818	0.4998	0.0000	1.0000
Age	2906	45.3617	12.6862	20.0000	65.0000
Marriage	2906	0.6487	0.4775	0.0000	1.0000
Having Children	2906	0.5420	0.4983	0.0000	1.0000
University Graduate	2906	0.5103	0.5000	0.0000	1.0000
Household Income (in JPY million)	2890	6.1576	4.1689	0.0000	25.0000
Pecuniary Discount Factor	2906	0.8757	0.1622	0.5000	1.0000
Present Bias for Money	2906	0.9726	0.1593	0.5000	2.0000
Long-run Discount Factor for Money	2906	0.9069	0.1373	0.5000	1.0000
Absolute Risk Aversion (x1000)	2906	0.0881	0.0848	-0.0471	0.1960
Ambiguity Aversion	2906	1.1401	1.9424	-7.0000	7.0000

Table 2: Conditional logit and mixed logit estimates of policy choices

	Variable	Conditional Logit Coefficient (Std. Error)		Mixed Logit Coefficient (Std. Error)	
(1)	Cost	-1.1337	(0.0249) ***	-2.3235	(0.0658) ***
(2)	Improvement Effect	0.0398	(0.0026) ***	0.0533	(0.0032) ***
(3)	Delay	-0.1661	(0.0098) ***	-0.3323	(0.0233) ***
(4)	Delay 0.5 Year x Improvement	0.0142	(0.0017) ***	0.0396	(0.0031) ***
(5)	Delay 1 Year x Improvement	0.0142	(0.0019) ***	0.0325	(0.0037) ***
(6)	Delay 2 Years x Improvement	0.0200	(0.0027) ***	0.0608	(0.0059) ***
(7)	Delay 3 Years x Improvement	0.0210	(0.0036) ***	0.0320	(0.0079) ***

Note: The dependent variable is coded 1 for a chosen policy, and 0 for the other policies in a given policy choice set. *** Statistical significance at the 1% level. ** Statistical significance at the 5% level. * Statistical significance at the 10% level.

Table 3: 95% Confidence intervals for the discount factors, rates of time preferences, δ, and β

Panel A: First survey

(1) Period	(2) Discount Factor		(3) Rate of Time Preference		(4) Delta		(5) Beta	
0-0.5 year	1.3573	(1.2413, 1.4733)	-0.2633	(-0.3262, -0.2003)	---	---	---	---
0-1 year	1.1644	(1.1101, 1.2186)	-0.1412	(-0.1812, -0.1012)	0.9988	(0.9361, 1.0616)	1.3589	(1.1992, 1.5186)
0-2 years	1.1072	(1.0746, 1.1397)	-0.0968	(-0.1233, -0.0702)	1.0345	(1.0100, 1.0589)	1.3121	(1.1995, 1.4247)
0-3 years	1.0731	(1.0469, 1.0992)	-0.0681	(-0.0908, -0.0454)	1.0238	(1.0032, 1.0445)	1.3258	(1.2154, 1.4361)

Panel B: Follow-up survey

(1) Period	(2) Discount Factor		(3) Rate of Time Preference		(4) Delta		(5) Beta	
0-0.5 year	1.2712	(1.1243, 1.4181)	-0.2133	(-0.3043, -0.1224)	---	---	---	---
0-1 year	1.1218	(1.0506, 1.1931)	-0.1086	(-0.1653, -0.0520)	0.9901	(0.8988, 1.0813)	1.2839	(1.0708, 1.4970)
0-2 years	1.0912	(1.0464, 1.1360)	-0.0836	(-0.1212, -0.0459)	1.0371	(0.9997, 1.0744)	1.2258	(1.0807, 1.3708)
0-3 years	1.0621	(1.0255, 1.0986)	-0.0584	(-0.0908, -0.0260)	1.0246	(0.9939, 1.0552)	1.2407	(1.1000, 1.3814)

Note: The 95% confidence intervals are in parentheses.

Table 4: Conditional logit estimates with the individual characteristics interactions

	Variable	Coefficient	(Std. Error)	
(1)	Cost	-1.1363	(0.0251)	***
(2)	Improvement Effect	0.0405	(0.0026)	***
(3)	Delay	-0.1643	(0.0098)	***
(4)	Delay 0.5 Year x Improvement	0.0030	(0.0048)	
(5)	x Pecuniary Discount Factor	0.0356	(0.0121)	***
(6)	x Risk Aversion	5.3012	(21.4790)	
(7)	x Ambiguity Aversion	0.0052	(0.0010)	***
(8)	x University Graduate	0.0141	(0.0033)	***
(9)	x Participation in Outdoor Activities	-0.0075	(0.0037)	**
(10)	x Pro-environmental Attitude	0.0157	(0.0031)	***
(11)	x Male	0.0089	(0.0034)	***
(12)	Delay 1 Year x Improvement	0.0114	(0.0047)	**
(13)	x Pecuniary Discount Factor	0.0349	(0.0120)	***
(14)	x Risk Aversion	-39.5604	(20.4438)	
(15)	x Ambiguity Aversion	0.0031	(0.0009)	***
(16)	x University Graduate	0.0069	(0.0031)	**
(17)	x Participation in Outdoor Activities	0.0017	(0.0035)	
(18)	x Pro-environmental Attitude	0.0049	(0.0029)	*
(19)	x Male	-0.0035	(0.0032)	
(20)	Delay 2 Years x Improvement	0.0143	(0.0060)	**
(21)	x Pecuniary Discount Factor	0.0324	(0.0149)	**
(22)	x Risk Aversion	6.3906	(25.8372)	
(23)	x Ambiguity Aversion	0.0037	(0.0011)	***
(24)	x University Graduate	0.0065	(0.0039)	*
(25)	x Participation in Outdoor Activities	-0.0065	(0.0043)	
(26)	x Pro-environmental Attitude	0.0055	(0.0036)	
(27)	x Male	0.0064	(0.0041)	
(28)	Delay 3 Years x Improvement	0.0188	(0.0062)	***
(29)	x Pecuniary Discount Factor	0.0346	(0.0150)	**
(30)	x Risk Aversion	9.0095	(24.7594)	
(31)	x Ambiguity Aversion	0.0026	(0.0011)	**
(32)	x University Graduate	0.0065	(0.0037)	*
(33)	x Participation in Outdoor Activities	0.0008	(0.0042)	
(34)	x Pro-environmental Attitude	-0.0025	(0.0035)	
(35)	x Male	0.0030	(0.0039)	
(36)	Control Variables Interacted with Delay x Improvement	Yes		

Note: The dependent variable is coded 1 for a chosen policy, and 0 for the other policies in a given policy choice set. Control (interaction) variables are not shown. Control (interaction) variables include age, marriage, child, income, pecuniary present bias parameter. *** Statistical significance at the 1% level. ** Statistical significance at the 5% level. * Statistical significance at the 10% level.

Table 5: OLS regression on individual characteristics using the mixed logit estimates

	Variable	0-0.5year Coefficient (Std. Error)			0-3years Coefficient (Std. Error)		
(1)	Pecuniary Discount Factor	0.5393	(0.1297)	***	1.0838	(0.3449)	***
(2)	Risk Aversion	-269.7636	(231.3039)		-752.2856	(614.9455)	
(3)	Ambiguity Aversion	0.0620	(0.0101)	***	0.1418	(0.0269)	***
(4)	University Graduate	0.1755	(0.0356)	***	0.4332	(0.0947)	***
(5)	Participation in outdoor Activities	-0.0910	(0.0388)	**	0.0275	(0.1031)	
(6)	Pro-environmental Attitude	0.1861	(0.0348)	***	0.6202	(0.0925)	***
(7)	Male	0.0586	(0.0366)		0.2653	(0.0974)	***
(8)	Constant	1.0414	(0.1886)	***	-0.2300	(0.5015)	***
(9)	Control Variables	Yes			Yes		

Note: The dependent variable is individuals' environmental discount factor estimated from the mixed logit model. Control variables are not shown. Control variables include age, marriage, child, income, pecuniary present bias parameter. In the case where the dependent variable is the environmental discount factor (0-0.5year), the environmental discount factor (0.5-3year) is added to the control variables. *** Statistical significance at the 1% level. ** Statistical significance at the 5% level. * Statistical significance at the 10% level.

Table 6: OLS regression on individual characteristics and expectation of future temperature changes using the mixed logit estimates

	Panel A: Shortest Horizon (0-0.5year Setting)						
		Model1			Model2		
	Variable	Coefficient (Std. Error)			Coefficient (Std. Error)		
(1)	Pecuniary Discount Factor	0.5815	(0.1828)	***	0.4035	(0.1749)	**
(2)	Risk Aversion	88.8067	(324.5667)		315.2736	(310.0381)	
(3)	Ambiguity Aversion	0.0635	(0.0140)	***	0.0526	(0.0134)	***
(4)	University Graduate	0.2026	(0.0510)	***	0.1614	(0.0488)	***
(5)	Participation in outdoor Activities	-0.1251	(0.0549)	**	-0.0912	(0.0524)	*
(6)	Pro-environmental Attitude	0.1547	(0.0505)	***	0.1279	(0.0482)	***
(7)	Male	0.0586	(0.0527)		0.0565	(0.0502)	
(8)	**Expected Change of Temperature**	**0.8931**	**(0.2700)**	***	**0.7544**	**(0.2577)**	***
(9)	Environmental Discount Factor (0-0.5year) of Follow-up Suvey				0.2622	(0.0221)	***
(10)	Constant	0.9408	(0.2667)	***	0.6280	(0.2556)	***
(11)	Control Variables	Yes			Yes		

	Panel B: Longest Horizon (0-3year Setting)						
		Model1			Model2		
	Variable	Coefficient (Std. Error)			Coefficient (Std. Error)		
(1)	Pecuniary Discount Factor	0.9901	(0.4883)	**	0.6633	(0.4689)	
(2)	Risk Aversion	-703.0850	(866.6482)		-88.4120	(832.3989)	
(3)	Ambiguity Aversion	0.1235	(0.0374)	***	0.1083	(0.0359)	***
(4)	University Graduate	0.4527	(0.1362)	***	0.3484	(0.1308)	***
(5)	Participation in outdoor Activities	-0.1282	(0.1466)		-0.0806	(0.1406)	
(6)	Pro-environmental Attitude	0.5793	(0.1349)	***	0.4563	(0.1298)	***
(7)	Male	0.3038	(0.1407)	**	0.2394	(0.1350)	*
(8)	**Expected Change of Temperature**	**1.4791**	**(0.7213)**	**	**0.8391**	**(0.6937)**	
(9)	Environmental Discount Factor (0-3year) of Follow-up Suvey				0.2992	(0.0268)	***
(10)	Constant	-0.5801	(0.7122)	***	-0.9079	(0.6832)	***
(11)	Control Variables	Yes			Yes		

Note: The dependent variable is the mixed logit estimate of individuals' environmental discount factor from the first survey. Control variables are not shown. Control variables include age, marriage, child, income, pecuniary present bias parameter. In the case where the dependent variable is the environmental discount factor (0-0.5year), the environmental discount factor (0.5-3year) is added to the control variables.
*** Statistical significance at the 1% level. ** Statistical significance at the 5% level. * Statistical significance at the 10% level.

Suppose that the government is planning an "Earth Is Our Friend" policy to improve the environment in your region.

The policy uniformly reduces the environmental risk from landslides and other natural disasters, and the environmental burden of air, water, and soil pollution.

Residents must pay the total costs (around JPY 20–36 billion) in the form of a special environmental tax over a period of **10 years from now onwards**.

The environment-improving effect of the policy continues for **10 years after it takes effect** .

There are alternative policies, which differ in (i) the rate of environmental improvement, (ii) the annual cost (tax) per household, and (iii) the delay before the environmental improvement begins.

Please indicate which of the three policies below you prefer.

	Policy A	Policy B	Policy C
the delay before the environmental improvement begins	3 years	1 year	2 years
the rate of environmental improvement	20%	5%	10%
the annual cost per household	JPY 3,600 per year	JPY 4,600 per year	JPY 5,100 per year
Which policy do you most prefer?	☐	☐	☐

Figure 1: Policy choices

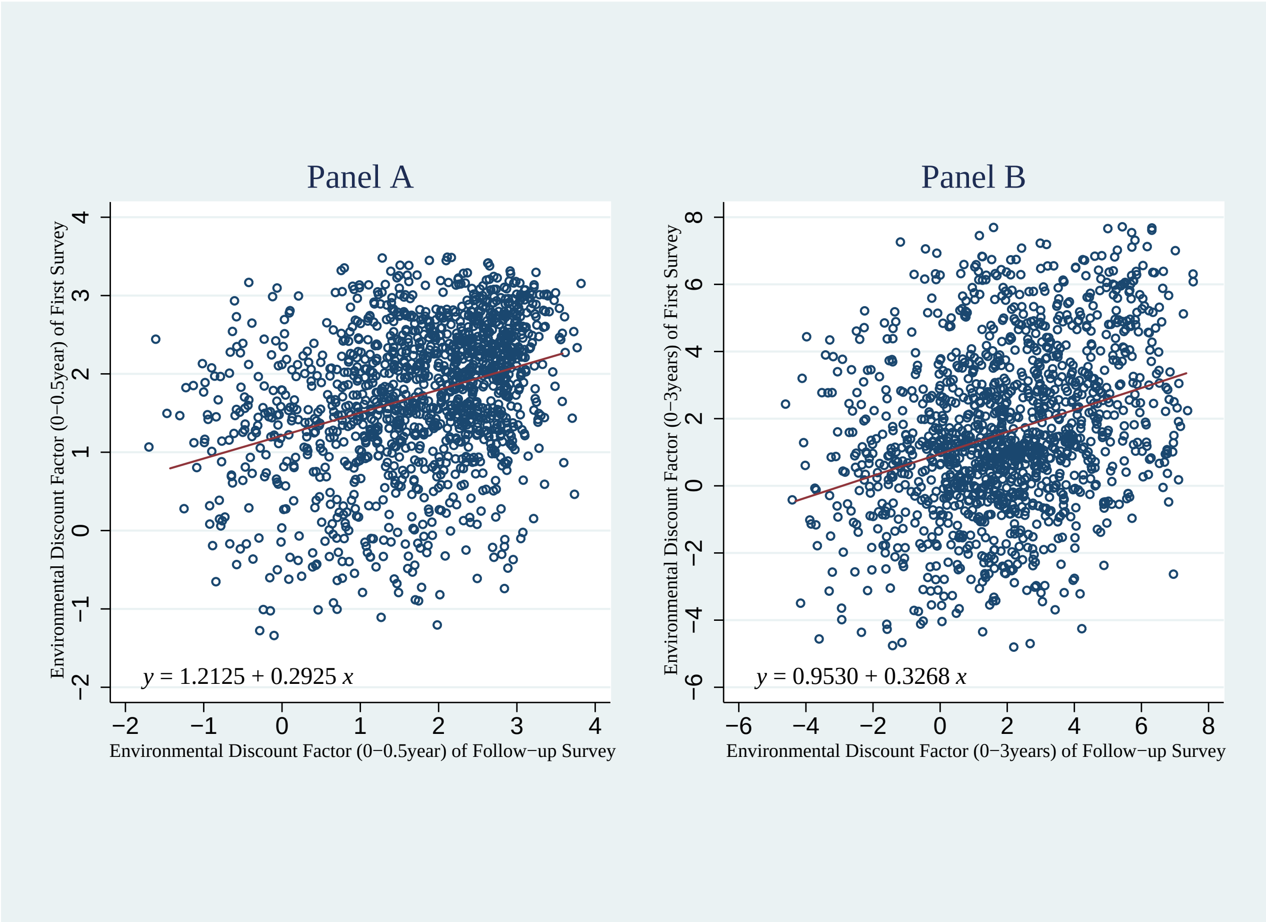
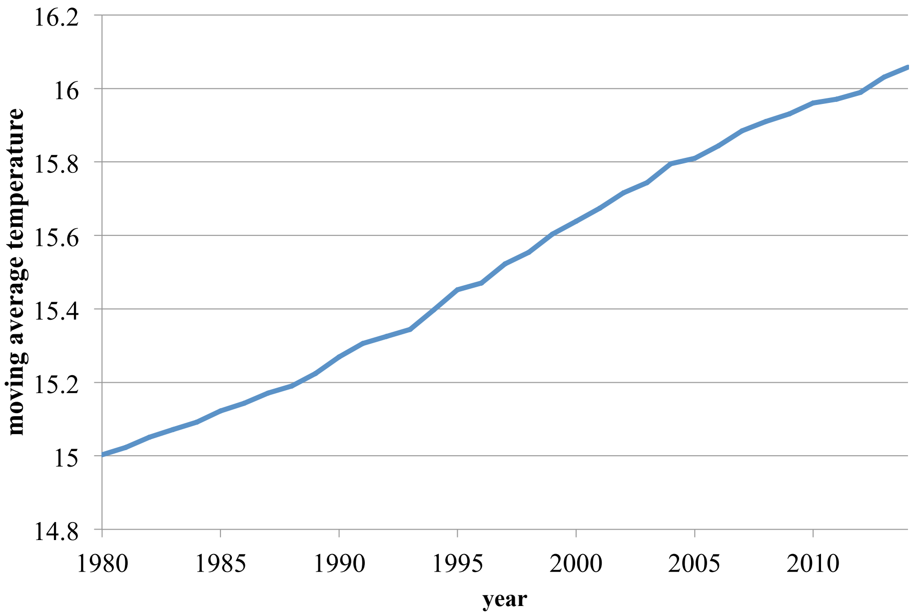


Figure 2: Jitter scatterplots of individuals' environmental discount factors between the first survey and follow-up survey

The following figure indicates the trend of the moving average temperature in Tokyo, which is a series of averages calculated by averaging the temperature over the past 50 years. According to the data, the moving average temperature has increased by 1.1°C (from 15.6°C to 16.1°C) over the past 35 years (1980–2014).

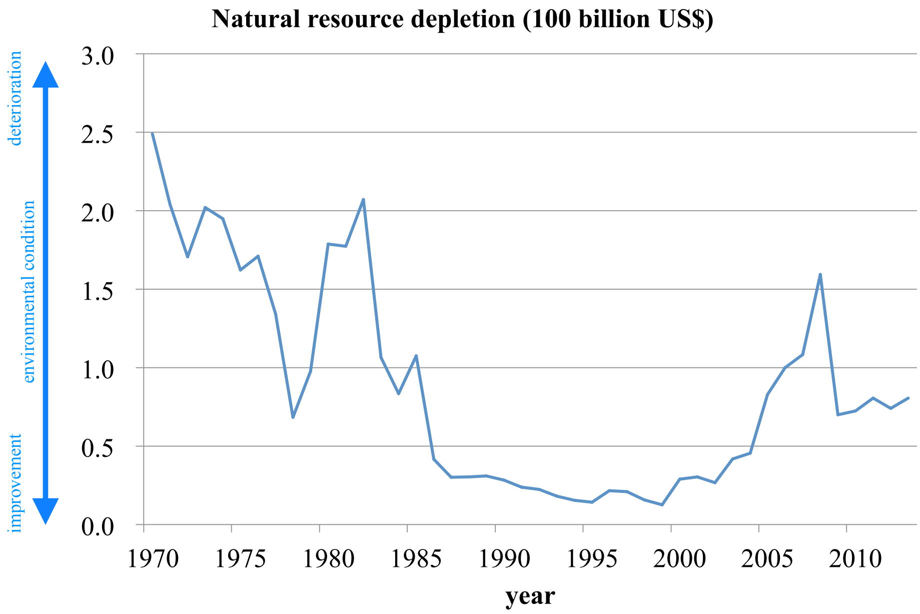


What would you predict the moving average temperature in Tokyo after 35 years to be? From the following nine answers, please choose the one that comes closest to your prediction.

- ☐ decrease by 4°C
- ☐ decrease by 2°C
- ☐ decrease by 1.1°C
- ☐ decrease by 0.5°C
- ☐ no change
- ☐ increase by 0.5°C
- ☐ increase by 1.1°C
- ☐ increase by 2°C
- ☐ increase by 4°C

Figure 3: AQ1

The following graph presents the value of natural resource depletion in Japan estimated by World Bank-published data gathered from around 200 countries and regions. Natural resource depletion, which is the sum of energy depletion, mineral depletion, net forest depletion, and carbon dioxide and local air pollution damage, is an indicator of environmental degradation developed by the World Bank. The data shown from 1970 to 2013 are reported in constant 2005 prices. Thus, you can compare the value in 1980 with the value in 2005 without worrying about the effect of inflation.

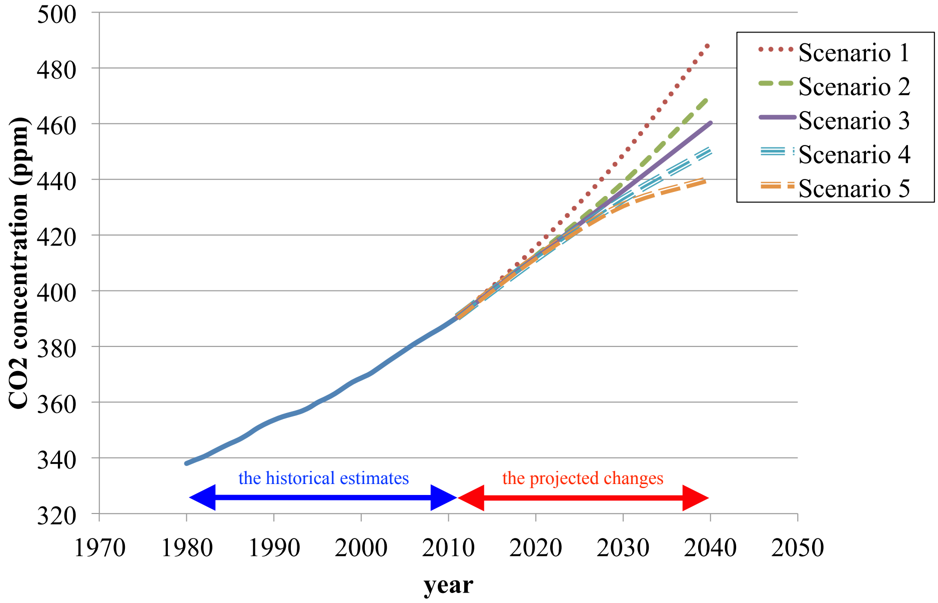


Please take a careful look at the graph below and answer the following question. What would you predict natural resource depletion to be after 2015?

- ☐ increase significantly
- ☐ increase
- ☐ no change
- ☐ decrease
- ☐ decrease significantly

Figure 4: AQ2

The solid line over the period between 1980 and 2011 shows the historical estimates. The five lines show the projected changes in CO2 concentration over the period between 2012 and 2040 for each of the five emissions scenarios. This graph shows the projections from our original scenarios using data published in the Fifth Assessment Report (Climate Change 2013) WGI: The Physical Science Basis of IPCC.



From the following five scenarios, please choose the one that comes closest to your prediction.

- ☐ Scenario 1
- ☐ Scenario 2
- ☐ Scenario 3
- ☐ Scenario 4
- ☐ Scenario 5

Figure 5: AQ3

Q18 (Question on discount rates for immediate future)
Which one do you prefer? Choose the one you prefer.

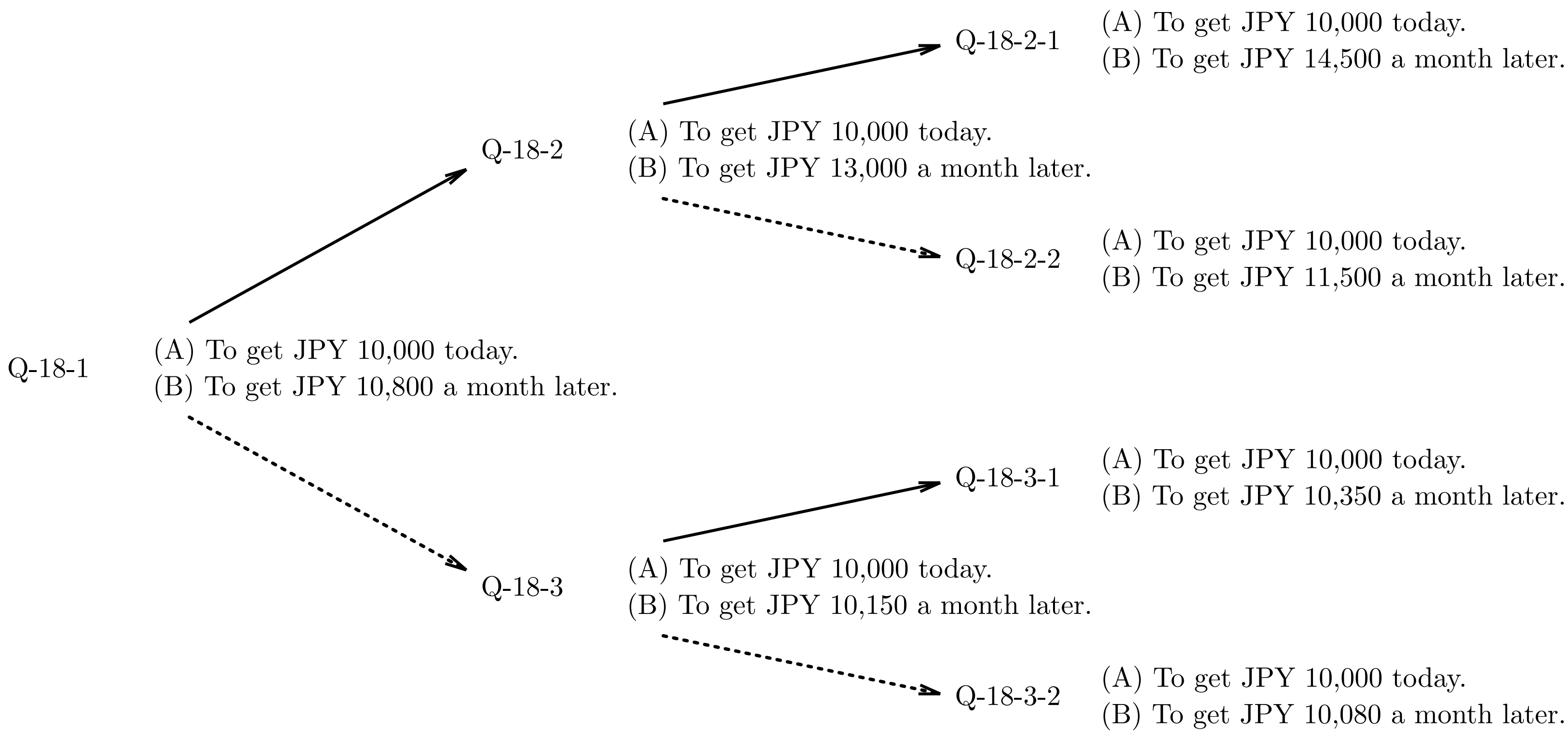


Figure A1: Q18

Q20 (Question about a lottery that offers a prize of JPY 10,000 when the composition of the urn is known)
Which one do you prefer? Choose the one you prefer.

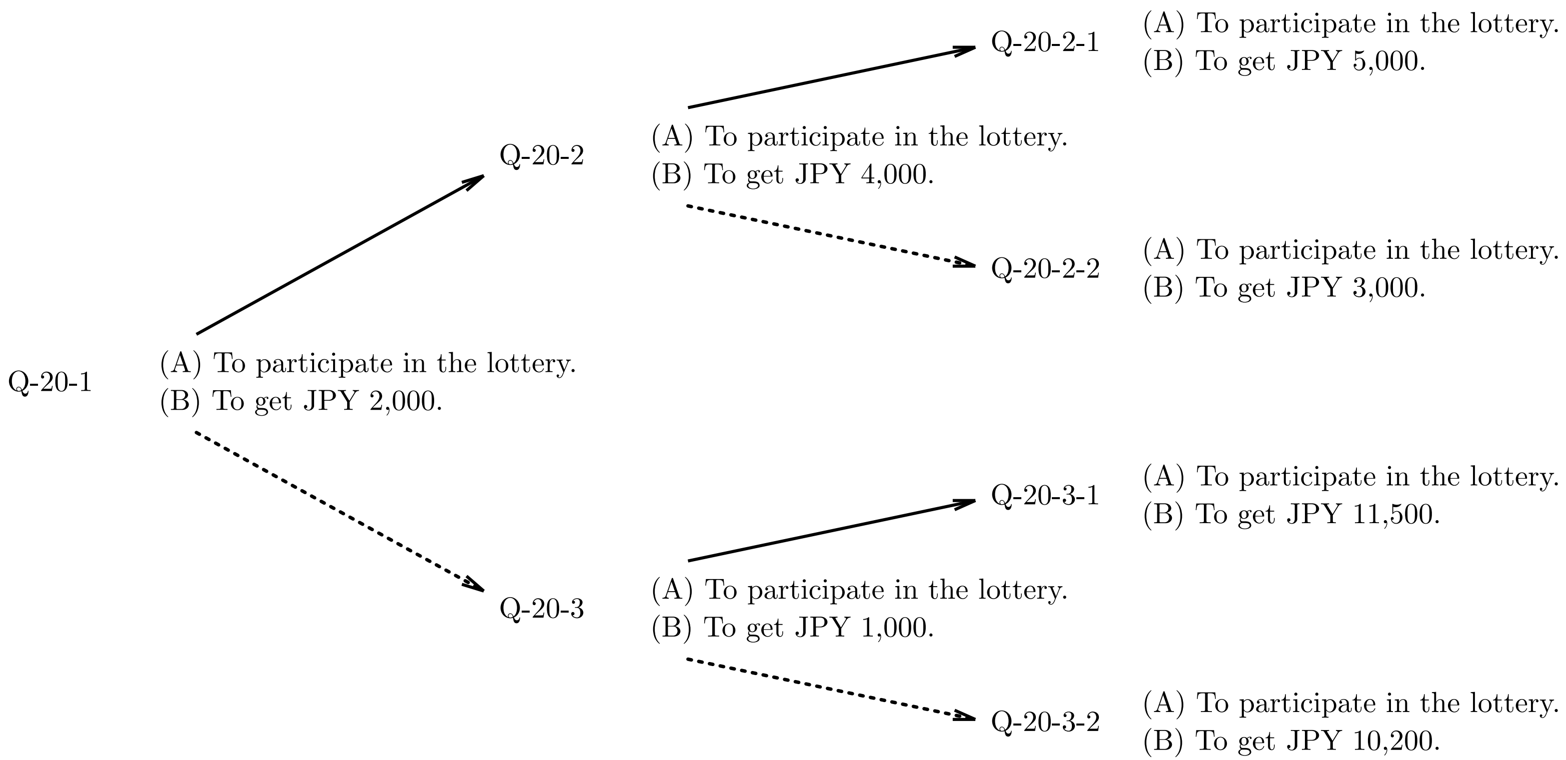


Figure A2: Q20