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Discounting Environmental Goods

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Understanding individual discounting behavior of future costs and benefits is critical for designing environmental policy. Although there is some empirical evidence of hyperbolic discounting, others have found that exponential discounting is more accurate when behavioral factors are properly considered. Further, there is little research on how environmental discount rates differ from monetary rates. We use experimental methods to determine how individuals discount monetary and environmental goods. Our findings suggest that individual discounting behavior is approximately exponential, environmental goods are discounted at lower rates than monetary goods, and discount rates vary widely across environmental goods when accounting for appropriate behavioral factors.

Key words: experimental analysis, exponential discounting, hyperbolic discounting

Introduction

Understanding how individuals discount future costs and benefits is necessary for developing effective environmental policy. Two key questions regarding the nature of discounting when applied to environmental goods must be considered: i) what rate to use, and ii) is the discount function exponential or hyperbolic? Some argue that environmental goods should be discounted at lower rates than market goods because they are unique, with few substitutes, and provide intergenerational benefits relative to market goods (Hepburn, 2007). Others maintain that market rates should be used because they reflect social preferences (Boardman et al., 2010). Further, a large body of experimental research suggests that individuals discount hyperbolically (Frederick, Loewenstein, and O'Donoghue, 2002). However, some studies have found the exponential model to be more representative of discounting behavior (Andersen et al., 2008; Andreoni and Sprenger, 2012a). In this paper, we use experimental methods to examine discounting behavior for environmental and monetary goods over a range of planning horizons. Our intention is to better understand discounting behavior regarding environmental goods relative to monetary goods, not to determine what discount functions and rates should be applied to environmental policy. There are several important concerns for justifying differential discount rates between environmental and monetary goods, but we focus here on examining individual discounting behavior.

The standard approach for discounting future costs and benefits is to apply the exponential discount function with a market-based discount rate (Boardman et al., 2010); however, opinions vary widely on the proper discount rate for environmental goods (Mehra and Prescott; Moore et al., 2004). Some argue that the discount rate for environmental goods should be lower than that for market goods (Arrow et al., 1996; Weitzman, 2001), while others argue they should be higher (Nordhaus, 1994; Gattig and Hendrickx, 2007). In addition to technical considerations, there are substantial ethical concerns when selecting the discount rate because it impacts the distribution of

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costs and benefits across generations (Stern, 2006).[1] We use experimental methods to examine the issue of whether individuals discount monetary and environmental goods differently by estimating discount rates for different types of goods within the same sample of individuals.

Behavioral research examines the practice of using the same discount rate across all domains (i.e., monetary, environmental, health, etc.), testing whether discount rates are domain specific (Chapman, 1996; Hardisty and Weber, 2009; Weatherly, Terrell, and Derenne, 2010). In general, studies find that goods from different domains are not discounted at the same rates, which suggests that people value goods across domains differently over time. Other studies examine intertemporal choices for environmental goods with an aim of better understanding individuals' implied discounting behavior for public goods (e.g., Svenson and Karlsson, 1989, radioactive waste; Nicolaij and Hendrickx, 2003, greenhouse gases; Hendrickx and Nicolaij, 2004, soil and water pollution; Bohm and Pfister, 2005, water pollution; Viscusi, Huber, and Bell, 2008, water quality). However, each of these studies examines discounting for a specific environmental good using different samples and methodologies, so there is no direct comparison between discounting market and environmental goods. We estimate discount rates for monetary goods and several environmental goods within the same experiment, allowing a direct comparison across different types of goods.

Regardless of the appropriate rate, whether empirical discount functions are hyperbolic or exponential remains a key question in the policy literature (Phelps and Pollak, 1968; Loewenstein and Prelec, 1992; Laibson, 1997; Prelec, 2004). While some studies find that individual discounting behavior is more hyperbolic, or quasi-hyperbolic, than exponential in structure (Frederick, Loewenstein, and O'Donoghue, 2002; Benhabib, Bisin, and Schotter, 2010), others find the exponential discounting model to be more accurate if confounding factors, diminishing marginal utility, and uncertainty of payment are properly accounted for (Andersen et al., 2008; Andreoni and Sprenger, 2012a,b; Meyer, 2013; Andersen et al., 2014). This study follows the recent literature by controlling for these features while examining discounting behavior for monetary and environmental goods.

Heterogeneity in individual behavior represents an additional source of variation in discounting behavior that is rarely considered. We explicitly control for individual heterogeneity by employing a random-parameter model framework (Greene, 2004; Train, 2009), which allows us to estimate individual-specific discount rates while holding other potentially confounding factors constant.

We estimate empirical discount rates for three types of environmental goods (park restoration, improvements in water quality, and reductions in carbon emissions) and monetary rewards using an incentive-compatible, multiple price list (MPL) experimental approach (Kahneman, Knetsch, and Thaler, 1990; Coller and Williams, 1999; Andersen et al., 2006). By comparing discounting behavior across all types of reward, elicited using the same approach from the same sample of individuals, we are able to cleanly disentangle the effects of domain, risk, and timing on empirical discount rates.

An Economic Model of Environmental Discounting

Theoretical Background

We model intertemporal choice by comparing the utility of benefits, either from monetary or environmental goods, in the current period to the discounted utility of receiving an indifference benefit at time t in the future:

$$U_i(x) = D_i(t)U_i(y_t), \tag{1}$$

where $D_i(t)$ is individual i's discount function, $U_i(\cdot)$ is the utility over benefits, x indicates the benefits received in the current period, and y_t is the indifference value received at time t in the future.

[1] Regardless of the rate, there is also some question as to whether it should stay constant or decline over the life of the project (Zhuang et al., 2007; Arrow et al., 2014).

We are primarily interested in studying the structure of $D_i(t)$ while accounting for the curvature of $U_i(\cdot)$. The exponential discount function is represented by

$$D_i(t) = \exp(-\delta_i t),\ \delta_i > 0, \tag{2}$$

where δ_i is the individual's exponential discount rate.

In addition to being parsimonious, the exponential discount function has the added benefit of being time consistent, implying that an individual chooses a particular path of consumption and maintains that path over time. Hyperbolic discount functions, however, imply time inconsistency, with the result that current choices made between today and tomorrow may be reversed when considering the same choice at some future date, say 1 year and 1 year and a day from now, *ceteris paribus*.

Though there are many ways to represent hyperbolic discounting mathematically (Doyle, 2013), the main feature is that the discount rate declines over time. We use a form derived by Prelec (2004) that nests exponential discounting as a special case:

$$D_i(t) = \exp(-\delta_i t^{\alpha}),\ \delta_i > 0,\ \text{and}\ \alpha > 0, \tag{3}$$

where α measures the departure of discounting from exponential and hyperbolic discounting is implied when $\alpha > 1$.[2] We also include a variable-cost component, τ, that allows the model to capture an individual who distinguishes sharply between time 0 and all future times—often referred to as quasi-hyperbolic discounting (Laibson, 1997; O'Donoghue and Rabin, 1999). Specifically, τ multiplies the exponential discount function and so does not impact discounting at time $t = 0$ but increases discounting over time for $0 < t$.

Empirical Model

In modeling equation (1), we assume that $U_i(\cdot)$ allows for curvature of the utility function, thus combining equations (1) and (3); adding the variable-cost component τ gives

$$x_i^r = y_i^r D(\mathbf{z_i},\ t;\ \tau,\ \delta_i,\ \alpha) = y_i^r \tau \exp(-\delta_i t^{\alpha})\varphi(\varepsilon_i), \tag{4}$$

where x_i is the promised benefit for the particular question for individual i, y_i is the subject's indifference value, r is a utility curvature parameter that converts x and y to utility, $D(\bullet)$ is the discount function, t is the number of days over which the subject is being asked to discount (defined as a proportion of a year), $\mathbf{z_i}$ is a vector of subject attributes, δ_i is the discount rate, α measures the departure of discounting from exponential, τ is a variable-cost component that also measures the departure from exponential discounting, and $\varphi(\varepsilon_i)$ represents the random component of the model, which is introduced to address the heterogeneity that is common across individual discounting behavior (Andersen et al., 2008; Andreoni and Sprenger, 2012a).

The random components of the model are assumed to reflect both observed and unobserved heterogeneity, such that $\delta_i \sim N(\mathbf{z_i}'\delta_i,\ \sigma_\delta)$ and ε_i is an unobserved random effect $\varepsilon_i \sim N(\mu_\varepsilon,\ \sigma_\varepsilon)$. Because individual-level discount functions are likely to contain a large amount of both observed and unobserved heterogeneity, we employ a random-parameters specification to allow the discount rate to depend on a set of demographic and behavioral variables, $\mathbf{z_i}$, as well as a purely random effect (Train, 2009). As a result, the model is able to test whether observed individual-level characteristics, behaviors, and heterogeneity are associated with different discount rates, which makes the function in equation (4) ideally suited to testing the pattern of discounting for environmental goods (Greene, 2004).

Equation (4) is estimated for monetary and environmental goods using simulated maximum likelihood (SML), which is necessary given the random-parameters assumption described above.

[2] Other models of hyperbolic discounting were examined; however, because they are generally nested within model (3) we do not include them. These are fully discussed in Doyle (2013).

Table 1. 1-Month vs. 3-Month Time Horizon

Question	Payment Option A (1 month)	Payment Option B (3 months)	Interest Rate (%)
1	$20	$20.10	2
2	$20	$20.25	5
3	$20	$20.48	10
4	$20	$20.71	15
5	$20	$20.93	20
6	$20	$21.15	25
7	$20	$21.56	35
8	$20	$21.95	45
9	$20	$22.32	55
10	$20	$22.84	70
11	$20	$23.33	85
12	$20	$23.78	100

With this specification, however, it was not possible to estimate the curvature parameter in the same SML optimization as the other parameters. Consequently, we use a two-stage procedure that estimates the curvature parameter r and time sensitivity parameter α using nonlinear least squares in the first stage (Richards and Green, 2015). The remaining parameters are estimated with SML in the second stage, conditional on the estimated values of r and α.

Experiment

We conducted a time-value elicitation experiment using 108 graduate and undergraduate students from Seattle University. The model is estimated on the responses of 93 students because 15 respondents did not complete the survey. The online survey had three sets of questions—demographic and behavioral, timing of monetary payments, and timing of environmental quality improvements—which were presented to participants in a random order. The demographic and behavioral questions gathered data on individual characteristics, environmental preferences, and present-bias behavior to determine the degree to which respondents' characteristics and behavior relate to their discounting behavior.

The monetary and environmental questions employed a multiple price list (MPL) procedure, which has been used with excellent results in numerous studies to elicit discount rates (Andersen et al., 2006; Coller and Williams, 1999; Andreoni and Sprenger, 2012a). The survey carefully explained that monetary payments would be based on a random draw from one of their choices, so it would be in their best interest to select dollar values based on their preferences. In doing so, the survey ensures that the experimental design is incentive compatible (Carson and Groves, 2007). All respondents completed the same monetary MPL instrument. The MPL monetary questionnaire implicitly assumes that the indifference value can be inferred from the responses by identifying when the subject switches from the early period value (1 month) to the future period value (3, 6, 12, 18, or 24 months). Each respondent completed five MPL tables, one for each delay (see Table 1 as an example).

Environmental policy is long run in nature, making it difficult to evaluate using experimental methods. To examine discounting behavior for benefits occurring in the future—like those for environmental projects—it was important for survey respondents to face a similar level of uncertainty across the range of benefits they would receive (Camerer, 1992; Harless and Camerer, 1994; Starmer, 2000). We used a 1-month front-end delay to account for uncertainty across all intertemporal choices (Andersen et al., 2008, 2014; Harrison, Lau, and Williams, 2002); that is, subjects had to wait *at least* 1 month before being compensated for all choices in the experiment. Although short relative to benefits from environmental projects, waiting for 1 month or more to receive benefits from an experiment reduces the "passion for the present" found in many studies (Andersen et al., 2008, 2014). Further, benefits from environmental improvements are generally not immediate, so the front-end delay is consistent with public policy analysis (Meyer, 2013). We included a front-end delay for both the monetary and environmental MPL questions, so the results are comparable.

Elicitation questions for environmental goods used the same MPL framework as those for monetary rewards. Subjects were randomly assigned into one of three treatments representing a different type of environmental good: short-horizon, private-benefit (SV); short-horizon, public-benefit (SB); or long-horizon, public-benefit (LB). Each good was selected to be slightly different in either or both time horizon and the degree of private and public benefit. This design ensured that subjects could make consistent choices across good types. Once the subjects were placed in treatment groups, we provided information about the specific environmental good they would be evaluating.

The first treatment used park restoration to examine whether SV environmental goods and monetary goods are discounted at different rates. We selected public parks because they provide private benefit, similar to monetary goods, yet also provide substantial public benefit and can be developed in a relatively short period of time. Comparing the discount rates from these two goods indicates how people discount a public good with private benefits relative to a pure private good.

The second treatment used improvements in water quality from reducing storm-water runoff to examine whether SB and SV environmental goods are discounted at different rates. We used a regional body of water—Puget Sound—an example of improvement in water quality from storm-water runoff reductions. Reducing storm-water runoff in Puget Sound, which is not used for drinking or significant recreation (other than viewing), is primarily a public good. The second treatment compared discounting behavior for SV and SB goods; though the relatively short time horizon is similar, the degree of private benefit is the primary difference. Unfortunately, differences in the familiarity with, uncertainty about, and scope of these two environmental goods may weaken the claims we can make regarding the results because survey respondents only read the description of the environmental treatment good for their own group and so could not make comparisons across SV and SB goods.

The third treatment used reductions in carbon emissions as an improvement in environmental quality to elicit discount rates for LB goods. Carbon reductions allow us to compare discounting behaviors for SB and LB goods, which are different primarily because of time horizon; however, there may also be a difference in participants' familiarity with, uncertainty about, and scope of these two environmental goods.

Appendix A provides the descriptions of each resource given to survey respondents. Existing research indicates that we should expect participants to discount benefits more heavily if they benefit other individuals (Hardisty and Weber, 2009) and to discount longer-term goods at a lower rate (Weitzman, 1998). As such, we would expect SV goods to be discounted less than SB goods (due to the difference in who receives the benefit) and LB goods to be discounted at a lower rate than SB goods (due to the timing of benefits). It is unclear how SV goods will be discounted relative to LB goods. Using these types of environmental goods allows us to directly compare goods with different characteristics[3] as well as compare environmental and monetary goods.

The MPL environmental questions were designed to be incentive compatible, similar to the monetary questions. Respondents were informed that a donation would be made in their name to a nonprofit organization to achieve the stated amount of physical improvement they selected from the MPL tables. After this explanation, the respondent selected from a number of quantities of the environmental good at different time delays. Each environmental treatment described improvements

[3] Kahneman and Knetsch (1992) raised the issue of whether responses to environmental valuation surveys reflect willingness to pay for the moral satisfaction of contributing to public goods rather than the economic value of the goods. We feel the distinction is not critical in this application as we are interested in the relative response to different goods, not the absolute value necessary for estimating willingness to pay.

Table 2. 1-Month vs. 12-Month Time Horizon, Quantity for $20 Donation

Question	Quantity Option A (1 month)	Quantity Option B (12 months)	Interest Rate (%)
1	33.0 sq. ft.	33.7 sq. ft.	2
2	33.0 sq. ft.	34.7 sq. ft.	5
3	33.0 sq. ft.	36.3 sq. ft.	10
4	33.0 sq. ft.	38.0 sq. ft.	15
5	33.0 sq. ft.	41.3 sq. ft.	25
6	33.0 sq. ft.	44.6 sq. ft.	35
7	33.0 sq. ft.	47.9 sq. ft.	45
8	33.0 sq. ft.	52.8 sq. ft.	60
9	33.0 sq. ft.	57.8 sq. ft.	75
10	33.0 sq. ft.	66.0 sq. ft.	100

in terms of physical quantity: square feet for park restoration, cubic meters for water quality improvements, and metric tons for carbon reduction. Each treatment group had three time delays (6, 12, and 24 months) and three donation levels ($20, $30, and $40). The environmental MPL questions depended on the same implicit assumption as the monetary questions: that the subject would be able to identify a specific improvement quantity that they are indifferent to receiving in the future (6, 12, or 24 months) relative to the base quantity in 1 month. Each subject completed six MPL tables for the environmental good in their treatment group (see Table 2 for an example).

The quantities respondents selected in the MPL were denoted in physical units, and subjects' beliefs were anchored regarding the financial implications of the donation by varying the donation levels. We specifically wanted respondents to think in terms of the physical quantity of environmental goods rather than a stated monetary value since environmental goods are not traded directly in markets. We used this approach to encourage respondents to respond in terms of their utility from environmental goods rather than their utility from money. Our goal was to test whether respondents valued environmental goods that are not traded in a market similarly to monetary goods that are. Thus, if we find environmental discount rates that are similar to monetary discount rates, we can be more confident that the different types of goods are treated in a similar manner than if we were to find similar discount rates for the stated monetary values of each. That is, if instead we were to frame the experiment in terms of dollar amounts for environmental and monetary goods, we would be less confident the results were due to the type of good rather than both being measured in monetary units.

The cost and quantity of physical improvement for each environmental good was based on information received from the nonprofit organizations. For example, the Seattle Parks Foundation—the nonprofit organization we reference for public park improvements—provided cost estimates of $30 per square foot for improving public parks. The Puget Soundkeeper Alliance and the Bonneville Environmental Foundation—the nonprofit organizations for water quality improvements and reductions of carbon emissions—provided similar cost figures. We also provided respondents with a link to the nonprofit's website, with detailed information provided in the survey so that students could verify the validity of the nonprofit and the environmental good. Including this information is intended to reinforce the understanding that the donation was being made to the nonprofit in the respondent's name to enhance the incentive compatibility of the survey instrument (see Appendix A for descriptions of each environmental good provided in the survey).

We pilot-tested the survey multiple times for all goods and chose many increments to minimize the interval problem typical of MPL studies (Coller and Williams, 1999; Harrison, Lau, and Williams, 2002; Andersen et al., 2006). We selected maximum and minimum choice values to be within the bounds suggested by the pilot-survey data for monetary and environmental goods. Because the range of responses offered lies within the pretest range, it is unlikely the sample subjects would want to make choices outside of the sample range.

Table 3. Descriptive Statistics

Variable	Mean	Std. Dev.
Park restoration[a]	0.381	0.486
Carbon reduction[a]	0.317	0.466
Age	29.222	9.507
Male[a]	0.370	0.444
Sacrifice for the environment[a]	0.603	0.489
Days/week use parks (98% use parks)	1.134	2.786
Hours/year volunteer for env. cause (31% vol)	0.736	2.334
Gov. address climate change[a]	0.810	0.393
Drinks/week	2.254	0.908
BMI	23.449	5.194

Notes: [a] Units 0/1, yes = 1.

We selected individual characteristics to explain discounting behavior based on standard demographics, environmental behavior, and previous discounting studies, as shown in Table 3. Though a broad range of characteristics was gathered, many had to be eliminated due to lack of variation or multicollinearity, as discussed below. There was a relatively even distribution of students participating in each environmental good treatment group, ranging from 30% for water quality restoration (the base variable) to 38% for park restoration. The sample is typical of an undergraduate and graduate student population, with a mean age of 29.2 years and a minority of 37% male students. Our campus is roughly 40% male and 60% female. We eliminated standard demographic variables like education and income because they were highly correlated with age, which is not surprising for a population of undergraduate and part-time graduate students. Though our sample is ethnically diverse, we had no theoretical or empirical reason to include race variables.

A number of environmental-behavior variables are included: whether the person regularly makes sacrifices to reduce pollution, the number of days per week they use parks, the number of hours per year spent volunteering for environmental causes, and whether the respondent believed the government should commit resources to reducing climate change relative to other social concerns.[4] We also included variables that have been included in other discounting studies relating obesity and drinking to present-bias behavior (Tu et al., 2004; Richards and Hamilton, 2012). We included Body Mass Index and alcohol consumption to determine whether our sample's behavior was consistent with that of participants in those studies. Our sample consumed an average of 2.25 drinks per week (low relative to other student surveys) and has an average body mass index (BMI) of 23.45, around the 50th percentile for women and men combined. Though we gathered additional demographic and environmental data, there was either not enough variation or significant multicollinearity, so these variables were not included.

Findings

The primary questions we address are i) whether individual discount functions and rates differ between monetary and environmental goods, ii) whether and how they differ across environmental goods, and iii) how individual characteristics influence discounting behavior across different types of environmental goods. These questions are addressed by estimating the model in equation (4) across monetary rewards and three environmental good treatment groups.[5]

[4] These behavioral variables have very low correlation with each other, which makes us confident that they capture different types of individual behavior.

[5] The model in equation (4) encompasses models (1)–(3). Equations for other hyperbolic models were examined but not included because the hyperbolic parameters were small and insignificant, indicating that discounting behavior is not hyperbolic, and the other estimated coefficients were similar to results found in Tables 4 and 5. Results are available upon request from the authors.

Table 4. Monetary and Combined Environmental Good Results

	Monetary		Combined Environmental	
Variable	**Estimate**	**Std. Err.**	**Estimate**	**Std. Err.**
r – utility curvature	0.988***	0.023	0.995***	0.016
α – departure from exp.	0.972***	0.039	0.986***	0.030
First-stage LLF and obs.	−989	$n = 93$	−1,386	$n = 93$
τ – variable cost	1.039	1.011	1.014	1.012
δ – discount rate[a]	−0.151***	0.022	−0.103***	0.019
σ_δ – std. dev. discount rate	0.065***	0.004	0.060***	0.003
Park restoration			0.040***	0.007
Carbon reduction			0.013*	0.007
Age	0.001	0.000	−0.001*	0.000
Male	0.056***	0.008	0.001	0.006
Sacrifice for environment	−0.032***	0.007	−0.022***	0.006
Days/week park use	0.001	0.001	0.001	0.001
Hours/year vol. env. cause	−0.003*	0.002	0.006***	0.001
Gov. add. climate change	−0.024***	0.009	−0.024***	0.007
Drinks/week	−0.011***	0.004	−0.023***	0.003
BMI	−0.003***	0.001	−0.003***	0.001
Standard deviation	0.298***	0.003	0.307***	0.001
Second-stage LLF	−1,232		−2,078	
Wald coefficient	−0.143***	0.024	−0.090***	0.020

Notes: Single, double, and triple asterisks (*, **, ***) indicate statistical significance at the 10%, 5%, and 1% level.
[a] Negative signs on the discount rates come from the structure of the model; they do not indicate negative discount rates.

Discount Functions and Rates

Estimating equation (4)—which nests the exponential, hyperbolic (Prelec, 2004), and quasi-hyperbolic (Laibson, 1997) models—makes it possible to compare the discount functions directly. In the following discussion, we discuss two sets of results. First, we compare monetary goods and all environmental goods combined, as shown in Table 4. In this case, the different environmental goods are captured by a dummy variable with storm water reductions as the base. Second, we compare the individual environmental goods, as shown in Table 5. We take this approach because previous research indicates that people may discount classes of goods differently from individual goods (Chapman, 1996; Hardisty and Weber, 2009). A two-stage approach is used for each model, first estimating the curvature and time-sensitivity parameters and then estimating the random-parameter model with robust standard errors. Variables include a variable-cost component to test quasi-hyperbolic discounting, time delay to estimate the discount rate, individual characteristics, and heterogeneity parameters.

Table 4 indicates that the monetary and combined environmental models, and the stages of each model, perform well based on the log-likelihood functions (LLF) and statistical significance of individual variables. Interestingly, the estimates for monetary goods and the combined environmental goods are similar and close to exponential discounting. That is, in both models, α and τ are not statistically different from 1, indicating the models are effectively exponential. Specifically, α is slightly less than 1 in both models, indicating time insensitivity, which is the opposite of hyperbolic. Further, though results indicate that $\tau > 1$, indicating time insensitivity, it is not statistically different from 1, so discounting is not quasi-hyperbolic.

Table 5. Individual Environmental Good Results

	Park Restoration		Storm Water Reduction		Carbon Reduction	
Variable	**Estimate**	**Std. Err.**	**Estimate**	**Std. Err.**	**Estimate**	**Std. Err.**
r – utility curvature	0.995***	0.029	0.996***	0.027	0.994***	0.029
α – departure from exp.	0.986***	0.054	0.989***	0.047	0.984***	0.052
First-stage LLF and obs.	−477	$n = 35$	−477	$n = 28$	−465	$n = 30$
τ – variable cost	1.010	1.020	1.020	1.034	1.012	1.018
δ – discount rate[a]	−0.042	0.035	−0.333***	0.097	−0.086**	0.034
σ_δ – std. dev. discount rate	0.057***	0.005	0.004	0.005	0.042***	0.005
Age	−0.001**	0.001	0.000	0.001	0.005***	0.001
Male	−0.014	0.010	0.043	0.032	0.020	0.013
Sacrifice for environment	−0.076***	0.011	−0.022	0.020	−0.055***	0.013
Days/week park use	0.009***	0.003	0.001	0.003	0.008***	0.002
Hours/year vol. env. cause	0.015***	0.003	0.038	0.056	0.006***	0.002
Gov. add. climate change	−0.031**	0.015	−0.006	0.024	−0.180***	0.017
Drinks/week	−0.056***	0.006	0.027	0.018	−0.037***	0.006
BMI	−0.001	0.001	−0.000	0.006	−0.002*	0.001
Standard deviation	0.304***	0.002	0.314***	0.007	0.303***	0.002
Second-stage LLF	−748		−660		−632	
Wald coefficient	−0.166***	0.034	−0.246*	0.132	−0.141***	0.038

Notes: Single, double, and triple asterisks (*, **, ***) indicate statistical significance at the 10%, 5%, and 1% level.
[a] Negative signs on the discount rates come from the structure of the model; they do not indicate negative discount rates.

Given the general consensus from the behavioral literature indicating that individuals discount hyperbolically (Frederick, Loewenstein, and O'Donoghue, 2002; Hardisty and Weber, 2009; Benhabib, Bisin, and Schotter, 2010), finding exponential discounting is surprising. However, exponential discounting is consistent with studies that have used a front-end delay and account for curvature of the utility function (Andersen et al., 2008, 2014), so it could be that the findings that support hyperbolic discounting are an artifact of differing levels of uncertainty across time-delay choices and not accounting for curvature of the utility function. Examining our results more closely, it is evident that the curvature parameter r is not statistically different from 1. Consequently, the front-end delay is likely the largest driver of exponential discounting found in this study, which could indicate that discounting behavior is more likely to be hyperbolic for very-near-term decisions and more likely exponential for longer-term decisions.

The discount rate for monetary goods is higher than that for environmental goods—15% compared to 10%—and both are statistically significant at a similar level. These discount rates account for, but do not include, the impact of individual characteristics. A Wald test is used to estimate the full discount rate, including the individual characteristics, shown at the bottom of Table 4. Here, results show that the discount rates for the monetary and environmental goods are quite different, 0.14 and 0.9, respectively. This difference is inconsistent with existing research (Hardisty and Weber, 2009) and could be due to our experimental method of using different units for monetary and environmental goods. For the monetary good we used dollars, but for environmental goods we used physical quantities of the environmental good. This approach was used to capture the difference in utility from money versus utility from the environmental goods.

Further, the discount rates found here are lower and more consistent with market rates than those found in previous research. This finding indicates environmental discount rates are statistically lower than monetary discount rates by around 50% if individual characteristics are accounted for.

Table 6. Discount Rates Difference *t*-Tests

Comparison of Goods	Difference	*t*-Ratio
Monetary vs. combined environmental	−0.049*	−1.680
Monetary vs. park restoration	−0.110***	−2.656
Monetary vs. storm water reduction	0.182*	1.828
Monetary vs. carbon reduction	−0.065*	−1.622
Park restoration vs. storm water reduction	0.291***	2.825
Park restoration vs. carbon reduction	0.044	−0.914
Storm water reduction vs. carbon reduction	−0.247**	−2.404

Notes: Single, double, and triple asterisks (*, **, ***) indicate statistical significance at the 10%, 5%, and 1% level.

To further test the difference between monetary and environmental discount rates, we performed a *t*-test on the estimated discount rates from the random-parameter model. We find a difference of −0.049 between the discount rates at approximately a 10% level of statistical significance. That is, the discount rate on the combined environmental goods is significantly lower than that on monetary goods, indicating that individuals discount environmental goods at a rate of 50% less than monetary goods (see Table 6).

We also find that unobserved heterogeneity is important. Specifically, the variance parameters from the random-parameter model for monetary and environmental goods are statistically significant and similar in magnitude. Examining individual characteristics, age has little impact on any of the discount rates, but gender has a large and significant impact on the discount rate for monetary goods: males have a 0.056 lower discount rate for monetary goods.[6] This is not the case for environmental goods, where gender has no impact. Among the four variables related to environmental behavior, all but the park-use variable have a statistically significant impact on the monetary and environmental discount rates. The impacts of the environmental behavior variables are similar in sign, magnitude, and significance for both monetary and environmental goods, except for the hours volunteered for environmental cause variable, which increases the monetary and decreases the environmental discount rates. Making sacrifices for the environment and hours volunteered for environmental causes both represent a personal cost of time and effort for the environment, so it is not clear why they have a different impact on discounting behavior of environmental goods. It could be that making sacrifices for the environment encompasses a wider range of actions than volunteering, so the larger coefficient represents those activities. Wanting the government to address climate change has the largest impact, increasing the discount rate by 0.024 for both goods. Finally, the dummy variable for park restoration in the environmental goods model is large and significant, indicating that the discount rate for park restoration (an SV good) is lower than that for storm-water reduction (an SB good). Carbon reductions have a small and statistically significant impact on the discount rate compared to storm water, but this is consistent with the idea that goods received further in the future are discounted at a lower rate than those that occur sooner. Both of these findings are consistent with earlier research (Weitzman, 1998; Hardisty and Weber, 2009).

The number of alcoholic drinks and BMI were included as variables to check the consistency of our sample with other discounting studies (Tu et al., 2004; Richards and Hamilton, 2012). The number of drinks consumed increases the discount rate at a similar magnitude as previous studies, indicating that increased alcohol consumption is related to higher discount rates. Our results show small coefficients on the BMI variable, but these are of the same sign as other studies, indicating a small increase in the discount rate.

Taken together, these results suggest that monetary rewards and benefits from the general class of environmental goods are discounted at a lower rate if individual characteristics are accounted for, that discounting behavior is accurately captured by the exponential model, and that individual characteristics generally influence discounting behavior similarly for the two domains of goods.

[6] A positive coefficient indicates a decrease in the discount rate, while a negative coefficient indicates an increase in the discount rate, both in absolute terms.

Discounting across Environmental Goods

Recall that we define public park restoration as an SV good, storm-water reduction as an SB good, and carbon reduction as an LB good. Table 5 shows that the first-stage estimates are similar to each other, with α and τ being approximately 1, similar to the models given in Table 4. The hyperbolic and quasi-hyperbolic parameters are not statistically different from 1, which indicates that the exponential discounting model effectively captures discounting behavior. This finding is in contrast to some of the recent empirical discounting literature (Frederick, Loewenstein, and O'Donoghue, 2002) and much of the environmental discounting literature (Gattig and Hendrickx, 2007; Viscusi, Huber, and Bell, 2008; Hardisty and Weber, 2009). We contend that most studies on discounting behavior have biased their results toward hyperbolic discounting because they did not control for uncertainty across payments (front-end delay) and curvature of the utility function (see Andersen et al., 2008; Andreoni and Sprenger, 2012b, as a counter example).

Examining estimates for individual environmental goods provides some further insight into the nature of the heterogeneity in discounting behavior. First, we find that the discount rate for park restoration has the same sign as the discount rate for other environmental goods, but it is not statistically different from 0. The discount rate for parks is smallest, which is consistent with earlier research that hypothesizes that goods with private benefit will be discounted at a lower rate than goods with public benefits. The discount rates for the other two environmental goods are negative and significant.[7] Further, the discount rate for storm-water reduction is substantially higher than that for carbon reduction and park restoration. A Wald test is used to estimate the full discount rate, including all individual characteristics. As illustrated at the bottom of Table 5, the discount rate is 16.6% for park restoration, 24.6% for storm water, and 14.1% for carbon reductions—all significant at the 1% level. The variance of the storm-water discount rate (0.004) is an order of magnitude smaller than that of any of the other goods, which may signal a consistently low level of concern for improving water quality for a body of water that has little private benefit. We performed *t*-tests on the estimated discount rates from the random-parameter model to test the difference in discounting across domains. To elaborate on our finding that monetary goods are discounted differently from the general group of environmental goods, we used a *t*-test for the monetary good versus each of the environmental goods and also compared across the environmental goods (see Table 6). We found that the environmental goods and monetary good were all different from each other, with the exception of park restoration and carbon reduction. The differences were all statistically significant at a 10% level or higher. A natural conclusion to draw from these findings is that people discount specific environmental goods at different rates and that individually these rates vary dramatically from monetary discount rates. However, all goods have the same exponential discounting structure, not hyperbolic as suggested by other studies.

Influence of Individual Characteristics on Environmental Discounting

Among individual characteristics that influence the discounting of parks, we find that personal sacrifice to improve the environment is the most influential, increasing the discount rate by 0.076, which implies a higher discount rate for those willing to make personal sacrifices (see Table 5). If an individual is willing to make a sacrifice, they want park restoration to occur sooner. Consuming alcoholic drinks has a similar effect, increasing the discount rate by 0.056. Surprisingly, using parks more often and volunteering for environmental causes reduce the discount rate by 0.015% and 0.009%, respectively. This contrast in findings seems to indicate that individuals who devote time to using and improving environmental goods are more patient than those who make sacrifices like recycling. Note that these variables have very low correlation, ranging from −0.05 to 0.02, so we

[7] The negative sign comes from the structure of the model. The discount rates themselves are positive.

are confident that they capture different behaviors. Further, our estimates show that demographics like age and gender only slightly impact discounting, as do other characteristics not discussed here.

None of the coefficients on the individual characteristics were statistically significant in the storm-water reductions model, though they are generally the same sign as the other models. The lack of statistical significance is in stark contrast to the models of the other environmental goods. In hindsight, it could be that storm-water reduction is the least known of the environmental goods tested, so there is less consistent behavior. The standard deviation of the characteristics is similar in magnitude and significance to that of the other goods at 0.314, so we see similar variation.

In terms of carbon reduction, the estimates in Table 5 show that different characteristics emerge as important relative to our findings in the previous two models. Specifically, favoring the government addressing climate change had no impact on discounting of park restoration or storm-water reduction, but it is the largest, most statistically significant impact on discounting for reduced carbon emissions, increasing the discount rate by 0.18. Essentially, we find that people who feel strongly about the government taking action on climate change are impatient for carbon reduction to occur. Recall, the process used for both park use and carbon emissions questions and tasks were similar, but the results were not the same. However, we did not see a similar pattern for the days of park use variable in the park restoration model, so we cannot conclude the finding was influenced by respondents completing the environmental goods donation survey task or environmental behavior questions.

Other behavioral variables in the carbon model exhibit effects that differ quantitatively. Although the signs are the same, making sacrifices for the environment, using parks, and volunteering for environmental causes each has a much smaller impact on individual discounting behavior for carbon reductions than for park restoration. The same set of variable coefficients has the same sign for storm-water reduction, but all were insignificant. We can conclude that, in general, individual characteristics and opinions impact discounting environmental goods in the same direction, although the magnitude and consistency (i.e., statistical significance) of the impact differs dramatically across environmental goods.

Comparing results across the five models shows that results from the individual environmental good models are consistent with the results from the combined environmental good model. Similarly, seven of the eight individual characteristic variables exhibit similar patterns across the monetary and environmental models. Only the variable for hours volunteered for environmental causes increases discounting for monetary goods but reduces discounting for environmental goods. Across other characteristics, discounting is fairly consistent in sign but different in magnitude. For example, making sacrifices for the environment increases the discount rate across all goods, but the impact is much larger for parks than for all other goods. Wanting the government to address climate change has a much smaller impact on discounting for monetary goods than for environmental goods. The primary conclusion is that individual characteristics influence discounting behavior in a similar direction but vary in magnitude across different types of goods.

Conclusions

Our results indicate that—in contrast with the well-established literature on hyperbolic discounting—individual discounting behavior of monetary and environmental goods can be accurately captured using the exponential discount model. We attribute the finding of exponential discounting to two features of the experiment. First, the front-end delay used for both monetary payments and donations produces comparable levels of uncertainty across the time delay of payments. Given that most present-bias behavior occurs in the near term, some may find this structure objectionable. However, we feel the front-end delay structure is appropriate for examining environmental goods because most environmental benefits take time to occur. Unfortunately, these results do not allow us to compare behavior when individuals have a choice to consume immediately versus sometime in the future.

Second, we account for curvature of the utility function. Earlier studies that examined discounting of environmental goods assumed linear utility functions (Viscusi, Huber, and Bell, 2008; Hardisty and Weber, 2009), which have been shown to overestimate discount rates both theoretically and empirically (Andersen et al., 2008). In response to these studies, we specifically examined discounting of environmental goods under the more rigorous and realistic setting of concave utility. However, our results did not indicate that curvature of the utility function was a critical factor in finding exponential discounting: even though the curvature parameter was less than 1, it was not statistically different from 1. As such, in this study the front-end delay is likely the key factor driving the finding of exponential discounting. Recall that we implemented front-end delay to create more similar levels of uncertainty across all intertemporal choices. That is, immediate payoffs used in many discounting studies have a different level of uncertainty than future payoffs, but waiting at least 1 month creates a similar level of uncertainty across all payoffs. As such, it could be that discounting behavior is more likely to be hyperbolic for very-near-term decisions and more likely exponential for longer-term decisions.

We also found that the general class of environmental goods is discounted 50% lower than monetary goods. This finding supports the practice of several government agencies to discount environmental goods at lower rates than other investments (as noted in Arrow et al., 2014). This is the first empirical support we know of that supports this practice. Discounting environmental goods at a lower rate than common goods has been promoted primarily using an argument for generational equity and other ethical concerns, not discounting behavior. Our findings on discounting behavior provide further support for the practice of differential discounting across domains for general classes of goods, specifically lower rates for environmental goods.

Finally, there has been a substantial debate regarding long-term discounting due to concerns regarding climate change. Much of the research has pointed to the recommendation of applying declining discount rates for long-term environmental projects (Arrow et al., 2014). Declining discount rates are consistent with hyperbolic discounting, which would not be consistent with the exponential discounting supported by our findings. However, we also found that long-term environmental goods are discounted lower than short-term environmental goods, which lends support to the use of declining discount rates. Although we have found that individuals discount goods with different time frames differently, we feel it is difficult to extend our findings from this short-run analysis to make claims about how the distant future should be discounted. There is need for further research in this area, specifically with a larger sample from a broader population. Although there have been large sample studies supporting exponential discounting (Andersen et al., 2008, 2014) and that individual characteristics influence discounting behavior for environmental goods (Viscusi, Huber, and Bell, 2008), more large-sample research is necessary before we can make strong cost-benefit policy recommendations about discounting environmental and monetary goods differently from a behavioral perspective.

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References

Andersen, S., G. W. Harrison, M. I. Lau, and E. E. Rutström. "Elicitation Using Multiple Price List Formats." *Experimental Economics* 9(2006):383–405.

———. "Eliciting Risk and Time Preferences." *Econometrica* 76(2008):583–618. doi: 10.1111/j.1468-0262.2008.00848.x.

———. "Discounting Behavior: A Reconsideration." *European Economic Review* 71(2014):15–33. doi: 10.1016/j.euroecorev.2014.06.009.

Andreoni, J., and C. Sprenger. "Estimating Time Preferences from Convex Budgets." *American Economic Review* 102(2012a):3333–3356. doi: 10.1257/aer.102.7.3333.

———. "Risk Preferences Are Not Time Preferences." *American Economic Review* 102(2012b):3357–3376. doi: 10.1257/aer.102.7.3357.

Arrow, K. J., W. R. Cline, K. G. Maler, M. Munasinghe, R. Squitieri, and J. E. Stiglitz. "Intertemporal Equity, Discounting, and Economic Efficiency." In J. P. Bruce, H. S. Yi, and E. F. Haites, eds., *Climate Change 1995: Economic and Social Dimensions of Climate Change, Contribution of Working Group III to the Second Assessment Report of the Intergovernmental Panel on Climate Change,* Cambridge, UK: Cambridge University Press, 1996, 125–144.

Arrow, K. J., M. L. Cropper, C. Gollier, B. Groom, G. M. Heal, R. G. Newell, W. D. Nordhaus, R. S. Pindyck, W. A. Pizer, P. R. Portney, T. Sterner, R. S. J. Tol, and M. L. Weitzman. "Should Governments Use a Declining Discount Rate in Project Analysis?" *Review of Environmental Economics and Policy* 8(2014):145–163. doi: 10.1093/reep/reu008.

Benhabib, J., A. Bisin, and A. Schotter. "Present-Bias, Quasi-Hyperbolic Discounting, and Fixed Cost." *Games and Economic Behavior* 69(2010):205–223. doi: 10.1016/j.geb.2009.11.003.

Boardman, A., D. Greenberg, A. Vining, and D. Weimer. *Cost-Benefit Analysis*. Upper Saddle River, NJ: Prentice Hall, 2010, 4th ed.

Böhm, G., and H. Pfister. "Consequences, Morality, and Time in Environmental Risk Evaluation." *Journal of Risk Research* 8(2005):461–479. doi: 10.1080/13669870500064143.

Camerer, C. F. "Recent Tests of Generalizations of Expected Utility Theory." In W. K. Viscusi and W. Edwards, eds., *Utility Theories: Measurements and Applications,* vol. 3. Dordrecht, Netherlands: Springer Netherlands, 1992, 207–251. doi: 10.1007/978-94-011-2952-7_9.

Carson, R. T., and T. Groves. "Incentive and Informational Properties of Preference Questions." *Environmental and Resource Economics* 37(2007):181–210. doi: 10.1007/s10640-007-9124-5.

Chapman, G. B. "Temporal Discounting and Utility for Health and Money." *Journal of Experimental Psychology: Learning, Memory, and Cognition* 22(1996):771–791. doi: 10.1037/0278-7393.22.3.771.

Coller, M., and M. B. Williams. "Eliciting Individual Discount Rates." *Experimental Economics* 2(1999):107–127. doi: 10.1007/BF01673482.

Doyle, J. R. "Survey of Time Preference, Delay Discounting Models." *Judgment and Decision Making* 8(2013):116–135.

Frederick, S., G. Loewenstein, and T. O'Donoghue. "Time Discounting and Time Preference: A Critical Review." *Journal of Economic Literature* 40(2002):351–401. doi: 10.1257/002205102320161311.

Gattig, A., and L. Hendrickx. "Judgmental Discounting and Environmental Risk Perception: Dimensional Similarities, Domain Differences, and Implications for Sustainability." *Journal of Social Issues* 63(2007):21–39. doi: 10.1111/j.1540-4560.2007.00494.x.

Greene, W. H. "Interpreting Estimated Parameters and Measuring Individual Heterogeneity in Random Coefficient Models." NYU Working Paper 2451/26121, New York University, New York, NY, 2004. Available online at http://people.stern.nyu.edu/wgreene/RandomParameters.pdf.

Hardisty, D. J., and E. U. Weber. "Discounting Future Green: Money versus the Environment." *Journal of Experimental Psychology: General* 138(2009):329–340. doi: 10.1037/a0016433.

Harless, D. W., and C. F. Camerer. “The Predictive Utility of Generalized Expected Utility Theories.” *Econometrica* 62(1994):1251–1289. doi: 10.2307/2951749.

Harrison, G. W., M. I. Lau, and M. B. Williams. “Estimating Individual Discount Rates in Denmark: A Field Experiment.” *American Economic Review* 92(2002):1606–1617. doi: 10.1257/000282802762024674.

Hendrickx, L., and S. Nicolaij. “Temporal Discounting and Environmental Risks: The Role of Ethical and Loss-Related Concerns.” *Journal of Environmental Psychology* 24(2004):409–422. doi: 10.1016/j.jenvp.2004.12.001.

Hepburn, C. “Valuing the Far-Off Future: Discounting and Its Alternatives.” 2007.

Kahneman, D., and J. L. Knetsch. “Valuing Public Goods: The Purchase of Moral Satisfaction.” *Journal of Environmental Economics and Management* 22(1992):57–70. doi: 10.1016/0095-0696(92)90019-S.

Kahneman, D., J. L. Knetsch, and R. H. Thaler. “Experimental Tests of the Endowment Effect and the Coase Theorem.” *Journal of Political Economy* 98(1990):1325–1348. doi: 10.1086/261737.

Laibson, D. “Golden Eggs and Hyperbolic Discounting.” *Quarterly Journal of Economics* 112(1997):443–478. doi: 10.1162/003355397555253.

Loewenstein, G., and D. Prelec. “Anomalies in Intertemporal Choice: Evidence and an Interpretation.” *Quarterly Journal of Economics* 107(1992):573–597. doi: 10.2307/2118482.

Mehra, R., and E. C. Prescott. “The Equity Premium in Retrospect.” In *Handbook of the Economics of Finance, Volume 1B: Financial Markets and Asset Pricing,* Amsterdam, Netherlands: North-Holland, . doi: 10.1016/S1574-0102(03)01023-9.

Meyer, A. “Estimating Discount Factors for Public and Private Goods and Testing Competing Discounting Hypotheses.” *Journal of Risk and Uncertainty* 46(2013):133–173. doi: 10.1007/s11166-013-9163-y.

Moore, M. A., A. E. Boardman, A. R. Vining, D. L. Weimer, and D. H. Greenberg. “‘Just Give Me a Number!’ Practical Values for the Social Discount Rate.” *Journal of Policy Analysis and Management* 23(2004):789–812. doi: 10.1002/pam.20047.

Nicolaij, S., and L. C. W. P. Hendrickx. “The Influence of Temporal Distance of Negative Consequences on the Evaluation of Environmental Risks.” In L. C. W. P. Hendrickx, W. Jager, and L. Steg, eds., *Human Decision Making and Environmental Perception, Understanding and Assisting Human Decision Making in Real-Life Situations,* Groningen, Netherlands: University of Groningen, 2003, 47–67.

Nordhaus, W. D. *Managing the Global Commons: The Economics of Climate Change*. Cambridge, MA: MIT Press, 1994.

O’Donoghue, T., and M. Rabin. “Doing It Now or Later.” *American Economic Review* 89(1999):103–124. doi: 10.1257/aer.89.1.103.

Phelps, E. S., and R. A. Pollak. “On Second-Best National Saving and Game-Equilibrium Growth.” *The Review of Economic Studies* 35(1968):185. doi: 10.2307/2296547.

Prelec, D. “Decreasing Impatience: A Criterion for Non-stationary Time Preference and âĂIJHyperbolic” Discounting.” *Scandinavian Journal of Economics* 106(2004):511–532. doi: 10.1111/j.0347-0520.2004.00375.x.

Richards, T. J., and G. P. Green. “Environmental Choices and Hyperbolic Discounting: An Experimental Analysis.” *Environmental and Resource Economics* 62(2015):83–103. doi: 10.1007/s10640-014-9816-6.

Richards, T. J., and S. F. Hamilton. “Obesity and Hyperbolic Discounting: An Experimental Analysis.” *Journal of Agricultural and Resource Economics* 37(2012):181–198.

Starmer, C. “Developments in Non-Expected Utility Theory: The Hunt for a Descriptive Theory of Choice under Risk.” *Journal of Economic Literature* 38(2000):332–382. doi: 10.1257/jel.38.2.332.

Stern, N. “The Stern Review on the Economic Effects of Climate Change.” *Population and Development Review* 32(2006):793–798. doi: 10.1111/j.1728-4457.2006.00153.x.

Svenson, O., and G. Karlsson. "Decision-Making, Time Horizons, and Risk in the Very Long-Term Perspective." *Risk Analysis* 9(1989):385–399. doi: 10.1111/j.1539-6924.1989.tb01004.x.

Train, K. *Discrete Choice Methods with Simulation*. New York: Cambridge University Press, 2009, 2nd ed.

Tu, Q., B. Donkers, B. Melenberg, and A. van Soest. "The Time Preference of Gains and Losses." Working Paper, Tilburg University, Tilburg, Netherlands, 2004.

Viscusi, W. K., J. Huber, and J. Bell. "Estimating Discount Rates for Environmental Quality from Utility-Based Choice Experiments." *Journal of Risk and Uncertainty* 37(2008):199–220. doi: 10.1007/s11166-008-9045-x.

Weatherly, J. N., H. K. Terrell, and A. Derenne. "Delay Discounting of Different Commodities." *Journal of General Psychology* 137(2010):273–286. doi: 10.1080/00221309.2010.484449.

Weitzman, M. L. "Why the Far-Distant Future Should Be Discounted at Its Lowest Possible Rate." *Journal of Environmental Economics and Management* 36(1998):201–208. doi: 10.1006/jeem.1998.1052.

———. "Gamma Discounting." *American Economic Review* 91(2001):260–271. doi: 10.1257/aer.91.1.260.

Zhuang, J., Z. Liang, T. Lin, and F. DeGuzman. "Theory and Practice in the Choice of Social Discount Rate for Cost-Benefit Analysis: A Survey." Economic Research and Development Working Paper No. 94, Asian Development Bank, Manila, Philippines, 2007. Available online at http://www.adb.org/publications/theory-and-practice-choice-social-discount-rate-cost-benefit-analysis-survey.

Appendix A: Survey Descriptions of Environmental Good Treatments

City Park Restoration Treatment

City parks are an important source of green space for recreational activities within Seattle. Though most city parks have been in existence for many decades, many have experienced a reduction in use due to the deterioration of park facilities over time. The restoration budgets for public parks have been particularly hard hit during this recession and maintenance has declined dramatically. Restoring and maintaining public parks is important for maintaining access to green spaces and improving outdoor recreational activities. There are a number of low cost options for improving public parks, including installing landscaping, play structures and picnic/gathering areas.

Seattle Parks Foundation (www.seattleparksfoundation.org/) is a non-profit organization with the mission to "improve, expand, and connect parks and green spaces, building a more vibrant community." We have funding to make a donation in your name to the Seattle Parks Foundation, specifically for the purpose of restoring public parks in Seattle. There are several parks near Seattle University that students are known to use regularly. At this point we are trying to determine when you think the best time to make the donation is. Below we will ask you a series of questions related to the timing of the donation and quantity of restoration. It is in your interest to answer the questions based on your preferences because we will select one of your answers at random to determine how much restoration to fund and when to make the donation in your name. We will send your receipt for the donation once it is made based on the random selection.

In this section, we will give you a number of choices regarding funding a quantity of park restoration of 33 square feet in one month or a larger quantity at a specified time in the future. We will vary the future quantities over different lengths of time till a donation will be made in your name (one month to two years). To ensure that it is in your best interest to report the quantities based on your preferences accurately, we will randomly choose one combination of quantity and time delay to determine the quantity and time of restoration. As such, the best way to receive the most benefit is to answer based on your preferences. Please indicate which quantity you would prefer for each of the 10 choices for each time horizon. In all you will answer 90 time value questions, but each will only take several seconds.

Storm Water Reduction Treatment

Reduction of water pollution in Washington's Puget Sound is an urgent issue, there are many instances where the water quality is in violation of the U.S. Clean Water Act. Thirty percent of pollution in Washington's water bodies is from storm water runoff. Pollutants deposit on roads, parking lots and other developed land, and then rain storms wash the pollutants to rivers and lakes, which in Western Washington eventually flow to the Puget Sound. A low cost method for reducing storm water pollution is to install low impact retention systems, like Bioswales and Wet Basins, which capture storm water and filter the pollutants from the water.

Puget Soundkeeper Alliance (www.pugetsoundkeeper.org/) is a non-profit organization with the mission to "protect and preserve Puget Sound by monitoring, cleaning up and preventing pollutants from entering its waters." We have funding to make a donation in your name to Puget Soundkeeper Alliance, specifically for the purpose of building low impact storm water retention systems. At this point we are trying to determine when you think the best time to make the donation is. Below we will ask you a series of questions related to the timing of the donation and quantity of storm water reduction. It is in your interest to answer the questions based on your preferences because we will select one of your answers at random to determine when to make a donation in your name. We will send you a receipt for the donation once it is made based on the random selection. If you prefer that no donation be made you may select the No Donation button and money will be returned to the funding agency.

In this section, we will give you a number of choices regarding funding a quantity of storm water reduction of 10 cubic meters in one month or a larger amount at a specified time in the future. We will vary the future quantities over different lengths of time till a donation will be made in your name (one month to two years). To ensure that it is in your best interest to report the quantities based on your preferences accurately, we will randomly choose one combination of quantity and time delay to determine the quantity and time of restoration. As such, the best way to receive the most benefit is to answer based on your preferences. Please indicate which quantity you would prefer for each of the 10 choices for each time horizon. In all you will answer 90 time value questions, but each will only take several seconds.

Carbon Reduction Treatment

There is significant evidence that burning fossil fuels like gasoline, natural gas and coal during the last century has led to increased carbon in the earth's atmosphere. Though there is debate regarding the impact of increased carbon in the atmosphere, many leading scientists believe it will lead to climate change that will cause irreversible damage to human and animal populations. There are a variety of methods to reduce carbon in the atmosphere.

Bonneville Environmental Foundation (www.b-e-f.org/) is a non-profit organization with the mission to apply entrepreneurial thinking and innovation to solve the world's most pressing environmental issues. Their Carbon Offsets help businesses and consumers take action to reduce their impact on the environment. Bonneville Environmental Foundation Carbon Offsets represent the capture or reduction of harmful greenhouse gases emitted from sources such as fossil fuels, animal waste, landfills and refrigerants. A carbon offset represents the reduction of greenhouse gases equivalent to 1 metric ton of carbon dioxide, which equates to a reduction of carbon emissions from approximately 112 gallons of gasoline. We have funding to make a donation in your name to the Bonneville Environmental Foundation specifically for the purpose of purchasing carbon offsets. At this point we are trying to determine when you think the best time to make the donation is. Below we will ask you a series of questions related to the timing of the donation and quantity of carbon reduction. It is in your interest to answer the questions based on your preferences because we will select one of your answers at random to determine when to make a donation in your name. We will send you a receipt for the donation once it is made based on the random selection. If you prefer that no donation be made you may select the No Donation button and money will be returned to the funding agency.

In this section, we will give you a number of choices regarding funding a quantity of Carbon Offsets for 1 metric ton in one month or a larger quantity at a specified time in the future. We will vary the future quantities over different lengths of time till a donation will be made in your name (one month to two years). To ensure that it is in your best interest to report the quantities based on your preferences accurately, we will randomly choose one combination of quantity and time delay to make the donation in your name. As such, the best way to receive the most benefit is to answer based on your preferences. Please indicate which quantity you would prefer for each of the 10 choices for each time horizon. In all you will answer 90 time value questions, but each will only take several seconds.