Estimating Time Preferences from Convex Budgets

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Web Appendix

A Estimating Preference Parameters

A.1 Nonlinear Least Squares

Let there be N experimental subjects and P CTB budgets. Assume that each subject j makes her $c_{t_{ij}}$, $i = 1, 2, ..., P$, decisions according to (5) but that these decisions are made with some mean-zero, potentially correlated error. That is let

$$g(m, r, k, t; \beta, \delta, \alpha, \omega_1, \omega_2) = \left\{ \begin{array}{lll} [\frac{1}{1+(1+r)(\beta\delta^k(1+r))^{(\frac{1}{\alpha-1})}}]\omega_1 + [\frac{(\beta\delta^k(1+r))^{(\frac{1}{\alpha-1})}}{1+(1+r)(\beta\delta^k(1+r))^{(\frac{1}{\alpha-1})}}](m-\omega_2) & if & t=0 \\ [\frac{1}{1+(1+r)(\delta^k(1+r))^{(\frac{1}{\alpha-1})}}]\omega_1 + [\frac{(\delta^k(1+r))^{(\frac{1}{\alpha-1})}}{1+(1+r)(\delta^k(1+r))^{(\frac{1}{\alpha-1})}}](m-\omega_2) & if & t>0 \end{array} \right\},$$

then

$$c_{t_{ij}} = g(m, r, k, t; \beta, \delta, \alpha, \omega_1, \omega_2) + e_{ij}.$$

Stacking the P observations for individual j, we have

$$\mathbf{c_{t_j}} = \mathbf{g}(m, r, k, t; \beta, \delta, \alpha, \omega_1, \omega_2) + \mathbf{e_j}.$$

The vector $\mathbf{e_j}$ is zero in expectation with variance covariance matrix $\mathbf{V_j}$, a $(P \times P)$ matrix, allowing for arbitrary correlation in the errors e_{ij}. We stack over the N experimental subjects to obtain

$$\mathbf{c_t} = \mathbf{g}(m, r, k, t; \beta, \delta, \alpha, \omega_1, \omega_2) + \mathbf{e}.$$

We assume that the terms e_{ij} may be correlated within individuals but that the errors are uncorrelated across individuals, $E(\mathbf{e_j}'\mathbf{e_g}) = 0$ for $j \neq g$. And so $\mathbf{e}$ is zero in expectation with covariance matrix $\mathbf{\Omega}$, a block diagonal $(NP \times NP)$ matrix of clusters, with individual covariance matrices, $\mathbf{V_j}$.

We define the usual criterion function $S(m, r, k; \beta, \delta, \alpha, \omega_1, \omega_2)$ as the sum of squared residuals,

$$S(m, r, k, t; \beta, \delta, \alpha, \omega_1, \omega_2) = \sum_{j=1}^{N} \sum_{i=1}^{P} (c_{t_{ij}} - g(m, r, k, t; \beta, \delta, \alpha, \omega_1, \omega_2))^2,$$

and minimize $S(\cdot)$ using non-linear least squares with standard errors clustered on the individual level to obtain $\hat{\beta}$, $\hat{\delta}$, $\hat{\alpha}$, $\hat{\omega}_1$ and $\hat{\omega}_2$. NLS procedures permitting the estimation of preference parameters at the aggregate or individual level are implemented in many standard econometrics packages (in our case, *Stata*). Additionally, an estimate of the annual discount rate can be calculated as $(1/\hat{\delta})^{365} - 1$ with standard error obtained via the delta method. $\hat{\mathbf{\Omega}}$ is estimated as the individual-level clustered error covariance matrix. Given additional assumptions on the individual covariance matrix $\mathbf{V_j}$, such as diagonal or block-diagonal, individual parameter estimates can also be obtained via the same estimation procedure.

It is important to recognize the strengths and weaknesses of such an NLS preference estimator. Background parameters ω_1 and ω_2 can be estimated as opposed to assumed, which is an advantage. A potential disadvantage is that the NLS estimator is not well-suited to the censored data issues inherent to potential corner solutions without additional assumptions.

The NLS estimator can be adapted to account for possible corner solutions by adapting the criterion function and making additional distributional assumptions. Let c_t^* be a latent variable for period t allocation that follows $c_t^* = g(m, r, k, t; \beta, \delta, \alpha, \omega_1, \omega_2) + \epsilon$. We observe $c_t = 0$ if $c_t^* \leq 0$, $c_t = m/1 + r$ if $c_t^* \geq m/1 + r$ and $c_t = c_t^*$ otherwise. As discussed in Wooldridge (2002) Chapter 16, c_t^* here does not have an interpretation, but the latent variable vocabulary and associated censored techniques are applicable to corner solution applications. Borrowing from Greene (2003) Chapter 22, assume that ϵ is continuous random variable, with density $f(\epsilon)$ and distribution $F(\epsilon)$, that ϵ is orthogonal to the data (m, r, k, t) and has mean 0 and variance σ^2.

Then the expectation

$$E[c_t|m,r,k,t] = P[c_t^* \leq 0|m,r,k,t] \cdot 0 + P[c_t^* \geq \frac{m}{1+r}|m,r,k,t] \cdot \frac{m}{1+r} + P[0 < c_t^* < \frac{m}{1+r}] \cdot E[c_t^*|0 < c_t^* < \frac{m}{1+r}|m,r,k,t]$$

can be rewritten

$$E[c_t|m,r,k,t] = F_l \cdot 0 + (1 - F_h) \cdot \frac{m}{1+r} + (F_h - F_l) \cdot E[c_t^*|0 < c_t^* < \frac{m}{1+r}|m,r,k,t],$$

where $F_h = F(\frac{m/(1+r)-g(\cdot)}{\sigma})$ and $F_l = F(\frac{0-g(\cdot)}{\sigma})$. A distributional assumption is imposed on ϵ to provide functional form. In particular ϵ is taken to follow a normal distribution. This provides the following form,

$$E[c_t|m,r,k,t] = \Phi_l \cdot 0 + (1 - \Phi_h) \cdot \frac{m}{1+r} + (\Phi_h - \Phi_l) \cdot (g(\cdot) + (\frac{\phi_l - \phi_h}{\Phi_h - \Phi_l})\sigma),$$

with $\Phi(\cdot)$ and $\phi(\cdot)$ representing the standard normal distribution and density, respectively.

We introduce $\tilde{g}(m,r,k,t;\beta,\delta,\alpha,\omega_1,\omega_2,\sigma) = \Phi_l \cdot 0 + (1-\Phi_h) \cdot \frac{m}{1+r} + (\Phi_h - \Phi_l) \cdot (g(\cdot) + (\frac{\phi_l - \phi_h}{\Phi_h - \Phi_l})\sigma)$, with $g(\cdot)$ defined as before. This motivates a new criterion function

$$\tilde{S}(m,r,k,t;\beta,\delta,\alpha,\omega_1,\omega_2) = \sum_{j=1}^{N}\sum_{i=1}^{P}(c_{t_{ij}} - \tilde{g}(m,r,k,t;\beta,\delta,\alpha,\omega_1,\omega_2,\sigma))^2, \tag{9}$$

which is minimized using non-linear least squares with standard errors clustered on the individual level. Estimates are discussed in the text and presented in Appendix Table A1.

A.2 Censored Regression Techniques

Next we consider more standard censored regression techniques that can address corner solution issues. We consider the tangency condition of (4). If we assume ω_1 and ω_2 are non-estimated, known values, we can take logs to obtain

$$ln(\frac{c_t - \omega_1}{c_{t+k} - \omega_2}) = \left\{ \begin{array}{ll} (\frac{ln\ \beta}{\alpha-1}) + (\frac{ln\ \delta}{\alpha-1}) \cdot k + (\frac{1}{\alpha-1}) \cdot ln(1+r) & if \quad t = 0 \\ (\frac{ln\ \delta}{\alpha-1}) \cdot k + (\frac{1}{\alpha-1}) \cdot ln(1+r) & if \quad t > 0 \end{array} \right\},$$

which is linear in the in the data k and $ln(1+r)$, and reduces to,

$$ln(\frac{c_t - \omega_1}{c_{t+k} - \omega_2}) = (\frac{ln\ \beta}{\alpha - 1}) \cdot \mathbf{1}_{t=0} + (\frac{ln\ \delta}{\alpha - 1}) \cdot k + (\frac{1}{\alpha - 1}) \cdot ln(1+r),$$

where $\mathbf{1}_{t=0}$ is an indicator for the time period $t = 0$.

Let there be N experimental subjects and P CTB budgets. Assume that each subject j makes her $c_{t_{ij}}$, $i = 1, 2, ..., P$, decisions according to the above log-linearized relationship but that these decisions are made with some additive mean-zero, potentially correlated error. That is,

$$ln(\frac{c_t - \omega_1}{c_{t+k} - \omega_2})_{ij} = (\frac{ln\ \beta}{\alpha - 1}) \cdot \mathbf{1}_{t=0} + (\frac{ln\ \delta}{\alpha - 1}) \cdot k + (\frac{1}{\alpha - 1}) \cdot ln(1+r) + e_{ij},$$

Stacking the P observations for individual j, we have

$$\mathbf{ln}(\frac{\mathbf{c_t} - \omega_\mathbf{1}}{\mathbf{c_{t+k}} - \omega_\mathbf{2})_\mathbf{j} = (\frac{ln\ \beta}{\alpha - 1}) \cdot \mathbf{1}_{t=0} + (\frac{ln\ \delta}{\alpha - 1}) \cdot \mathbf{k} + (\frac{1}{\alpha - 1}) \cdot \mathbf{ln(1+r)} + \mathbf{e_j}$$

The vector $\mathbf{e_j}$ is zero in expectation with variance covariance matrix $\mathbf{V_j}$, a $(P \times P)$ matrix, allowing for arbitrary correlation in the errors e_{ij}. We stack over the N experimental subjects to obtain

$$\mathbf{ln}(\frac{\mathbf{c_t} - \omega_\mathbf{1}}{\mathbf{c_{t+k}} - \omega_\mathbf{2}}) = (\frac{ln\ \beta}{\alpha - 1}) \cdot \mathbf{1}_{t=0} + (\frac{ln\ \delta}{\alpha - 1}) \cdot \mathbf{k} + (\frac{1}{\alpha - 1}) \cdot \mathbf{ln(1+r)} + \mathbf{e}$$

We assume that the terms e_{ij} may be correlated within individuals but that the errors are uncorrelated across individuals, $E(\mathbf{e_j'e_g}) = 0$ for $j \neq g$. And so $\mathbf{e}$ is zero in expectation with covariance matrix $\mathbf{\Omega}$, a block diagonal $(NP \times NP)$ matrix of clusters, with individual covariance matrices, $\mathbf{V_j}$.

The above linear model is easily estimated with ordinary least squares. However the log consumption ratio is censored by corner solution responses,

$$ln(\frac{c_t - \omega_1}{c_{t+k} - \omega_2}) \in [ln(\frac{0 - \omega_1}{c_{t+k} - \omega_2}), ln(\frac{c_t - \omega_1}{0 - \omega_2})],$$

motivating censored regression techniques such as the two-limit Tobit model more appropriate. Wooldridge (2002) presents corner solutions as the primary motivation for two-limit Tobit regression techniques and Chapter 16, Problem 16.3 corresponds closely to the above. Parameters can be estimated via the two-limit Tobit regression.

$$\mathbf{ln}(\frac{\mathbf{c_t} - \boldsymbol{\omega_1}}{\mathbf{c_{t+k}} - \boldsymbol{\omega_2}}) = \gamma_1 \cdot \mathbf{1}_{t=0} + \gamma_2 \cdot \mathbf{k} + \gamma_3 \cdot \mathbf{ln(1 + r)} + \mathbf{e}$$

With parameters of interest recovered via the non-linear combinations

$$\hat{\alpha} = \frac{1}{\hat{\gamma}_3} + 1 \; ; \; \hat{\delta} = exp(\frac{\hat{\gamma}_2}{\hat{\gamma}_3}) \; ; \; \hat{\beta} = exp(\frac{\hat{\gamma}_1}{\hat{\gamma}_3}),$$

and standard errors obtained via the delta method. Additionally, an estimate of the annual discount rate can be calculated as $(1/\hat{\delta})^{365} - 1$ with standard error obtained via the delta method. $\hat{\boldsymbol{\Omega}}$ is estimated as the individual-level clustered error covariance matrix.

Given additional assumptions on the individual covariance matrix $\mathbf{V_j}$, such as diagonal or block-diagonal as well as a sufficient number of non-censored observations (one less than the number of parameters), individual parameter estimates can also be obtained via the same estimation procedure.

Censored regression techniques are helpful in addressing the critical issues of corner solutions. However, there are disadvantages to the technique. First, the values ω_1 and ω_2 must be assumed rather than estimated from the data. Second, the consumption ratio $(\frac{c_t - \omega_1}{c_{t+k} - \omega_2})$ must be strictly positive such that the log consumption ratio is well defined. This restricts the values of ω_1 and ω_2 to be strictly negative.

Under alternative preference models, the difficulty of background parameters is eliminated. Consider for example constant absolute risk aversion utility, $u(c_t) = -exp(-\rho(c_t - \omega_1)) = -exp(-\rho c_t) \cdot exp(\rho\omega_1)$. Under this CARA parameterization and $\omega_1 = \omega_2$, the background parameters drop out of the marginal condition such that the tangency can be written

$$exp(-\rho(c_t - c_{t+k})) = \left\{ \begin{array}{lll} \beta\delta^k \cdot (1+r) & if & t = 0 \\ \delta^k \cdot (1+r) & if & t > 0 \end{array} \right\}.$$

Taking logs and rearranging, this is linear in the data $\mathbf{1}_{t=0}$, k, and $ln(1+r)$, reducing to

$$c_t - c_{t+k} = (\frac{ln\ \beta}{-\rho}) \cdot \mathbf{1}_{t=0} + (\frac{ln\ \delta}{-\rho}) \cdot k + (\frac{1}{-\rho}) \cdot ln(1+r).$$

This can again be estimated with censored regression techniques and parameters of interest recovered as before. Additionally, the solution function,

$$c_t = (\frac{ln\ \beta}{-\rho}) \cdot \frac{\mathbf{1}_{t=0}}{2+r} + (\frac{ln\ \delta}{-\rho}) \cdot \frac{k}{2+r} + (\frac{1}{-\rho}) \cdot \frac{ln(1+r)}{2+r} + \frac{m}{2+r},$$

can also be estimated with censored regression techniques with the coefficient on the nuisance term $\frac{m}{2+r}$ constrained to be 1. As the strategies employed for these censored CARA regressions are virtually identical to those just discussed for CRRA utility, further matrix notation is unnecessary.

B About Arbitrage

A relevant issue with monetary incentives in time preference experiments, as opposed to experiments using primary consumption as rewards, is that, in theory, monetary payments should be subject to extra-lab arbitrage opportunities. Subjects who can borrow (save) at external interest rates inferior (superior) to the rates offered in the lab should arbitrage the lab by taking the later (sooner) experimental payment. As such, discount rates measured using monetary incentives should collapse to the interval of external borrowing and savings interest rates and present bias should be observed only if liquidity positions or interest rates are expected to change. In the CTB context, this arbitrage argument also implies that subjects should *never* choose intermediate allocations unless they are liquidity constrained.[39] Furthermore, for 'secondary' rewards, such as money, it is possible that there could be less of a visceral temptation for immediate gratification than for 'primary' rewards that can be immediately consumed. As a result, one might expect limited present bias when monetary incentives are used.

Contrary to the arbitrage argument, others have shown that experimentally elicited discount rates are generally not measured in a tight interval near market rates (Coller and Williams, 1999; Harrison, Lau and Williams, 2002); they are not remarkably sensitive to the provision of external rate information or to the elaboration of arbitrage opportunities (Coller and Williams, 1999); and they are uncorrelated with credit constraints (Meier and Sprenger, 2010). In our CTB environment, a sizeable proportion of chosen allocations are intermediate (30.4 percent of all responses, average of 13.7 per subject) and the number of intermediate allocations is uncorrelated with individual liquidity proxies such as credit-card holdership ($\rho = -0.049,\ p = 0.641$) and bank account holdership ($\rho = -0.096,\ p = 0.362$).

Despite the fact that money is not a primary reward, monetary experiments do generate evidence of present-biased preferences (Dohmen et al., 2006; Meier and Sprenger, 2010). Of further interest is the finding by McClure et al. (2004, 2007) that discounting and present bias over primary and monetary rewards have very similar neural images. As well, discount factors elicited over primary and monetary rewards correlate highly at the individual level (Reuben, Sapienza and Zingales, 2010). The fact that we find significant but limited utility function curvature is therefore consistent with the evidence of strict convexity of preferences in the presence of arbitrage.

[39] If an arbitrage opportunity exists, the lab offered budget set is inferior to the extra-lab budget set everywhere except one corner solution. This corner should be the chosen allocation. Liquidity constraints could yield intermediate allocations if individuals are unable to move resources through time outside of the lab and desire smooth consumption streams. Additionally intermediate allocations could be obtained if the lab-offered rate lay in between borrowing and savings rates. Cubitt and Read (2007) provide substantial discussion on the limits of the preference information that can be obtained from intertemporal choice experiments.

C Additional Aggregate Estimates

In this appendix we provide two table of additional aggregate estimates. Table A1 provides NLS estimates adapted for censoring as described in Appendix Section A.1 with the normalization $\sigma = 1$. Table A2 demonstrates the sensitivity of estimates to alternate assumptions on background parameters ω_1 and ω_2 with NLS and Two-Limit Tobit estimates.

Table A1: NLS Discounting and Curvature Parameter Estimates

	(1)	(2)	(3)	(4)
Method:	NLS	NLS	NLS	NLS
Annual Discount Rate	0.297	0.377	0.374	0.371
	(0.063)	(0.087)	(0.027)	(0.027)
Present Bias: $\hat{\beta}$	1.007	1.006	1.007	1.006
	(0.005)	(0.006)	(0.006)	(0.006)
CRRA Curvature: $\hat{\alpha}$	0.919	0.921	0.899	0.810
	(0.006)	(0.006)	(0.004)	(0.006)
$\hat{\omega}_1$	1.340			
	(0.297)			
$\hat{\omega}_2$	-0.083			
	(1.580)			
$\hat{\omega}_1 = \hat{\omega}_2$		1.321	0	-7.046
		(0.302)	-	-
R^2	0.2396	0.2393	0.2355	0.2231
# Observations	4365	4365	4365	4365
# Clusters	97	97	97	97

Notes: NLS estimators of equation (9) accounting for censoring. Column (1): Unrestricted CRRA regression. Column (2): CRRA regression with restriction $\omega_1 = \omega_2$. Column (3) CRRA regression with restriction with restriction $\omega_1 = \omega_2 = 0$. Column (4): CRRA regression with restriction $\omega_1 = \omega_2 = -7.046$ (the negative of average reported daily spending). Clustered standard errors in parentheses. Annual discount rate calculated as $(1/\hat{\delta})^{365} - 1$. Standard errors calculated via the delta method.

Table A2: Background Consumption, Parameter Estimates and Goodness of Fit

	NLS Estimates				*Two-Limit Tobit Estimates*			
$\omega_1 = \omega_2$	Discount Rate (s.e.)	$\hat{\beta}$ (s.e)	$\hat{\alpha}$ (s.e.)	R^2	Discount Rate (s.e.)	$\hat{\beta}$ (s.e)	$\hat{\alpha}$ (s.e.)	Log-Likelihood
-25	.151	1.04	.24	.433	.264	1.027	.711	-4173.8
	(.151)	(.01)	(.045)		(.16)	(.01)	(.041)	
-20	.159	1.039	.361	.434	.266	1.027	.754	-4393.04
	(.149)	(.009)	(.037)		(.16)	(.01)	(.035)	
-15	.175	1.037	.487	.437	.268	1.027	.799	-4660.35
	(.145)	(.009)	(.03)		(.161)	(.01)	(.029)	
-14	.18	1.036	.513	.438	.269	1.027	.808	-4721.82
	(.144)	(.009)	(.028)		(.161)	(.01)	(.028)	
-13	.186	1.035	.539	.439	.27	1.027	.817	-4786.7
	(.142)	(.009)	(.027)		(.161)	(.01)	(.026)	
-12	.192	1.034	.566	.44	.27	1.027	.826	-4855.43
	(.141)	(.009)	(.025)		(.161)	(.01)	(.025)	
-11	.2	1.033	.593	.441	.271	1.027	.835	-4928.58
	(.139)	(.009)	(.024)		(.161)	(.01)	(.024)	
-10	.209	1.032	.621	.443	.272	1.027	.845	-5006.81
	(.137)	(.008)	(.022)		(.161)	(.01)	(.022)	
-9	.22	1.03	.649	.445	.273	1.027	.854	-5091.02
	(.134)	(.008)	(.02)		(.161)	(.01)	(.021)	
-8	.232	1.028	.678	.447	.274	1.026	.864	-5182.36
	(.131)	(.008)	(.019)		(.162)	(.01)	(.02)	
-7	.246	1.026	.707	.45	.275	1.026	.874	-5282.39
	(.127)	(.008)	(.017)		(.162)	(.01)	(.018)	
-6	.263	1.023	.737	.453	.277	1.026	.884	-5393.3
	(.123)	(.008)	(.016)		(.162)	(.01)	(.017)	
-5	.282	1.02	.767	.458	.279	1.026	.894	-5518.36
	(.118)	(.007)	(.014)		(.162)	(.01)	(.015)	
-4	.302	1.017	.796	.463	.281	1.026	.904	-5662.8
	(.113)	(.007)	(.013)		(.163)	(.01)	(.014)	
-3	.323	1.014	.824	.468	.284	1.026	.916	-5835.85
	(.107)	(.007)	(.012)		(.163)	(.01)	(.012)	
-2	.342	1.011	.851	.475	.288	1.026	.928	-6056.91
	(.101)	(.006)	(.01)		(.164)	(.01)	(.01)	
-1	.359	1.009	.875	.481	.295	1.025	.943	-6382.19
	(.095)	(.006)	(.009)		(.166)	(.01)	(.008)	

Notes: NLS and two-limit Tobit estimators with restriction $\omega_1 = \omega_2$ equal to first column as in Table 2. 4365 observations (1329 uncensored) for each row. Clustered standard errors in parentheses. Annual discount rate calculated as $(1/\hat{\delta})^{365} - 1$, standard errors calculated via the delta method.

D Additional Individual Estimates

In this appendix we provide three summary tables and two tables of individual estimates of additional individual level estimates with alternative specifications and estimators. All three tables are in the form of Table 3. In A3 we impose the restriction $\omega_1 = \omega_2 = -7.05$, minus average daily background consumption, and provide NLS estimates. In A4, we impose the same restriction and provide Tobit estimators. For individuals with one or fewer interior solutions, we estimate via OLS as the Tobit requires at least two uncensored observations for estimation. See Appendix Section A.2 for details. In A5 we impose the restriction $\omega_1 = \omega_2 = -B$, where B corresponds to the subject's own self-reported daily background consumption, and provide NLS estimates for responders. The number of subjects for whom estimation is achieved is also reported and varies across tables. Tables A6 and A7 provide NLS estimates for each subject with $\omega_1 = \omega_2 = 0$ as in Table 2, column (3) and discussed in the text.

Table A3: Individual Discounting, Present Bias and Curvature Parameter Estimates

	N	Median	5th Percentile	95th Percentile	Min	Max
Annual Discount Rate	88	.4277	-.8715	5.6481	-1	55.4768
Daily Discount Factor: $\hat{\delta}$	88	.999	.9948	1.0056	.989	1.031
Present Bias: $\hat{\beta}$	88	1.0285	.8963	1.1566	.8016	1.1961
CRRA Curvature: $\hat{\alpha}$	88	.7536	.1293	.8977	-3.273	.9052

Notes: NLS estimators with restriction $\omega_1 = \omega_2 = -7.05$.

Table A4: Individual Discounting, Present Bias and Curvature Parameter Estimates

	N	Median	5th Percentile	95th Percentile	Min	Max
Annual Discount Rate	84	.3923	-.9868	7.9005	-1	42.9775
Daily Discount Factor: $\hat{\delta}$	84	.9991	.994	1.0119	.9897	1.4535
Present Bias: $\hat{\beta}$	84	1.0238	.9102	1.3384	.8426	5.7041
CRRA Curvature: $\hat{\alpha}$	84	.7836	-.0838	.9846	-50.4261	.9916

Notes: Tobit and OLS (for subjects with one or fewer uncensored observations) estimators with restriction $\omega_1 = \omega_2 = -7.05$.

Table A5: Individual Discounting, Present Bias and Curvature Parameter Estimates

	N	Median	5th Percentile	95th Percentile	Min	Max
Annual Discount Rate	82	.3734	-.9169	3.7477	-.9989	80.6357
Daily Discount Factor: $\hat{\delta}$	82	.9991	.9957	1.0068	.988	1.0187
Present Bias: $\hat{\beta}$	82	1.0087	.905	1.2156	.8208	1.2223
CRRA Curvature: $\hat{\alpha}$	82	.7987	-.0155	.9859	-.6922	.9955

Notes: NLS estimators with restriction $\omega_1 = \omega_2 = -B$, the subject's own self-reported daily background consumption. Reporters only.

Table A6: Individual Estimates 1

Subject #	Annual Rate	$\hat{\beta}$	$\hat{\alpha}$	Interior	Proportion of Responses Zero Tokens Sooner	All Tokens Sooner
1	.123	.958	.984	.4	.56	.04
2	.73	1.054	1	.16	.64	.2
3	.931	.988	.986	0	.71	.29
4	.55	1.017	.935	.6	.27	.13
5	.117	1.001	.999	0	.98	.02
6	.117	1.001	.999	0	.98	.02
7	.339	1.02	.979	.18	.78	.04
8	1.906	1	.911	.13	.44	.42
9	.117	1.001	.999	0	.98	.02
10	.	.	.	0	1	0
11	.735	.931	1	.07	.62	.31
12	1.966	.979	.955	.13	.38	.49
13	.496	1.027	.993	.51	.4	.09
14	.	.	.	0	.22	.78
15	.965	.993	.98	0	.69	.31
16	.305	.994	.916	.51	.49	0
17	.723	.938	.996	0	.71	.29
18	14.452	1.107	.951	.31	.09	.6
19	1.318	1.105	.885	.84	.11	.04
20	-.16	.904	.956	.16	.84	0
21	1.592	.984	.952	.13	.49	.38
22	5.618	.971	.772	.13	.2	.67
23	.707	.999	1	0	.8	.2
24	.117	1.001	.999	0	.98	.02
25	.117	1.001	.999	0	.98	.02
26	.117	1.001	.999	0	.98	.02
27	1.145	.993	.975	.07	.56	.38
28	2.742	.994	.933	.42	.22	.36
29	.	.	.	1	0	0
30	.676	1.043	.906	.64	.29	.07
31	.144	1.015	.966	.33	.64	.02
32	.73	.973	.963	.49	.42	.09
33	.788	1.002	.954	0	.73	.27
34	17.243	.912	.927	.18	.04	.78
35	.	.	.	0	0	1
36	.117	1.001	.999	0	.98	.02
37	.736	1.006	.997	.07	.71	.22
38	-.837	.852	.167	1	0	0
39	1.134	1.131	.887	.98	0	.02
40	.117	1.001	.999	0	.98	.02
41	1.81	.911	.885	.6	.04	.36
42	1.186	.967	.933	.58	.2	.22
43	.899	.975	.935	.18	.6	.22
44	.257	.979	1	0	.89	.11
45	.1	1.033	.89	.96	.04	0
46	-.995	.999	-.133	1	0	0
47	.476	1.078	.975	.22	.73	.04
48	.	.	.	0	1	0
49	1.545	1.062	.953	.36	.33	.31
50	.116	.94	.997	0	.89	.11

Table A7: Individual Estimates 2

Subject #	Annual Rate	$\hat{\beta}$	$\hat{\alpha}$	Interior	Proportion of Responses Zero Tokens Sooner	All Tokens Sooner
51	29.583	1.138	.918	.13	0	.87
52	.	.	.	.04	.76	.2
53	2.536	1.191	.847	.71	.09	.2
54	.219	1.003	.976	.16	.82	.02
55	.169	.975	.968	.09	.87	.04
56	.744	.916	.95	.16	.56	.29
57	-.144	1.042	.944	.38	.62	0
58	.306	1.01	.999	0	.91	.09
59	-.88	.974	.771	.98	.02	0
60	3.462	.768	.915	.11	.2	.69
61	1.511	.957	.904	.89	0	.11
62	-.123	1.037	.419	1	0	0
63	.513	.992	.761	1	0	0
64	.732	.949	1	.16	.62	.22
65	.126	1	.993	.69	.29	.02
66	1.073	.957	.834	.91	.04	.04
67	.291	1.003	.951	.36	.6	.04
68	.117	1.001	.999	0	.98	.02
69	.117	1.001	.999	0	.98	.02
70	3.225	.959	.89	.71	0	.29
71	.117	1.001	.999	0	.98	.02
72	35.356	1.324	.991	0	.22	.78
73	.117	1.001	.999	0	.98	.02
74	.117	1.001	.999	0	.98	.02
75	.109	1.059	.884	.42	.58	0
76	-.474	1.003	.708	1	0	0
77	.117	1.001	.999	0	.98	.02
78	0	1.003	.999	.02	.98	0
79	.	.	.	0	1	0
80	-.178	.982	.913	.47	.53	0
81	.834	1.009	.907	.56	.38	.07
82	.219	.986	.543	1	0	0
83	.117	1.001	.999	0	.98	.02
84	.	.	.	.8	.2	0
85	-.001	1.007	.973	.87	.13	0
86	.117	1.001	.999	0	.98	.02
87	.	.	.	0	0	1
88	1.206	.959	.972	.49	.22	.29
89	.117	1.001	.999	0	.98	.02
90	1.954	.935	.905	.38	.16	.47
91	.732	1.027	.943	.62	.33	.04
92	.999	.986	.967	.36	.49	.16
93	.	.	.	0	1	0
94	.117	1.001	.999	0	.98	.02
95	.117	1.001	.999	0	.98	.02
96	.555	1.051	.938	.76	.22	.02
97	.	.	.	0	.64	.36

E Welcome Text and Payment Explanation

Welcome and thank you for participating

Eligibility for this study: To be in this study, you need to meet these criteria. You must have a campus mailing address of the form:

YOUR NAME

9450 GILMAN DR 92(MAILBOX NUMBER)

LA JOLLA CA 92092-(MAILBOX NUMBER)

You must live in:

- XXX College.
- XXX College AND have a student mail box number between 92XXXX and 92XXXX
- XXX College AND have a student mail box number between 92XXXX through 92XXXX.

Your mailbox must be a valid way for you to receive mail from now through the end of the Spring Quarter. You must be willing to provide your name, campus mail box, email address, and student PID. This information will only be seen by Professor Andreoni and his assistants. After payment has been sent, this information will be destroyed. Your identity will not be a part of any subsequent data analysis.

You must be willing to receive your payment for this study by check, written to you by Professor James Andreoni, Director of the UCSD Economics Laboratory. The checks will be drawn on the USE Credit Union on campus. This means that, if you wish, you can cash your checks for free at the USE Credit Union any weekday from 9:00 am to 5:00 pm with valid identification (drivers license, passport, etc.). The checks will be delivered to you at your campus mailbox at a date to be determined by your decisions in this study, and by chance. The latest you could receive payment is the last week of classes in the Spring Quarter.

If you do not meet all of these criteria, please inform us of this now.

E.1 Payment Explanation

Earning Money

To begin, you will be given a $10 thank-you payment, just for participating in this study! You will receive this thank-you payment in two equally sized payments of $5 each. The two $5 payments will come to you at two different times. These times will be determined in the way described below.

In this study, you will make 47 choices over how to allocate money between two points in time, one time is "earlier" and one is "later." Both the earlier and later times will vary across decisions. This means you could be receiving payments as early as today, and as late as the last week of classes in the Spring Quarter, or possibly two other dates in between. Once all 47 decisions have been made, we will randomly select one of the 47 decisions as the decision-that-counts. We will use the decision-that-counts to determine your actual earnings. Note, since all decisions are equally likely to be chosen, you should make each decision as if it will be the decision-that-counts. When calculating your earnings from the decision-that-counts, we will add to your earnings the two $5 thank you payments. Thus, you will always get paid at least $5 at the chosen earlier time, and at least $5 at the chosen later time.

IMPORTANT: All payments you receive will arrive to your campus mailbox. That includes payments that you receive today as well as payments you may receive at later dates. On the scheduled day of payment, a check will be placed for delivery in campus mail services by Professor Andreoni and his assistants. *By special arrangement, campus mail services has guaranteed delivery of 100% of your payments on the same day.*

As a reminder to you, the day before you are scheduled to receive one of your payments, we will send you an e-mail notifying you that the payment is coming.

On your table is a business card for Professor Andreoni with his contact information. Please keep this in a safe place. If one of your payments is not received you should immediately contact Professor Andreoni, and we will hand-deliver payment to you.

Your Identity

In order to receive payment, we will need to collect the following pieces of information from you: name, campus mail box, email address, and student PID. This information will only be seen by Professor Andreoni and his assistants. After all payments have been sent, this information will be destroyed. Your identity will not be a part of subsequent data analysis.

You have been assigned a participant number. This will be linked to your personal information in order to complete payment. After all payments have been made, only the participant number will remain in the data set.

On your desk are two envelopes: one for the sooner payment and one for the later payment. Please take the time now to address them to yourself at your campus mail box.

University of California San Diego, Economics Department

Instructions

The Study

In this study you are asked to make a series of 47 decisions about how to divide a set of tokens between two dates. Tokens will later be exchanged for money. The tokens you allocate to later date will always be worth more money than tokens you allocate to the earlier date. This process is best described by an example.

Below is a sample Decision Screen, like what you will see in the study.

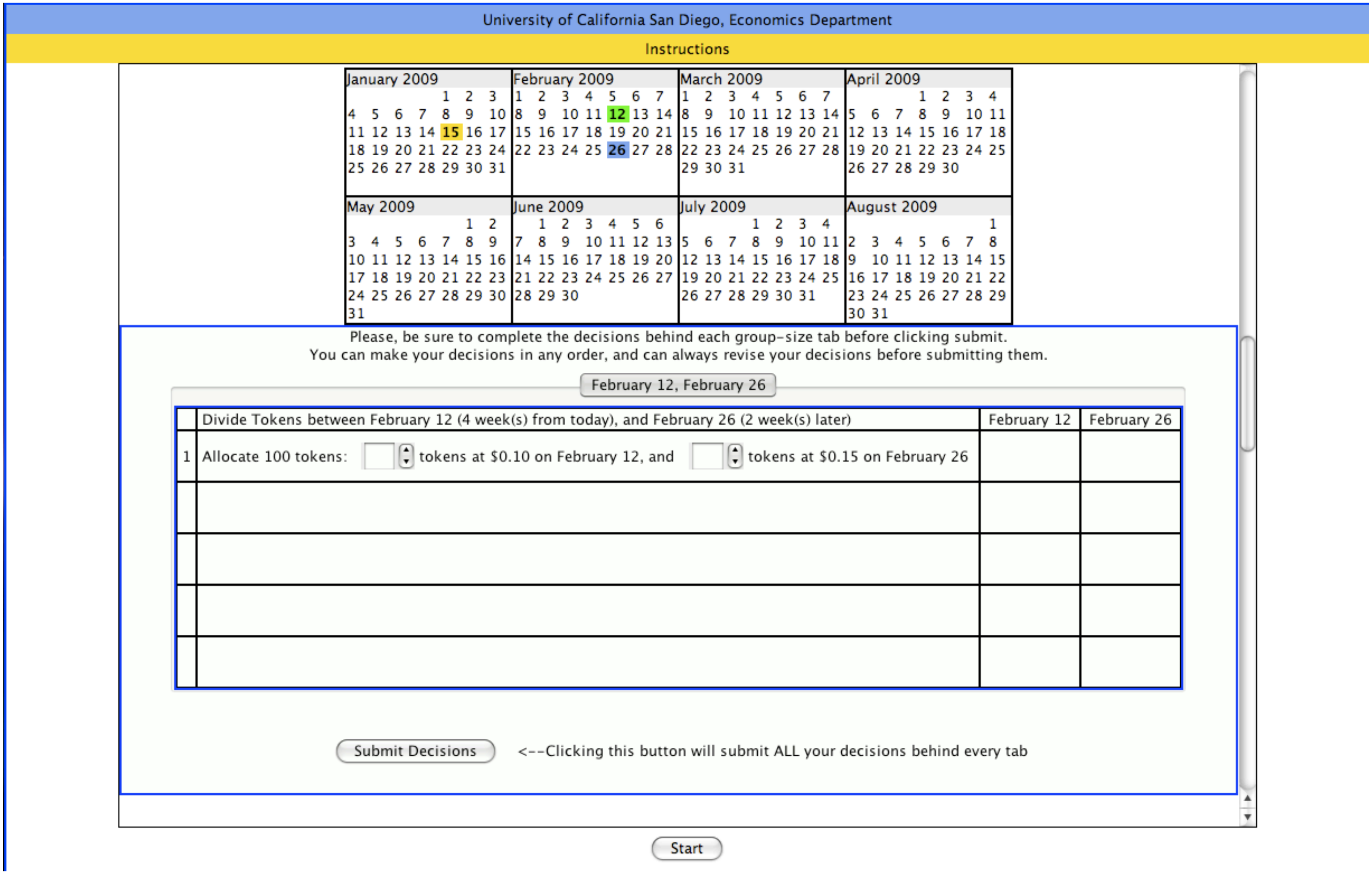
Choosing the Decision-that-Counts

The first decision on the screen shows the choice to allocate 100 tokens between February 12th and February 26th. Notice that today's date is high-lighted in yellow on the calendar above the tab. Also note that the earlier date (February 12th) is highlighted in green while the later date (February 26th) is highlighted in blue. In each decision the dates are highlighted so that you can easily see when the decision begins and ends.

In this decision, each token you allocate to February 12th is worth $0.10, while each token you allocate to February 26th is worth $0.15. So, if you allocate all 100 tokens to February 12th you will earn $10 on this date, and nothing on February 26th. If you allocate all 100 tokens to February 26th you will receive $15 on this date an nothing on February 12th. You are also free to allocate some tokens to the earlier date and some to the later date. For instance, if you allocate 50 tokens to February 12th and 50 to February 26th, you will earn $5.00 on February 12th and $7.50 on February 26th. Remember that however you allocate the tokens, any earnings will be added to your $5 thank-you payment for both the earlier and later dates. So, even if you allocate all your tokens to one of the dates, you will still receive a check of at least $5 on both the earlier and later dates.

Notice that you can navigate through all 47 decisions by using the tabs at the top of the decision screen. Notice also that, on the right, the computer automatically calculates how much you will receive on both the earlier and later dates, if this is chosen as the decision-that-counts. You can revise your choices as much as you like. Once you are satisfied will all of your decisions, you can click on the "submit decisions" button.

Start


University of California San Diego, Economics Department
Instructions
January 2009
February 2009
March 2009
April 2009
May 2009
June 2009
July 2009
August 2009
Please, be sure to complete the decisions behind each group-size tab before clicking submit.
You can make your decisions in any order, and can always revise your decisions before submitting them.
February 12, February 26
Divide Tokens between February 12 (4 week(s) from today), and February 26 (2 week(s) later)
February 12
February 26
1 Allocate 100 tokens:
tokens at $0.10 on February 12, and
tokens at $0.15 on February 26
Submit Decisions
<--Clicking this button will submit ALL your decisions behind every tab
Start

University of California San Diego, Economics Department

Instructions

Consider another example. The screen below shows an allocation of 47 tokens for February 12th and 75 tokens for February 26th. Notice how the cash values are automatically computed. Suppose this decision was chosen as the decision-that-counts for payment. Then this subject would be paid $2.50 on February 12th and $11.25 on February 26th. The person's earlier payment of $2.50 + $5.00 (thank-you payment) = $7.50 would be placed in campus mail on February 12th. The person's later payment of $11.25 + $5.00 (thank-you payment) = $16.25 would be placed in campus mail on February 26th.

Please, be sure to complete the decisions behind each group-size tab before clicking submit.
You can make your decisions in any order, and can always revise your decisions before submitting them.

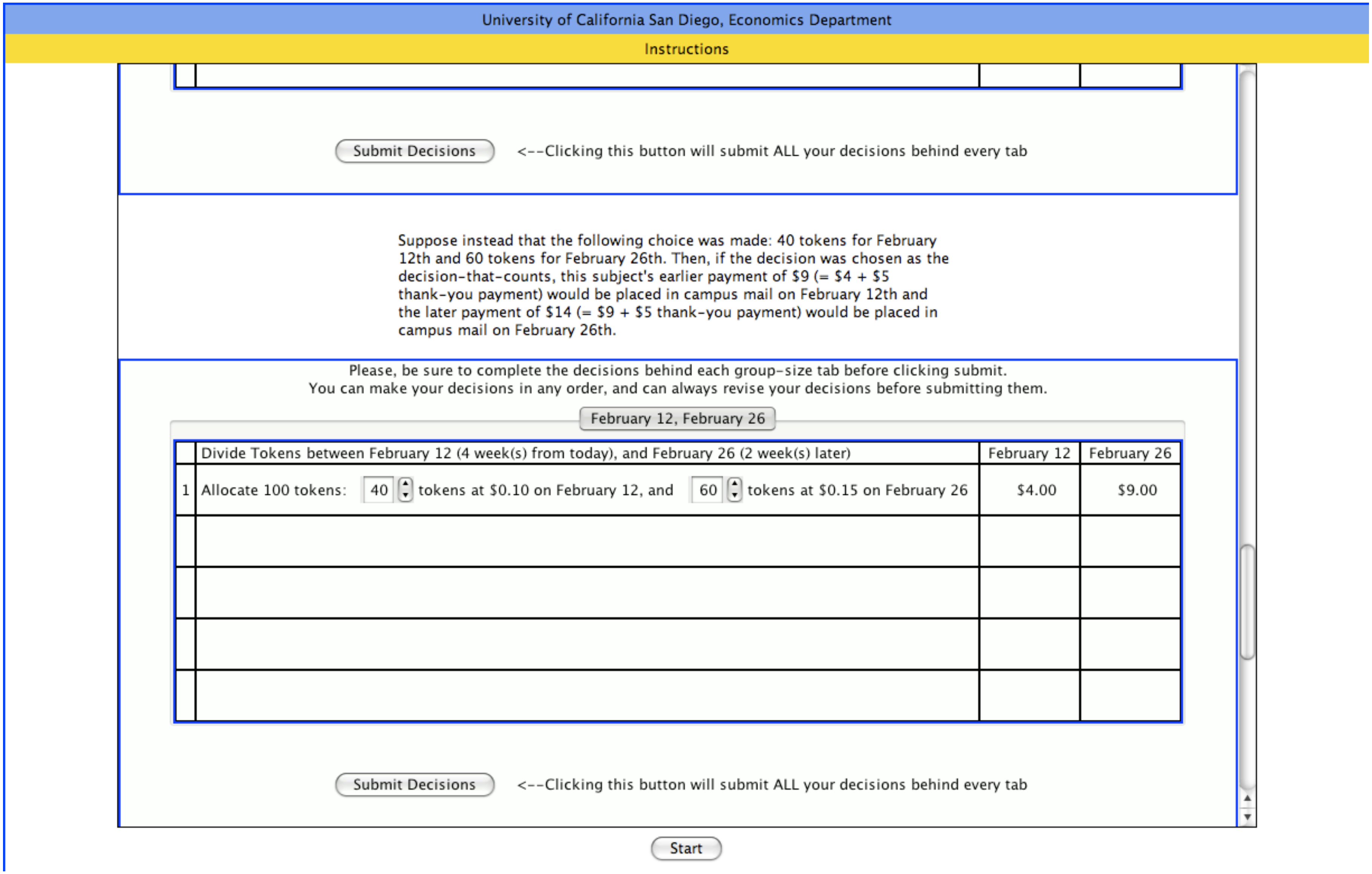
February 12, February 26

	Divide Tokens between February 12 (4 week(s) from today), and February 26 (2 week(s) later)	February 12	February 26
1	Allocate 100 tokens: 25 tokens at $0.10 on February 12, and 75 tokens at $0.15 on February 26	$2.50	$11.25

Submit Decisions <--Clicking this button will submit ALL your decisions behind every tab

Suppose instead that the following choice was made: 40 tokens for February 12th and 60 tokens for February 26th. Then, if the decision was chosen as the decision-that-counts, this subject's earlier payment of $9 (= $4 + $5

Start


University of California San Diego, Economics Department
Instructions
Submit Decisions
<--Clicking this button will submit ALL your decisions behind every tab
Suppose instead that the following choice was made: 40 tokens for February 12th and 60 tokens for February 26th. Then, if the decision was chosen as the decision-that-counts, this subject's earlier payment of $9 (= $4 + $5 thank-you payment) would be placed in campus mail on February 12th and the later payment of $14 (= $9 + $5 thank-you payment) would be placed in campus mail on February 26th.
Please, be sure to complete the decisions behind each group-size tab before clicking submit.
You can make your decisions in any order, and can always revise your decisions before submitting them.
February 12, February 26
Divide Tokens between February 12 (4 week(s) from today), and February 26 (2 week(s) later)
February 12
February 26
1
Allocate 100 tokens: 40 tokens at $0.10 on February 12, and 60 tokens at $0.15 on February 26
$4.00
$9.00
Submit Decisions
<--Clicking this button will submit ALL your decisions behind every tab
Start

E.2 Multiple Price Lists and Holt Laury Risk Price Lists

NAME: ______________________________________ PID: ______________________

<u>How It Works:</u>

In the following sheets you are asked to choose between smaller payments closer to today and larger payments further in the future. For each row, choose one payment: either the smaller, sooner payment or the larger, later payment. There are 22 decisions in total. Each decision has a number from 1 to 22.

NUMBERS 1 THROUGH 7: Decide between payment <u>today</u> and payment in <u>five weeks</u>
NUMBERS 8 THROUGH 15: Decide between payment <u>today</u> and payment <u>in fourteen weeks</u>
NUMBERS 16 THROUGH 22: Decide between payment <u>in five weeks</u> and payment <u>in ten weeks</u>

This sheet represents one of the 47 choices you make in the experiment. If the number 47 is drawn, this sheet will determine your payoffs. If the number 47 is drawn, a second number will also be drawn from 1 to 22. This will determine which decision (from 1 to 22) on the sheet is the decision-that-counts. The payment you choose (either sooner or later) in the decision that counts will be added to either your earlier $5 thank-you payment or your later $5 thank-you payment.

Remember that each decision could be the decision-that-counts! Treat each decision as if it could be the one that determines your payment.

TODAY VS. FIVE WEEKS FROM TODAY

WHAT WILL YOU DO IF YOU GET A NUMBER BETWEEN 1 AND 7?

Decide for **each** possible number if you would like the smaller payment for sure **today** or the larger payment for sure in **five weeks**? Please answer for each possible number (1) through (7) by filling in one box for each possible number.

Example: *If you prefer $19 today in Question 1 mark as follows:* ☑ *$19* ***today*** *or* ☐ *$20 in* ***five weeks***
If you prefer $20 in five weeks in Question 1, mark as follows: ☐ *$19* ***today*** *or* ☑ *$20 in* ***five weeks***

If you get number (1):	Would you like to receive	☐ $19 **today**	or ☐ $20 in **five weeks**
If you get number (2):	Would you like to receive	☐ $18 **today**	or ☐ $20 in **five weeks**
If you get number (3):	Would you like to receive	☐ $16 **today**	or ☐ $20 in **five weeks**
If you get number (4):	Would you like to receive	☐ $14 **today**	or ☐ $20 in **five weeks**
If you get number (5):	Would you like to receive	☐ $11 **today**	or ☐ $20 in **five weeks**
If you get number (6):	Would you like to receive	☐ $8 **today**	or ☐ $20 in **five weeks**
If you get number (7):	Would you like to receive	☐ $5 **today**	or ☐ $20 in **five weeks**

TODAY VS. FOURTEEN WEEKS FROM TODAY

WHAT WILL YOU DO IF YOU GET A NUMBER BETWEEN 8 AND 15?

Decide for **each** possible number if you would like the smaller payment for sure **today** or the larger payment for sure in **fourteen weeks**? Please answer for each possible number (8) through (15) by filling in one box for each possible number.

Example: *If you prefer $19 today in Question 8 mark as follows:* ☑ *$19* ***today*** *or* ☐ *$20 in* ***14 weeks***
If you prefer $20 in fourteen weeks in Question 8, mark as follows: ☐ *$19* ***today*** *or* ☑ *$20 in* ***14 weeks***

If you get number (8):	Would you like to receive	☐ $20 **today**	or	☐ $20 in **fourteen weeks**
If you get number (9):	Would you like to receive	☐ $19 **today**	or	☐ $20 in **fourteen weeks**
If you get number (10):	Would you like to receive	☐ $18 **today**	or	☐ $20 in **fourteen weeks**
If you get number (11):	Would you like to receive	☐ $16 **today**	or	☐ $20 in **fourteen weeks**
If you get number (12):	Would you like to receive	☐ $13 **today**	or	☐ $20 in **fourteen weeks**
If you get number (13):	Would you like to receive	☐ $10 **today**	or	☐ $20 in **fourteen weeks**
If you get number (14):	Would you like to receive	☐ $7 **today**	or	☐ $20 in **fourteen weeks**
If you get number (15):	Would you like to receive	☐ $4 **today**	or	☐ $20 in **fourteen weeks**

FIVE WEEKS FROM TODAY VS. TEN WEEKS FROM TODAY

WHAT WILL YOU DO IF YOU GET A NUMBER BETWEEN 16 AND 22?

Decide for **each** possible number if you would like the smaller payment for sure in **five weeks** or the larger payment for sure in **ten weeks**? Please answer for each possible number (16) through (22) by filling in one box for each possible number.

Example: If you prefer \$19 in four weeks in Question 16 mark as follows: ☑ *\$19* ***in 5 weeks or*** ☐ *\$20 in* ***10 weeks***
If you prefer \$20 in ten weeks in Question 16, mark as follows: ☐ *\$19* ***in 5 weeks*** *or* ☑ *\$20 in* ***10 weeks***

If you get number (16): Would you like to receive ☐ \$19 **in five weeks** or ☐ \$20 in **ten weeks**
If you get number (17): Would you like to receive ☐ \$18 **in five weeks** or ☐ \$20 in **ten weeks**
If you get number (18): Would you like to receive ☐ \$16 **in five weeks** or ☐ \$20 in **ten weeks**
If you get number (19): Would you like to receive ☐ \$14 **in five weeks** or ☐ \$20 in **ten weeks**
If you get number (20): Would you like to receive ☐ \$11 **in five weeks** or ☐ \$20 in **ten weeks**
If you get number (21): Would you like to receive ☐ \$8 **in five weeks** or ☐ \$20 in **ten weeks**
If you get number (22): Would you like to receive ☐ \$5 **in five weeks** or ☐ \$20 in **ten weeks**

2.

NAME: ______________________________________ PID:______________________

<u>How It Works:</u>

In the following two sheets you are asked to choose between options: Option A or Option B. On each sheet you will make ten choices, one on each row. For each decision row you will have to choose either Option A or Option B. You make your decision by checking the box next to the option you prefer more. You may choose A for some decision rows and B for other rows, and you may change your decisions and make them in any order.

There are a total of 20 decisions on the following sheets. The sheets represent one of the 47 choices you make in the experiment. If the number 46 is drawn, these sheets will determine your payoffs. If the number 46 is drawn, a second number will also be drawn from 1 to 20. This will determine which decision (from 1 to 20) on the sheets is the decision-that-counts. The option you choose (either Option A or Option B) in the decision-that-counts will then be played. You will receive your payment from the decision–that-counts immediately. Your $5 sooner and later thank-you payments, however, will still be mailed as before. The sooner payment will be mailed today and the later payment will be mailed in 5 weeks.

Playing the Decision-That-Counts:

Your payment in the decision-that-counts will be determined by throwing a 10 sided die. Now, please look at Decision 1 on the following sheet. Option A pays $10.39 if the throw of the ten sided die is 1, and it pays $8.31 if the throw is 2-10. Option B yields $20 if the throw of the die is 1, and it pays $0.52 if the throw is 2-10. The other Decisions are similar, except that as you move down the table, the chances of the higher payoff for each option increase. In fact, for Decision 10 in the bottom row, the die will not be needed since each option pays the highest payoff for sure, so your choice here is between $10.39 or $20.

Remember that each decision could be the decision-that-counts! It is in your interest to treat each decision as if it could be the one that determines your payoff.

Decision	Option A							Option B					
		If the die reads	you receive	and	If the die reads	you receive		If the die reads	you receive	and	If the die reads	you receive
1	☐	1	10.39		2-10	8.31	☐	1	20		2-10	0.52
2	☐	1-2	10.39		3-10	8.31	☐	1-2	20		3-10	0.52
3	☐	1-3	10.39		4-10	8.31	☐	1-3	20		4-10	0.52
4	☐	1-4	10.39		5-10	8.31	☐	1-4	20		5-10	0.52
5	☐	1-5	10.39		6-10	8.31	☐	1-5	20		6-10	0.52
6	☐	1-6	10.39		7-10	8.31	☐	1-6	20		7-10	0.52
7	☐	1-7	10.39		8-10	8.31	☐	1-7	20		8-10	0.52
8	☐	1-8	10.39		9-10	8.31	☐	1-8	20		9-10	0.52
9	☐	1-9	10.39		10	8.31	☐	1-9	20		10	0.52
10	☐	1-10	10.39		-	8.31	☐	1-10	20		-	0.52

Decision	Option A							Option B					
		If the die reads	you receive	and	If the die reads	you receive			If the die reads	you receive	and	If the die reads	you receive
11	☐	1	13.89		2-10	5.56		☐	1	25		2-10	0.28
12	☐	1-2	13.89		3-10	5.56		☐	1-2	25		3-10	0.28
13	☐	1-3	13.89		4-10	5.56		☐	1-3	25		4-10	0.28
14	☐	1-4	13.89		5-10	5.56		☐	1-4	25		5-10	0.28
15	☐	1-5	13.89		6-10	5.56		☐	1-5	25		6-10	0.28
16	☐	1-6	13.89		7-10	5.56		☐	1-6	25		7-10	0.28
17	☐	1-7	13.89		8-10	5.56		☐	1-7	25		8-10	0.28
18	☐	1-8	13.89		9-10	5.56		☐	1-8	25		9-10	0.28
19	☐	1-9	13.89		10	5.56		☐	1-9	25		10	0.28
20	☐	1-10	13.89		-	5.56		☐	1-10	25		-	0.28