APPENDIX - NOT FOR PUBLICATION

A Simulation Appendix

This appendix focuses on two questions related to the estimation strategies laid out in section 3. First, we examine the extent to which the implemented estimators identify the true parameters of interest, β, δ and γ at the aggregate and individual level. As our individual estimates restrict γ to be constant across subjects, this exercise is conducted under various correlation structures for β and γ to understand the sensitivity of our parameter estimates to this restriction. Further, the correlation structure also helps to investigate the sensitivity of identifying β via a non-linear combination involving γ in the aggregate estimates.

Second, we investigate the sensitivity of aggregate and individual estimates to uncertainty. Subjects may make allocations in Week 1 that minimize their discounted *expected* cost in future weeks given the potential realizations of future parameters. This uncertainty may be subsequently resolved in Week 2, such that subjects minimize their discounted cost at specific realizations of key parameters. As the minimizer of the expectation need not be the expectation of the minimizer, such issues can lead to inconsistencies between initial allocations and subsequent reallocations. To explore the extent to which this issue hampers identification of present bias, we conduct simulations under several uncertainty structures.

Our procedure for conducting the first simulation exercise is straightforward. We draw 100 samples of 80 individuals with underlying true parameters drawn from distributions centered roughly around our aggregate estimates. That is, for each sample β is drawn from a normal distribution with mean 0.9 and standard deviation 0.2; δ is drawn from a normal distribution with mean 0.99 and standard deviation 0.2; and γ is drawn from a normal distribution with mean 1.6 and standard deviation of 0.2. We introduce five correlation structures for the relationship between β and γ, $\rho(\beta, \gamma) \in \{-0.75, -0.25, 0, 0.25, 0.75\}$. For simplicity and to focus attention on the sensitivity of present bias we assume $\rho(\beta, \delta) = 0$ and $\rho(\delta, \gamma) = 0$ when drawing each sample.

For each of these correlation structures we conduct two key analyses. First, for every sample we estimate the aggregate parameters, $\widehat{\beta}$, $\widehat{\delta}$ and $\widehat{\gamma}$. The empirical distribution of $\widehat{\beta}$ over the 100 samples is summarized by the empirical mean, $\overline{\widehat{\beta}}$, the empirical standard deviation, $s(\widehat{\beta})$. Similar values summarize the empirical distributions of $\widehat{\delta}$ and $\widehat{\gamma}$. We investigate the extent to which the estimated values for $\widehat{\beta}$ correspond to the underlying data generating process by comparing $\overline{\widehat{\beta}}$ to the true mean β of 0.9. We also provide a measure of type I error in the form of the probability of rejecting $\beta = 0.9$ from each of our 100 drawn samples, $0.9 \notin CI(\beta)$, and a measure of type II error in the form of the probability of rejecting $\beta = 1$, $1 \notin CI(\beta)$. Table A1, Panel A provide these analyses. With zero correlation structure we precisely estimate all parameters close to the true underlying distribution. We reject the truth with probability around 0.10 and remain powered to reject $\beta = 1$. With extreme negative correlation of $\rho(\beta, \gamma) = -0.75$, this precision is largely unaffected, though with extreme positive correlation of $\rho(\beta, \gamma) = 0.75$ the aggregate estimator falters. We begin to overestimate the extent of present bias and reject the truth with frequency. This exercise documents the sensitivity of our aggregate estimates to extreme correlation structures.

Next, we focus on individual estimates. Table A1, Panel A provides the results. In each sample of 80 observations, we estimate individual parameters based on the fixed effects regression described in section 3. We consider the median and mean level of the individual estimate $\widehat{\beta}_i$, $\overline{\widehat{\beta}_i}$ and $\widehat{\beta}_i^{med}$, and the correlation between the true draw of β_i and the estimated value $\widehat{\beta}_i$, $r(\beta_i, \widehat{\beta}_i)$. For each of the 100 samples, we construct a correlation coefficient, and present the average value. Across correlation structures, we estimate broadly correct average and median values. Importantly, even when the accuracy of the level of behavior deteriorates due to extreme negative correlation between β and γ, we find the correlation between the true β_i and $\widehat{\beta}_i$ remains above 0.9. This indicates that the individual estimates remain capable of identifying differences across individuals in present bias, providing a solid foundation for our individual analysis.

The remainder of Table A1 analyzes the effect of uncertainty. We focus on uncertainty in γ realized only in Week 2. Hence the Week 1 allocations are made under uncertainty that is resolved in Week 2. To operationalize this exercise we again have β and δ drawn from the distributions above in advance. However, we assume that in Week 1, subjects do not know their true γ but optimize subject to the knowledge that γ is drawn from a normal distribution with mean 1.6 and standard deviation of σ. We consider five values of $\sigma \in \{0, 0.05, 0.1, 0.2\}$. In Panel B, we provide aggregate and individual analysis.. Though the aggregate estimates and error rates are unaffected for the lower value of uncertainty, as parametric uncertainty is increased, we begin to overestimate β and reject the truth with frequency. A similar pattern is observed in the individual estimates. Importantly, the presence of parametric uncertainty greatly reduces the correlation between between the true β_i and $\widehat{\beta}_i$ which drops below 0.3 in the more extreme case.

A natural question is why parametric uncertainty leads towards upward-biased estimates of β, pushing away from present bias. Intuitively, a subject with parametric uncertainty attempts to avoid situations of high work under extremely convex cost functions that are rarely realized. As this encourages subjects to spread their initial allocations, we estimate a more convex cost function. When the uncertainty is realized, they allocate less evenly over time on average, but the cost function is required by the estimator to remain constant. This change in behavior in Week 2 winds up being captured partially in the form of an increased β in our parameter space of interest.

Table A1: Simulation Exercises

	Aggregate Estimates							Individual Estimates		
Panel A:	Simulations: $\delta \sim N(0.99, 0.2^2)$, $\beta \sim N(0.9, 0.2^2)$, $\gamma \sim N(1.6, 0.2^2)$ Correlation Structure: $r(\beta, \gamma) \in \{-0.75, -0.25, 0, 0.25, 0.75\}$									
	N	$\overline{\widehat{\beta}}$	$s(\widehat{\beta})$	$0.9 \notin CI(\beta)$	$1 \notin CI(\beta)$	$\widehat{\gamma}$	$\widehat{\delta}$	$\overline{\widehat{\beta}_i}$	$\widehat{\beta}_i^{med}$	$r(\beta_i, \widehat{\beta}_i)$
$r(\beta,\gamma)$=0	80x100	.8828	.0242	11%	95%	1.552	.9955	.9080	.9077	0.971
$r(\beta,\gamma)$=-0.25	80x100	.8884	.0235	11%	98%	1.552	.9960	.9113	.9029	0.965
$r(\beta,\gamma)$=-0.75	80x100	.9169	.0235	13%	86%	1.537	.9955	.9359	.9071	0.931
$r(\beta,\gamma)$=+0.25	80x100	.8712	.0228	19%	96%	1.556	.9957	.8997	.9116	0.971
$r(\beta,\gamma)$=+0.75	80x100	.8541	.0265	45%	96%	1.545	.9953	.8872	.9103	0.964
Panel B:	Simulations: $\delta \sim N(0.99, 0.2^2)$, $\beta \sim N(0.9, 0.2^2)$, $\gamma \sim N(1.6, \sigma^2)$ Uncertainty Structure: $\sigma \in \{0, 0.05, 0.1, 0.2\}$, Unrealized at Initial Allocation									
	N	$\overline{\widehat{\beta}}$	$s(\widehat{\beta})$	$0.9 \notin CI(\beta)$	$1 \notin CI(\beta)$	$\widehat{\gamma}$	$\widehat{\delta}$	$\overline{\widehat{\beta}_i}$	$\widehat{\beta}_i^{med}$	$r(\beta_i, \widehat{\beta}_i)$
$\sigma = 0$	80x100	.8800	.0202	13%	94%	1.601	.9957	.9044	.9017	0.995
$\sigma = 0.05$	80x100	.9001	.0287	7%	92%	1.608	.9949	.9336	.9122	0.824
$\sigma = 0.1$	80x100	.9593	.0369	26%	17%	1.632	.9952	1.022	.9539	0.590
$\sigma = 0.2$	80x100	1.186	.0823	98%	58%	1.736	.9957	1.367	1.164	0.325

B Additional Tables and Figures

B.1 Estimates Including Nine Subjects With Limited Effort Allocation Variation

We re-conduct the primary aggregate analysis including 9 subjects with limited variation in their effort allocation choices.

Table A2: Parameter Estimates Including 9 Additional Subjects

	Monetary Discounting		Effort Discounting		
	(1) All Delay Lengths	(2) Three Week Delay Lengths	(3) Job 1 Greek	(4) Job 2 Tetris	(5) Combined
Present Bias Parameter: $\hat{\beta}$	0.975 (0.008)	0.988 (0.008)	0.870 (0.045)	0.848 (0.042)	0.858 (0.040)
Daily Discount Factor: $\hat{\delta}$	0.998 (0.000)	0.997 (0.000)	0.999 (0.005)	1.002 (0.005)	1.000 (0.005)
Monetary Curvature Parameter: $\hat{\alpha}$	0.976 (0.006)	0.977 (0.005)			
Cost of Effort Parameter: $\hat{\gamma}$			1.666 (0.122)	1.580 (0.101)	1.621 (0.109)
# Observations	1680	1260	890	890	1780
# Clusters	84	84	89	89	89
Job Effects					Yes
$H_0 : \beta = 1$	$\chi_2(1) = 9.09$ ($p < 0.01$)	$\chi_2(1) = 2.12$ ($p = 0.15$)	$\chi_2(1) = 8.41$ ($p < 0.01$)	$\chi_2(1) = 13.39$ ($p < 0.01$)	$\chi_2(1) = 12.23$ ($p < 0.01$)
$H_0 : \beta(Col.\ 1) = \beta(Col.\ 5)$	$\chi_2(1) = 11.45$ ($p < 0.01$)				
$H_0 : \beta(Col.\ 2) = \beta(Col.\ 5)$		$\chi_2(1) = 13.79$ ($p < 0.01$)			

Notes: Parameters identified from two-limit Tobit regressions of equations (6) and (4) for monetary discounting and effort discounting, respectively. Parameters recovered via non-linear combinations of regression coefficients. Standard errors clustered at individual level reported in parentheses, recovered via the delta method. Effort regressions control for Job Effects (Task 1 vs. Task 2). Tested null hypotheses are zero present bias, $H_0 : \beta = 1$, and equality of present bias across effort and money, $H_0 : \beta(Col.\ 1) = \beta(Col.\ 5)$ and $H_0 : \beta(Col.\ 2) = \beta(Col.\ 5)$.

B.2 Estimates For Effort Discounting By Week

We re-estimate parameters by week and test the null hypothesis of equality of discount rates identified from initial allocations and subsequent reallocations.

Table A3: Parameter Estimates By Week

	Effort Discounting			
	(1) Week 1 Initial Allocations	(2) Week 2 Reallocations	(3) Week 3 Initial Allocations	(4) Week 4 Reallocations
Daily Discount Factor: $\hat{\delta}$	1.000 (0.004)	0.985 (0.004)	0.991 (0.003)	0.984 (0.004)
Cost of Effort Parameter: $\hat{\gamma}$	1.668 (0.126)	1.521 (0.097)	1.463 (0.074)	1.528 (0.092)
# Observations	800	800	800	800
# Clusters	80	80	80	80
Job Effects	Yes	Yes	Yes	Yes
$H_0 : \delta(Col.\ 1) = \delta(Col.\ 2)$	$\chi_2(1) = 7.09$ $(p < 0.01)$			
$H_0 : \delta(Col.\ 3) = \delta(Col.\ 4)$			$\chi_2(1) = 4.01$ $(p = 0.05)$	

Notes: Parameters identified from two-limit Tobit regressions of equation (4) assuming $\beta = 1$ for effort discounting, respectively. Parameters recovered via non-linear combinations of regression coefficients. Standard errors clustered at individual level reported in parentheses, recovered via the delta method. Effort regressions control for Job Effects (Task 1 vs. Task 2). Tested null hypotheses are equal discounting in Weeks 1 vs. 2 and Weeks 4 and 5, $H_0 : \delta(Col.\ 1) = \delta(Col.\ 2)$ and $H_0 : \delta(Col.\ 3) = \delta(Col.\ 4)$.

B.3 Full Effort Data Set Tables Figures

We reconduct all analyses using Block 1 and Block 2 data to identify effort discounting parameters.

Table A4: Parameter Estimates: Full Effort Data Set

	Monetary Discounting		Effort Discounting		
	(1) All Delay Lengths	(2) Three Week Delay Lengths	(3) Job 1 Greek	(4) Job 2 Tetris	(5) Combined
Present Bias Parameter: $\hat{\beta}$	0.974	0.988	0.927	0.927	0.927
	(0.009)	(0.009)	(0.022)	(0.021)	(0.020)
Daily Discount Factor: $\hat{\delta}$	0.998	0.997	0.997	0.997	0.997
	(0.000)	(0.000)	(0.003)	(0.003)	(0.003)
Monetary Curvature Parameter: $\hat{\alpha}$	0.975	0.976			
	(0.006)	(0.005)			
Cost of Effort Parameter: $\hat{\gamma}$			1.566	1.510	1.537
			(0.090)	(0.081)	(0.084)
# Observations	1500	1125	1600	1600	3200
# Clusters	75	75	80	80	80
Block Effects			Yes	Yes	Yes
Job Effects					Yes
$H_0 : \beta = 1$	$\chi_2(1) = 8.77$	$\chi_2(1) = 1.96$	$\chi_2(1) = 11.1$	$\chi_2(1) = 11.9$	$\chi_2(1) = 13.94$
	$(p < 0.01)$	$(p = 0.16)$	$(p < 0.01)$	$(p < 0.01)$	$(p < 0.01)$
$H_0 : \beta(Col.\ 1) = \beta(Col.\ 5)$	$\chi_2(1) = 5.46$				
	$(p < 0.01)$				
$H_0 : \beta(Col.\ 2) = \beta(Col.\ 5)$		$\chi_2(1) = 8.61$			
		$(p < 0.01)$			

Notes: Parameters identified from two-limit Tobit regressions of equations (6) and (4) for monetary discounting and effort discounting, respectively. Parameters recovered via non-linear combinations of regression coefficients. Standard errors clustered at individual level reported in parentheses, recovered via the delta method. Effort regressions control for Block Effects (Weeks 1,2,3 vs. 4,5,6) and Job Effects (Task 1 vs. Task 2). Tested null hypotheses are zero present bias, $H_0 : \beta = 1$, and equality of present bias across effort and money, $H_0 : \beta(Col.\ 1) = \beta(Col.\ 5)$ and $H_0 : \beta(Col.\ 2) = \beta(Col.\ 5)$.

Table A5: Validation of Individual Parameter Estimates: Full Effort Data Set

Dependent Variable:	*Budget Share Distance*			
	Effort Discounting		Monetary Discounting	
	(1)	(2)	(3)	(4)
Real Effort Present Bias Parameter: $\hat{\beta}_e$	0.444***			
	(0.025)			
Present Biased$_e$ (=1)		-0.092***		
		(0.012)		
Monetary Present Bias Parameter:$\hat{\beta}_m$			2.393***	
			(0.052)	
Present Biased$_m$ (=1)				-0.201***
				(0.026)
Constant	-0.430***	0.034***	-2.391***	0.044***
	(0.021)	(0.011)	(0.049)	(0.015)
Block x Job Effects	Yes	Yes	-	-
Choice Set Effects	-	-	Yes	Yes
# Observations	1600	1600	750	750
# Uncensored Observations	1593	1593	731	731
# Clusters	80	80	75	75

Notes: Coefficients from tobit regressions of budget share distance $\in [-1, 1]$ on identified individual discounting parameters. 20 reallocations per individual for effort decisions and 10 reallocations per individual for monetary decisions. Standard errors clustered on individual level in parentheses. Block x Job fixed effects for effort and choice set fixed effects for monetary discounting included but not reported. Discounting parameters identified from OLS regressions for monetary discounting and real effort discounting with individual specific effects for both $\hat{\delta}$ and $\hat{\beta}$. Curvature parameter, α, and cost parameter, λ, assumed constant across individuals. Effort regressions identifying parameters control for Block Effects (Weeks 1,2,3 vs. 4,5,6) and Job Effects (Job 1 vs. Job 2). Monetary Present Bias (=1) and Effort Present Bias (=1) calculated as individuals with estimated $\hat{\beta} < 0.99$ in the relevant domain. Levels of significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Table A6: Monetary and Real Effort Discounting by Commitment: Full Effort Data Set

	Monetary Discounting		Effort Discounting	
	Commit (=0)	Commit (=1)	Commit (=0)	Commit (=1)
	(1) Tobit	(2) Tobit	(3) Tobit	(4) Tobit
Present Bias Parameter: $\hat{\beta}$	0.999 (0.010)	0.981 (0.013)	0.989 (0.018)	0.880 (0.031)
Daily Discount Factor: $\hat{\delta}$	0.997 (0.000)	0.997 (0.001)	0.987 (0.005)	1.004 (0.004)
Monetary Curvature Parameter: $\hat{\alpha}$	0.981 (0.009)	0.973 (0.007)		
Cost of Effort Parameter: $\hat{\gamma}$			1.485 (0.123)	1.579 (0.116)
# Observations				
# Clusters	28	47	33	47
Block Effects			Yes	Yes
Job Effects			Yes	Yes
$H_0 : \beta = 1$	$\chi_2(1) = 0.01$ $(p = 0.94)$	$\chi_2(1) = 2.15$ $(p = 0.14)$	$\chi_2(1) = 0.34$ $(p = 0.56)$	$\chi_2(1) = 15.12$ $(p < 0.01)$
$H_0 : \beta(Col.\ 1) = \beta(Col.\ 2)$	$\chi_2(1) = 1.29$ $(p = 0.26)$			
$H_0 : \beta(Col.\ 3) = \beta(Col.\ 4)$			$\chi_2(1) = 9.35$ $(p < 0.01)$	

Notes: Parameters identified from OLS regressions of equations (1) and (2) for monetary discounting and real effort discounting. Parameters recovered via non-linear combinations of regression coefficients. Standard errors clustered at individual level reported in parentheses, recovered via the delta method. Commit (=1) or Commit (=0) separates individuals into those who did (1) or those who did not (0) choose to commit at a commitment price of zero dollars. Effort regressions control for Block Effects (Weeks 1,2,3 vs. 4,5,6) and Job Effects (Job 1 vs. Job 2). Tested null hypotheses are zero present bias, $H_0 : \beta = 1$, and equality of present bias across commitment and no commitment, $H_0 : \beta(Col.\ 1) = \beta(Col.\ 2)$ and $H_0 : \beta(Col.\ 3) = \beta(Col.\ 4)$.

Table A7: Predicting Commitment Demand: Full Effort Data Set

	Dependent Variable : Commit (=1)					
	(1)	(2)	(3)	(4)	(5)	(6)
$\hat{\beta}_e$	-4.932** [-1.184]				-5.634** [-1.283]	
	(1.915)				(2.346)	
Present Biased$_e$ (=1)		1.417*** [0.333]				1.728*** [0.384]
		(0.485)				(0.554)
$\hat{\beta}_m$			-3.146 [-0.735]		-1.685 [-0.384]	
			(4.140)		(3.672)	
Present Biased$_m$ (=1)				0.622 [0.140]		0.215 [0.048]
				(0.533)		(0.567)
Constant	5.019***	-0.405	3.635	0.323	7.541*	-0.402
	(1.809)	(0.347)	(4.092)	(0.288)	(3.909)	(0.377)
# Observations	80	80	75	75	75	75
Log-Likelihood	-49.718	-49.652	-49.280	-48.838	-44.649	-43.203
Pseudo R^2	0.083	0.084	0.006	0.014	0.099	0.128
Mean of Dependent Variable	0.59	0.59	0.63	0.63	0.63	0.63

Notes: Coefficients from logistic regression of demand for commitment on identified individual discounting parameters. Marginal effects in brackets. Robust standard errors in parentheses. Commit (=1) or Commit (=0) separates individuals into those who did (1) or those who did not (0) choose to commit at a commitment price of zero dollars. Discounting parameters identified from OLS regressions of equations (1) and (2) for monetary discounting and real effort discounting with individual specific effects for both $\hat{\delta}$ and $\hat{\beta}$. Curvature parameter, α, and cost parameter, λ, assumed constant across individuals. Effort regressions identifying parameters control for Block Effects (Weeks 1,2,3 vs. 4,5,6) and Job Effects (Job 1 vs. Job 2). Present Biased$_m$ (=1) and Present Biased$_e$ (=1) calculated as individuals with estimated $\hat{\beta} < 0.99$ in the relevant domain. Levels of significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Figure A1: Real Effort Discounting Behavior: Full Effort Data Set

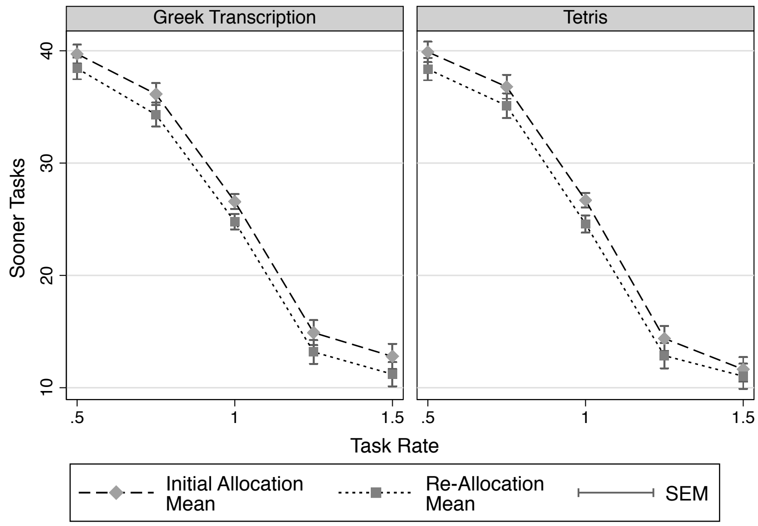


Figure A2: Individual Estimates of Present Bias: Full Effort Data Set

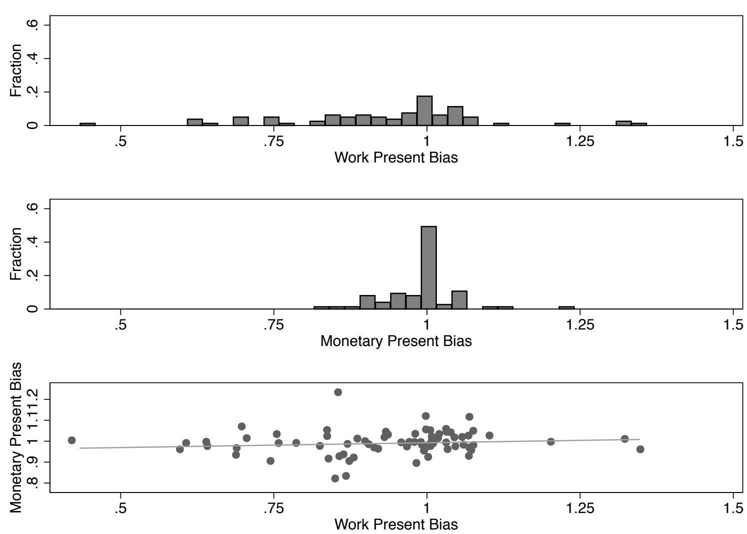
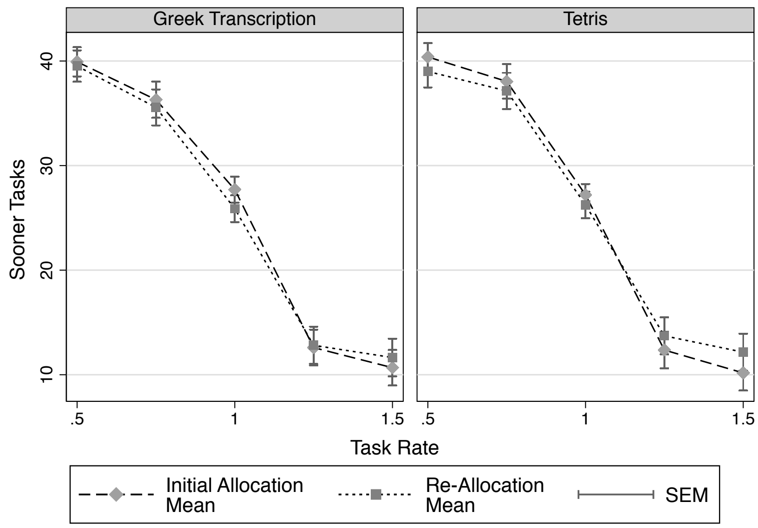


Figure A3: Commitment Demand: Full Effort Data Set

Panel A: Commit (=0)



Panel B: Commit (=1)