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Replication Report: Concentration Bias in Intertemporal Choice*

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Abstract

Dertwinkel-Kalt et al. (2022) examine the effect of *concentration bias* - the tendency to overweight advantages that are concentrated in time relative to costs that are spread over multiple time periods - on intertemporal choice in a laboratory experiment. In their preferred empirical specification, the authors report that concentration bias leads to a 22.4% higher willingness to work than explained by a standard model of intertemporal discounting. We conduct a computational replication of the main results of the paper using the same procedures and original data. Our results confirm the sign, magnitude and statistical significance of the author's reported estimates across each of their five main findings.

KEYWORDS: concentration bias, intertemporal choice, laboratory experiment, computational replication

JEL CODES: D01. D9.

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1 Introduction

Dertwinkel-Kalt et al. (2022), hereafter DGRSS, investigate how the relative distribution of costs and benefits across time periods affects the intertemporal decision-making of agents. The authors refer to the relative over-weighting of the concentrated in time gains relative to dispersed over time costs as *concentration bias.* Although choices that exhibit concentration bias violate the predictions of standard intertemporal choice models, such choices are consistent with the *"focusing model"* of Kőszegi and Szeidl (2013) which posits that decision makers focus disproportionately on outcomes that are concentrated on fewer attributes. The authors investigate the magnitude of concentration bias, the mechanisms behind it, and its generalizability in different contexts through a series of laboratory experiments and econometric analyses of subjects' decisions.

In the present paper, we investigate the computational reproducibility of DGRSS's empirical results. Using the *processed* data provided by the replication package, we re-estimate the main regression specifications behind their five main results. We successfully reproduce all five of DGRSS's main results when we use the measures of concentration bias provided by the authors. We extend our analysis (where possible) to compute our own measure of concentration bias from subject's choice data. The analysis yields results that are closely aligned to those reported DGRSS. Small differences only occur at the third decimal point. This does not change the economic or statistical significance of the original study's findings.

The remainder of the paper proceeds as follows. Section 2 provides a brief introduction to the experiments of DGRSS to contextualize the task and the study's findings. Section 3 outlines the replication materials and describes how we estimate concentration bias from subject choice data, comparing our estimate to the original. Section 4 presents results from our re-analysis alongside those of the original study, highlighting that the original results are reproducible. Section 5 provides a brief conclusion and discusses main takeaways from the replication task.

2 Context: The Lab Experiments

DGRSS conduct a series of experiments to investigate the presence of concentration bias and quantify the magnitude by which it distorts intertemporal choice relative to the predictions of conventional intertemporal choice models. In a first set of experiments, subjects are asked to complete a series of choice tasks over eight consecutive days in exchange for a payment in the form of a restaurant voucher paid out on day nine. Across these eight "balanced" choice tasks ($j = 1, 2, \ldots, 8$) subjects report how many extra real effort tasks x_j they would be willing to complete on each work day $t = j$ relative to a baseline, to receive a restaurant voucher of greater value.[1] Following these eight balanced choice tasks, a ninth task offers an "unbalanced" choice scenario where the extra tasks are spread over each work day in return for the bonus payment that is paid on the final day. Evidence for concentration bias in this setup comes from observing a higher willingness to complete tasks in the unbalanced choice scenario than in the balanced choice tasks. Throughout the original study this is referred to as the MAIN-TREATMENT.

DGRSS extend the first set of experiments to isolate the mechanisms driving concentration bias, examine its cross-domain stability and test for the underlying assumption of preference stability across choice tasks. The authors disentangle the mechanism and highlight the importance of both payoff concentration in time and framing by comparing choices made in the setup above to a treatment that splits the restaurant voucher into a composite voucher. The authors refer to this treatment as the MECHANISM-TREATMENT. If the concentration bias is also explained by framing, the authors expect the concentration bias in their mechanism treatment to be smaller than in their main treatment because dispersed framing of benefits counteracts the dispersion of costs over time. Cross-domain stability is examined by

[1] "Balanced" refers to the notion that the costs in terms of extra tasks are paid on *one* of the eight work days and the extra payment is also earned on one day. This is in contrast to an "unbalanced" task where the costs in terms of extra tasks are incurred across each of the eight work days whereas the extra payment is earned only on one day. See Section 2.3 of Dertwinkel-Kalt et al. (2022) for further details.

replacing the restaurant voucher payment with a charitable donation and testing for concentration bias in the donation treatment, DONATION-TREATMENT. Preference stability is examined by asking participants to make the same balanced choice task twice and seeing that the decisions are similar.

3 Data Replication Materials

Data Sources & Replication Materials. We access the data and code provided by DGRSS on Zenodo.[2] The authors of the original study include their STATA code, two processed data files and the oTree source files for replicating the experiment. The codes and data used in this replication are made available on OSF.[3]

Reconstruction of Outcome Variables. The data provided by the authors consists of two separate `csv` files containing processed data files, one file for treatments using restaurant vouchers as a form of payment (MAIN-TREATMENT) and another for treatments utilizing monetary payments (MONEY-TREATMENT). The provision of processed data files aligns with The Review of Economic Studies' Replication Policy that requires "the analysis code to construct the research outputs displayed in the paper".[4] Throughout the rest of our analysis we rely on this processed data, but note that it was not possible to verify that the data cleaning steps from the raw data outputs to these processed data files has been correctly implemented.

In our re-analysis of the MAIN-TREATMENT, we take a two step approach to assessing reproducibility. First, we reproduce the empirical results using the value of concentration bias provided at the subject level provided by DGRSS in the data set. This provides us with a measure of (average) absolute concentration bias reported in the data as a lower bound, midpoint and upper bound, along with a relative measure. Second, we use the elicited indifference points of subjects from each task

[2]Zenodo URL: https://doi.org/10.5281/zenodo.5091975

[3]OSF URL: https://osf.io/d42xr/.

[4]See https://restud.github.io/data-editor/after/ for the complete description of what must be contained in the replication package of an article accepted at The Review of Economic Studies.

combined with the effort costs parameterized by the author's to compute our own measure of relative concentration bias. We compute the relative concentration bias using the formula for each decision at time t and for individual i:[5]

$$\tilde{d}_i^{rel} = \frac{1}{8}\sum_{t=1}^{8}\frac{\tilde{d}_i}{(x_{it}+e_{it})}$$

$\tilde{d}$ is the measure for concentration bias which in this setup is the number of per-workday tasks that subjects are willing to complete in the unbalanced trade-off. $x + e$ is the elicited indifference point for each workday.

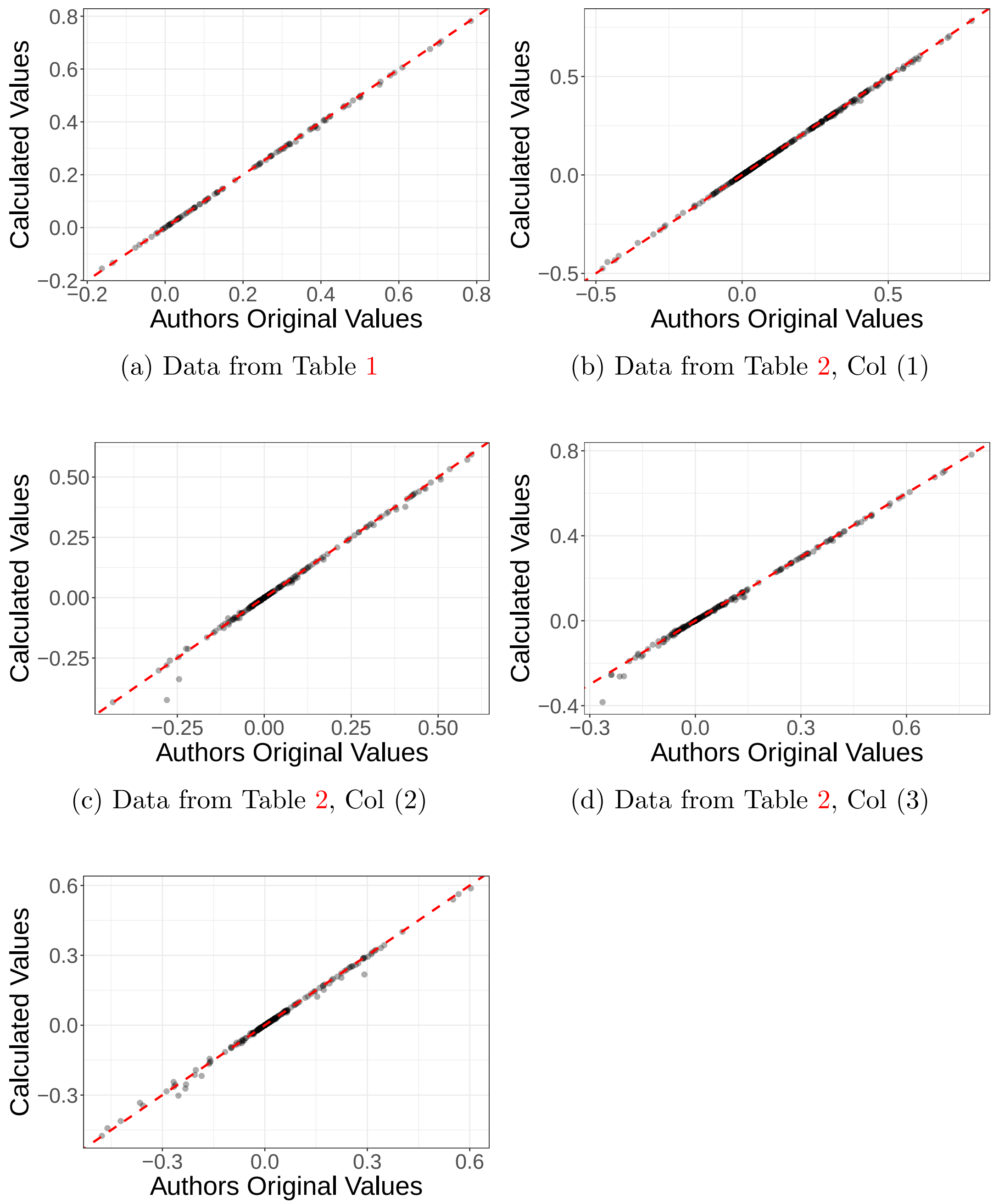
Although we are able to reconstruct a measure of the relative amount of concentration bias in the treatments featuring voucher payments, in the data provided for the monetary payment treatments do not contain enough information for us to reconstruct a measure of concentration bias. In this part of our re-analysis, in Section 4.3, our approach rests on re-coding the original author's analysis using the values of concentration bias provided in the data files.

Comparing Author Provided and Our Computed Outcome Variables. Figure 1 compares our measure of relative concentration bias to those provided by DGRSS. We report these correlations split across different slices of the data, with each panel representing a set of observations used in its own econometric specification. Two patterns clearly emerge. First, there is a high degree of similarity between the original measure of DGRSS and our own. Second, differences only occur for subjects that have negative values of relative concentration bias.[6] In these situations our estimates are typically lower than those reported by DGRSS. Our best guess as to where these differences arise is a combination of differences in rounding and dealing with corner solutions.

[5] From the data provided in the replication package, the script and information in the README files of the authors did not contain sufficient information for us to reconstruct all measures of concentration bias used in Table 2 of DGRSS. We needed to carefully read the paper, add the baseline values in the experiment and combine them with the provided data to compute the relative concentration bias.

[6] A negative measure for concentration bias states that subjects are willing to complete fewer tasks when benefits are concentrated in time and costs are dispersed in time.

Figure 1: Computed vs Provided Measure of Relative Concentration Bias, $\tilde{d}^{rel}$



(a) Data from Table 1

(b) Data from Table 2, Col (1)

(c) Data from Table 2, Col (2)

(d) Data from Table 2, Col (3)

(e) Data from Table 2, Col (4)

Notes: Each figure reports the measure of relative concentration bias per subject provided by the authors in their replication data (along the x-axis) and our own computation (along the y-axis). See Section 3 for details on computation of $\tilde{d}^{rel}$. The red dashed line is the 45 degree line, showing where the respective measures are identical. Comparisons are split across different slices of data, depending on where they are used in the empirical analysis.

4 Assessing Computational Reproducibilty of Main Findings

We test the computational reproducibility using the original data provided and by re-coding the main analysis.[7] The remainder of this section is divided into subsections by each of the main result tables we replicate.

4.1 Evidence for Concentration Bias - Main-Treatment (Table 2 of DGRSS)

For our replication analysis we rely on the same econometric specifications as the original authors and estimate the mean concentration bias averaged across all subjects, as follows:

$$y_i = \beta_0 + \epsilon_i \tag{1}$$

where y_i takes the value of either the absolute ($\tilde{d}$) or relative ($\tilde{d}^{rel}$) concentration bias of subject i, β_0 is the mean of the outcome variable and ε_i is the deviation from the mean level of concentration bias for subject i.

Table 1: Replication of Main-Treatment

	Panel A: Estimates Reported by DGRSS (2021) in Table 2				
	OLS				Tobit
	Lower Bound (1)	Midpoint (2)	Upper Bound (3)		(4)
$\tilde{d}$ in Main-Treatment	31.64***	37.61***	43.58***		37.094
	(2.685)	(3.575)	(4.683)		(3.658)
$\tilde{d}^{rel}$ in Main-Treatment	0.190***	0.224***	0.259***		
	(0.016)	(0.021)	(0.027)		
Observations	100	100	100		100
	Panel B: Our Estimates				
	OLS				Tobit
	Lower Bound (1)	Midpoint (2)	Upper Bound (3)	Midpoint (4)	(5)
$\tilde{d}$ in Main-Treatment	31.64***	37.61***	43.58***		37.094
	(2.685)	(3.575)	(4.683)		(3.658)
$\tilde{d}^{rel}$ in Main-Treatment	0.190***	0.224***	0.259***	0.223***	
	(0.016)	(0.021)	(0.027)	(0.021)	
Dependent Variable	Provided	Provided	Provided	Computed	Provided
Observations	100	100	100	100	100

Notes: Robust (HC1) standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. In Panel B, 'Provided' Dependent Variable refers to using the pre-computed dependent variable provided in the original dataset privided by the authors, whereas 'Computed' refers to our own computation of the $\tilde{d}^{rel}$. See Section 3 for further details. See the original study for definitions of Lower Bound, Upper Bound and Midpoint constructions of concentration bias.

Table 1 reports the means of the absolute and relative concentration bias along with their standard errors. Panel A displays the estimates reported by the original

replication package.

study authors and Panel B reports our estimates. We find that the point estimates and standard errors are perfectly identical between the two sets of estimates when using DGRSS's computed measures of absolute and relative concentration bias. Column 4 of Panel B shows that using our own calculated measure concentration bias reveals results that are almost identical to the author's midpoint estimates.[8] In line with the preferred specification of DGRSS, using the midpoint estimates of relative concentration bias, we find that concentration bias leads to subjects working an average of 22.4% more when gains are concentrated in time and efforts are dispersed over multiple time periods. The effect is statistically significant at all conventional thresholds.

4.2 Mechanisms & Stability of Concentration Bias

With estimates of concentration bias in hand, Dertwinkel-Kalt et al. (2022) turn to (i) separating out the mechanisms behind concentration bias, (ii) concentration bias' presence across domains, and (iii) preference stability across treatment conditions. To quantify each of the above, the authors use data from two comparable treatments and run regressions of decision maker choices on a constant and a treatment indicator:

$$\tilde{d}^{rel} = \beta_0 + \beta_1 \text{Treatment}_i + \epsilon_i \tag{2}$$

where i denotes subjects and $\tilde{d}^{rel}$ is the measure of relative concentration bias. β_0 is then the estimate of concentration bias in one of the two treatments being compared and β_1 is the difference in relative concentration bias between the two treatments being compared. Our results along with the original estimates reported by DGRSS are reported in Table 2.

Looking across Panel A and Panel B of Table 2 we can see that our estimates align exactly with those reported by in the study when we use the provided outcome

[8] Refer to Section 3 on the reconstruction of the relative measures for concentration bias.

Table 2: Replication of Mechanism-Treatment

Panel A: Estimates Reported by DGRSS (2021) in Table 3				
	(1)	(2)	(3)	(4)
$\tilde{d}^{rel}$ in Mechanism Treatment	0.075***			
	(0.019)			
Difference	0.149***			
Main-Treatment - Mechanism-Treatment	(0.028)			
$\tilde{d}^{rel}$ in Donation-Treatment		0.135***		
Donation-Treatment - Donation-Control		(0.021)		
Difference		-0.158***		
Donation-Treatment - Donation-Control		(0.022)		
$\tilde{d}^{rel}$ in Main-Control			0.023***	
			(0.008)	
Difference			-0.247***	
Main-Treatment - Main-Control			(0.023)	
$\tilde{d}^{rel}$ in Mechanism-Control				-0.014
				(0.010)
Difference				0.090***
Mechanism-Treatment - Mechanism-Control				(0.021)
Panel B: Our Estimates using $\tilde{d}^{rel}$ provided by DGRSS (2021)				
	(1)	(2)	(3)	(4)
$\tilde{d}^{rel}$ in Mechanism Treatment	0.075***			
	(0.019)			
Difference	0.149***			
Main-Treatment - Mechanism-Treatment	(0.028)			
$\tilde{d}^{rel}$ in Donation-Treatment		0.135***		
Donation-Treatment - Donation-Control		(0.021)		
Difference		-0.158***		
Donation-Treatment - Donation-Control		(0.022)		
$\tilde{d}^{rel}$ in Main-Control			0.023***	
			(0.008)	
Difference			-0.247***	
Main-Treatment - Main-Control			(0.023)	
$\tilde{d}^{rel}$ in Mechanism-Control				-0.014
				(0.010)
Difference				0.090***
Mechanism-Treatment - Mechanism-Control				(0.021)
Panel C: Our Estimates using $\tilde{d}^{rel}$ computed by Us				
	(1)	(2)	(3)	(4)
$\tilde{d}^{rel}$ in Mechanism Treatment	0.075***			
	(0.019)			
Difference	0.148***			
Main-Treatment - Mechanism-Treatment	(0.028)			
$\tilde{d}^{rel}$ in Donation-Treatment		0.133***		
Donation-Treatment - Donation-Control		(0.021)		
Difference		-0.159***		
Donation-Treatment - Donation-Control		(0.022)		
$\tilde{d}^{rel}$ in Main-Control			0.027***	
			(0.009)	
Difference			-0.249***	
Main-Treatment - Main-Control			(0.023)	
$\tilde{d}^{rel}$ in Mechanism-Control				-0.017
				(0.0100)
Difference				0.092***
Mechanism-Treatment - Mechanism-Control				(0.021)
No. Observations	200	200	200	200

Notes: Robust (HC1) standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Panel A reports the estimates and standard errors from Table 3 in Dertwinkel-Kalt et al. (2022). In Panel B, we report estimates and standard errors using our code and $\tilde{d}^{rel}$ provided in the replication package. Panel C reports estimates from specifications using our computation of $\tilde{d}^{rel}$ from the choice data provided in the author's replication package.

variable. Using our own computation of relative concentration bias, Panel C, leads to small quantitative differences at the third decimal point. These have no impact on the statistical or economic significance of the results. We highlight the main findings:

- In the Mechanism-Treatment subjects complete 7.5% ($p < 0.001$, see Column 1) more tasks in the unbalanced tasks that their preferences account for. This is significantly less than in the Main-Treatment. Combined, this suggests concentration of gains in time *and* framing play a role in concentration bias.
- Concentration bias extends to charitable donations, with subjects completing 13.5% ($p < 0.001$, see Column 2) more tasks in the unbalanced tasks than their preferences predict.
- Concentration bias is not confounded by preference instability. Estimates of concentration bias when subjects are faced with the same task twice are close to zero (See Columns 3 and 4).

4.3 Concentration Bias with Real Money

The final empirical component of DGRSS's analysis on concentration bias investigates it's presence and magnitude in intertemporal payoffs with real money. In this Money-Treatment, subjects allocate a monetary budget over two periods given a positive interest rate. The variable of interest is the savings rate, and evidence for concentration bias in this setup is present when subjects overweight concentrated payoff relative to their dispersed counterpart. In the balanced choice scenario payoffs *early* and *late* payoffs are concentrated on a single payment date, whereas in the unbalanced case, either the early or late payoff is dispersed over two, four or eight payment dates.[9] The data provided in the replication package contains measures of relative concentration bias of interest and treatment indicators for each subject

[9] We refer the interested reader to Section 5 of Dertwinkel-Kalt et al. (2022) and their Supplementary Appendix D for further details on the experiment design.

Table 3: Replication of Money Experiment Results

	Dependent Variable: $\tilde{d}$					
	(1)	(2)	(3)	(4)	(5)	(6)
	PANEL A: ESTIMATES REPORTED BY DGRSS (2021)					
Concentration Bias (β_0)	0.057	0.068	0.081	0.066	0.026	0.065
	(0.014)	(0.015)	(0.015)	(0.012)	(0.013)	(0.006)
MONEY-MAIN (β_1)						0.036
						(0.013)
	PANEL B: OUR ESTIMATES					
Concentration Bias (β_0)	0.058	0.068	0.081	0.066	0.026	0.065
	(0.014)	(0.015)	(0.015)	(0.012)	(0.013)	(0.006)
MONEY-MAIN (β_1)						0.036
						(0.013)
Treatment	Dispersed Late	Dispersed Early	8 payments	4 payments	2 payments	-
N. Obs	139	138	277	277	184	461

Notes: Robust (HC1) standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Panel A reports the estimates from DGRSS that are reported in the main text of Section 5. Standard errors are extracted from STATA log files in their replication package. Panel B reports estimates and standard errors from our replication. The outcome and explanatory variables used are the same as in the original study. Treatment refers to the treatment used to compute concentration bias. Dispersed Late refers to a treatment where later payment dates are dispersed rather than concentrated. Dispersed Early refers to a treatment where early payment dates are dispersed rather than concentrated Treatments listed as 'x' payments refer to treatments where the dispersed payment is spread over 2, 4, or 8 payment dates.

but not the choices that subjects made in the experiment. Thus what follows is a re-analysis of DGRSS's final data. We are unable to verify their construction of the outcome variable of interest, relative concentration bias, because subject's choice data is not released in the replication package.

To measure relative concentration bias, $\tilde{d}$, between a concentrated early payment, C and a dispersed late payment, D, DGRSS regress the savings in the concentrated choice scenario relative to the dispersed scenario on a constant:

$$\tilde{d}_{C-D,i} = \beta_0 + \varepsilon_i \tag{3}$$

where i denotes subjects. β_0 is the relative additional amount of money invested by subjects in the , and ε_i is subject i's deviation from the average. The result is reported in Column 1 of Table 3. Our estimates and those of DGRSS closely align. Subjects allocate 5.8 percentage points less money to later payment dates when late payment is dispersed.

Column 2 of Table 3 reports estimates of relative concentration bias when the early payment is dispersed and the later payment is concentrated, $\tilde{d}_{D-C}$. Estimates are again identical, and show that subjects allocate 6.8 percentage points more to the concentrated, later payment. Results in columns 3 through 5 show how concentration bias shifts as the amount of dispersion varies. Our estimates align with those in DGRSS, the degree of concentration bias depends on the amount of payoff dispersion. Concentration bias is highest when payments are dispersed across 8 payment dates, with 8.8 percentage points more budget allocated to concentrated payoffs, and lowest when there's two payment dates, with 3.7 percentage points of the budget allocated to concentrated payoffs.

In a similar vein to Section 4.2, DGRSS investigate whether framing contributes to their measure of concentration bias. To do so they compare subject's decisions when unbalanced choices feature payments dispersed over multiple days, what they call MONEY-MAIN, to those where dispersion of payments occurs *within* one day, MONEY-MECHANISM. If framing contributes to concentration bias, there should be *less* concentration bias in subject decision making in MONEY-MECHANISM relative to MONEY-MAIN. This hypothesis is tested via the following linear regression:

$$\tilde{d}_{C-D,i} = \beta_0 + \beta_1 \text{MONEY-MAIN}_i + \varepsilon_i \quad (4)$$

where $\tilde{d}_{C-D}$ measures the relative allocation of money to concentrated versus dispersed payoffs, MONEY-MAIN is a binary variable that takes the value one when a subject is in the MONEY-MAIN treatment and zero when they are in MONEY-MECHANISM treatments, and ε_i is an idiosyncratic error term that captures subject's individual deviation from the average. β_0 is the average degree of concentration bias in the MONEY-MECHANISM treatment and β_1 is the average difference in concentration bias in MONEY-MAIN compared to MONEY-MECHANISM. DGRSS's hypothesis that framing contributes to concentration bias suggests that $\beta_0 > 0$ but and that concentration bias is relatively less in MONEY-MECHANISM due to payments still being made within one day suggests that $\beta_1 > 0$. Estimates are reported in column 6 of Table 3. Our estimates align with those reported by DGRSS. Subjects allocate 2.6 percentage points more to concentrated in one payoff compared to concentrated within a day payoffs, and concentration bias is 3.6 percentage points higher in Money-Main than Money-Mechanism.

5 Conclusion

We conducted a computational replication of Dertwinkel-Kalt et al. (2022), using a mix of re-analysing their data 'as-is' used in their original study and where possible re-computing the outcome variable of interest, relative concentration bias. Our point estimates and standard errors align with the original article, suggesting their results are reproducible. The replication package does not provide all raw data on subject choices used to compute measures of concentration bias across all experimental conditions and regression specifications. Future work could explore the data cleaning and construction of concentration bias measures calculated by the original authors if such data were available. We would encourage (i) journal editorial teams to update replication policies to mandate provision of the raw data from experiment sessions and the scripts that clean and transform raw experimental data to 'final' data used in regressions and statistical tests to facilitate reproducible research, and (ii) authors of experimental work to make the raw data available for replication even when not explicitly required by the journal.

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