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Comment on "Risk Preferences Are Not Time Preferences": On the Elicitation of Time Preference under Conditions of Risk†

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Andreoni and Sprenger (2012a, b) report evidence that distinct utility functions govern choices under certainty and risk. I investigate the robustness of this result to the experimental design. I find that the effect disappears completely when a multiple price list instrument is used instead of a convex time budget design. Alternatively, the effect is reduced by half when sooner and later payment risks are realized using a single lottery instead of two independent lotteries. The result is thus at least partially driven by intertemporal diversification, supporting an explanation in terms of concavity of the intertemporal, and not only atemporal, utility function. (*JEL* C91, D81, D91)

The past decade has seen rapid advances in the development of both experimental designs and estimation procedures to measure the utility and discount functions that govern individual choices over time. These advances are significant both because many important economic decisions entail consequences at different points in time, and because a substantial earlier literature found wide disparities in estimated discount rates—including many that seem extraordinarily large.[1]

One important reason for these high discount rate estimates is the fact that estimates which assume a linear utility function will be upwardly biased when the utility function is, in fact, concave. This is because under concave utility, both diminishing marginal utility and discounting for time delay will tend to favor the choice of a smaller, sooner reward. Therefore, if the former is assumed away, then the effect of the latter will be overstated. The recent literature identifies at least three approaches to correcting for this bias. These are the joint estimation strategy

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[1] This early literature is thoroughly reviewed by Frederick, Loewenstein, and O'Donoghue (2002).

of Andersen et al. (2008); the convex time budget (CTB) design of Andreoni and Sprenger (2012a); and the "binary lottery" procedure of Laury, McInnes, and Swarthout (2012). In this article, I consider the properties of the first two of these approaches, under conditions in which the payments in a discounting experiment are subject to risk.

The Andersen et al. (2008) approach combines two sets of tasks—one designed to elicit curvature of the utility function, and the other designed to elicit time preference—in a joint estimation procedure, with the curvature estimated from the former used to correct the discount rate estimated from the latter. In the Andersen et al. experimental design, both tasks utilize multiple price list (MPL) instruments, in which subjects make a series of binary choices.[2] In particular, in each decision in a discounting MPL, a subject chooses to receive *either* a smaller sooner payment or a larger later one. By contrast, the key design innovation in the CTB approach of Andreoni and Sprenger (2012a) is to allow the subject to choose *any convex combination of the two payments*.[3] The subject is given an endowment of tokens to allocate between two dates, with tokens allocated to the sooner date yielding a smaller return than ones allocated to the later date. As the exchange rate between the two dates is varied, a subject's choices trace out a price expansion path in terms of sooner and later earnings, along which optimal choices depend upon both the utility curvature and discounting parameters. Within this framework, Andreoni and Sprenger (2012a) derive the analytical solution function and demonstrate how it is possible to obtain estimates of both parameters using only a single instrument.

Harrison, Lau, and Rutström (2013) review the CTB design and associated estimation procedures adopted by Andreoni and Sprenger (2012a) and express a range of misgivings in relation to both. For present purposes, two of their concerns are worth noting. Firstly, Harrison, Lau, and Rutström argue that the CTB design cannot infer the curvature of utility under alternatives to expected utility theory such as rank dependent utility (Quiggin 1982). They note that this could be remedied through the introduction of an additional task for the purpose of identifying probability weighting, as well as utility curvature, yet this would also undermine the "design parsimony" that makes the CTB approach appealing.

Secondly, Harrison, Lau, and Rutström highlight the fact that in Andreoni and Sprenger (2012a)—in which payments were not subject to risk—the majority of observed choices are corner solutions, and moreover choices are observed at *both* the all-sooner and all-later corners. The data is thus bimodal, yet Andreoni and Sprenger model it using a nonlinear least squares (NLS) estimator, which seeks to explain the mean of the data. As Harrison, Lau, and Rutström observe, these estimates indeed do a good job of predicting the mean; unfortunately, very few of the actual choices are found to fall around that mean. To avoid this difficulty, Harrison, Lau, and Rutström propose an alternative multinomial logit (MNL) estimator that seeks to explain the entire distribution of the data. Applying this estimator to the original data, they find that it in fact implies a *convex* utility function, which is

[2] The MPL design for curvature is based upon Holt and Laury (2002), while the MPL for time preference is due to Coller and Williams (1999). Although the Holt and Laury instrument is typically interpreted as a measure of risk preference, Andersen et al. are not concerned with this per se but rather the implied curvature of the utility function.

[3] A version of this procedure was proposed by Cubitt and Read (2007).

explained by the fact that the model needs to account for corner solutions at both boundaries. Since Harrison, Lau, and Rutström consider convex utility to be a priori implausible, they interpret this result to cast doubt upon subjects' comprehension of the CTB instrument.

In a companion paper, Andreoni and Sprenger (2012b) extend the CTB design to settings in which payments are subject to risk and report evidence of a "direct preference for certainty" (p. 3357) in intertemporal choice, indicating that different utility functions govern choices under certainty as distinct from risk. In their main manipulation, Andreoni and Sprenger (2012b) compare CTB decisions in which payments on both dates are certain to ones in which both payments are received with 50 percent probability, as realized by two independent lotteries. They find that in the risky condition, subjects choose more balanced portfolios of sooner and later payments (Andreoni and Sprenger 2012b, Figure 2), consistent with their interpretation that these choices are governed by a (atemporal) utility function that is *more concave* than that which applies under conditions of certainty.[4]

The proposition that different utility functions might apply under certainty as distinct from risk has immediate implications for the joint estimation strategy of Andersen et al. (2008). In particular, since Andersen et al. elicit utility curvature *under conditions of risk*, and combine this with discounting behavior elicited *under conditions of certainty*, their approach implicitly assumes that a single utility function governs choices in both sets of tasks. However, if Andreoni and Sprenger (2012b) are correct in suggesting that there are distinct utility functions under risk and certainty, then joint estimation may itself result in misleading inferences. In particular, if the utility function were indeed more concave under risk, then the Andersen et al. procedure would *overcorrect* for utility curvature in discounting under certainty, resulting in an *underestimate* of the discount rate. To obtain an unbiased estimate, it would be necessary to combine discounting and curvature data obtained under comparable risk conditions.

On the other hand, recall that in a discounting MPL a subject chooses *either* to receive a smaller sooner or a larger later payment, whereas in a CTB decision it is possible to choose a *mixture* of the two. This distinction becomes critical when the element of risk is added to the payments, as first pointed out by Andersen et al. (2011, Section 5) and Harrison, Lau, and Rutström (2013). Since Andreoni and Sprenger (2012b) realize their sooner and later CTB payments using *two independent lotteries*, a subject could spread these risks by choosing a mixture of the two payments, whereas at a corner allocation payment depends only on a single lottery. Since this "intertemporal diversification" motive does not arise when both payments are certain, it provides an alternative explanation for Andreoni and Sprenger's finding of more balanced intertemporal portfolio allocations under risk as compared to certainty.

Motivated by these two observations—the first being an implication of Andreoni and Sprenger's (2012b) result for the joint estimation strategy of Andersen et al.

[4] Andreoni and Sprenger interpret their result as supporting a "u–v" preference model characterized by discontinuity at certainty. Appendix Table A2 in Andreoni and Sprenger (2012b) reports their structural estimates indicating that the "v" function estimated under certainty is close to linear, whereas the "u" function estimated under risk is substantially more concave.

(2008), and the second being a procedural aspect of the CTB design as applied to choices involving risk—in this article I investigate the robustness of Andreoni and Sprenger's result to two simple modifications of the experimental design. Firstly, in my MPL experiment I replicate the design and estimation procedures of Andersen et al., adding a set of discounting MPLs in which payments are received with 50 percent probability. With these data, I can compare the results of joint estimation when both utility curvature and discounting are elicited under risk to when the latter is elicited under certainty as in Andersen et al. (2008), and thus assess the magnitude of any bias in the joint estimation procedure. Moreover, this experiment embeds a replication of the main (1, 1) versus (0.5, 0.5) manipulation in Andreoni and Sprenger (2012b) in which the CTB instrument is replaced by an MPL. Secondly, in my CTB experiment I replicate the design and estimation procedures of Andreoni and Sprenger (2012b), adding a set of CTBs in which both payments are received with 50 percent probability *as realized by a single lottery*. In this condition the sooner and later payment risks are perfectly correlated, and by comparing it to a corresponding independent lotteries condition I can assess what portion of Andreoni and Sprenger's result is driven by diversification behavior.

In my MPL data, I find almost no evidence of differences in intertemporal choice under risk compared to certainty. As a result, the riskiness of payments has a negligible effect upon the results of the Andersen et al. joint estimation procedure. One possible explanation may be that the binary choice nature of the MPL does not permit intertemporal diversification: in a discounting MPL, even when payments are subject to risk, there is only ever a single payment as realized by a single lottery.

The CTB experiment identifies the effect of removing diversification opportunities from the Andreoni and Sprenger (2012b) design. The CTB data indicate that in the correlated risks condition—in which payments are subject to risk but diversification is not possible—the difference in behavior relative to certainty is reduced by just over one-half when compared to the independent risks condition. Direct examination of the choice data indicates clearly that the three risk conditions are distinct and differ significantly from one another. However, at the same time, an implementation of the structural MNL model introduced by Harrison, Lau, and Rutström (2013) cannot reject the hypothesis that a single set of curvature and discounting parameters explains choices under both certainty and correlated risks (with the independent risks condition being distinct from these two).

Just as the standard model of discounted expected utility (DEU) cannot explain the original Andreoni and Sprenger (2012b) finding of a difference between certainty and independent risks, it also cannot explain my finding of a difference between independent and correlated risks, since the standard model in fact predicts the same behavior in all three conditions. In particular, the linearity of the *intertemporal* utility function in the standard model implies that it does not predict intertemporal diversification. A simple extension to allow concavity of intertemporal utility—corresponding to the "correlation aversion" model examined by Andersen et al. (2011)—generates a prediction of differential behavior under independent versus correlated risks. Through an extension of the MNL framework, I am able to estimate the parameters of this model using my CTB data and confirm the finding of concave intertemporal utility.[5] Yet even this model does not predict any difference in behavior between certainty and correlated risks,[6] and insofar as I find evidence of such a difference this remains open for interpretation.

The remainder of the article is organized as follows. Section I presents the design and results of my MPL experiment, Section II presents the design and results of my CTB experiment, Section III presents support for the concave intertemporal utility hypothesis, and Section IV concludes. Statements of model predictions, detailed enumeration of experiment parameters, and the full text of the instructions are provided in the online Appendices.

I. Multiple Price List Experiment

A. *Design and Procedures*

The design of my MPL experiment was based upon Andersen et al. (2008). Each subject completed four risk preference MPL tables to identify utility curvature, as well as eight time preference MPL tables, with a total of ten binary decision rows in each table. In four of the discounting tasks both the sooner and later payment options were certain, while the other four were identical except that both payment options were received with 50 percent probability. The risk preference and certain discounting components thus replicate the design of Andersen et al., while the certain and risky discounting components replicate the main conditions in Andreoni and Sprenger (2012b) using an MPL instrument instead of a CTB. In particular, the standard DEU model predicts the same pattern of choices under both the certain and risky discounting conditions, just as it does in the CTB design of Andreoni and Sprenger (see online Appendix A for details).

The payoffs in the risk preference tasks were chosen to span a similar range as the time preference tasks, and thus measure curvature over the relevant region of the utility function. In the discounting tasks, the sooner payment option always carried a front-end delay of one week, while the later payment option was delayed by a further 3, 6, 9, or 12 weeks.[7] All payment dates thus fell on the same weekday as the experiment itself and were also designed to fall within teaching weeks of the current semester, avoiding holidays.

Each subject was paid for one randomly chosen risk preference decision, received in cash before leaving the laboratory. Each subject also had one time preference decision randomly chosen to count for payment. If this decision was one that involved risk, the lottery to determine whether or not the payment option chosen by the subject would in fact be sent was also realized before leaving the laboratory. However, the

[5] Using a different experimental design and estimation procedure, Andersen et al. (2011) previously obtained this result in a sample representative of the adult Danish population.

[6] Formal statements of the implications of the two models are set out in online Appendix A.

[7] Full details of the parameters of the MPL decisions are provided in online Appendix B.1. In the 3- and 9-week discounting horizons, the smaller sooner payment option was fixed, and the larger later option varied, consistent with the design of Andersen et al. In the 6- and 12-week horizons, the larger later option was fixed and the smaller sooner option varied, consistent with the design of Andreoni and Sprenger.

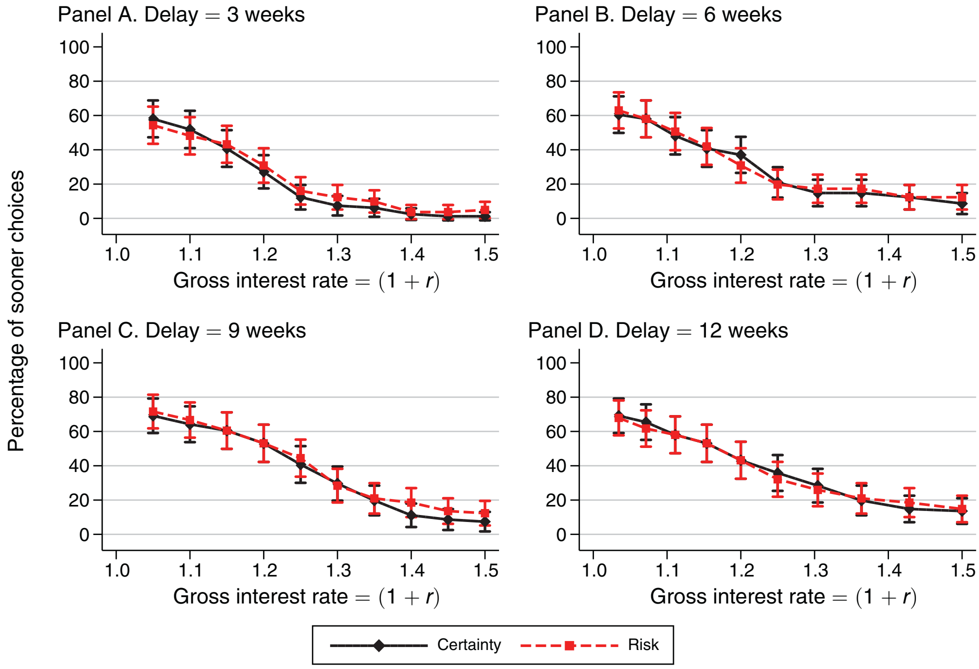

Figure 1. Aggregate Behavior in MPL Discounting Tasks

actual payment, being delayed, was made by check, drawn on the campus branch of the National Australia Bank and mailed by Australia Post guaranteed Express Post.[8]

A total of 81 student subjects completed the MPL experiment at an Australian research university on July 26 and 27, 2011. The realized average payments were AUD 19 for the risk preference component, and AUD 21 for the time preference component.[9] The experiment was conducted using pen and paper and took approximately 90 minutes to complete.[10]

B. *Results of the MPL Experiment*

Figure 1 summarizes aggregate discounting behavior in the MPL experiment, with each panel corresponding to a different delay length between the sooner and later payment options. In each panel, the percentage of subjects who chose the sooner option in each decision is plotted against the gross experimental interest rate (i.e., the ratio of the value of the later to the sooner payment options), with the confidence

[8] Australia Post guarantees next-day delivery for articles mailed by Express Post, at a cost of approximately AUD 5 per envelope. The procedures also incorporated several other measures adopted by Andreoni and Sprenger (2012a) to minimize the background risk associated with future payments. In particular, subjects addressed their own envelopes, wrote their own payment amounts and dates inside their envelopes, and were given the business card of the experimenter to contact in the event of a payment not arriving as expected.

[9] At the time of the MPL experiment, one AUD was worth approximately USD 1.10.

[10] The full text of the instructions for the MPL experiment are provided in online Appendix C. The risk preference tasks were always completed first, and half of the subjects completed the discounting tasks under certainty before discounting under risk, while for the other half this order was reversed. There was no evidence of any order effect.

Table 1—Estimates of Utility Curvature and Annual Discount Rates from MPL Data

	Assuming linear utility (1)				Allowing concave utility (2)			
	Coef.	SE	95 percent CI		Coef.	SE	95 percent CI	
α					0.430	0.050	0.332	0.529
ρ_{Cert}	1.153	0.242	0.678	1.628	0.391	0.082	0.230	0.552
ρ_{Risk}	1.142	0.271	0.612	1.673	0.388	0.089	0.213	0.563
μ					0.065	0.008	0.050	0.081
ν_{Cert}	0.114	0.011	0.093	0.136	0.049	0.007	0.035	0.063
ν_{Risk}	0.129	0.014	0.102	0.156	0.056	0.009	0.038	0.073
$H_0 : \rho_{Cert} = \rho_{Risk}$	$\chi^2(1) = 0.01, p = 0.933$				$\chi^2(1) = 0.01, p = 0.933$			
log-likelihood	−3,443.067				−4,357.753			
Observations	6,480				9,720			
Clusters	81				81			

Notes: ML estimates with the restriction $\omega = 0$. The structural "noise" parameters μ and ν model decision errors in the curvature and discounting choices, respectively. Robust standard errors are clustered at the level of individual subjects.

bars representing the normal approximation to the 95 percent confidence interval for a binomial proportion. This presentation thus mirrors that of Figure 2 in Andreoni and Sprenger (2012b).

In contrast to Andreoni and Sprenger's results using a CTB instrument, Figure 1 clearly shows that in my MPL data there is very little evidence of any systematic deviation in discounting behavior under risk as compared to certainty. In particular, out of 40 possible pairwise comparisons, there are none in which the proportion of sooner choices in the certain condition falls outside of the 95 percent confidence interval for the risky condition, and only three cases in which the converse holds.[11] In short, the effect reported by Andreoni and Sprenger (2012b) largely disappears when an MPL design is used in place of their CTB.

Recall that the MPL experiment was motivated by the possibility that differences in preferences under risk versus certainty might cause the joint estimation procedure developed by Andersen et al. (2008) to be biased. To examine this possibility, I replicate the Andersen et al. estimates using my MPL data and report the results in Table 1. In particular, I adopt the same structural model and notation as Andreoni and Sprenger (2012b, Appendix B), who assume an exponentially discounted CRRA utility function:

$$U = \delta^t (c_t - \omega)^\alpha + \delta^{t+k} (c_{t+k} - \omega)^\alpha, \tag{1}$$

where t is the front-end delay in days to the sooner payment option, k is the additional delay to the later option, c denotes experimental earnings, and ω is a "background"

[11] These correspond to the gross interest rates of 1.45 and 1.5 in the three-week horizon, and the gross interest rate of 1.4 in the nine-week horizon. However, as can be seen in Figure 1, even these differences are slight.

parameter.[12] The parameter α measures utility curvature such that $(1 - \alpha)$ is the coefficient of relative risk aversion, and δ is the daily exponential discount factor such that $\rho \equiv 1/\delta^{365} - 1$ is the implied (net) annual discount rate. Andreoni and Sprenger (2012b) assume an exponential discount function because the analysis of quasi-hyperbolic discounting is precluded by the fact that all sooner payments carry a front-end delay. However, as I emphasize in stating model predictions in online Appendix A, the specification of the discount function is not germane to the core issue of differential behavior under risk versus certainty.

Model (1) in Table 1 reports estimates of the annual discount rate using the time preference data only and assuming linear utility. Model (2) reports joint estimates of utility curvature and discounting using both the risk and time preference data and allowing for concave utility. In each model, the estimate of the annual discount rate ρ is permitted to differ between the discounting tasks elicited under certainty as compared to risk. In particular, the joint estimate of ρ_{Cert} in model (2) combines utility curvature elicited under *risk* with discounting elicited under *certainty* and corresponds to the original estimation procedure in Andersen et al. (2008). This estimate is potentially misspecified if those choices are governed by distinct utility functions. By contrast, the joint estimate of ρ_{Risk} is estimated from discounting choices under risk, and as a result it is robust to this form of misspecification.

The parameters μ and ν are structural "noise" terms to model decision errors in the curvature and discounting choices, respectively, and moreover, the estimate of ν is permitted to differ between the discounting tasks elicited under risk and certainty. Specifically, in each risk preference decision, given a candidate value of the curvature parameter α the expected utility is evaluated for each of the two alternatives, A and B, and the likelihood that A is chosen is modeled as $EU_A^{1/\mu}/\left(EU_A^{1/\mu} + EU_B^{1/\mu}\right)$; the ν parameters enter the discounting specification analogously. The models were estimated by maximum likelihood in Stata 10.1 following procedures set out in Andersen et al. (2008), with the background parameter set to $\omega = 0$ and robust standard errors clustered on individual subjects.

In model (1) of Table 1, which does not correct for curvature of the utility function, the annual discount rate is estimated at 115.3 percent when payments are certain and 114.2 percent when they are received with 50 percent probability. The difference between these estimates is clearly not statistically significant ($p = 0.933$). This confirms what was already apparent from Figure 1, namely that in the MPL data discounting behavior under the two risk conditions is virtually indistinguishable.

In model (2), the estimate of the utility curvature parameter α is 0.430, implying a coefficient of relative risk aversion of 0.570. Correcting for this curvature in joint estimation lowers the estimated annual discount rate to 39.1 percent under certainty and 38.8 percent under risk. These estimates are clearly very close, and the difference between them is both inconsequential compared to the effect of correcting for curvature relative to the estimates in model (1) and clearly not statistically significant ($p = 0.933$). This establishes the main result from the MPL experiment, namely that the possibility that distinct utility functions might govern discounting

[12] If ω is positive, it may be interpreted as a Stone-Geary minimum or reference point. If it is negative, $B \equiv -\omega$ may be interpreted as background consumption.

under risk versus certainty does not appear to bias the results of the Andersen et al. (2008) joint estimation procedure for estimating discount rates from MPL data.

The finding that discounting behavior does not differ under risk versus certainty in an MPL experiment is consistent with the standard DEU model. However, given that Andreoni and Sprenger (2012b) do not obtain the same result in their CTB design, it cannot automatically be taken as endorsement of that model. One potential explanation for the difference in results is that in a discounting MPL under risk, the possibility of intertemporal diversification is precluded by the fact that there is only ever a single payment determined by a single lottery. The purpose of my CTB experiment is to further examine this conjecture, by removing the opportunity for diversification from the Andreoni and Sprenger (2012b) design.

II. Convex Time Budget Experiment

A. *Design and Procedures*

The design of my CTB experiment was based closely upon that of Andreoni and Sprenger (2012b). In each CTB decision, a subject had an endowment of 100 tokens which he was free to allocate as he pleased between the sooner and later payment dates at specified exchange rates. Across all decisions, the exchange rate for tokens redeemed on the later payment date was fixed, while the sooner token exchange rate was adjusted to generate variation in the gross experimental interest rate. Each subject made a total of 42 such decisions, comprising seven gross interest rates crossed with two delay lengths, all repeated under three different risk conditions.

In the *certainty* condition the payments on both dates would be sent for sure, while in the *independent risks* condition both payments would be sent with 50 percent probability, *as realized by two independent lotteries*. These conditions thus replicate the (1, 1) and (0.5, 0.5) conditions in Andreoni and Sprenger (2012b). Finally, in the *correlated risks* condition both payments would be sent with 50 percent probability, *as realized by a single lottery*. Thus, in this condition it was not possible for a subject to spread her risks over two lotteries by choosing a mixture of sooner and later payments. Andreoni and Sprenger (2012b) show that the standard DEU model predicts the same pattern of choices under certainty and independent risks; moreover, it turns out that the same holds for correlated risks as well (see online Appendix A for details).

The parameters of the CTB experiment were identical to those of Andreoni and Sprenger (2012b, Table 1), except that the delay lengths between sooner and later payments were changed from four and eight weeks in Andreoni and Sprenger (2012b) to five and ten weeks, and payments were denominated in AUD instead of USD.[13] The sooner payment always carried a one-week front-end delay, and all payment dates fell on the same weekday as the experiment itself, within teaching weeks of the current semester, and avoiding holidays. The decision tables for the experiment replicated the format adopted by Andreoni and Sprenger (2012b), with

[13] Full details of the parameters of the CTB decisions are provided in online Appendix B.2. The reason for the change in delay lengths was to avoid having one of the payment dates falling adjacent to a public holiday.

the addition of a background color-shading convention to distinguish between the three risk conditions.[14]

Each subject had one CTB decision randomly chosen to count for pay. If this decision was one involving risk, then the lottery or lotteries to determine whether or not the chosen payments would, in fact, be sent were realized before leaving the laboratory. Both the sooner and later payments were made by check, drawn on the campus branch of the National Australia Bank, and mailed by guaranteed next-day Express Post. Following Andreoni and Sprenger's procedures, each subject received a show-up fee comprising two payments of AUD 5 each, sent on the sooner and later payment dates respectively, with any additional earnings from the experiment added to these. Since this implied that every subject would always receive two checks, it ensured that there was no convenience benefit to choosing a corner allocation accruing entirely on a single payment date. Since every subject addressed his own envelopes prior to making his decisions, subjects could observe that the experimenter was prepared to pay approximately AUD 5 to mail a check to the value of as little as AUD 5 by Express Post. This imparted a high level of credibility to the payments.[15]

A total of 63 student subjects completed the CTB experiment on March 20 and 22, 2012. The realized average payment was AUD 24, inclusive of the show-up fee.[16] The experiment was conducted using pen and paper and took approximately 60 minutes to complete.[17]

B. *Results of the CTB Experiment*

Figure 2 summarizes aggregate behavior in the CTB experiment, with each panel corresponding to a different delay length, using the same presentation as Figure 2 in Andreoni and Sprenger (2012b). The mean allocation of tokens (out of 100) to the sooner payment date is plotted as a function of the gross interest rate (i.e., the ratio of the later to the sooner token redemption values) for each risk condition, together with the corresponding 95 percent ($\pm$ 1.96 standard error) confidence intervals. The mean allocations are also reported in tabular form on the left-hand side of Table 2, in which the right-hand columns report *p*-values for Wilcoxon signed-ranks tests of equality of token allocations in each pairwise comparison of risk conditions, at each delay and gross interest rate combination. The patterns that emerge from close inspection of Figure 2 and from the signed-ranks tests are very similar, and in the discussion that follows I use the latter as the preferred basis for comparison since

[14] As per Andreoni and Sprenger (2012b, Figure 1), subjects were provided with a calendar on the left-hand side of each table with the date of the experiment and the sooner and later payment dates highlighted. In addition, in the independent risks condition the columns corresponding to the sooner and later token allocations were shaded in two different colors to represent the colors of the two separate dice that would be rolled to determine the payments. In the correlated risks condition, both columns were shaded alike to indicate that a single die roll would determine both payments. Finally, in the certainty condition both columns were unshaded to indicate that the payments would not depend upon any die roll at all. Online Appendix E shows a sample decision sheet from the independent risks condition.

[15] In the postexperiment questionnaire for the CTB experiment, 100 percent of subjects responded that they trusted that they would be paid exactly as stated in the instructions.

[16] At the time of the CTB experiment, one AUD was worth approximately USD 1.05.

[17] The full text of the instructions for the CTB experiment are provided in online Appendix D. Subjects who participated in the earlier MPL experiment were excluded from the CTB study. Half of the subjects completed the risk conditions in the order *independent-certain-correlated*, while for the other half this was reversed.

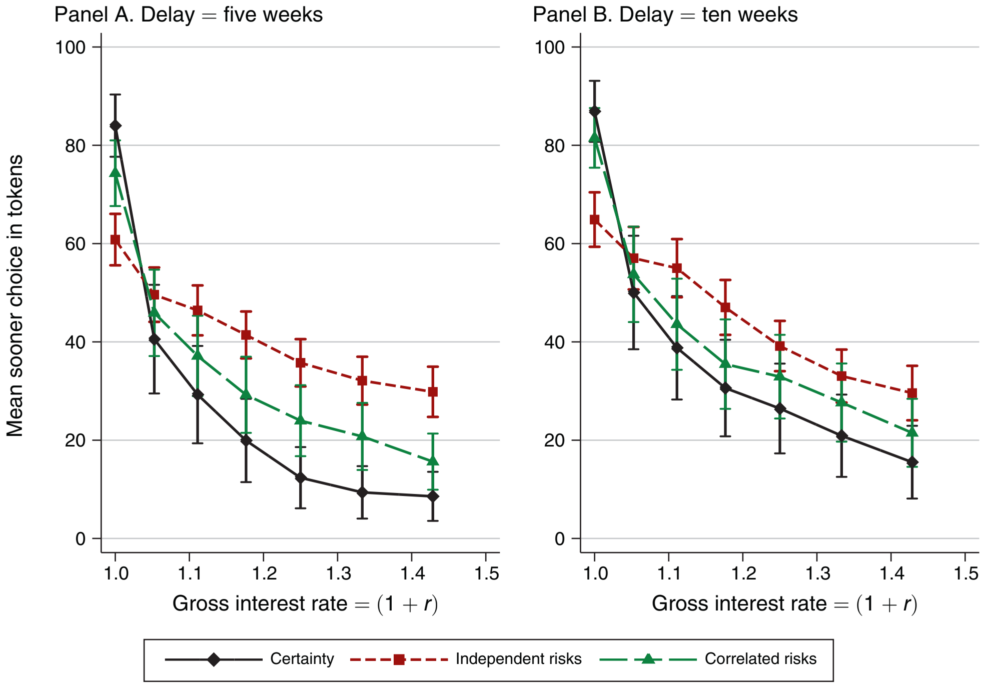

Figure 2. Aggregate Behavior in CTB Discounting Tasks

Table 2—Tests of Equality of Allocations in the CTB Experiment

	Mean sooner token allocation			Wilcoxon signed-ranks *p*-values		
Gross rate	*Certain*	*Independent*	*Correlated*	*Cert = Ind*	*Cert = Corr*	*Ind = Corr*
Panel A. Delay = five weeks						
1.00	84.0	60.8	74.3	0.000	0.003	0.000
1.05	40.6	49.6	45.9	0.067	0.191	0.266
1.11	29.3	46.4	37.1	0.001	0.076	0.015
1.18	19.9	41.4	29.2	0.000	0.038	0.000
1.25	12.4	35.7	24.0	0.000	0.006	0.001
1.33	9.4	32.1	20.8	0.000	0.001	0.000
1.43	8.6	29.8	15.6	0.000	0.009	0.000
Panel B. Delay = ten weeks						
1.00	86.9	64.9	81.5	0.000	0.010	0.000
1.05	50.0	57.0	53.7	0.117	0.508	0.436
1.11	38.8	55.0	43.6	0.001	0.248	0.008
1.18	30.6	47.0	35.5	0.000	0.130	0.007
1.25	26.4	39.2	32.9	0.001	0.077	0.064
1.33	20.9	33.0	27.7	0.003	0.040	0.134
1.43	15.5	29.6	21.5	0.001	0.038	0.038

they avoid distributional assumptions and recognize the within-subjects nature of the data.

The first important result that is apparent is that choices under certainty and independent risks replicate the pattern observed by Andreoni and Sprenger (2012b) in their (1, 1) and (0.5, 0.5) conditions: the mean token allocation between sooner and later payments is consistently more balanced under independent risks compared to

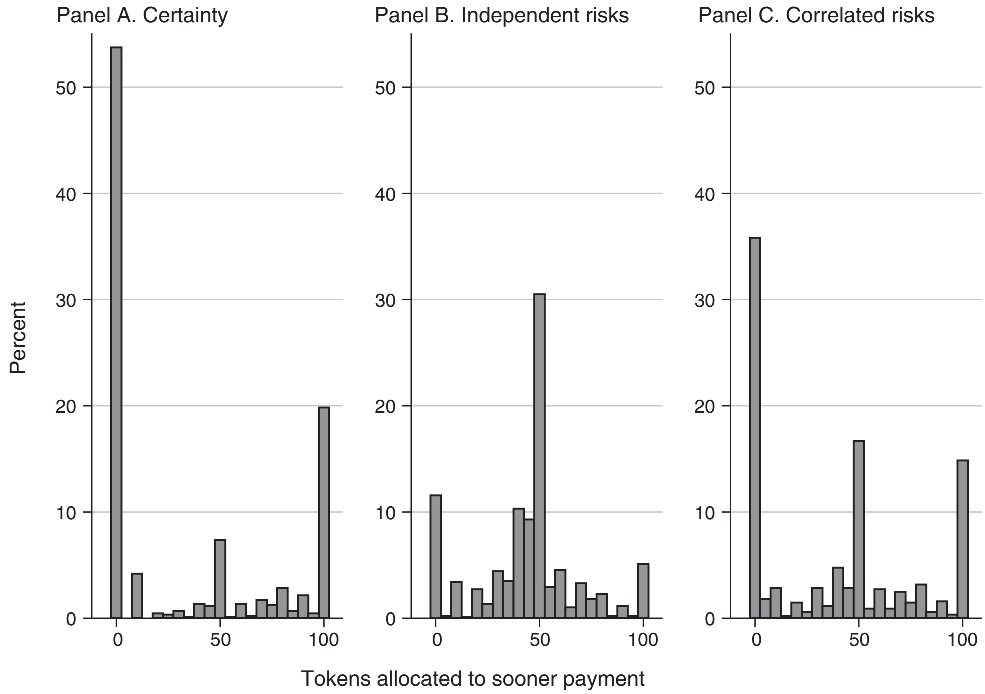

Figure 3. Observed CTB Choices by Risk Condition

certainty. The differences between these two conditions are always highly significant, except at the gross interest rate of 1.05 where the two functions "cross over."

This pattern is inconsistent with the standard DEU model; however behavior under independent risks may also reflect a diversification motive that is absent when all payments are certain. The correlated risks condition eliminates this possibility of diversification while retaining the riskiness of payments. If Andreoni and Sprenger's (2012b) result were robust to removing opportunities for diversification, then behavior under correlated risks would coincide with that under independent risks. On the other hand, if their result were driven entirely by diversification, then it would disappear under correlated risks, such that behavior would coincide with that under certainty.

Figure 2 reveals that behavior under correlated risks is in fact clearly intermediate between certainty and independent risks. Moreover, the test statistics reported in Table 2 indicate that the differences in choices between all three risk conditions are generally significant. This is especially the case in the five-week delay horizon, in which they are consistently significant except at the gross interest rate of 1.05; in the ten-week horizon the differences become somewhat narrower, especially in the comparison between certainty and correlated risks.

Direct evidence that behavior under independent risks is likely motivated in part by diversification may be seen by examining the incidence of corner solutions. Figure 3 reports the histogram of sooner token allocations, pooled over all decisions within each risk condition. Under certainty corner solutions are endemic, accounting for over 70 percent of all allocations (19.8 percent all sooner and 52.4 percent all later).[18] Under independent risks—where diversification favors the choice of an interior solution—corner allocations are far less prevalent (5.1 and 11.6 percent, respectively), and the modal allocation is a 50–50 split. Under correlated risks—where the opportunity for diversification is taken away—corner solutions are three times as prevalent as under independent risks, accounting for over 50 percent of all allocations (14.9 and 35.6 percent, respectively).

For each pairwise comparison of risk conditions, I next follow Andreoni and Sprenger (2012b, p. 3367) in performing nonparametric regressions of sooner token allocations on indicators for each delay and gross interest rate combination interacted with the risk condition, with standard errors clustered on individual subjects, and test for the joint significance of all treatment interactions. The results confirm that all three risk conditions are distinct, with all differences found to be highly significant.[19,20] Averaging over all decisions by all subjects, the mean absolute difference in allocations between certainty and independent risks is 29.65 tokens, while between certainty and correlated risks it is 14.75 tokens. Thus, overall, the effect reported by Andreoni and Sprenger (2012b) is reduced by slightly over one-half when the opportunity for diversification is taken away. This is the main aggregate conclusion from my CTB experiment.

How do these results affect the structural estimates of utility curvature and discount rates estimated from CTB data? Andreoni and Sprenger (2012b, Appendix B) derive the solution function for the optimal sooner token allocation under the exponentially discounted CRRA specification in equation (1), and from this estimate models by NLS in which the structural parameters are permitted to differ across their (1, 1) and (0.5, 0.5) risk conditions. They find that the curvature estimates differ significantly between risk conditions but that discount rates do not, and they interpret the separate curvature parameters to represent two distinct utility functions: $v(\cdot)$ under certainty and $u(\cdot)$ under risk.

In model (1) of Table 3, I replicate Andreoni and Sprenger's NLS estimation using data from my CTB experiment. Panel A reports estimates of utility curvature α and the annual discount rate ρ, which are permitted to vary across the three risk conditions. Panel B reports hypothesis tests of both pairwise and joint equality of these parameters across risk conditions. The model was estimated by NLS in Stata 10.1, following the procedures set out by Andreoni and Sprenger (2012a; 2012b, Appendix B), with the "background" parameter ω set to zero (for comparability with the other estimates that I report) and robust standard errors clustered on individual subjects.

The NLS estimates in model (1) display the same pattern that was evident in the results reported by Andreoni and Sprenger (2012b): the differences in behavior

[18] This counts only allocations exactly at the corners, whereas Figure 3 rounds allocations to the nearest five tokens.

[19] For the comparison of certainty to independent risks, $F_{14,62} = 11.04$, $p < 0.001$. For certainty and correlated risks, $F_{14,62} = 2.29$, $p = 0.013$. For independent and correlated risks, $F_{14,62} = 5.13$, $p < 0.001$. When the ten-week horizon is considered in isolation, the difference between certainty and correlated risks ceases to be significant: $F_{7,62} = 1.65$, $p = 0.137$. However, all other comparisons are highly significant in both the five- and ten-week horizons.

[20] An analysis of the consistency of choices at the individual level, comparing certainty to independent risks, closely replicates the pattern reported in Andreoni and Sprenger (2012b, Figure 3, panel A). However, turning to the comparison between certainty and correlated risks, there is a clear shift in the direction of fewer and smaller deviations in individual choice behavior, although these differences also clearly do not go away completely.

TABLE 3—ESTIMATES OF UTILITY CURVATURE AND ANNUAL DISCOUNT RATES FROM CTB DATA

	Nonlinear least squares (1)				Multinomial logit (2)			
	Coef.	SE	95 percent CI		Coef.	SE	95 percent CI	
Panel A. Parameter estimates								
α_{Cert}	0.924	0.008	0.908	0.941	1.152	0.013	1.127	1.176
α_{Ind}	0.796	0.022	0.751	0.841	0.913	0.054	0.807	1.019
α_{Corr}	0.883	0.013	0.857	0.908	1.163	0.022	1.120	1.207
ρ_{Cert}	0.592	0.133	0.326	0.858	0.987	0.202	0.592	1.381
ρ_{Ind}	0.787	0.190	0.407	1.167	0.394	0.332	−0.257	1.044
ρ_{Corr}	0.705	0.165	0.376	1.034	1.045	0.256	0.543	1.547
Panel B. Hypothesis tests for equality of parameters across risk conditions								
$\alpha_{Cert} = \alpha_{Ind}$	$F_{1,62} = 34.61, p < 0.001$				$\chi^2(1) = 21.35, p < 0.001$			
$\alpha_{Cert} = \alpha_{Corr}$	$F_{1,62} = 17.77, p < 0.001$				$\chi^2(1) = 0.41, p = 0.524$			
$\alpha_{Ind} = \alpha_{Corr}$	$F_{1,62} = 15.17, p < 0.001$				$\chi^2(1) = 23.74, p < 0.001$			
$\alpha_{Cert} = \alpha_{Ind} = \alpha_{Corr}$	$F_{2,62} = 22.37, p < 0.001$				$\chi^2(2) = 23.77, p < 0.001$			
$\rho_{Cert} = \rho_{Ind}$	$F_{1,62} = 1.50, p = 0.226$				$\chi^2(1) = 4.35, p = 0.037$			
$\rho_{Cert} = \rho_{Corr}$	$F_{1,62} = 1.70, p = 0.197$				$\chi^2(1) = 0.20, p = 0.656$			
$\rho_{Ind} = \rho_{Corr}$	$F_{1,62} = 0.26, p = 0.611$				$\chi^2(1) = 5.06, p = 0.025$			
$\rho_{Cert} = \rho_{Ind} = \rho_{Corr}$	$F_{2,62} = 1.27, p = 0.289$				$\chi^2(2) = 5.08, p = 0.079$			
R^2/log-likelihood	$R^2 = 0.697$				$LL = -6{,}711.386$			
Observations	2,646				2,646			
Clusters	63				63			

Notes: Model (1): nonlinear least squares estimates. Model (2): multinomial logit estimates. Models estimated under the restriction $\omega = 0$, with robust standard errors clustered at the level of individual subjects.

across the three risk conditions express themselves as differences in utility curvature as opposed to the estimated discount rates. The differences in the estimated curvature parameters are always highly significant in both pairwise and joint tests; by contrast, the corresponding differences in estimated discount rates are consistently not statistically significant. Thus, in the NLS specification it is not possible to reject the null hypothesis that a single discount function governs intertemporal choices across all three risk conditions.

However, a concern with the NLS estimator, as first pointed out by Harrison, Lau, and Rutström (2013), is that it focuses on explaining the mean of the data, whereas Figure 3 indicates that under certainty and correlated risks—the two conditions in which diversification is not possible—the mass of the data is located at the corners. To address this issue, Harrison, Lau, and Rutström introduce an alternative MNL estimator which compares the discounted utility of a subject's preferred token allocation to that of each of the permissible alternatives. In model (2) of Table 3, I report a version of this estimator as extended to CTB choices in which the payments are potentially subject to risk, under the DEU specification of equation (1).[21]

In my implementation of the MNL estimator, I first round the observed sooner allocation to the nearest multiple of five tokens, resulting in a multinomial choice from one of 21 allocations, $\{0, 5, 10, \ldots, 100\}$. Given candidate values of the structural

[21] I thank an anonymous referee for suggesting the use of this estimator.

parameters α and ρ, the experimental parameters of a given decision (specifically, the delay lengths and token exchange rates), and setting the background parameter ω to zero as I do in my other estimates, I then compute the discounted expected utility of *each* of the 21 alternative portfolios of sooner and later earnings:

$$\delta^t p c_t^\alpha \ + \ \delta^{t+k} p c_{t+k}^\alpha,$$

where the probability that payment is received is $p = 1$ under certainty and $p = 0.5$ under both independent and correlated risks. Then, given the allocation actually chosen by the subject in this task, the multinomial logit probability of the observed choice is given by

$$\frac{\exp(U^*)}{\exp(U_0) + \exp(U_5) + \cdots + \exp(U_{100})},$$

and the estimates of α and ρ are chosen so as to maximize the likelihood of the observed choices. Once again, these estimates were permitted to vary by risk condition, and the model was estimated by maximum likelihood in Stata 10.1, with robust standard errors clustered on individual subjects.

The MNL estimates in model (2) of Table 3 display some notable differences when compared to the corresponding NLS estimates in model (1). Firstly, the curvature estimates indicate that choices under certainty and correlated risks are best explained by a *convex* utility function. This is consistent with what Harrison, Lau, and Rutström (2013) find in their reanalysis of the data from Andreoni and Sprenger (2012a), in which payments were not subject to risk. As they observe, it can be explained theoretically by the need for the model to account for choices at both corners. By contrast, under independent risks, where corner solutions are far less prevalent, the point estimate of curvature indicates concave utility, although the hypothesis of linear utility cannot be rejected.

More generally, the hypothesis tests in panel B of Table 3 indicate that the NLS and MNL models attribute the differences in choice behavior between the three risk conditions differently. As noted earlier, the NLS estimates point to a single discount function and three distinct curvature values. By contrast, the MNL estimates point to a distinction between independent risks on one hand, and certainty and correlated risks on the other. *For both the curvature and discounting parameters* the difference between certainty and correlated risks is not significant, and as a result the joint hypotheses that $\alpha_{Cert} = \alpha_{Corr}$ and $\rho_{Cert} = \rho_{Corr}$ cannot be rejected ($\chi^2(2) = 0.60$, $p = 0.741$). At the same time, and again for both structural parameters, the difference between independent risks and either of the two other conditions is always found to be significant. In short, the MNL model draws a sharp distinction between the two conditions in which the possibility of intertemporal diversification does not arise, and the independent risks condition in which it does.

III. An Alternative Interpretation

In the standard DEU model of equation (1), and in Andreoni and Sprenger's (2012b) interpretation of their results, differences in discounting behavior under risk and certainty are attributed to differences in the *concavity of atemporal utility* as captured by the parameter α. This form of concavity suffices to generate diversification in the familiar static setting in which a decision maker is exposed to two risks that arise simultaneously. However, as discussed in online Appendix A, and as first noted by Andersen et al. (2011, Section 5) and Harrison, Lau, and Rutström (2013), it does not generate intertemporal diversification across risks that accrue on different dates, since the *linearity of intertemporal utility* under standard DEU implies that the same behavior is predicted under all three of my risk conditions.

Since intertemporal diversification does indeed appear to be important under independent risks—as evident from the far greater prevalence of interior choices compared to both certainty and correlated risks—it seems more appropriate to attribute this behavior to *concavity of intertemporal utility*. A simple specification that captures this is to replace equation (1) with

$$U = \left[\delta^t (c_t - \omega)^\alpha + \delta^{t+k} (c_{t+k} - \omega)^\alpha\right]^\gamma, \tag{2}$$

where the parameter γ captures curvature of intertemporal utility such that $(1 - \gamma)$ is a coefficient of relative intertemporal risk aversion or "correlation aversion" (Andersen et al. 2011, cf. their equation 12). Andersen et al. (2011) extend the joint estimation methodology to include tasks that elicit correlation aversion, permitting it to be jointly estimated with discounting and curvature of atemporal utility. They find that their subjects, a sample representative of adult Danes, are indeed correlation averse, rejecting the specification in (1) in favor of (2).

In the context of a CTB-based design, estimation of the parameters of (2) by NLS is complicated by the fact that there does not appear to exist any closed form solution function under independent risks. On the other hand, the logic of the MNL estimator extends straightforwardly to this model. Given candidate values of the atemporal curvature parameter α, annual discount rate ρ, and intertemporal curvature parameter γ, one proceeds as before to evaluate the expected intertemporal utility of every possible portfolio in the CTB. Then, given the actual allocation that was chosen, the multinomial logit probability of the observed choice is defined as before. The only additional complication is to note that in each correlated risks decision there are two possible outcomes (either the subject receives the entire portfolio or not), whereas in each independent risks decision there are four. Specifically, setting the background parameter ω to zero as before, under certainty and correlated risks the expected intertemporal utility of a given portfolio allocation is

$$p\left[\delta^t c_t^\alpha + \delta^{t+k} c_{t+k}^\alpha\right]^\gamma$$

with $p = 1$ under certainty and $p = 0.5$ under correlated risks. However under independent risks the expected intertemporal utility is given by

$$p\left\{p\left[\delta^t c_t^\alpha + \delta^{t+k} c_{t+k}^\alpha\right]^\gamma + (1 - p)\left[\delta^t c_t^\alpha\right]^\gamma\right\} + (1 - p)\left\{p\left[\delta^{t+k} c_{t+k}^\alpha\right]^\gamma\right\},$$

where the first set of brackets represents the event that sooner payment is received, and within it the first term represents the event that later payment is also received, and so on.

Table 4—Estimates of a Model Allowing Intertemporal Curvature, from CTB Data

	Coefficient	Standard error	95 percent CI	
α	1.315	0.039	1.239	1.391
ρ	1.042	0.286	0.481	1.602
γ	0.768	0.028	0.713	0.824
log-likelihood		6,817.608		
Observations		2,646		
Clusters		63		

Note: Multinomial logit model estimated under the restriction $\omega = 0$, with robust standard errors clustered at the level of individual subjects.

I report my MNL estimates of this specification in Table 4. In presenting these results, I emphasize that—in contrast to Andersen et al. (2011)—my CTB experiment was not specifically designed for the purpose of estimating γ. Rather, the purpose of these estimates is simply to illustrate how the intertemporal curvature hypothesis accounts for the patterns observed in my CTB data. The estimates in Table 4 indicate that it does this by finding *a combination of convex atemporal utility and concave intertemporal utility*, with both estimates differing significantly from linearity. While the finding of convex atemporal utility is arguably unappealing—and in sharp contrast to the concave estimate reported by Andersen et al. (2011)—it is again explained by the theoretical need for atemporal utility to account for the presence of corner solutions at both endpoints under certainty and correlated risks. On the other hand, the finding of concave intertemporal utility motivates the preference for intertemporal diversification observed under independent risks.

Finally, while the correlation aversion model predicts the difference I observe between independent and correlated risks, it does not explain any residual difference between certainty and correlated risks, since the model predicts the same behavior under both. Insofar as I find evidence of a difference between these two conditions, it thus remains open for interpretation.[22] Note, however, that the structural MNL estimates in model (2) of Table 3 *do not* support an interpretation in terms of separate atemporal utility functions, along the lines suggested by Andreoni and Sprenger (2012b).

IV. Conclusion

In this article, I investigate the robustness of Andreoni and Sprenger's (2012b) finding of systematic differences in intertemporal choice behavior under risk versus certainty to two manipulations of their CTB design. Firstly, in principle Andreoni and Sprenger's claim that utility is more concave under risk compared to certainty has the direct implication that joint estimates combining data generated from these two distinct preferences are potentially biased. In my MPL experiment I find very

[22] One explanation, suggested by an anonymous referee, is that some subjects may have been confused by the correlated risks condition and mistakenly believed that they might still benefit from diversification. Evidence consistent with this conjecture may be seen in Figure 3, which shows the number of 50-50 choices under correlated risks to be fewer than under independent risks, but still greater than under certainty.

little support for this proposition, quite simply because I do not replicate Andreoni and Sprenger's main result when using an MPL instrument.

Next, I examine the role of diversification opportunities in driving Andreoni and Sprenger's finding of more balanced intertemporal portfolio choices under risk compared to certainty. I find that when the possibility of diversification is removed, while the element of risk is maintained, the effect observed by Andreoni and Sprenger (2012b) is reduced in magnitude by just over one-half. This suggests a role for curvature of the intertemporal utility function, and not only of atemporal utility, in explaining intertemporal choice under risk—and I report new structural estimates that support the hypothesis of concave intertemporal utility.

My results also shed new light on the relative merits of the MPL and CTB instruments, informing the design of future studies of time preference under conditions of risk. By permitting subjects to choose any point along a budget set instead of forcing them to choose between the endpoints, a CTB potentially provides richer information than an MPL. This may contribute to why the CTB detects differences between risk and certainty where an MPL does not. However, when implemented under risk, a CTB may introduce opportunities for diversification where an MPL does not. Moreover, once the possibility of diversification is removed through a correlated risks design, the CTB yields a high incidence of corner solutions leading to the troubling implication of convex utility.

Finally, my finding of pronounced differences in behavior under independent versus correlated risks illustrates how procedural considerations such as the manner in which payments are realized are not merely arcane details of experimental design but can exert a powerful influence on behavior—potentially to the point of driving a large portion of the observed effects. In this respect, my results also echo the important recent work of Cox, Sadiraj, and Schmidt (2015). Moreover, they serve as a reminder that design choices that might appear innocuous under standard models such as DEU may, in fact, be highly consequential under alternative models such as correlation aversion.

REFERENCES

Andersen, Steffen, Glenn W. Harrison, Morten I. Lau, and E. Elisabet Rutström. 2008. "Eliciting Risk and Time Preferences." *Econometrica* 76 (3): 583–618.

Andersen, Steffen, Glenn W. Harrison, Morten I. Lau, and E. Elisabet Rutström. 2011. "Multiattribute Utility Theory, Intertemporal Utility, and Correlation Aversion." Center for the Economic Analysis of Risk Working Paper WP-2011-04.

Andreoni, James, and Charles Sprenger. 2012a. "Estimating Time Preferences from Convex Budgets." *American Economic Review* 102 (7): 3333–56.

Andreoni, James, and Charles Sprenger. 2012b. "Risk Preferences Are Not Time Preferences." *American Economic Review* 102 (7): 3357–76.

Cheung, Stephen L. 2015. "Comment on 'Risk Preferences Are Not Time Preferences': On the Elicitation of Time Preference under Conditions of Risk: Dataset." *American Economic Review*. http://dx.doi.org/10.1257/aer.20120946.

Coller, Maribeth, and Melonie B. Williams. 1999. "Eliciting Individual Discount Rates." *Experimental Economics* 2 (2): 107–27.

Cox, James C., Vjollca Sadiraj, and Ulrich Schmidt. 2015. "Paradoxes and Mechanisms for Choice under Risk." *Experimental Economics* 18 (2): 215–50.

Cubitt, Robin P., and Daniel Read. 2007. "Can Intertemporal Choice Experiments Elicit Time Preferences for Consumption?" *Experimental Economics* 10 (4): 369–89.

Frederick, Shane, George Loewenstein, and Ted O'Donoghue. 2002. "Time Discounting and Time Preference: A Critical Review." *Journal of Economic Literature* 40 (2): 351–401.

Harrison, Glenn W., Morten I. Lau, and E. Elisabet Rutström. 2013. "Identifying Time Preferences with Experiments: Comment." Center for the Economic Analysis of Risk Working Paper WP-2013-09.

Holt, Charles A., and Susan K. Laury. 2002. "Risk Aversion and Incentive Effects." *American Economic Review* 92 (5): 1644–55.

Laury, Susan K., Melayne Morgan McInnes, and J. Todd Swarthout. 2012. "Avoiding the Curves: Direct Elicitation of Time Preferences." *Journal of Risk and Uncertainty* 44 (3): 181–217.

Quiggin, John. 1982. "A Theory of Anticipated Utility." *Journal of Economic Behavior and Organization* 3 (4): 323–43.

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2. Joshua Lanier, Bin Miao, John K.-H. Quah, Songfa Zhong. 2024. Intertemporal Consumption with Risk: A Revealed Preference Analysis. *Review of Economics and Statistics* **106**:5, 1319-1333. [Crossref]
3. Keigo Inukai, Yuta Shimodaira, Kohei Shiozawa. 2024. Investigation of the convex time budget experiment by parameter recovery simulation. *Journal of Behavioral and Experimental Finance* **43**, 100962. [Crossref]
4. Kirsten I. M. Rohde, Xiao Yu. 2024. Intertemporal Correlation Aversion—A Model-Free Measurement. *Management Science* **70**:6, 3493-3509. [Crossref]
5. Jörg Ankel-Peters, Nathan Fiala, Florian Neubauer. 2024. Is economics self-correcting? Replications in the American Economic Review. *Economic Inquiry* **76**. . [Crossref]
6. Calvin Mudzingiri, Regret Sunge, Blessing Katuka, Nkopane Washington Miya. The mediation and moderation effect of risk preferences on time preference and financial literacy **9**, . [Crossref]
7. Stefan P. Penczynski, Maria Isabel Santana. 2024. Measuring trust in institutions and its causal effect. *Quantitative Economics* **15**:1, 213-243. [Crossref]
8. Markus Dertwinkel-Kalt, Sebastian Ebert, Mats Köster. 2023. On correlated lotteries in economic applications. *Journal of Economic Behavior & Organization* **215**, 292-306. [Crossref]
9. Nathaniel T. Wilcox. Unusual Estimates of Probability Weighting Functions 69-106. [Crossref]
10. Chiara Pastore, Stefanie Schurer, Agnieszka Tymula, Nicholas Fuller, Ian Caterson. 2023. Economic preferences and obesity: Evidence from a clinical lab-in-field study. *Health Economics* **32**:9, 2147-2167. [Crossref]
11. Chao Liu, Hongzhen Lei, Juanli Lan, Fan Li, Ye Liu. Psychological mechanisms of willingness to participate in high-value markets: an eye-tracking experiment **115**, . [Crossref]
12. Felix Kölle, Lukas Wenner. 2023. Is Generosity Time-Inconsistent? Present Bias across Individual and Social Contexts. *Review of Economics and Statistics* **105**:3, 683-699. [Crossref]
13. Nigar Hashimzade, Oleg Kirsanov, Tatiana Kirsanova. 2023. Distributional effects of endogenous discounting. *Mathematical Social Sciences* **122**, 1-6. [Crossref]
14. Jeeva Somasundaram, Vincent Eli. 2022. Risk and time preferences interaction: An experimental measurement. *Journal of Risk and Uncertainty* **65**:2, 215-238. [Crossref]
15. Stephen L. Cheung, Agnieszka Tymula, Xueting Wang. 2022. Present bias for monetary and dietary rewards. *Experimental Economics* **25**:4, 1202-1233. [Crossref]
16. Wolfgang Breuer, Torbjörn Müller, Eric Sachsenhausen. 2022. The determinants of discounting in intergenerational decision-making. *European Economic Review* **148**, 104215. [Crossref]
17. Chen Sun, Jan Potters. 2022. Magnitude effect in intertemporal allocation tasks. *Experimental Economics* **25**:2, 593-623. [Crossref]
18. Zhihua Li, Graham Loomes. 2022. Revisiting the diagnosis of intertemporal preference reversals. *Journal of Risk and Uncertainty* **64**:1, 19-41. [Crossref]
19. Xiaojun Yang, Fredrik Carlsson. 2021. Are People More Patient with Their Spouse's Money? An Experimental Study. *Journal of Behavioral and Experimental Economics* **94**, 101749. [Crossref]
20. An Chen, Manuel Rach. 2021. Demand for retirement products: An analysis of individual welfare. *SSRN Electronic Journal* **59**. . [Crossref]

21. Wenbo Zou. 2021. Risk as Excuses to Postpone Effort-Provision. *SSRN Electronic Journal* **57**. . [Crossref]
22. Markus Dertwinkel-Kalt, Sebastian Ebert, Mats Köster. 2021. A Note on Correlated Lotteries in Economic Applications. *SSRN Electronic Journal* **21**. . [Crossref]
23. Jonathan Cohen, Keith Marzilli Ericson, David Laibson, John Myles White. 2020. Measuring Time Preferences. *Journal of Economic Literature* **58**:2, 299-347. [Abstract] [View PDF article] [PDF with links]
24. Stephen L. Cheung. 2020. Eliciting utility curvature in time preference. *Experimental Economics* **23**:2, 493-525. [Crossref]
25. Matthew Gnagey, Therese Grijalva, Rong Rong. 2020. Spousal influence and assortative mating on time preferences: a field experiment in the USA. *Review of Economics of the Household* **18**:2, 461-512. [Crossref]
26. Felix Kubler, Larry Selden, Xiao Wei. 2020. Incomplete market demand tests for Kreps-Porteus-Selden preferences. *Journal of Economic Theory* **185**, 104973. [Crossref]
27. Luciano I. de Castro, Antonio F. Galvao, Gabriel Montes-Rojas, Jose Olmo. 2020. Eliciting Risk, Intertemporal Substitution, and Time Preferences. *SSRN Electronic Journal* **65**. . [Crossref]
28. Yan Chen, Ming Jiang, Erin L. Krupka. 2019. Hunger and the gender gap. *Experimental Economics* **22**:4, 885-917. [Crossref]
29. Jinrui Pan, Craig S. Webb, Horst Zank. 2019. Delayed probabilistic risk attitude: a parametric approach. *Theory and Decision* **87**:2, 201-232. [Crossref]
30. C. Oscar Lau. 2019. Disentangling Intertemporal Substitution and Risk Aversion Under the Expected Utility Theorem. *The B.E. Journal of Theoretical Economics* **19**:2. . [Crossref]
31. Rong Rong, Therese C. Grijalva, Jayson Lusk, W. Douglass Shaw. 2019. Interpersonal discounting. *Journal of Risk and Uncertainty* **58**:1, 17-42. [Crossref]
32. W. David Bradford, Paul Dolan, Matteo M. Galizzi. 2019. Looking ahead: Subjective time perception and individual discounting. *Journal of Risk and Uncertainty* **58**:1, 43-69. [Crossref]
33. Alastair Irvine, Marjon van der Pol, Euan Phimister. 2019. A comparison of professional and private time preferences of General Practitioners. *Social Science & Medicine* **222**, 256-264. [Crossref]
34. Keith Marzilli Ericson, David Laibson. Intertemporal choice 1-67. [Crossref]
35. Ehsan Taheri, Chen Wang. 2018. Eliciting Public Risk Preferences in Emergency Situations. *Decision Analysis* **15**:4, 223-241. [Crossref]
36. Rong Rong, Matthew Gnagey, Therese Grijalva. 2018. "The less you Discount, the more it shows you really care": Interpersonal discounting in households. *Journal of Economic Behavior & Organization* **154**, 1-23. [Crossref]
37. Therese C. Grijalva, Jayson L. Lusk, Rong Rong, W. Douglass Shaw. 2018. Convex Time Budgets and Individual Discount Rates in the Long Run. *Environmental and Resource Economics* **71**:1, 259-277. [Crossref]
38. Anke Gerber, Kirsten I. M. Rohde. 2018. Weighted temporal utility. *Economic Theory* **66**:1, 187-212. [Crossref]
39. Te Bao, Yun Dai, Xiaohua Yu. 2018. Memory and discounting: Theory and evidence. *Journal of Economic Dynamics and Control* **88**, 21-30. [Crossref]
40. Antoine Bommier, HHllne Schernberg. 2018. The Optimal Allocation of Longevity Risk with Perfect Insurance Markets. *SSRN Electronic Journal* **59**. . [Crossref]
41. Joshua Lanier, Bin Miao, John Kim-Ho Quah, Songfa Zhong. 2018. Intertemporal Consumption With Risk: A Revealed Preference Analysis. *SSRN Electronic Journal* **59**. . [Crossref]

42. Wolfgang Breuer, Torbjjrn MMller, Eric Sachsenhausen. 2018. The Determinants of Discounting in Intergenerational Decision-Making. *SSRN Electronic Journal* **6**. . [Crossref]

43. Felix Kölle, Lukas Wenner. 2018. Time-Inconsistent Generosity: Present Bias Across Individual and Social Contexts. *SSRN Electronic Journal* **6**. . [Crossref]

44. Kyoung Jin Choi, Minsuk Kwak, Gyoocheol Shim. 2017. Time preference and real investment. *Journal of Economic Dynamics and Control* **83**, 18-33. [Crossref]

45. Anujit Chakraborty, Evan M. Calford, Guidon Fenig, Yoram Halevy. 2017. External and internal consistency of choices made in convex time budgets. *Experimental Economics* **20**:3, 687-706. [Crossref]

46. Ismael Rodriguez-Lara, Giovanni Ponti. 2017. Social motives vs social influence: An experiment on interdependent time preferences. *Games and Economic Behavior* **105**, 177-194. [Crossref]

47. Rong Rong, Therese C. Grijalva, Jayson Lusk, W. Douglass Shaw. 2017. Interpersonal Discounting. *SSRN Electronic Journal* **6**. . [Crossref]

48. Stephen L. Cheung. 2016. Recent developments in the experimental elicitation of time preference. *Journal of Behavioral and Experimental Finance* **11**, 1-8. [Crossref]

49. Felix Kubler, Xiao Wei. 2016. Integrability of Demand in Incomplete Markets: Kreps-Porteus-Selden Preferences. *SSRN Electronic Journal* **102**. . [Crossref]

50. C. Oscar Lau. 2016. Disentangling Intertemporal Substitution and Risk Aversion under the Expected Utility Theorem. *SSRN Electronic Journal* **76**. . [Crossref]

51. Thomas Epper, Helga Fehr-Duda. 2015. Comment on "Risk Preferences Are Not Time Preferences": Balancing on a Budget Line. *American Economic Review* **105**:7, 2261-2271. [Abstract] [View PDF article] [PDF with links]

52. Bin Miao, Songfa Zhong. 2015. Comment on "Risk Preferences Are Not Time Preferences": Separating Risk and Time Preference. *American Economic Review* **105**:7, 2272-2286. [Abstract] [View PDF article] [PDF with links]

53. James Andreoni, Charles Sprenger. 2015. Risk Preferences Are Not Time Preferences: Reply. *American Economic Review* **105**:7, 2287-2293. [Abstract] [View PDF article] [PDF with links]

54. Sebastian Ebert, Gijs van de Kuilen. 2015. Measuring Multivariate Risk Preferences. *SSRN Electronic Journal* **57**. . [Crossref]

55. Yoram Halevy. 2015. Time Consistency: Stationarity and Time Invariance. *Econometrica* **83**:1, 335-352. [Crossref]

56. Andreas C. Drichoutis, Rodolfo M. Nayga. 2014. Do risk and time preferences have biological roots?. *Southern Economic Journal* 140528150321007. [Crossref]