Comment on "Risk Preferences are Not Time Preferences": Separating Risk and Time Preference

By Bin Miao, Songfa Zhong*

Andreoni and Sprenger (2012a, b) observe that utility functions are distinct for risk and time preferences, and show that their findings are consistent with a preference for certainty. We revisit this question in an enriched experimental setting in which subjects make intertemporal decisions under different risk conditions. The observed choice behavior supports a separation between risk attitude and intertemporal substitution rather than a preference for certainty. We further show that several models, including Epstein and Zin (1989), Chew and Epstein (1990), and Halevy (2008), exhibit such a separation and can account for the overall experimental findings.
JEL: C91, D81, D91
Keywords: risk preference, time preference, non-expected utility

Risk and time preferences are the cornerstones of economic analyses. Regarding risk preference, expected utility (EU) has been the predominant theory in which the curvature of the utility index captures risk attitude. Regarding time preference, discounted utility is the most widely used model in which the curvature of the utility index captures intertemporal substitution. When risk and time are intertwined, integrating the two theories yields discounted expected utility (DEU), which evaluates a contingent consumption plan $(\widetilde{c}_1, \widetilde{c}_2, \widetilde{c}_3, ...)$ as follows:

$$\sum_t \delta_t \mathrm{E}\left[u\left(\widetilde{c}_t\right)\right],$$

where δ_t is the discount factor for period t, and $\widetilde{c}_t$ is the random consumption in period t. Notice that DEU reduces to expected utility $\mathrm{E}[u(\widetilde{c})]$ for degenerate contingent consumption $\widetilde{c}$ and to discounted utility $\sum \delta_t u(c_t)$ for deterministic consumption stream $(c_1, c_2, c_3, ...)$. In this sense, under DEU, the same utility index u captures both risk attitude and intertemporal substitution.

* Miao: School of Economics, Shanghai University of Finance and Economics; Key Laboratory of Mathematical Economics (SHUFE), Ministry of Education, Shanghai 200433, China; binmiao11@gmail.com. Zhong: Department of Economics, National University of Singapore, Singapore; zhongsongfa@gmail.com. We would like to acknowledge Aurelien Baillon, Jie Chen, Richard Ebstein, Chew Soo Hong, John Ham, Teck Hua Ho, Fuhai Hong, Xiangyu Qu, Mathew Rabin, Eric Set, Erik Snowberg, Yang Nan, Xing Zhang, and the audiences at the International Meeting of Economic Science Association in June 2012, Risk Uncertainty and Decision conference in June 2013, and Singapore Economic Review conference in August 2013 for their helpful comments. The anonymous referees provided valuable comments that significantly improved our paper. We would like to thank Sun Yifei for providing excellent research assistance. We would also like to acknowledge the financial supports from the National University of Singapore. The authors declare no relevant or material financial interests that relate to the research described in this paper.

This property of DEU has recently been investigated in Andreoni and Sprenger (2012a, b). Andreoni and Sprenger (2012a) propose a novel experimental design termed Convex Time Budget (CTB) to elicit time preference. Under CTB, subjects allocate 100 experimental tokens between sooner and later payments at a given interest rate r, that is, receiving $x/(1+r)$ at period one and $100-x$ at period two (certainty condition/CER, see Figure 1). Given a convex choice set $\{(x/(1+r), 100-x)\}_{x\in[0,100]}$, CTB enables joint identification of the discount factor and utility curvature that reflects intertemporal substitution under discounted utility.[1] Concomitantly, the utility curvature that reflects risk attitude under expected utility is separately elicited using the multiple price list design (MPL, e.g., Holt and Laury, 2002). Employing this CTB method, Andreoni and Sprenger find that the utility indices are distinct for risk and time preferences.[2]

Subsequently, Andreoni and Sprenger (2012b) consider CTB under a risky environment, in which there is a 50 percent chance of receiving the sooner payment and, independently, another 50 percent chance of receiving the later payment (independent risk condition/IND, see Figure 1). Under DEU, the evaluations are $u(x/(1+r)) + \delta u(100-x)$ for CER and $0.5(u(x/(1+r)) + \delta u(100-x))$ for IND, respectively, which implies that the optimal allocations in the two conditions are identical given the same interest rate. Nevertheless, Andreoni and Sprenger observe a "cross-over" between the allocations in the two conditions. Specifically, subjects allocate more tokens to sooner payment in CER than in IND at low interest rates and allocate less tokens to sooner payment in CER than in IND at high interest rates. Put differently, subjects are more responsive to changes of interest rate in CER compared to IND.

Based on the observed behavior, Andreoni and Sprenger (2012a, b) conclude that risk preference is not time preference. They further attribute the distinction to a preference for certainty (Kahneman and Tversky, 1979), which allows different utility indices in certain and uncertain environments. In this study, we posit that the underlying mechanism of the findings in Andreoni and Sprenger (2012a, b) is a separation between risk attitude and intertemporal substitution rather than a preference for certainty. Towards testing our hypothesis, we examine the intertemporal allocation behavior in an enriched experimental setting that incorporates the following two additional risk conditions as originally proposed by Duffie and Epstein (1992):

Positive Correlated Risk Condition (POS, see Figure 1): 50 *percent chance of receiving both the sooner payment* $x/(1+r)$ *and the later payment* $100-x$; *otherwise,*

[1] The standard approach measuring time preference in the literature adopts the MPL design (e.g., Coller and Williams, 1999), in which subjects make binary choices between receiving a smaller sooner payment x and a larger later payment y. This would result in a choice set $\{(x,0),(0,y)\}$, which cannot simultaneously identify the discount factor and utility index over time. See Andreoni and Sprenger (2012a) for a detailed comparison between CTB and MPL.

[2] Abdellaoui et al. (2013) introduce a method to measure utility functions for risk preference and time preference separately, and find that utility function under risk is more concave than utility function over time.

receiving nothing.

Negative Correlated Risk Condition (NEG, see Figure 1): 50 *percent chance of receiving the sooner payment* $x/(1+r)$; *otherwise, receiving the later payment* $100-x$.[3]

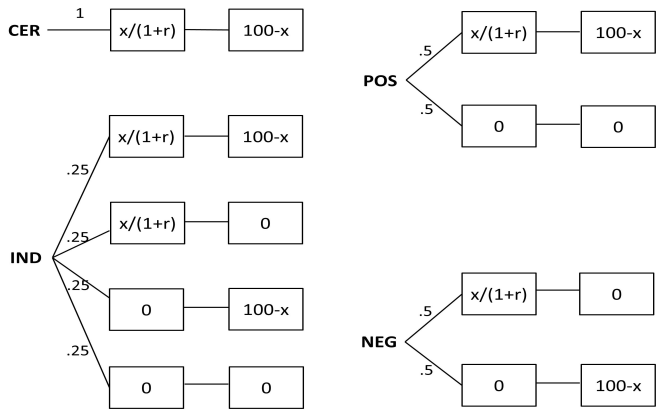

Figure 1. Illustration of the four risk conditions.

DEU delivers identical evaluations for POS, NEG, and IND, and thus predicts the same allocation behavior in all conditions, including CER. At the same time, preference for certainty predicts distinct behavior between CER and POS/NEG/IND but identical allocations in the latter three conditions. Nevertheless, we find that the allocations are similar between conditions CER and POS as well as between conditions NEG and IND. Moreover, a similar cross-over occurs between conditions CER/POS and NEG/IND. Therefore, the observed choice patterns are incompatible with either DEU or preference for certainty as proposed in Andreoni and Sprenger (2012a, b).

We hypothesize that the behavioral underpinning of the observed choice patterns is the distinction between risk attitude and intertemporal substitution. Consider conditions POS and NEG for example. Under POS, intertemporal substitution intuitively drives the allocation decisions since payments for both periods will be delivered under the same state. In contrast, NEG offers directly the opportunity for intertemporal diversification across states which relates to risk attitude. The distinction between risk attitude and intertemporal substitution is further supported by the substantially higher proportion of corner choices under CER/POS (75-90 percent) compared to NEG/IND (10-20 percent), suggesting that the need to smooth consumption over time is weaker than the need to diversify risks across states.

[3]Duffie and Epstein (1992) consider a choice problem between two consumption plans: POS as 50 percent chance of consuming x in periods one and two; otherwise, nothing in both periods; and NEG as 50 percent chance of consuming x in period one; otherwise, consuming x in period two.

Upon closer examination, the intertemporal allocation decision in DEU is independent of whether sooner payment and later payment are delivered in the same state or not, as long as the associated probabilities for the payments have the same ratio. This is the "common ratio" property of DEU observed in Andreoni and Sprenger (2012b). Theoretically, the underlying reasons for the property of risk-condition independence in DEU are threefold: additive utility in time, expected utility in risk, and identical utility index for risk and time preferences. These three assumptions together result in the non-separation between risk preference and time preference and lead to the failure to distinguish between substitution effect and diversification effect across conditions.[4]

Building on these findings, we show that by relaxing some properties of DEU, several existing theoretical models, including Epstein and Zin (1989), Chew and Epstein (1990), and Halevy (2008), can separate risk attitude from intertemporal substitution. Epstein and Zin (1989) maintain the EU framework but allow distinct utility indices to capture risk attitude and intertemporal substitution. Chew and Epstein (1990) depart from EU and consider non-EU instead in evaluating risk to disentangle risk preference from time preference.[5] One specific form of Chew–Epstein, adopting Yaari's (1987) dual theory in risk preference, is subsequently applied by Halevy (2008) to explain dynamic inconsistency. We characterize the conditions under which Epstein–Zin and Chew–Epstein–Halevy can accommodate the major findings in Andreoni and Sprenger (2012a, b) as well as those in our experiment. Notably, although the theories considered above can account for the choice behavior for the majority of the subjects, they cannot explain the behavior of a small proportion of subjects who make distinct decisions under conditions CER and POS.

Our study is related to two recent papers that share similar observations on Andreoni and Sprenger (2012b). Cheung (2013) employs both MPL and CTB to analyze intertemporal decisions under different risk conditions. In addition to the standard MPL design for time preference, Cheung introduces uncertainty into MPL, in which the payments at both time points are delivered with 50 percent chance. He finds no significant difference in choice behavior between MPL under certainty and that under uncertainty. In the CTB experiment, he includes conditions CER, POS, and IND, and observes a similar cross-over between CER and IND. Moreover, the allocations to sooner payment in POS are intermediate between those in CER and those in IND. Cheung (2013) shows that intertemporal diversification could partially explain the results. Additionally, Epper and Fehr-Duda (2013) show theoretically that rank-dependent probability weighting (Quiggin, 1982; Halevy, 2008) can account for the key findings in Andreoni and Sprenger (2012b). In the current study, we experimentally investigate intertemporal decision making in four different conditions using CTB, and find support for

[4]See Epstein and Zin (1989), Chew and Epstein (1990), and Duffie and Epstein (1992) for detailed discussions on separation issues.

[5]We do not focus on the additivity property in this paper mainly because of tractability concerns. We briefly discuss the implications of non-additive discounted utility in Section III.

a separation between risk attitude and intertemporal substitution as proposed in some existing decision theoretical models. The shared message from these recent studies is that DEU cannot account for differential preferences across different risk conditions. In addition, several existing approaches that allow for the separation of risk preference from time preference can more successfully accommodate the overall experimental findings.

The rest of this paper is organized as follows. We detail the experimental design in Section I and then report our experimental results in Section II. In Section III, we discuss the implications of related theories. Section IV states the concluding remarks.

I. Experimental Design

This section describes the design of our experiment. We adopt the CTB design proposed in Andreoni and Sprenger (2012a, b). In each CTB decision, subjects are provided with a budget of experimental tokens to be allocated between sooner and later payments. We include four risk-related conditions and two time menus. For each condition and time menu, subjects make seven CTB decisions with respect to different interest rates in one decision sheet. Altogether, each subject makes a total of 56 experimental decisions ($4 \times 2 \times 7$).

In each CTB decision, subjects are provided with a budget of 100 tokens. Tokens allocated to the sooner date have a value of p_1, and tokens allocated to the later date have a value of p_2. In all cases, p_2 is SGD 0.20 per token and p_1 varies from SGD 0.14 to SGD 0.20 per token (SGD 1 is about USD 0.80). The daily net interest rates in the experiment vary considerably across basic budgets, from 0 percent to 1.28 percent, implying an annual interest rate of between 0 percent and 2116.6 percent (compounded quarterly), which is identical in both menus because of the same time delay.

We introduce four risk-related conditions (Figure 1). In condition CER, both sooner and later payments are guaranteed to be received. In condition POS, the chance for both payments to be received is 50 percent; otherwise, no payment will be received. In condition NEG, the chance for the sooner payment to be received is 50 percent; otherwise, the later payment will be received. In condition IND, the chance for the sooner payment to be received is 50 percent; independently, the chance for the later payment to be received is also 50 percent. All uncertainties are resolved at the end of the experiment to control for preference for the timing of uncertainty resolution.[6]

We include two time menus. In the first menu, sooner payment is made one week after the experiment date, and the later payment is made five weeks after the experiment date. We use this front-end-delay to avoid factors associated with the "present", such as transaction cost (Holcomb and Nelson, 1992). In the second menu, the sooner payment is made 16 weeks after the experiment date, and the

[6]See Kreps and Porteus (1978) and Epstein and Zin (1989) for detailed discussions.

later payment is made 20 weeks after the experiment date. We have the same delay in the two menus to control for the potential confounding factor of sub-additivity in eliciting the time preference (Read, 2001). The dates of payment are set to avoid public holidays, weekends, and examination weeks.

To increase the credibility of payment (Andreoni and Sprenger, 2012a, b), subjects are paid with post-dated cheques that will not be honored by the local bank when presented prior to the date indicated. To further control for the potential difference in transaction cost at different time points (Andreoni and Sprenger, 2012a), subjects receive a minimum participation fee of SGD 12: SGD 6 sooner and SGD 6 later. Experimental earnings are added to these minimum payments. At the end of the experiment, 1 out of the 56 choices is randomly selected by tossing dices according to the Random Incentive Mechanism (RIM).[7] Subjects are informed to treat each decision as if it were the particular decision to determine their payments.

A total of 111 undergraduate students were recruited as participants through an advertisement posted in the Integrated Virtual Learning Environment at the National University of Singapore. The experiment was conducted using paper and pencil at the laboratory of the Center for Behavioral Economics at the National University of Singapore. Conducted by the authors and a research assistant, the experiment consisted of four sessions with 20 to 30 subjects in each session.[8] After the subjects arrived at the experimental venue, they were given the consent form approved by the Institutional Review Board of the National University of Singapore. Subsequently, the general instructions were read aloud to the subjects, and several examples were demonstrated to them before they started making decisions. The experimental instructions followed closely those in Andreoni and Sprenger (2012b) (See Appendix D for the Experimental Instructions). We randomized the order of eight decision sheets for each of the subjects to avoid the possible order effect. Most of our subjects completed the tasks within 30 minutes. At the end of the experiment, they approached the experimenters one by one, tossed the dice and received payments in cheques based on their choice. On average, the subjects were paid SGD 22, including the SGD 12 participation fee.

II. Results

Figure 2 below presents the aggregate behavioral patterns. The mean allocation to the sooner payment at each interest rate is reported for the 111 subjects. Eight data series are shown across four conditions and two time menus. Error bars represent 95 percent confidence intervals, taken as ± 1.96 standard errors of the mean. Three patterns are clearly revealed: (1) allocation decisions are similar in conditions CER and POS, (2) allocation decisions are similar in conditions NEG and IND, and (3) there exists a cross-over between CER/POS and NEG/IND.

[7] For the validity of RIM, readers can refer to Wakker (2007) for a detailed discussion.

[8] The first two sessions were conducted in January 2012, and we ran two additional sessions in January 2013 following the suggestion of an anonymous referee.

In particular, the cross-over between CER and IND replicates the findings in Andreoni and Sprenger (2012b). Table A1 in Appendix A reports the detailed mean allocations and the p-values for the non-parametric Wilcoxon signed rank tests of equality for pairwise comparison across all conditions at each interest rate and time menu. The patterns that emerge from Figure 2 and the tests in Table A1 are similar.

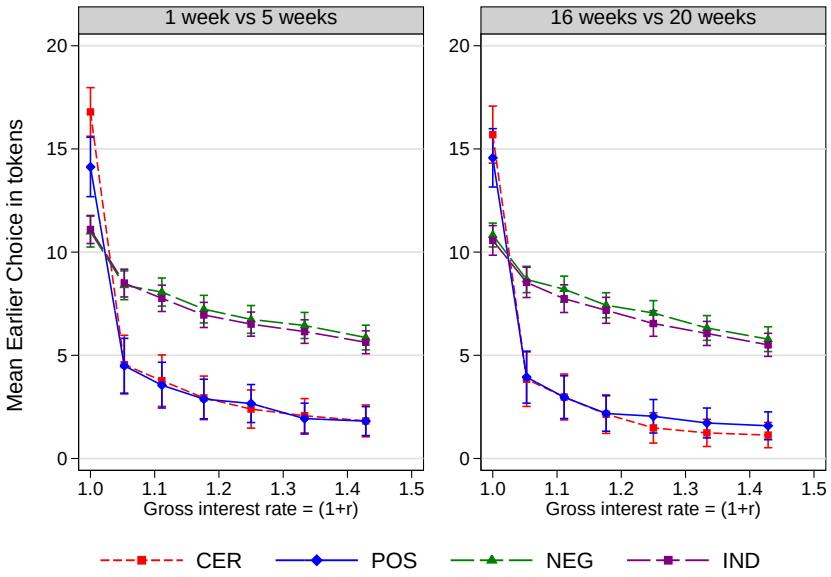

Figure 2. Allocation to the sooner payment across conditions.

Aside from the three main patterns, we observe a substantial proportion of corner decisions, ranging from 75 to 90 percent in CER/POS and from 10 to 20 percent in NEG/IND.[9] Moreover, 71 (62) percent of the subjects choose corner decisions for all 14 decisions in condition CER (POS), and 77 (78) percent of the subjects never choose corner decisions for all 14 decisions in condition NEG (IND) (see Figure A1 in Appendix A for details). Together with the cross-over behavior, the implication of these results is that subjects tend to allocate most of the tokens to the sooner (later) payment when the interest rate is low (high) in conditions CER and POS. By contrast, their allocations are smoother in conditions NEG and IND.[10]

[9]The observed proportions of corner decisions are similar to those in Andreoni and Sprenger (2012b), in which 81 and 26 percent of corner decisions are observed in CER and IND, respectively.

[10]We acknowledge that corner choice could be a concern from both theoretical and empirical perspectives. On the theory side, corner choices could be due to linear preferences over fungible monetary payments, since the subjects may treat money received at different time points effectively as perfect

Additionally, we use the two-limit Tobit regression for an aggregate comparison. We regress allocations to the sooner payment on a number of independent variables, including condition (binary variable), interest rate (ordered category variable), time menu (binary variable) as well as all the interactions of these three variables. Standard errors are clustered at the individual level (see Table A2 in Appendix A). We use an F-test to examine the null hypothesis that the condition-related terms have zero slopes. No significant difference is found between conditions NEG and IND ($p > 0.655$), whereas a significant difference is found between conditions CER and POS ($p < 0.010$).[11] By sharp contrast, the difference between conditions CER/POS and NEG/IND is highly significant ($p < 0.001$). We also test the effect of time menu using a similar F-test to check whether the allocation decisions in the two time menus are distinct. Should a decision maker be a hyperbolic discounter, he/she would allocate more tokens to the sooner payment in the 1-week versus 5-week time menu, than to that in the 16-week versus 20-week time menu. No significant difference is observed, replicating the findings in Andreoni and Sprenger (2012a, b).

We further investigate the three patterns at the individual level by comparing the number of tokens allocated to the sooner payment among different conditions. Each condition consists of 14 decisions with 7 gross interest rates and 2 time menus. We average the absolute difference in the 14 decisions for each comparison. If the average absolute difference is zero, the 14 decisions are identical for the two conditions.

When conditions CER and POS are compared, 50 percent of the subjects make identical allocations, 58 percent of the subjects have a difference less than 5 tokens, 70 percent of the subjects have a difference less than 10 tokens whereas only 5 percent of the subjects have a difference more than 40 tokens. When conditions NEG and IND are compared, 35 percent of the subjects have the same allocations, 55 percent of the subjects have a difference less than 5 tokens, 67 percent of the subjects have a difference less than 10 tokens whereas only 6 percent of the subjects have a difference more than 40 tokens. By contrast, in the other four pairwise comparisons of the different conditions, the percentage of subjects with identical allocations is between 5 percent and 10 percent, whereas the percentage of subjects with a difference more than 40 tokens ranges from 54

substitutes, especially for small stakes. In a recent study applying CTB to effort allocation across time, Augenblick, Niederle, and Sprenger (2013) observe that 31 percent of the allocations are corner choices, which is significantly less than that in the money allocation treatment. Despite the potential lack of incentive to smooth monetary payments compared with consumption goods, the intuition of separation remains valid in our experiment.

On the empirical side, we take into account the corner choices in our econometric analyses.. The Wilcoxon signed rank test, which we use to compare decisions across conditions for each interest rate, is based on ordinal scale and is compatible with corner choices. The two-limit Tobit regression we adopt subsequently for an aggregate comparison takes into account that the choices are censored between 0 and 100. In Appendix C, we build two-limit Tobit specifications into the structural estimation of aggregate preferences.

[11] The difference remains significant when we separate the analysis by two time menus (1 week vs 5 weeks, $p < 0.006$; 16 weeks vs 20 weeks, $p < 0.039$). See Table A3 in Appendix A for details.

to 60 percent. These results suggest that the observed patterns persist at the individual level (see Figure A2 in Appendix A for details).

Notably, the difference between CER and POS is significant at both aggregate level and at some particular interest rates. A closer examination reveals that the majority of subjects, ranging from 77 to 87 percent, make identical decisions between CER and POS in each of the 14 interest rates (see Table A4 in Appendix A). This finding suggests that the observed difference is driven by a small proportion of subjects. In Cheung (2013), the significant difference between CER and POS is more prominent as the aggregate allocations in POS are observed to lie in between those in CER and in IND. We posit that the different patterns between these two studies are likely driven by some subtle features of the experimental design and instructions.[12]

We also test the correlations between the allocations in different conditions for the 14 decisions (7 interest rates $\times$ 2 time menus), which are reported in Table A5 in Appendix A, with the average correlation in the last row. The average correlation between CER and POS is about 75 percent, and the average correlation between NEG and IND is about 50 percent. By contrast, between CER/POS and NEG/IND, the average correlation ranges from 10 to 20 percent. These results suggest that the decisions under CER/POS are most likely determined by a similar mechanism, which is possibly distinct from that underlying NEG/IND.

Finally, we classify each individual as a particular type, combining the six pairwise comparisons in Figure A2. Overall, the analysis reveals four types of particular interest. The first one is the DEU type, which makes identical decisions for each of the six comparisons. The second type comprises subjects who make identical decisions between CER and POS, as well as between NEG and IND, but behave differently across CER/POS and NEG/IND. The third type consists of those who make identical decisions between CER and POS, whereas they behave differently for the other comparisons. The last type treats CER as distinct from the other three conditions, but treats the other three conditions as identical. The last type of behavior is in accordance with preference for certainty.

Figure 3 below reports the number of subjects with and without choice errors for each type. When no choice errors are allowed, the decisions in different conditions are considered identical only if the average absolute difference is zero. With choice

[12]We conduct a similar analysis on the data in Cheung (2013) to draw a comparison. Among 63 subjects in Cheung (2013), 16 (25 percent) subjects make identical allocations between CER and POS, 23 (37 percent) subjects have an average difference less than 5 tokens, and 31 (49 percent) subjects have an average difference less than 10 tokens. These proportions are substantially less than those observed in our data, which could be driven by some subtle differences in the experimental design and instructions. For the experimental design, our experiment includes one more condition NEG compared with that in Cheung (2013). We posit that the additional condition could have enhanced the difference between POS and IND. This is in accordance with the comparative ignorance hypothesis proposed by Fox and Tversky (1995), according to which ambiguity aversion could be enhanced by introducing less ambiguous events. For the experimental instructions, our instructions include four risk conditions as examples, and we explain in detail how the payments are determined in each condition. By contrast, Cheung's (2013) instructions provide one example with partially correlated risk, and the nature of the correlation structure for different conditions become clear only after subjects start making choices in the decision sheets.

errors, we consider the decisions to be identical if the average absolute difference is less than 10 tokens out of the 100 tokens.

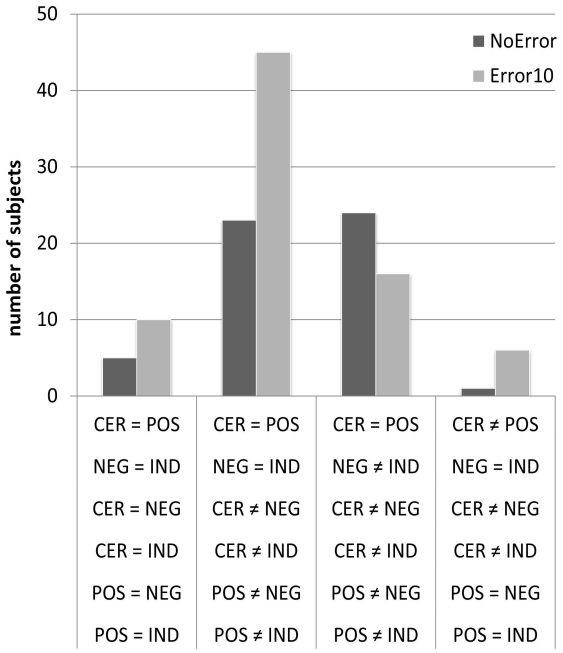

Figure 3. Individual types.

Without choice errors, 5 subjects are classified as DEU type, and 23 subjects make similar decisions between CER and POS as well as between NEG and IND, and behave differently between CER/POS and NEG/IND. A total of 24 subjects make distinct decisions for all the comparisons except between CER and POS. We observe only a single subject exhibiting preference for certainty. With choice errors, 10 subjects are classified as DEU type. The second type, which makes similar decisions between CER and POS as well as between NEG and IND and behaves differently between CER/POS and NEG/IND, comprises 45 subjects. Among these 45 subjects, 38 subjects have elasticities of allocations in CER/POS lesser than those in NEG/IND and 7 subjects have the reverse.[13] A total of 16 subjects make similar decisions between CER and POS and distinct decisions for other comparisons. Among these 16 subjects, 13 exhibit lower elasticities of allocations in CER/POS than those in NEG/IND and 3 show the reverse. By contrast, 6 subjects are identified to have preference for certainty. Finally, 34 out of the 111 subjects cannot be clearly classified as any type. Among these

[13]The elasticities are measured using the coefficients from the regressions of ln(allocation) on ln(interest rate).

34 subjects, 12 treat all the conditions differently, and 11 treat all the conditions differently except for the comparison between NEG and IND.

III. Theoretical Discussion

This section shows that some existing models, including those of Epstein and Zin (1989), Chew and Epstein (1990), and Halevy (2008), can account for the major findings in both Andreoni and Sprenger (2012a, b) and our experiment. We also discuss the relations between these theories in a general setup.

As all uncertainties are resolved immediately at the end of the experiment, different conditions induce different distributions over deterministic consumption paths. Consider the following representative distribution μ:

$$\begin{array}{ccc} & t_1 & t_2 \\ p & c_1 & c_2 \\ 1-p & c_1' & c_2' \end{array}$$

which represents an intertemporal lottery with p chance of receiving (c_1, c_2) and $1-p$ chance of receiving (c_1', c_2').

A general intertemporal utility function for μ first evaluates (c_1, c_2) and (c_1', c_2') in terms of their present equivalents, $\mathrm{PE}(c_1, c_2)$ and $\mathrm{PE}'(c_1', c_2')$, such that receiving PE/PE$'$ at t_1 is indifferent to receiving $(c_1, c_2)/(c_1', c_2')$ on the time horizon. Subsequently, it evaluates the static contingent consumption induced by μ, that is, p chance of receiving PE and $1-p$ chance of receiving PE$'$, to deliver an overall certainty equivalent (CE). The aggregation of CE and PE relates to risk and time preferences, respectively, which can be different from each other.[14]

In the case of DEU,

$$\mathrm{PE}(c_1, c_2) = u^{-1}(u(c_1) + \delta u(c_2)), \tag{1}$$

and

$$\mathrm{CE}(\mu) = u^{-1}(\mathrm{E}_\mu[u(\mathrm{PE})]), \tag{2}$$

with the same u to aggregate PE and CE. Therefore, DEU does not differentiate risk preference from time preference and fails to account for the observed different behavior in various risk conditions.

[14]We use equivalents instead of utilities because of theoretical concerns. Suppose the utility indices for risk preference and time preference differ, with the utility for (c_1, c_2) as $u(c_1) + \delta u(c_2)$ and the utility for $(p, c_1; 1-p, c_1')$ as $pv(c_1) + (1-p)v(c_1')$. An intuitive way of integrating these two utilities is to evaluate μ as $pv(u(c_1) + \delta u(c_2)) + (1-p)v(u(c_1') + \delta u(c_2'))$. This behavioral model can also capture the intuition of separation. However, the interpretation is problematic as the utility function v does not exactly capture the risk attitude given that the utility of one-period contingent consumption $\widetilde{c}$ is $\mathrm{E}[v \circ u(\widetilde{c})]$. Therefore, adopting equivalents instead of utilities facilitates a consistent comparison among various time, risk, and riskless conditions when considering the separation issue. Moreover, it helps us to understand the links among different models.

One can consider a distinct utility index v in the CE aggregator:

$$\mathrm{CE}(\mu) = v^{-1}\left(\mathrm{E}_{\mu}\left[v\left(\mathrm{PE}\right)\right]\right). \tag{3}$$

This generalization maintains EU in risk, with distinct utility indices u and v, separately capturing intertemporal substitution and risk attitude. Epstein and Zin (1989) provide a specific form using different CES functions in risk and time preferences:

$$\mathrm{CE}(\mu) = \left(\mathrm{E}_{\mu}\left[\left(\left(c_1^{\rho} + \delta c_2^{\rho}\right)^{1/\rho}\right)^{\alpha}\right]\right)^{1/\alpha}. \tag{4}$$

Under this specification, the PE for a deterministic consumption path (c_1, c_2) is $(c_1^{\rho} + \delta c_2^{\rho})^{1/\rho}$ and the CE for a static contingent consumption plan $(p, c_1; 1-p, c_1')$ is $(pc_1^{\alpha} + (1-p)\, c_1'^{\alpha})^{1/\alpha}$. Thus, α captures risk attitude and ρ captures intertemporal substitution in this model. The utility function reduces to DEU when $\alpha = \rho$. As Epstein–Zin permits different utility indices for risk and time preferences, it can straightforwardly account for the observed difference between the elicited utility curvature for risk using MPL and that for time using CTB in Andreoni and Sprenger (2012a). The CEs for the four conditions in our setup are as follows:

$$\begin{aligned}
\mathrm{CE}_{CER} &= (c_1^{\rho} + \delta c_2^{\rho})^{1/\rho} \\
\mathrm{CE}_{POS} &= \left(\frac{1}{2}\left(c_1^{\rho} + \delta c_2^{\rho}\right)^{\alpha/\rho}\right)^{1/\alpha} \\
\mathrm{CE}_{NEG} &= \left(\frac{1}{2}c_1^{\alpha} + \frac{1}{2}\left(\delta^{1/\rho}c_2\right)^{\alpha}\right)^{1/\alpha} \\
\mathrm{CE}_{IND} &= \left(\frac{1}{4}\left(c_1^{\rho} + \delta c_2^{\rho}\right)^{\alpha/\rho} + \frac{1}{4}c_1^{\alpha} + \frac{1}{4}\left(\delta^{1/\rho}c_2\right)^{\alpha}\right)^{1/\alpha}
\end{aligned}$$

Given the budget constraint $(1+r)\, c_1 + c_2 = 100$, it is immediate that the optimal allocations in CER and POS are identical. In comparing POS and NEG, we obtain the following first-order conditions characterizing the optimal solutions in POS and NEG respectively:

$$\left(\frac{c_{1,P}^{\star}}{c_{2,P}^{\star}}\right)^{\rho-1} = \delta\,(1+r) \text{ and } \left(\frac{c_{1,N}^{\star}}{c_{2,N}^{\star}}\right)^{\alpha-1} = \delta^{\alpha/\rho}\,(1+r).$$

As δ is close to 1 in our experimental setup, the difference between δ and $\delta^{\alpha/\rho}$ is negligible, and the decision maker smoothes consumption mainly based on the parameters ρ and α in these two conditions. Under the condition $\alpha < \rho < 1$, $c_{1,P}^{\star}$ is more responsive to the change in r than $c_{1,N}^{\star}$ because $(1+r)^{\frac{1}{\rho-1}}$ approaches

0 faster than $(1+r)^{\frac{1}{\alpha-1}}$ does, and we have a cross-over between POS and NEG as observed.[15] A similar intuition suggests that the incentive for consumption smoothing in IND comes from both ρ and α, and $c^{\star}_{1,I}$ can be close to $c^{\star}_{1,N}$ under certain parameter specifications, as shown in Appendix B.1.

Alternatively, Chew and Epstein (1990) distinguish between risk and time preferences by adopting non-EU preference to aggregate the CE. Halevy (2008) considers a specific non-EU form, the dual theory (Yaari 1987), to explain dynamic inconsistency. The Chew–Epstein–Halevy representation essentially permits rank-dependent utility (Quiggin 1982) for the induced contingent consumption:

$$\mathrm{CE}(\mu) = \begin{cases} u^{-1}\left[f(p)\,u(\mathrm{PE}) + (1-f(p))\,u(\mathrm{PE}')\right] & if\ \mathrm{PE} \succeq \mathrm{PE}' \\ u^{-1}\left[f(p)\,u(\mathrm{PE}') + (1-f(p))\,u(\mathrm{PE})\right] & if\ \mathrm{PE} \prec \mathrm{PE}' \end{cases}$$

where f is a probability weighting function, and the valuation depends on the relative ranks between PE and PE′. Note that the PE of (c_1, c_2) is $u^{-1}(u(c_1) + \delta u(c_2))$ and the CE of $(p, c_1; 1-p, c_1')$ is $u^{-1}(f(p)\,u(c_1) + (1-f(p))\,u(c_1'))$ (for $c_1 \succeq c_1'$). Therefore, intertemporal substitution is captured solely by u and risk attitude by u and the probability weighting function f in this model. The utility function reduces to DEU when $f(p) = p$. As Andreoni and Sprenger (2012a) estimate risk preference assuming EU and find distinct utility indices for risk preference and time preference, Chew–Epstein–Halevy can also account for the distinction with the additional probability weighting function partially capturing risk attitude. Similar comparative statics analysis reveals that Chew–Epstein–Halevy can also generate the cross-over as observed in Andreoni and Sprenger (2012b) as well as in this current study through the changes in probability weights. (see Appendix B.2 for a detailed discussion).[16]

Both Epstein–Zin and Chew–Epstein–Halevy adopt additive utility in time: $\mathrm{PE}(c_1, c_2) = u^{-1}(u(c_1) + \delta u(c_2))$.[17] A number of behavioral models can also permit a separation between risk and time preferences by allowing for non-additive utility in time (see Frederick, Loewenstein, and O'Donoghue, 2002, for a review). We do not discuss these models in detail mainly because of tractability concerns. In fact, most of these models (e.g., habit formation model, reference point utility, and anticipation utility) enable positive cross partial derivatives with respect to

[15] We still need $c^{\star}_{1,P} > c^{\star}_{1,N}$ at $r = 0$ to have a cross-over, and this is due to $\frac{1}{\rho-1} < \frac{\alpha}{\rho(\alpha-1)}$.

[16] The specific forms of Epstein–Zin and Chew–Epstein–Halevy considered here are incompatible with the distinct choice behavior between CER and POS in the CTB design. Although preference for certainty can generate such a difference, it fails to account for the differences across various conditions. One alternative is to consider the implicit risk approach in Halevy (2008), which suggests that there exists systematic uncertainty for future payments (due to mortality or disappearance). Under such a consideration, in CER, the sooner payment is delivered with probability 1 and the later payment with probability $r < 1$. In POS, the probabilities of receiving sooner and later payments are 0.5 and $0.5r$, respectively. Therefore, the allocation behavior in the two conditions will differ if the two ratios, $f(1)/f(r)$ and $f(0.5)/f(0.5r)$, are not equal. See Keren and Roelofsma (1995) for a related discussion on implicit risk.

[17] See Appendix B.3 for a further discussion on the relation between Epstein-Zin and Chew–Epstein–Halevy in a general dynamic environment. We also conduct a structural estimation of these two models in Appendix C, and the results support the separation.

c_1 and c_2, and predict a preference for POS over NEG. We conduct a survey to test this prediction and find that 31 out of 39 subjects prefer NEG over POS.[18]

IV. Concluding Remarks

Our study strengthens the distinction between risk and time preferences in the recent works of Andreoni and Sprenger (2012a, b). Moreover, our experimental evidence suggests that the distinction is unlikely to be due to preference for certainty. We show theoretically that Epstein–Zin and Chew–Epstein–Halevy allow for a separation between risk attitude and intertemporal substitution and can account for the overall findings.

Our results also shed lights on recent experimental literature exploring the interactions between risk and time preferences, for example, Abdellaoui, Attema, and Bleichrodt (2010) and Takeuchi (2011). These studies use the property of non-separation in DEU to jointly elicit the utility index and discount factors, which has been questioned by Andreoni and Sprenger (2012a). We further emphasize that, under the frameworks with separation, the estimated discount factor may be distorted. For example, Takeuchi (2011) elicits the discount factor through an equivalent risk treatment, in which he first identifies probability p such that receiving x with probability p is indifferent to receiving y for sure. Moreover, he elicits the equivalent delay t such that the subject is indifferent between receiving x in period t and receiving y in period one. Under DEU, the discount factor δ_t is equal to p. Under Epstein and Zin (1989), the equivalence is $(px^{\alpha})^{1/\alpha} = (D_t x^{\rho})^{1/\rho} = y$, which implies that the real discount factor D_t satisfies $D_t^{\alpha/\rho} = p$. Therefore, we will not have the equivalence $D_t = p$ if $\alpha \neq \rho$. In particular, it will result in an over-estimated discount factor ($\delta_t > D_t$) if $\alpha < \rho$. Similarly, the equivalence becomes $f(p)\,u(x) = D_t u(x) = u(y)$ in Halevy (2008), which will again lead to distortions in the estimated discount factor given a non-linear probability weighting function f.

Finally, we note that the experiment in this study is based on monetary reward and may be subject to the concern that decision makers do not have enough incentives for smoothing monetary payoffs over time. Indeed, the behavior we observe in conditions CER and POS tends to suggest that most decision makers have little smoothing incentives between different periods. In principle, consumption goods could be used in place of monetary incentives to induce more intertemporal smoothing than that observed in our current study.[19] Notwithstanding

[18] In our classroom survey, subjects are asked to choose among (1) 50 percent chance of receiving SGD 30 one week later and SGD 0 five weeks later; otherwise, receiving SGD 0 one week later and SGD 30 five weeks later; (2) 50 percent chance of receiving SGD 30 both one week later and five weeks later; otherwise, receiving SGD 0 both one week later and five weeks later; (3) indifference between (1) and (2). Among the 39 subjects, 31 subjects choose (1), one subject chooses (2), and 7 subjects choose (3).

[19] In most of the experiments on intertemporal choice, monetary reward is adopted to elicit time preference. Reuben, Sapienza, and Zingales (2010) argue that if the discount rates inferred from monetary rewards and consumption goods are significantly correlated, the measurement through monetary reward might be ecologically valid. In their experiment, they elicit discount factors for both monetary rewards

these caveats, we posit that the overall patterns would nevertheless persist, and the general message regarding the separation between risk preference and time preference would remain valid.

REFERENCES

Abdellaoui, Mohammed, Arthur E Attema, and Han Bleichrodt. 2010. "Intertemporal Tradeoffs for Gains and Losses: An Experimental Measurement of Discounted Utility." *The Economic Journal*, 120(545): 845-66.

Abdellaoui, Mohammed, Han Bleichrodt, Olivier l'Haridon, and Corina Paraschiv. 2013. "Is There One Unifying Concept of Utility? An Experimental Comparison of Utility under Risk and Utility over Time." *Management Science*, 59(9): 2153-69.

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.

Augenblick, Ned, Muriel Niederle, and Charles Sprenger. 2013. "Working over Time: Dynamic Inconsistency in Real Effort Tasks." Working paper, National Bureau of Economic Research.

Cheung, Stephen L. 2013. "On the Elicitation of Time Preference under Conditions of Risk." *American Economic Review*, forthcoming.

Chew, Soo Hong, and Larry G. Epstein. 1990. " Non-expected Utility Preferences in a Temporal Framework with an Application to Consumption-Savings Behaviour." *Journal of Economic Theory*, 50(1): 54-81.

Chew, Soo Hong, Edi Karni, and Zvi Safra. 1987. " Risk Aversion in the Theory of Expected Utility with Rank Dependent Probabilities." *Journal of Economic theory*, 42(2), 370-81.

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

Duffie, Darrell, and Larry G. Epstein. 1992. "Stochastic Differential Utility." *Econometrica*, 60(2): 353-94.

Epper, Thomas, and Helga Fehr-Duda. 2013. "Balancing on a Budget Line: Comment on Andreoni and Sprenger's 'Risk Preferences Are Not Time Preferences'." *American Economic Review*, forthcoming.

Epstein, Larry G., and Stanley E. Zin. 1989. "Substitution, Risk Aversion, and the Temporal Behavior of Consumption and Asset Returns: A Theoretical Framework." *Econometrica*, 57(4): 937-69

Fox, Craig R., and Amos Tversky. 1995. "Ambiguity Aversion and Comparative Ignorance." *The Quarterly Journal of Economics*, 110(3): 585-603.

and primary rewards (chocolate) and find a positive and statistically significant relation between short-term discount rates elicited using monetary and primary rewards. More recently, see also Augenblick, Niederle, and Sprenger (2013).

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.

Halevy, Yoram. 2008. "Strotz Meets Allais: Diminishing Impatience and the Certainty Effect." *American Economic Review*, 98(3): 1145-62.

Holcomb, James H., and Paul S. Nelson. 1992. "Another Experimental Look at Individual Time Preference." *Rationality and Society*, 4(2): 199-220.

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

Kahneman, Daniel, and Amos Tversky. 1979. "Prospect Theory: An Analysis of Decision under Risk." *Econometrica*, 47(2): 263-91.

Keren, Gideon, and Peter Roelofsma. 1995. "Immediacy and Certainty in Intertemporal Choice." *Organizational Behavior and Human Decision Making*, 63: 287-97.

Kreps, David M., and Evan L. Porteus. 1978. "Temporal Resolution of Uncertainty and Dynamic Choice Theory." *Econometrica*, 46(1): 185-200.

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

Read, Daniel. 2001. "Is Time-Discounting Hyperbolic or Subadditive." *Journal of Risk and Uncertainty*, 23(1): 5-32.

Reuben, Ernesto, Paola Sapienza, and Luigi Zingales. 2010. "Time Discounting for Primary and Monetary Rewards." *Economics Letters*, 106(2): 125-27.

Takeuchi, Kan. 2011. "Non-Parametric Test of Time Consistency: Present Bias and Future Bias." *Games and Economic Behavior*, 71(2): 456-78.

Wakker, Peter P. 2007. http://people.few.eur.nl/wakker/miscella/debates/randomlinc.htm

Yaari, Menahem E. 1987. "The Dual Theory of Choice under Risk." *Econometrica*, 55(1): 95-115.

Comment on "Risk Preferences are Not Time Preferences": Separating Risk and Time Preference

Online Appendices

Bin Miao, Songfa Zhong*

Oct 2014

Contents

*Miao: School of Economics, Shanghai University of Finance and Economics; binmiao11@gmail.com. Zhong: Department of Economics, National University of Singapore, Singapore; zhongsongfa@gmail.com.

A Supplementary Tables and Figures

Table A1. Mean Allocation to Sooner Payment and Pairwise Wilcoxon Tests of Equality.

Gross Interest	CER	POS	NEG	IND	CER POS	CER NEG	CER IND	POS NEG	POS IND	NEG IND
				1 week	vs	5 weeks				
1	83.96	70.63	54.96	55.49	0.001	0.001	0.001	0.001	0.001	0.542
1.05	23.95	23.66	44.17	44.74	0.249	0.001	0.001	0.001	0.001	0.771
1.11	20.96	19.75	44.81	43.12	0.907	0.001	0.001	0.001	0.001	0.104
1.18	17.29	16.96	42.57	40.92	0.698	0.001	0.001	0.001	0.001	0.231
1.25	14.97	16.65	42.13	40.69	0.263	0.001	0.001	0.001	0.001	0.511
1.33	13.8	12.89	42.97	41	0.67	0.001	0.001	0.001	0.001	0.203
1.43	13.01	12.95	41.87	40.23	0.542	0.001	0.001	0.001	0.001	0.315
				16 weeks	vs	20 weeks				
1	78.47	72.84	54.14	52.84	0.038	0.001	0.001	0.001	0.001	0.647
1.05	20.22	20.75	45.66	44.91	0.453	0.001	0.001	0.001	0.001	0.926
1.11	16.56	16.51	45.58	43.03	0.465	0.001	0.001	0.001	0.001	0.232
1.18	12.64	12.83	43.69	42.23	0.402	0.001	0.001	0.001	0.001	0.694
1.25	9.27	12.79	44.06	40.87	0.036	0.001	0.001	0.001	0.001	0.12
1.33	8.27	11.48	42.17	40.4	0.003	0.001	0.001	0.001	0.001	0.223
1.43	8.099	11.32	41.3	39.34	0.008	0.001	0.001	0.001	0.001	0.227

Table A2. Tobit Regression Results.

	CER vs POS	NEG vs IND	CER/POS vs NEG/IND
treatment	-134.7**	-7.881	-280.1***
	(58.21)	(8.46)	(28.07)
interest rate	3,439***	183.7***	252.4***
	(681.1)	(48.75)	(52.83)
time	-92.33*	-0.439	1.108
	(55.91)	(5.405)	(4.152)
treatment x interest rate	819.7**	39.8	1,411***
	(319.2)	(45.91)	(143.7)
treatment x time	-62.61	2.185	-47.17**
	(71.3)	(7.739)	(20.8)
interest rate x time	451.1	6.2	-6.945
	(288.6)	(31.03)	(23.98)
treatment x interest rate x time	261.5	-20.07	219.6**
	(376.7)	(46.27)	(106.7)
constant	-648.1***	12.77	-1.107
	(136.1)	(9.445)	(10.47)
# clusters	111	111	111
Pseudo R-square	0.052	0.004	0.046
F-test: risk (p-value)	0.01	0.655	0.001
F-test: time (p-value)	0.162	0.923	0.189
F-test: interest rate (p-value)	0.001	0.001	0.001

Table A3. Tobit Regression between CER and POS for Two Time Menus.

	1 week vs 4 weeks	16 weeks vs 20 weeks
treatment	-133.0**	-200.3**
	(56.75)	(79.76)
interest rate	3,397***	3,946***
	(683.2)	(826.7)
treatment x interest rate	809.1***	1,097**
	(311.3)	(431.5)
constant	-639.6***	-751.8***
	(136.5)	(165.8)
# clusters	111	111
Pseudo R-square	0.004	0.059
F-test: risk (p-value)	0.006	0.039
F-test: interest rate (p-value)	0.001	0.001

Table A4. Individual Level Difference between CER and POS with Varying Choice Errors.

Gross	error = 0			error ≤ 5			error ≤ 10		
Interest	CER > POS	CER = POS	CER < POS	CER > POS	CER = POS	CER < POS	CER > POS	CER = POS	CER < POS
				1 week	vs	5 weeks			
1	24	85	2	24	85	2	24	85	2
1.05	8	89	14	8	91	12	8	94	9
1.11	12	86	13	12	88	11	12	90	9
1.18	10	89	12	9	92	10	9	93	9
1.25	8	90	13	7	93	11	6	95	10
1.33	12	89	10	11	91	9	9	95	7
1.43	9	90	12	8	91	12	8	95	8
				16 weeks	vs	20 weeks			
1	19	84	8	18	85	8	18	85	8
1.05	10	87	14	9	90	12	8	93	10
1.11	10	87	14	10	89	12	9	93	9
1.18	8	91	12	8	91	12	8	93	10
1.25	5	92	14	5	92	14	3	95	13
1.33	2	95	14	2	96	13	2	98	11
1.43	3	94	14	3	94	14	2	97	12

Table A5. Spearman Correlation across Conditions.

Interest	CER/POS	CER/NEG	CER/IND	POS/NEG	POS/IND	NEG/IND
			1 week vs 5 weeks			
1	0.61	0.14	0.07	0.25	0.28	0.57
1.05	0.8	0.16	0.13	0.11	0.12	0.3
1.11	0.79	0.14	0.21	0.11	0.21	0.56
1.18	0.84	0.21	0.3	0.23	0.3	0.6
1.25	0.86	0.17	0.24	0.08	0.26	0.59
1.33	0.82	0.14	0.27	0.09	0.25	0.54
1.43	0.79	0.04	0.22	0.02	0.2	0.53
			16 weeks vs 20 weeks			
1	0.61	-0.03	0.22	0.21	0.27	0.53
1.05	0.74	0.17	0.17	0.21	0.14	0.26
1.11	0.73	0.05	0.18	0.17	0.13	0.44
1.18	0.71	0.16	0.15	0.15	0.13	0.45
1.25	0.76	0.06	0.08	0.03	0.19	0.44
1.33	0.74	0.04	0.18	0.02	0.19	0.59
1.43	0.73	0.1	0.11	0.07	0.15	0.59
Average	0.75	0.11	0.18	0.13	0.2	0.5

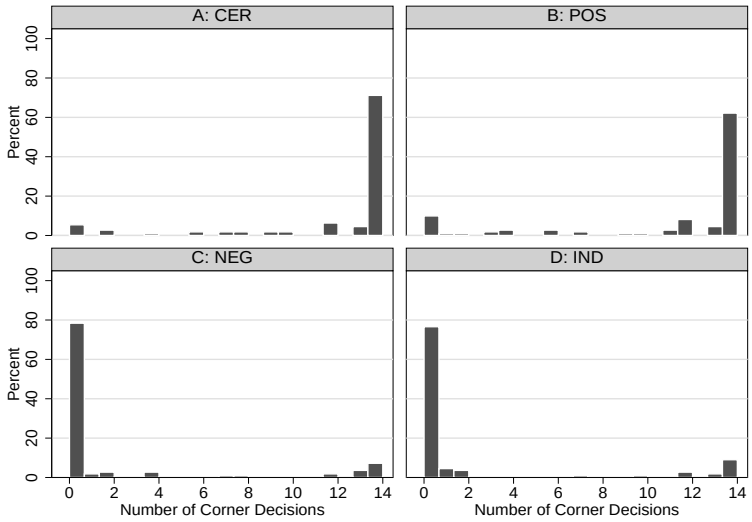

Figure A1. Individual Level Corner Decisions across Conditions.

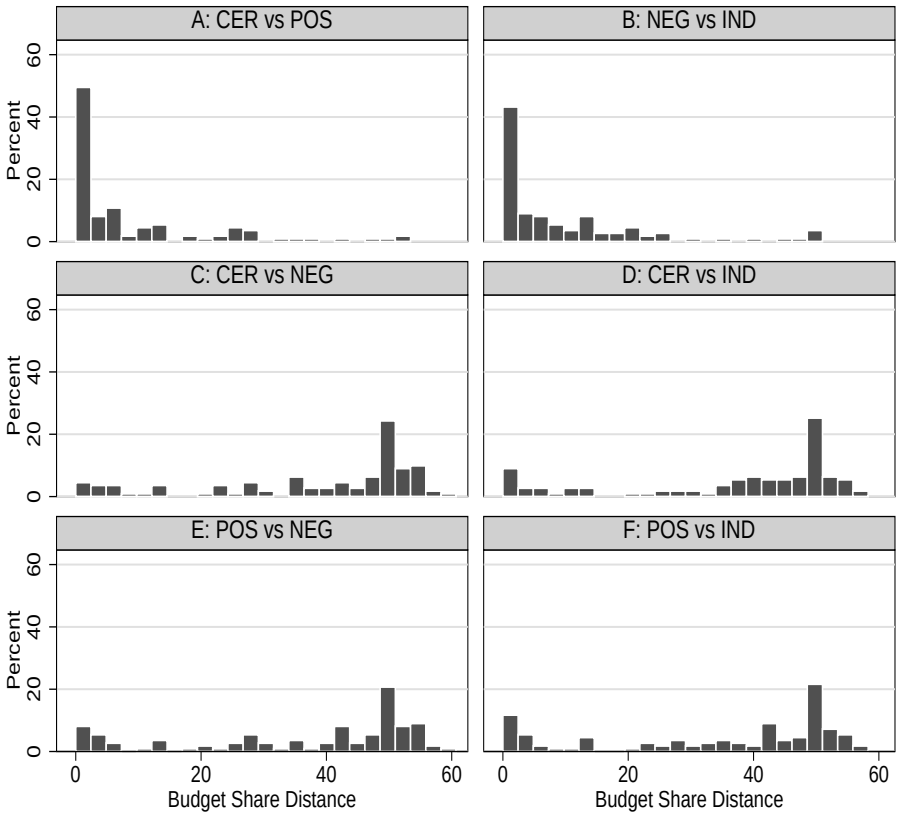

Figure A2. Individual Budget Share Distance across Conditions.

B Existence of a Cross-over in Epstein–Zin and Chew–Epstein–Halevy

In this appendix, we show how Epstein-Zin and Chew–Epstein–Halevy can exhibit a cross-over between CER/POS and NEG/IND as observed.

B.1 Cross-over in Epstein–Zin

We show here Epstein–Zin can generate a cross-over under the condition of $\alpha < \rho < 1$. First, we have the optimal solutions in conditions CER, POS, and NEG: $c^{\star}_{1,C/P} = \frac{100(\delta(1+r))^{\frac{1}{\rho-1}}}{\delta^{\frac{1}{\rho-1}}(1+r)^{\frac{\rho}{\rho-1}}+1}$, $c^{\star}_{1,N} = \frac{100\delta^{\frac{\alpha}{\rho(\alpha-1)}}(1+r)^{\frac{1}{\alpha-1}}}{\delta^{\frac{\alpha}{\rho(\alpha-1)}}(1+r)^{\frac{\alpha}{\alpha-1}}+1}$. The FOC characterizing $c^{\star}_{1,I}$ is given by

$$\left(c_1^{\rho}+\delta c_2^{\rho}\right)^{\frac{\alpha}{\rho}-1}\left[c_1^{\rho-1}-\delta\left(1+r\right)c_2^{\rho-1}\right]+\left[c_1^{\alpha-1}-\delta^{\alpha/\rho}\left(1+r\right)c_2^{\alpha-1}\right]=0,$$

which does not have an explicit solution. Notice that the function in the first square bracket corresponds to the FOC characterizing $c^{\star}_{1,C/P}$ and the function in the second square bracket characterizes $c^{\star}_{1,N}$. Therefore, $c^{\star}_{1,I}$ would be between $c^{\star}_{1,C/P}$ and $c^{\star}_{1,N}$ under certain monotonicity conditions. Moreover, we have $(c_1^{\rho}+\delta c_2^{\rho})^{\frac{\alpha}{\rho}-1} \ll 1$ given $\alpha < \rho$, which could make $c^{\star}_{1,I}$ close to $c^{\star}_{1,N}$.

When $r = 0$, we have $c^{\star}_{1,C/P} = \frac{100\delta^{\frac{1}{\rho-1}}}{\delta^{\frac{1}{\rho-1}}+1}$ and $c^{\star}_{1,N} = \frac{100\delta^{\frac{\alpha}{\rho(\alpha-1)}}}{\delta^{\frac{\alpha}{\rho(\alpha-1)}}+1}$ with $c^{\star}_{1,I}$ in between. As $\frac{1}{\rho-1} < \frac{\alpha}{\rho(\alpha-1)}$ given $\alpha < \rho < 1$, the four optimal solutions satisfy $c^{\star}_{1,C/P} > c^{\star}_{1,I} > c^{\star}_{1,N}$. Moreover, the change in $c^{\star}_1$ to the change in r is more sensitive in CER/POS than in NEG because $(1+r)^{\frac{1}{\rho-1}}$ vanishes faster than $(1+r)^{\frac{1}{\alpha-1}}$ does. To sum up, it could generate the observed cross-over. Finally, note that $\alpha < \rho$ implies a preference for NEG over POS as $(c_1^{\rho}+\delta c_2^{\rho})^{\alpha/\rho} < c_1^{\alpha}+\delta^{\alpha/\rho}c_2^{\alpha}$ by triangular inequality, and we may have a reverse cross-over if $\rho < \alpha < 1$.

B.2 Cross-over in Chew–Epstein–Halevy

We show here Chew–Epstein–Halevy can generate a cross-over under the conditions of $f\left(0.5\right) < 1 - f\left(0.5\right)$ and $f\left(0.5\right) < f\left(0.75\right) + f\left(0.25\right) - f\left(0.5\right)$.

First, notice that one can simply represent Chew–Epstein–Halevy in terms of utilities given that there is a unique utility index u. The evaluations of four different conditions in

our experiment are as follows:

$$
\begin{aligned}
U_{CER} &= u(c_1) + \delta u(c_2) \\
U_{POS} &= f(0.5)\left(u(c_1) + \delta u(c_2)\right) \\
U_{NEG} &= \begin{cases} f(0.5)\,u(c_1) + (1 - f(0.5))\,\delta u(c_2) \;\; if \;\; u(c_1) \geq \delta u(c_2) \\ (1 - f(0.5))\,u(c_1) + f(0.5)\,\delta u(c_2) \;\; if \;\; u(c_1) < \delta u(c_2) \end{cases} \\
U_{IND} &= \begin{cases} f(0.5)\,u(c_1) + (f(0.75) + f(0.25) - f(0.5))\,\delta u(c_2) \;\; if \;\; u(c_1) \geq \delta u(c_2) \\ (f(0.75) + f(0.25) - f(0.5))\,u(c_1) + f(0.5)\,\delta u(c_2) \;\; if \;\; u(c_1) < \delta u(c_2) \end{cases}
\end{aligned}
$$

The optimal allocations in CER and POS coincide. We proceed to show that a cross-over may exist between POS and NEG under the condition of $f(0.5) < 1 - f(0.5)$.[1]

When r is small, the optimal allocations $c^{\star}_{1,P}$ and $c^{\star}_{1,N}$ are likely to fall in the region in which $u(c_1) \geq \delta u(c_2)$. As $f(0.5) < 1 - f(0.5)$, we have the following relation on the first-order conditions characterizing $c^{\star}_{1,P}$ and $c^{\star}_{1,N}$:

$$
\frac{u'\left(c^{\star}_{1,P}\right)}{u'\left(c^{\star}_{2,P}\right)} = \delta(1+r) < \delta(1+r)\frac{1 - f(0.5)}{f(0.5)} = \frac{u'\left(c^{\star}_{1,N}\right)}{u'\left(c^{\star}_{2,N}\right)},
$$

which implies $c^{\star}_{1,P} > c^{\star}_{1,N}$ at r small. As r increases, the optimal allocations will shift to the region in which $u(c_1) < \delta u(c_2)$ and the above relation reverses accordingly:

$$
\frac{u'\left(c^{\star}_{1,P}\right)}{u'\left(c^{\star}_{2,P}\right)} = \delta(1+r) > \delta(1+r)\frac{f(0.5)}{1 - f(0.5)} = \frac{u'\left(c^{\star}_{1,N}\right)}{u'\left(c^{\star}_{2,N}\right)},
$$

which results in $c^{\star}_{1,P} < c^{\star}_{1,N}$ at r large. Intuitively, the unfavored outcome gets overweighted in NEG compared to POS, which makes the unfavored outcome relatively more attractive. As the sooner payment is initially favored and eventually unfavored as the interest rate increases, a decision maker first allocates less in the sooner payment and then more in the sooner payment in NEG compared to POS, which generates the cross-over as observed. Similarly, a cross-over will occur between CER/POS and IND under the condition of $f(0.5) < f(0.75) + f(0.25) - f(0.5)$. Moreover, given $f(0.75) + f(0.25) - f(0.5) \approx 1 - f(0.5)$, $c^{\star}_{1,N}$ and $c^{\star}_{1,I}$ will be close to each other and we have the overall patterns as observed.

[1] The probability weighting function is commonly observed to be inverse S-shaped: initially concave and eventually convex with a cross-over point at around one third. Therefore, $f(0.5) < 1 - f(0.5)$ is a reasonable assumption behaviorally. See Wakker (2010, chapter 7) for details.

B.3 Further Discussion on Epstein–Zin and Chew–Epstein-Halevy

We note here that Epstein and Zin (1989) and Chew and Epstein (1990) adopt different approaches in the recursive environment. Specifically, Epstein and Zin (1989) maintain the consistency assumption and discard time neutrality, whereas Chew and Epstein (1990) maintain time neutrality and abandon recursivity. Our experiment involves only degenerate recursive cases as all uncertainties are resolved at period one, which makes these models comparable. In other settings, these two models can be further differentiated. For example, Epstein and Zin (1989) point out that their specification is incompatible with the experimental evidence against expected utility theory as it admits EU for static risks. [2] Moreover, Epstein–Zin predicts a positive correlation between preference for NEG over POS and preference for early resolution over later resolution of uncertainty, which is also testable by experimental instruments. Meanwhile, Chew–Epstein–Halevy employs non-EU in risk using the same utility index as that in time, which can be tested by extending Andreoni and Sprenger (2012a) to assume non-EU in risk preference estimation.[3]

Cheung (2013) and Epper and Fehr-Duda (2013) also provide theoretical frameworks to analyze the allocation behavior in Andreoni and Sprenger (2012b). Cheung (2013) considers a behavioral model $\mathrm{E}_{\mu} v\left(u\left(c_1\right)+\delta u\left(c_2\right)\right)$ and shows that it can account for the cross-over between CER and IND. The behavioral model shares similar implications with Epstein–Zin, given that u and v intuitively capture intertemporal substitution and risk attitude.[4] Epper and Fehr-Duda (2013) apply rank-dependent probability weighting to explain the major findings in Andreoni and Sprenger (2012b). The model considered in Epper and Fehr-Duda (2013) is the same as that in Halevy (2008), which is a special case of Chew and Epstein (1990).

We would like to point out that the observed similar choice pattern between certain and uncertain conditions under MPL in Cheung (2013) can be rationalized by both Epstein–Zin and Chew–Epstein–Halevy. Consider the choice between receiving x at t_1 with probability p and receiving y at t_2 with the same probability p, where p equals 1 (certainty condition) or 0.5 (uncertainty condition). Under Epstein–Zin, the CEs of $(x,0)$ and $(0,y)$ are x and $\delta^{1/\rho}y$ at $p=1$, and $\left(0.5x^{\alpha}\right)^{1/\alpha}$ and $\left(0.5\delta^{\alpha/\rho}y^{\alpha}\right)^{1/\alpha}$ at $p=0.5$. For Chew–Epstein–Halevy, the utilities of $(x,0)$ and $(0,y)$ are $u\left(x\right)$ and $\delta u\left(y\right)$ at $p=1$, and $f\left(0.5\right)u\left(x\right)$ and $f\left(0.5\right)\delta u\left(y\right)$

[2]Epstein and Zin (1989) provide a more general recursive form in which the risk aggregator complies with the betweenness axiom. One can also consider a recursive form using rank-dependent utility for risk, which reduces to Chew–Epstein–Halevy in a degenerate recursive environment.

[3]Epper, Fehr-Duda, and Bruhin (2011) elicit risk and time preferences in an experimental setting and estimate the rank-dependent probability weighting function and discount factor using the same utility index, which is in accordance with the model of Chew–Epstein–Halevy.

[4]The behavioral model in Cheung (2013) admits the specific form of $p\left(c_1^{\rho}+\delta c_2^{\rho}\right)^{\alpha}+\left(1-p\right)\left(c_1'^{\rho}+\delta c_2'^{\rho}\right)^{\alpha}$ when evaluating μ.

at $p = 0.5$. Thus, both theories predict identical choice behavior across the two conditions.

C Structural Estimation of Aggregate Preferences

In this appendix, we estimate the preference parameters in Epstein–Zin and Chew–Epstein–Halevy. We adopt the two-limit Tobit maximum likelihood estimation to account for corner solution censoring.[5] To start with, we posit a hyperbolic discounting utility function with the same background consumptions following the methodology developed in Andreoni and Sprenger (2012a). For example, we have the following equation for Epstein–Zin under condition CER:

$$\mathrm{CE}_{CER} = \left((c_1 + w)^{\rho} + \beta^s \delta \left(c_2 + w\right)^{\rho}\right)^{1/\rho}$$

where δ is the discount factor for 4 weeks, $s = 1$ for 1-week versus 5-week time menu and $s = 0$ for 16-week versus 20-week time menu to capture the discount factor difference between the two time menus. If β is significantly smaller than 1, the discount factor is smaller for first time menu than for the second time menu, which supports the hyperbolic discounting hypothesis. w can be interpreted as the classic Stone–Geary consumption minima, intertemporal reference point, or background consumption, which is also included in the estimations in Andreoni and Sprenger (2012a, b). Taking the term w under consideration, the optimization under condition CER can be regarded as $\left((c_1')^{\rho} + \beta^s \delta \left(c_2'\right)^{\rho}\right)^{1/\rho}$ with the constraint $(1 + r)\, c_1' + c_2' = 100 + (2 + r)\, w$. The optimal solution is as follows:

$$c_{1,C}'^{\star} = \frac{(100+(2+r)w)(\beta^s\delta(1+r))^{\frac{1}{\rho-1}}}{(\beta^s\delta)^{\frac{1}{\rho-1}}(1+r)^{\frac{\rho}{\rho-1}}+1}$$

By subtracting w from c_1', we obtain the optimal allocation to the sooner payment as follows:

$$c_{1,C}^{\star} = g\left(r, \alpha, \rho, \beta, \delta, w\right) = \frac{(100+(2+r)w)(\beta^s\delta(1+r))^{\frac{1}{\rho-1}}}{(\beta^s\delta)^{\frac{1}{\rho-1}}(1+r^j)^{\frac{\rho}{\rho-1}}+1} - w$$

For condition POS, we have the same optimal allocation. The optimal allocation for condition NEG is similarly specified as

$$c_{1,N}^{\star} = g\left(r, \alpha, \rho, \beta, \delta, w\right) = \frac{(100+(2+r)w)(\beta^s\delta)^{\frac{\alpha}{\rho(\alpha-1)}}(1+r)^{\frac{1}{\alpha-1}}}{(\beta^s\delta)^{\frac{\alpha}{\rho(\alpha-1)}}(1+r)^{\frac{\alpha}{\alpha-1}}+1} - w.$$

[5] The structural estimation for corner choices in CTB has been an issue of debate. Andreoni and Sprenger (2012a, b) mainly adopt the non-linear least squares technique and discuss in detail the censored data issue. They show that accounting for censoring issues has little influence on the estimates. In a recent study, Harrison et al. (2013) thoroughly discuss the potential problems with corner solutions and propose multinomial logit (MNL) as an alternative estimation technique. However, the MNL estimates indicate that the utility function over time is convex (Harrison et al., 2013; Cheung, 2013) and significantly different from being linear, which we think is unlikely. Therefore, we build the two-limit Tobit specification into the non-linear regression model to conduct the estimation.

$c^{\star}_{1,I}$ has no explicit solution, and the optimal c_1 in NEG satisfies the following FOC:

$$\begin{aligned}&\left((c_1+w)^{\rho}+\beta^s\delta\left((100+(2+r)\,w)-(1+r^j)\,(c_1+w)\right)^{\rho}\right)^{\alpha/\rho-1}\times\\&\left[(c_1+w)^{\rho-1}-\beta^s\delta\,(1+r)\left((100+(2+r)\,w)-(1+r)\,(c_1+w)\right)^{\rho-1}\right]+\\&\left[(c_1+w)^{\alpha-1}-(\beta^s\delta)^{\alpha/\rho}\,(1+r)\left((100+(2+r)\,w)-(1+r)\,(c_1+w)\right)^{\alpha-1}\right]=0.\end{aligned}$$

We assume that $c_1 = g\,(r,\alpha,\rho,\beta,\delta,w)+\varepsilon$, where $\varepsilon \sim \text{Normal}(0,\sigma)$. It can be interpreted as errors arising when subjects choose the optimal allocation. In the actual experiment, the observed allocation y_1 is censored between 0 and 100. We specify the two-limit Tobit likelihood as follows:

$$P\,(y_1)=\begin{cases}1-\Phi\left(g\,(r,\alpha,\rho,\beta,\delta,w)\,/\sigma\right),\ \text{if } y_1=0\\ \phi\left((y_1-g\,(r,\alpha,\rho,\beta,\delta,w))/\sigma\right),\ \text{if } 0<y_1<100\\ 1-\Phi\left((100-g\,(r,\alpha,\rho,\beta,\delta,w))/\sigma\right),\ \text{if } y_1=100\end{cases}$$

As we could not obtain an explicit solution for condition IND, we exclude it from the estimation.[6] The data generated by individual i with interest rate r^j and condition k are denoted by $\left\{y_i^{jk}, r^j, k\right\}$, where y_i^{jk} is the allocation to the sooner payment given the interest rate r^j under condition k. We then conduct group estimation for $\alpha,\rho,\beta,\delta,w$ and σ, and cluster robust standard error at the individual level using Stata 13.

For Chew–Epstein–Halevy, let $l = f\,(0.5)$ and $n = f\,(0.75)+f\,(0.25)$. We obtain the following candidate solutions:

$c^{\star}_{1,C/P} = \frac{(100+(2+r)w)(\delta(1+r))^{\frac{1}{\rho-1}}}{\delta^{\frac{1}{\rho-1}}(1+r)^{\frac{\rho}{\rho-1}}+1}$

$c'_{1,N} = \frac{(100+(2+r)w)[(1-l)(\delta(1+r))]^{\frac{1}{\rho-1}}}{((1-l)\delta)^{\frac{1}{\rho-1}}(1+r)^{\frac{\rho}{\rho-1}}+l^{\frac{1}{\rho-1}}}$ when $u\,(c_1)\geq\delta u\,(c_2)$ and $c''_{1,N} = \frac{(100+(2+r)w)[l(\delta(1+r))]^{\frac{1}{\rho-1}}}{(l\delta)^{\frac{1}{\rho-1}}(1+r)^{\frac{\rho}{\rho-1}}+(1-l)^{\frac{1}{\rho-1}}}$ when $u\,(c_1)<\delta u\,(c_2)$.

$c'_{1,I} = \frac{(100+(2+r)w)[(n-l)(\delta(1+r))]^{\frac{1}{\rho-1}}}{((n-l)\delta)^{\frac{1}{\rho-1}}(1+r)^{\frac{\rho}{\rho-1}}+l^{\frac{1}{\rho-1}}}$ when $u\,(c_1)\geq\delta u\,(c_2)$ and $c''_{1,I} = \frac{(100+(2+r)w)[l(\delta(1+r))]^{\frac{1}{\rho-1}}}{(l\delta)^{\frac{1}{\rho-1}}(1+r)^{\frac{\rho}{\rho-1}}+(n-l)^{\frac{1}{\rho-1}}}$ when $u\,(c_1)<\delta u\,(c_2)$.

Note that $c'_{1,N}$ may not satisfy $u\,(c_1)\geq\delta u\,(c_2)$, and $c''_{1,N}$ may not satisfy $u\,(c_1)<\delta u\,(c_2)$. If only one holds, that one will be the optimal solution. If both hold, the one delivering a higher utility will be the optimal solution. If both do not hold, the optimal solution will be in the kink, where $u\,(c_1)=\delta u\,(c_2)$. Therefore, we have the optimal solution for NEG as follows:

[6] For robustness check, we linearize the first-order condition in IND to obtain the approximate explicit solution and conduct Tobit estimation including all conditions. The results are not significantly different and support the separation. Specifically, given that the allocation behavior in NEG and IND are similar, we linearize the FOC in IND around $c^{\star}_{1,NEG}$ as a linear function $f\left(c^{\star}_{1,NEG}\right)+f'\left(c^{\star}_{1,NEG}\right)\times\left(c-c^{\star}_{1,NEG}\right)=0$ to solve the optimal $c^{\star}_{1,IND}=\left(f'\left(c^{\star}_{1,NEG}\right)\times c^{\star}_{1,NEG}-f\left(c^{\star}_{1,NEG}\right)\right)/f'\left(c^{\star}_{1,NEG}\right)$, which is a function of the known parameters. Then, we similarly build the Tobit specification and conduct a structural estimation including all four conditions.

$$c^{\star}_{1,N} = \begin{cases} c'_{1,N},\ if\ u\left(c'_{1,N}\right) \geq \delta u\left(c'_{2,N}\right),\ u\left(c''_{1,N}\right) > \delta u\left(c''_{2,N}\right) \\ c''_{1,N},\ if\ u\left(c'_{1,N}\right) < \delta u\left(c'_{2,N}\right),\ u\left(c''_{1,N}\right) \leq \delta u\left(c''_{2,N}\right) \\ c^{k}_{1},\ if\ u\left(c'_{1,N}\right) < \delta u\left(c'_{2,N}\right),\ u\left(c''_{1,N}\right) > \delta u\left(c''_{2,N}\right) \\ c'_{1,N},\ if\ u\left(c'_{1,N}\right) \geq \delta u\left(c'_{2,N}\right),\ u\left(c''_{1,N}\right) \leq \delta u\left(c''_{2,N}\right),\ U_N\left(c'_{1,N}, c'_{2,N}\right) > U_N\left(c''_{1,N}, c''_{2,N}\right) \\ c''_{1,N},\ otherwise \end{cases}$$

where c^k_1 represents the kink solution such that $u\left(c^k_1\right) = \delta u\left((100 + (2+r)\,w) - (1+r)\,c^k_1\right)$, and different c_2 refer to $(100 + (2+r)\,w) - (1+r)\,c_1$ for their corresponding c_1.

For IND, we specify the optimal solution in the same way as follows:

$$c^{\star}_{1,I} = \begin{cases} c'_{1,I},\ if\ u\left(c'_{1,I}\right) \geq \delta u\left(c'_{2,I}\right),\ u\left(c''_{1,I}\right) > \delta u\left(c''_{2,I}\right) \\ c''_{1,I},\ if\ u\left(c'_{1,I}\right) < \delta u\left(c'_{2,I}\right),\ u\left(c''_{1,I}\right) \leq \delta u\left(c''_{2,I}\right) \\ c^{k}_{1},\ if\ u\left(c'_{1,I}\right) < \delta u\left(c'_{2,I}\right),\ u\left(c''_{1,I}\right) > \delta u\left(c''_{2,I}\right) \\ c'_{1,I},\ if\ u\left(c'_{1,I}\right) \geq \delta u\left(c'_{2,I}\right),\ u\left(c''_{1,I}\right) \leq \delta u\left(c''_{2,I}\right),\ U_{IND}\left(c'_{1,I}, c'_{2,I}\right) > U_{IND}\left(c''_{1,I}, c''_{2,I}\right) \\ c''_{1,I},\ otherwise \end{cases}$$

As we can obtain the optimal solutions for each condition, we conduct a two-limit Tobit MLE that includes all conditions together. We specify a power function $u(c) = c^{\rho}$ to make the estimation comparable with that of Epstein–Zin. With only $f(0.5)$ and $f(0.25) + f(0.75)$ in the optimal solutions, we estimate l and n directly instead of specifying a probability weighting function for $f(p)$. The parameters β, δ, w are specified similarly as those in the estimation of Epstein–Zin.

Table C1 presents the results of the estimated parameters. For Epstein–Zin, the estimated risk aversion coefficient is 0.441, which is significantly smaller than 1 ($p < 0.001$). The estimated intertemporal substitution coefficient is 0.988, which is significantly smaller than 1 ($p < 0.001$). Moreover, the intertemporal substitution parameter is significantly larger than the risk aversion coefficient ($p < 0.001$). Should the two parameters be equal, Epstein–Zin would reduce to DEU. Hence, our result rejects DEU, and $\rho > \alpha$ further suggests a preference for NEG over POS.

For Chew–Epstein–Halevy, the non-parametric estimate of the probability weight for $f(0.5)$ is 0.420, which is significantly smaller than 0.5 ($p < 0.001$).[7] The non-parametric estimate of the probability weight for $f(0.25) + f(0.75)$ is 0.999, which is significantly higher than $2f(0.5)$ ($p < 0.001$) and not significantly different from 1 ($p > 0.316$). This finding supports the theoretical prediction of the cross-over between CER/POS and NEG/IND, and the similarity between NEG and IND when $f(0.5) < 1 - f(0.5) \approx f(0.25) + f(0.75) - f(0.5)$. If $f(p) = p$, Chew–Epstein–Halevy reduces to DEU. Therefore, our result again rejects DEU. The curvature of the utility function is 0.987, which is significantly smaller than 1 (p <

[7] On the one hand, given that the utility of NEG is $f(0.5)\,u(c_1) + (1 - f(0.5))\,\delta u(c_2)$ when $u(c_1) > \delta u(c_2)$, the assumption $c^{\star}_{1,NEG} > 50$ at $r = 0$ requires $f(0.5) > (1 - f(0.5))\,\delta$, which implies $f(0.5) \approx 0.5$ as δ is close to 1. On the other hand, one needs $f(0.5) < 0.5$ to generate a relatively smooth optimal sooner consumption in NEG. The estimation result shows that the effect of consumption smoothing is stronger.

Table C1. Estimated Parameters at the Aggregate Level.

	Coef.	Std. Err.	z	p > z	95% CI	
			Epstein–Zin			
α	0.441	0.098	4.51	0.000	0.249	0.632
ρ	0.988	0.002	573.11	0.000	0.984	0.991
δ	0.973	0.005	183.00	0.000	0.963	0.984
β	0.996	0.004	264.96	0.000	0.988	1.003
ω	5.240	5.843	4.48	0.000	2.950	7.530
σ	2.442	4.685	13.03	0.000	2.074	2.809
			Chew–Epstein–Halevy			
$f(0.5)$	0.420	0.001	417.20	0.000	0.418	0.422
$f(0.25) + f(0.75)$	0.999	0.001	1895.15	0.000	0.998	1.001
ρ	0.987	0.002	563.35	0.000	0.984	0.990
δ	0.974	0.004	231.51	0.000	0.966	0.982
β	0.999	0.001	1065.65	0.000	0.997	1.001
ω	3.439	4.872	3.53	0.000	1.529	5.349
σ	1.916	3.291	14.55	0.000	1.658	2.174

0.001). Overall, the estimation results of both Epstein–Zin and Chew–Epstein–Halevy show the distinction between risk and time preferences.

In Epstein–Zin, the four-week discount factor δ is estimated to be 0.973, which is significantly different from 1 ($p < 0.001$). The calculated annualized discount factor is 0.745. The estimated discount factor difference between the two time menus β is 0.004, which is not significantly different from 0 ($p > 0.239$), consistent with the findings in Andreoni and Sprenger (2012a). The estimates of δ and β in Chew–Epstein–Halevy are similar to those in Epstein–Zin.

D Experimental Instructions

Welcome to our study on decision making. The instructions are simple and if you follow them carefully and make good decisions, you could earn a considerable amount of money which will be paid to you in cheques before you leave today. Different subjects may earn different amounts of money. What you earn today depends partly on your decisions, and partly on chance. All information provided will be kept confidential. Information in the study will be used for research purposes only. If you have any questions, please raise your hand to ask our experimenters at any time. Cell phones and other electronic devices are not allowed, and please do not communicate with others during the experiment.

Earn Money:

To begin, you will be given $12 as show up fee. You will receive this payment in two payments of $6 each. The two $6 minimum payments will come to you at two different times. These times will be determined in the way described below. Whatever you earn from the study today will be added to these minimum payments.

In this study, you will make 56 choices over how to allocate money between two points in time, one time is sooner and one is later. Both the sooner and later times will vary across decisions. This means you could be receiving payments as soon as one week from today, and as late as 20 weeks from today.

It is important to note that the payments in this study involve chance. There could be a chance that your sooner payment, your later payment or both will not be sent at all. For each decision, you will be fully informed of the chance involved for the sooner and later payments. Whether or not your payments will be sent will be determined at the END of the experiment today. If, by chance, one of your payments is not sent, you will receive only the $6 minimum payment.

Once all 56 decisions have been made, we will randomly select one of the 56 decisions as the decision-that-counts. This will be done in three stages. First, we will pick a number from 1 to 56 at random to determine which one is the decision-that-counts and the corresponding sooner and later payment dates. We will then determine whether the payments will be sent based on chances, which we will describe in details later. Last, we will use the resolved chances to determine your actual earnings.

Note, since all decisions are equally likely to be chosen, you should make each decision as if it will be the decision-that-counts. When calculating your earnings from the decision-that-counts, we will add to your earnings the two $6 minimum payments. Thus, you will always get paid at least $6 at the chosen earlier time, and at least $6 at the chosen later time.

IMPORTANT: We will sign you cheques with the specified date at the end of today's experiment. Under Singapore banking practices, a cheque can be cashed only on or within 6 months of the date of the cheque. It is very IMPORTANT that you do not try to cash before the date of the cheque, since you will not be able to get the money, and it will also incur a $40 loss for the experimenter.

How it Works:

In each decision you are asked to divide 100 tokens between two payments at two different dates: Payment A (which is sooner) and Payment B (which is later). Tokens will be exchanged for money. The tokens you allocate to Payment B (later) will always be worth at least as much as the tokens you allocate to Payment A (sooner). The process is best described by example.

In the table below, in row 3, each token you allocate to one week later is worth $0.18, while each token you allocate to five weeks later is worth $0.20. So, if you allocate all 100 tokens to one week later, you may earn 100x$0.18 = $18 (+ $6 minimum payment) on this date and nothing on five weeks later (+ $6 minimum payment). If you allocate all 100 tokens to five weeks later, you may earn 100x$0.20 = $20 (+ $6 minimum payment) on this date and nothing on five week later (+ $6 minimum payment). You may also choose to allocate some tokens to the earlier date and some to the later date. For instance, if you allocate 60 tokens to one week later and 40 tokens to five weeks later, then one week later you may earn 60x$0.18 = $10.04 (+ $6 minimum payment) and five weeks later you would earn 40x$0.20 = $8 (+ $6 minimum payment). The Payoff Table shows some of the token-dollar exchanges at all relevant token exchange rates, which applies to all decisions in this experiment.

Sample Decision Making Sheet

Chance of Receiving Payments:

Each decision sheet lists the chances that each payment will be sent. Each decision in that sheet share the same chances that the payments will be sent. There are four cases.

Case A

If this decision were chosen as the decision-that-counts, both PAYMENT A and PAYMENT B will be sent for sure.

Case B

There are some chance that PAYMENT A and PAYMENT B will not be sent. If this decision were chosen as the decision-that-counts, we would determine the actual payments by throwing TWO ten-sided dices. There is 50% chance that PAYMENT A will be sent by throwing the first dice; there is 50% chance that PAYMENT B will be sent by throwing the

			Feb			
M	T	W	T	F	S	S
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29				
			MAR			
M	T	W	T	F	S	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
.	.	.	.	.	.	.
			MAY			
M	T	W	T	F	S	S
28	29	30	31			
			JUN			
M	T	W	T	F	S	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	

In Each Row ALLOCATE 100 TOKENS BETWEEN

	PAYMENT A (ONE WEEK from today)			AND	PAYMENT B (FIVE WEEKS from today)		
No	A Tokens	Rate A $ per token	Date A		B Tokens	Rate B $ per token	Date B
1	_____ tokens at $0.20 each one week later			&	_____ tokens at $0.20 each five weeks later		
2	_____ tokens at $0.19 each one week later			&	_____ tokens at $0.20 each five weeks later		
3	_____ tokens at $0.18 each one week later			&	_____ tokens at $0.20 each five weeks later		
4	_____ tokens at $0.17 each one week later			&	_____ tokens at $0.20 each five weeks later		
5	_____ tokens at $0.16 each one week later			&	_____ tokens at $0.20 each five weeks later		
6	_____ tokens at $0.15 each one week later			&	_____ tokens at $0.20 each five weeks later		
7	_____ tokens at $0.14 each one week later			&	_____ tokens at $0.20 each five weeks later		

second dice. Specifically, if the first dice tossed is odd, PAYMENT A will be sent; otherwise PAYMENT A will not be sent. If the second dice tossed is odd, PAYMENT B will be sent; otherwise PAYMENT B will not be sent.

Case C

There are some chance that PAYMENT A and PAYMENT B will not be sent. If this decision were chosen as the decision-that-counts, we would determine the actual payments by throwing ONE ten-sided dice. There is a 50% chance that both PAYMENT A and PAYMENT B will be sent, determined by the dice. Specifically, if the dice tossed is odd, both PAYMENT A and PAYMENT B will be sent; and there will be no payments if the dice tossed is even.

Case D

There are some chance that either PAYMENT A or PAYMENT B will not be sent. If this decision were chosen as the decision-that-counts, we would determine the actual payments by throwing ONE ten-sided dice. There is a 50% chance that either PAYMENT A or PAYMENT B will actually be sent, determined by the dice. Specifically, if the dice tossed is odd, PAYMENT A will be sent while PAYMENT B will not be sent; and PAYMENT B will be sent if the dice tossed is even while PAYMENT A will not be sent.

Things to Remember:

1. You will always be allocating exactly 100 tokens.
2. Tokens you allocate to Payment A (sooner) and Payment B (later) will be exchanged for money at different rates. The tokens you allocate to Payment B will always be worth at least as much as those you allocate to Payment A.

3. Payment A and Payment B will have different types of chance. You will be fully informed of the chances.
4. On each decision sheet you will be asked 7 questions. For each decision you will allocate 100 tokens. Allocate exactly 100 tokens for each decision row, no more, no less.
5. At the end of the study a random number will be drawn to determine which is the decision-that-counts. Because each question is equally likely, you should treat each decision as if it were the one that determines your payments. The payments you chose will actually be sent or not will be determined by chance, which is put down on the decision-that-counts.
6. Your payment, by cheque, will be given to you today.

References that do not appear in the main manuscript are as follows:

References

Epper, Thomas, Helga Fehr-Duda, and Adrian Bruhin. 2011. "Viewing the Future through a Warped Lens: Why Uncertainty Generates Hyperbolic Discounting." *Journal of Risk and Uncertainty*, 43(3): 169-203.

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

Wakker, Peter P. 2010. "Prospect Theory: For Risk and Ambiguity." Cambridge University Press, Cambridge, UK.