Exploring Higher-Order Risk Effects

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Abstract

Higher-order risk effects play an important role in examining economic behavior under uncertainty. A precautionary demand for saving has been linked to the property of prudence and the property of temperance has been used to show how the presence of an unavoidable risk affects one's behavior towards a second risk. These two properties also play key roles in aversion to negative skewness and to kurtosis, respectively. Both properties recently have been characterized by preferences over lottery pairs in simple 50-50 gambles. The simplicity of this characterization is ideal for experimental investigation. This paper reports the results of such experiments and concludes that there is behavioral evidence for prudence, but not for temperance. Implications of these results for both expected-utility and non-expected-utility models are examined.

JEL Code: C9, D8.

Keywords: risk, prudence, temperance, laboratory experiments.

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1. Introduction

Ever since Daniel Bernoulli (1738), risk aversion has played a key role in examining decision making under uncertainty. Although modeled in many different ways over the years, the basic premise has been the same: a risk-averse individual would prefer a payoff with certainty over a risky payoff with the same mean.[1]

Though much younger than the notion of risk aversion, the concept of *prudence* has been used in assessing a precautionary demand for saving for more than 40 years. Although the term "prudence" was not introduced until Kimball (1990), its relationship to saving behavior was noted much earlier by Leland (1968) and Sandmo (1970). In particular, these authors used an expected-utility setting to show how a risky future labor income did not guarantee that a consumer would decrease current consumption (or equivalently, increase saving), unless the individual exhibited prudence.

In addition to precautionary saving, prudence was also seen as being analogous to an aversion to "increases in downside risk," as defined by Menezes et al. (1980). A pure increase in downside risk does not change the mean nor the variance of a risky wealth prospect, but it does increase the negative skewness. More generally, prudence plays an important roll in the tradeoff between risk and skewness for economic decisions made under uncertainty, as shown by Chiu (2005). Yet these prudence effects as described above have been defined almost exclusively within an expected-utility (EU) context; and those outside of an EU context have been defined in such a way as to mimic properties inherent to the utility function.

A lesser known trait affecting behavior towards risk is *temperance*, a term also coined by Kimball (1992).[2] Kimball explains how temperance will lead an individual facing an

[1] A somewhat stronger version is sometimes used; namely that an individual dislikes any mean-preserving spread of his or her wealth distribution. For expected-utility preferences, these two characterizations coincide. See Rothschild and Stiglitz (1970).

[2] Within an expected utility setting, prudence has been characterized by utility of wealth having a positive third derivative and temperance has been characterized a as a negative fourth derivative. See Gollier and Pratt (1996) and

unavoidable risk to reduce exposure to another [independent] risk. Although not a perfect analog, in the same way that risk aversion is not a perfect analog for aversion to a higher variance (Rothschild and Siglitz 1970), a temperate individual generally dislikes kurtosis. In an EU setting, Eeckhoudt and Schlesinger (2008) show that temperance is both necessary and sufficient for an increase in the downside risk of future labor income to always increase the level of precautionary saving.

More recently, both prudence and temperance have been defined outside of an EU context. In particular, Eeckhoudt and Schlesinger (2006) define both concepts via preferences over particular classes of lottery pairs.[3] What makes these characterizations particularly appealing is their simplicity, as they are stated in terms of comparing simple 50-50 lottery pairs.

Whether or not people actually behave in a risk-averse manner has been studied in numerous empirical settings as well as in various experiments. Indeed, experiments have even gone so far as to see whether or not risk aversion is a biological trait common to other animals, as in Battalio et al. (1985). Although many studies have attempted to measure the intensity of risk aversion, which requires a particular preference structure, others have just noted whether or not risk aversion was a predominant trait. A good overview of both the laboratory experiments and the field experiments on risk aversion can be found in Deck et al. (2008) and Post et al. (2008).

A few papers have looked at empirical support for prudence, although these papers all trace prudence via the precautionary demand for saving. See, for example, Dynan (1993), Carroll (1994) and Carroll and Kimball (2008). We know of no empirical papers that intentionally test for temperance, although the results of Guiso et al. (1996) are consistent with temperate behavior.[4]

We are not aware of any experimental papers that test for temperance and are aware of only one that directly tests for prudence. Tarazona-Gomez (2004) sets up an experiment to test for the strength of the prudence effect. In doing so, her evidence points to some support for prudence, although the strength of the prudence effect is rather weak; very close to what she labels "prudence neutrality." Rather than directly eliciting comparisons of lotteries in her experiments, Tarazona-Gomez elicits certainty equivalents for sets of lotteries and uses them to indirectly

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Eeckhoudt et al. (1996). Kimball (1993) explains why these higher-order effects, and not just risk aversion, are important in understanding behavior under risk. For more on these effects and moments see Roger (2007).

[3] The equivalence of these lottery preferences to prudence within an EU framework had been noted earlier by Bigelow and Menezes (1995) and Eeckhoudt et al. (1995).

[4] Guiso et al. (1996) use survey Italian data to examine how pension-wealth risk affects non-pension investment portfolio decisions. They find that riskier perceptions of pension risk lead to less risky investment portfolios.

compare lotteries as well as to determine the strength of any prudence effect. Her methodology is largely based in expected-utility theory.

In this paper we exploit the simplicity of the Eeckhoudt and Schlesinger (2006) lottery-preference definitions and design an experiment to test for both prudence and for temperance. Although we do not attempt to measure the intensity of these two effects, our lottery comparisons have the benefit that they are much simpler for subjects to understand. Moreover, our experiment is not based in an expected-utility setting, so that the results can be applied within any decision-theoretic framework.

In addition to being simple 50-50 lottery pairs, each pair of lotteries in our experiment has the same expected payoff and the same variance. Thus, a risk-neutral agent would be indifferent to each pair of lotteries. Moreover, there is no second-order stochastic dominance in our lottery choice comparisons, so risk aversion alone cannot explain the choices. Indeed, each set of choices is designed to have a unique ranking if and only if preferences display a higher-order risk effect. Some of the choices involved in our experiment coincide with prudent behavior and others with temperate behavior. The lotteries used to detect prudence differ in their skewness, while those used to detect temperance have zero skewness but differ in their kurtosis.

Our results indicate some support for prudence, but not for temperance; indeed, they support intemperance. Although these results have nothing to say about the validity of EU theory in general, they would lead us to reject all of the most commonly used utility functions, including constant absolute risk aversion (CARA) and constant relative risk aversion (CRRA). However, our results are consistent with preferences defined via cumulative prospect theory, using parameters similar to those suggested by Tversky and Kahneman (1992).

We also test for a "stakes effect," to see if the size of the payoffs affects the decisions. There is weak support for the hypothesis that prudent behavior is more likely to be exhibited when the stakes are higher. Also, a stakes effect was evidenced for temperance in the sense that, although behavior was mostly intemperate, it was less intemperate when the stakes were higher. Both of these stakes effects are inconsistent with EU theory.

We begin in the next section by introducing the concepts of prudence and temperance as types of preferences over particular classes of lottery pairs. In section 3, we describe the experiment, while section 4 presents and interprets the behavioral results. The concluding two sections stress the significance of our findings for economic modeling in both EU and non-EU settings.

2. Prudence, Temperance and Lottery Preference

Consider a risk-averse individual with an initial wealth $W > 0$. Let $k > 0$ and let $\tilde{\varepsilon}_1$ and $\tilde{\varepsilon}_2$ be two statistically-independent zero-mean random variables. Consider the following two lotteries expressed via probability trees, as shown in Figure 1.[5] We assume that all branches have a probability of occurrence of one-half, and that all variables are defined so as to maintain a strictly positive total wealth.

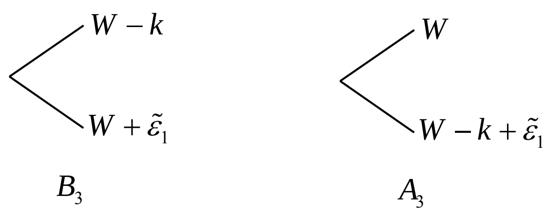


Figure 1: Lottery preference as prudence

In lottery B_3, the individual always receives one of the two "harms," either a sure loss of k or the addition of a zero-mean random wealth change $\tilde{\varepsilon}_1$. In lottery A_3 the individual has a 50-50 chance of either receiving both harms together or of receiving neither one. Eeckhoudt and Schlesinger (2006) define an individual as being *prudent* if she always prefers lottery B_3 to lottery A_3. They refer to this as a preference for "disaggregating the harms." Alternately, one could describe the behavior as preferring to attach the zero-mean lottery $\tilde{\varepsilon}_1$ to the state with the higher wealth vis-à-vis the state with the lower wealth. Although this definition is not specific to EU, Eeckhoudt and Schlesinger (2006) show that this lottery preference under EU, with differentiable utility, is equivalent to a positive third derivative of the utility function.[6]

To define temperance, Eeckhoudt and Schlesinger (2006) simply replace the "harm" of losing the fixed amount of wealth k with the "harm" of the second zero-mean risk $\tilde{\varepsilon}_2$. They define an individual as being temperate if she always prefers lottery B_4 to lottery A_4, where these lotteries are as depicted in Figure 2. Again, this is a preference for "disaggregating the harms."

[5] Our notation here matches the descriptions in Eeckhoudt and Schlesinger (2006), who also extend these concepts to arbitrarily high orders.

[6] Unlike under certainty, the signs of all of the higher-order derivatives of the utility function have some economic significance in an EU context. The link between the sign of the third derivative and precautionary saving was established by Leland (1968) and Sandmo (1970).

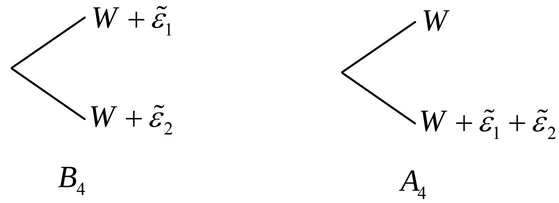


Figure 2: Lottery preference as temperance

3. Experimental Design and Procedures

The experiment was conducted at the Universities of Alabama and Arkansas. The subjects were students from the Colleges of Business at these two universities. In total there were 59 participants from the University of Alabama and 40 from the University of Arkansas. The objective of the experiment was to determine if participants exhibit behavior consistent with prudence and/or temperance.

Subjects were presented with a series of tasks in which they revealed their preferred combination of fixed dollar amounts and zero-mean random variables, consistent with the framework of Eeckhoudt and Schlesinger (2006). Each zero-mean random variable was itself a simple lottery of the form: gain \$*x* with 50% probability and lose \$*x* with 50% probability.[7] To aid subject comprehension, lotteries were presented graphically as divided circles containing the payoff amounts.

Subjects were endowed with an initial amount of money in every task and knew that one of two equally likely states would occur.[8] For simplicity, the states are denoted as *Heads* and *Tails*, since the state was ultimately determined by a coin flip in the experiment. Prior to the state being realized, subjects had to determine in which state they wanted to receive each of the two additional items.

[7] As explained to the subjects in the directions, lotteries were implemented by a spinner with a face that was half green and half red. If the spinner stopped on green the subject received the positive amount and if the spinner stopped on red the subject received the negative amount.

[8] The endowment included a $5.00 participation payment that subjects received for the 30-45 minute experiment. Institutional constraints dictated that subjects could not lose this $5.00 payment, but by including it in the task endowment it was not possible for a subject to nominally earn $0 in any task. Therefore, the choices should not reflect a $0 payoff avoidance.

For tasks related to prudence, the two additional items were a lottery and a fixed dollar amount. For temperance, the items were two zero-mean lotteries. The following excerpt shows two of the tasks faced by some subjects.

> Task #2) You will receive $10.50 +
>
> (1 | -1) if the coin lands on *Heads* or *Tails* and $9.00 if the coin lands on the *Same* or *Different* outcome.

> Task #3) You will receive $55.00 +
>
> (45 | -45) if the coin lands on *Heads* or *Tails* and (5 | -5) if the coin lands on the *Same* or *Different* outcome.

In the first task a subject was endowed with $10.50. A subject had to identify her preference by circling the state in which she wanted to receive a lottery that would either add or subtract $1 from her payoff. She also indicated if she wanted to receive an additional $9 in the same or different state as the lottery.[9] A prudent person would prefer to have the two items in the same state. The answer to the first question is irrelevant, but the instrument is designed to give the subject the most flexibility and assurance that the experiment is not rigged.

The second task examines temperance. With an endowment of $55, a subject must indicate when she wishes to receive a lottery to gain or lose $45 and a lottery to gain or lose $5. A temperate person would want the lotteries in different states, so as to "disaggregate the harms."

A total of 6 prudence tasks and 4 temperance tasks were completed by each subject. Keeping with the methodology of experimental economics, subjects were paid based upon their choices and thus had salient motivation to truthfully reveal their preferences. All amounts denote the $US payments that a participant would received in cash at the conclusion of the experiment. Hence, the stakes in some tasks are an order of magnitude greater than what is typical for laboratory experiments. In the second task shown above, a subject could earn $105.

[9] Using the labels *Same* and *Different* is designed to reinforce to subjects the fact only one state will be realized (i.e. there is not a separate coin flip for each item).

<u>Table 1</u>. Decision Tasks

Version 1 Tasks	Endowment	Item 1	Item 2	Expected Payoff	Type	Version 2 Tasks	Version ~3 Tasks	Version ~4 Tasks
1	$30.00	+/- $25	$25	$42.50	P	10	5	6
2	$15.00	+/- $5	+/- $5	$15.00	T	9	4	7
3	$12.50	$9	+/- $5	$17.00	P	8	3	8
4	$15.00	+/- $9	+/- $1	$15.00	T	7	2	9
5	$12.50	+/- $5	$1	$13.00	P	6	1	10
6	$55.00	+/- $25	+/- $25	$55.00	T	5	10	1
7	$10.50	$9	+/- $1	$15.00	P	4	9	2
8	$55.00	+/- $5	+/- $45	$55.00	T	3	8	3
9	$12.50	$5	+/- $5	$15.00	P	2	7	4
10	$14.50	+/- $9	$1	$15.00	P	1	6	5

Version i Tasks indicate the order in which that task appeared on Version i. A ~ indicates that the order of the items was switched for each task in that version. +/- $x denotes the lottery in which a subject has a 50% change of gaining $x and a 50% chance of losing $x. Type indicates if the task is related to prudence (P) or temperance (T).

To control for effects from the sequence of the tasks and the ordering of items within a task, four versions of the experimental instrument were used. Table 1 details the 10 tasks that subjects completed.[10] The examples discussed above were from Version 4. A subject's payoff was determined by one task, which was randomly selected by rolling a ten sided die. This commonly employed technique was explained to the subjects before they began the experiment.[11] Prior to making their decisions, subjects were invited to inspect the coin, die, and spinner. The expected payoff from participating in the experiment was $25.80.

Given the exploratory nature of this research, the specific amounts were selected to allow for a variety of comparisons. Tasks 3, 5, and 9 of Version 1 have the same endowment and lottery but different fixed amounts. Tasks 7, 9, and 10 of Version 1 have identical expected values, but the relative size of the lottery and fixed payment vary. The impact of increasing the amount won or lost in a lottery can be measured by comparing Tasks 3 and 7 of Version 1 as well as Tasks 5 and 10 of Version 1. The lottery and fixed payment of Task 1 in Version 1 are five times those of Task 9, which is designed to measure a stakes effect on prudence. Tasks 2 and 4 in Version 1 are designed to determine if relative size of the lotteries impacts temperance. Tasks 6 and 8 are

[10] The task and item order for Version 1 was determined randomly. The other three versions were created based upon Version 1.
[11] Laury (2005) demonstrates that subjects do not discount the payoffs by the probability of the task being selected.

similar to Tasks 2 and 4, but with stakes that are 5 times greater allowing for identification of a stakes effect on temperance.

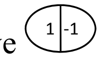
While the experiment involves only individual decisions, groups of approximately 20 subjects completed the pen and paper experiment in the same room at the same time. As a further control for extraneous factors, approximately equal numbers of each instrument version were used in each session. Subjects completed a single version and could not attend multiple sessions. Once the subjects entered the laboratory and completed the informed consent material, they read the instructions and answered a series of comprehension questions. After their responses had been checked, subjects were allowed to make their actual decisions for the 10 tasks. While the order in which the tasks were presented was dependent upon the instrument version, subjects were free to complete the tasks in any order they wished and were allowed to change their answers.

Once a subject had completed the 10 tasks and did not wish to change any responses, that subject was then allowed to privately roll the die to determine which task would be used for her actual payoff. The subject was also allowed to flip the coin to determine which state was realized. If necessary, the experimenter used the spinner to avoid any temptation on the part of subjects to cheat. The appendix contains the directions, comprehension questions, and Version 1 of the experimental instrument.

Once the initial data were collected, an additional version of the experiment was implemented.[12] Version 5 had two differences from the versions described above. First, the additional fixed amounts were presented as losses instead of gains. There is evidence that people view the domain of gains and losses differently. One of the most familiar models of this behavior is prospect theory (Kahneman and Tversky (1979) and Tversky and Kahneman (1992)), which holds that people are risk averse over gains and risk loving over losses. This design change affords an exploration of a similar phenomenon in a higher-order setting. To keep the expected value of each task constant across versions, this design change requires that the endowments are offset by the same amount. The second change involved the presentation. The superfluous decision of how to allocate the first item was removed and that item was received by the subject if the state was *Heads*. Thus, participants needed to make only one decision for each task: would

[12] Given that the instrument version did not influence behavior in the initial instrument versions, only one version of the new instrument was used. The order of the new version was the same as Version 1. The experiment was only conducted at Alabama, in a group with 24 business undergraduates who had not completed the experiment previously.

the second item be received on the *Same* or the *Different* outcome. For example, Task #2 in Version 4, which was shown above, was modified as follows.[13]

> Task #7) You will receive $19.50 to start.
>
> In addition, you will lose $9.00 if the coin lands on *Heads* and receive  if the coin lands on the *Same* or *Different* outcome.

The temperance tasks do not involve fixed amounts and thus do not have an analogous reversal. Here, the only change between the new version and the original versions are the changes in presentation. Hence, comparing temperance behavior across the experimental instruments provides a measure of the impact that these design changes have on behavior.[14]

4. Behavioral Results

The results are presented separately for the prudence and the temperance tasks. Note that the mean payoff is the same for each lottery within a lottery pair. Thus, a risk-neutral agent would be indifferent between the lotteries. Moreover, the variances of each lottery pair are also the same. Higher moments of the payoff distributions, however, are not the same. Given that prudence is examined over gains and losses with differing instruments, the analysis first considers temperance.

Temperance

In each of the temperance tasks, not only the mean and the variance, but also the skewness of the final payoff is independent of the choice made by the subject. Indeed, it easy to show that the less preferred temperate choice (i.e., a lottery of the form A_4 in section 2) has a more leptokurtic distribution. The higher kurtosis essentially tells us that, although the variances are the same, more of the variance in the A_4 lotteries are due to lower probability extreme events, also called "tail events." In other words, the probability distributions of the A_4 type lotteries have "fatter tails." The temperate individual always dislikes these fatter tails.

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[13] There were also slight modifications to the wording, which can be seen by comparing task #7 of Version 5 here to the previous wording we reported in task #2.

[14] It is conceivable that the presentation effects differ for temperance and prudence.

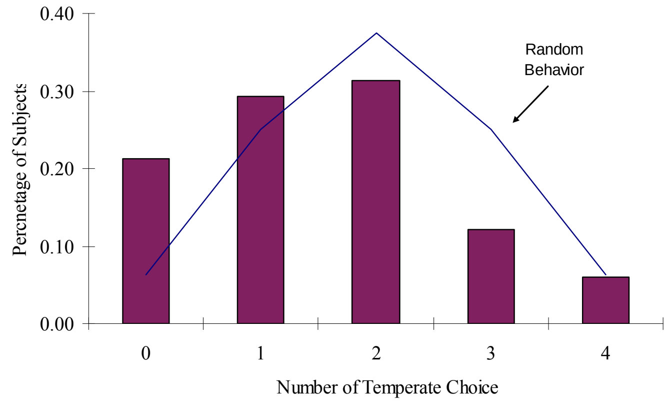


Figure 3. Distribution of the Number of Temperate Choices by Subjects

The subjects in our experiment showed no evidence of temperance, as only 38% of total responses assigned the two lotteries to the same state. In fact, the opposite behavior ("intemperance") appears to be occurring. Figure 3 shows the frequency of subjects making temperate choices. Overall, only 6% of the subjects acted temperately on all four tasks by always opting to have the lotteries separated. By comparison 50% of the subjects combined the lotteries on at least 3 of the 4 tasks. Formally, we reject the null hypothesis that subjects were selecting choices randomly in favor of the one sided alternative that subjects exhibited intemperance (Kolmogorov-Smirnov statistic = 0.1926). This is based upon a comparison of the distribution of temperate choices with that which would occur if subjects behaved randomly.

Table 2. Temperate Behavior

Task on Version 1	Endowment	Item 1	Item 2	Percent Temperate in Versions 1 - 4	Percent Temperate in Version 5	p-value
2	$15.00	+/- $5	+/- $5	44%	25%	0.0973
4	$15.00	+/- $9	+/- $1	36%	13%	0.0292
6	$55.00	+/- $25	+/- $25	39%	29%	0.3997
8	$55.00	+/- $5	+/- $45	47%	46%	0.9432

The last column reports the p-value associated testing the null hypothesis of no difference in the two proportions against the two sided alternative.

There was no statistical difference between testing locations for the temperance responses. Hence, the data are combined in the subsequent discussion. Table 2 shows the percentage of subjects who exhibited temperance on each task. In no case did a majority of the subjects exhibit temperance. Nominally, there was less temperance observed in version 5 for all four tasks. This difference was significant at the 5% level for one of the four tasks. This suggests that changing the instrument did have some impact on the choices that subjects made. However, the ultimate conclusion remains the same. There is little evidence to support the claim that subjects are temperate.

There is some modest evidence of a stakes effect. In Versions 1-4, only 21% of the subjects made fewer temperate choices with the higher stakes tasks than the lower stakes. In Version 5, that number falls to just 14%. However, for approximately half of the subjects, their behavior did not change with the stakes.[15] A comparison of tasks 2 and 6 with tasks 4 and 8, in Version 1 suggests that the relative size of the two zero-mean gambles with respect to each other (Item 1 vs. Item 2 in Table 2) does not influence behavior.

Subjects could not leave the experiment with less money than they had when they arrived at the experiment. In addition, they also were presented first with a fixed amount that they would receive ex ante of their decisions. Therefore, subjects might view themselves as playing with the house's money, which may tend to encourage risk seeking to some extent. See, for example, Thaler and Johnson (1990). As such, it could be that some of the participants were trying to give themselves a chance at the highest payoff, since there was "nothing to lose." The fact that 50% of our subjects paired the lotteries together on 3 out of the 4 temperance tasks indicates they might indeed be strategizing in such as way as to maximize the highest potential payoff. These individuals would prefer the "fat tails" in the distribution: willing to trade off potentially very bad outcomes for potentially very good ones.

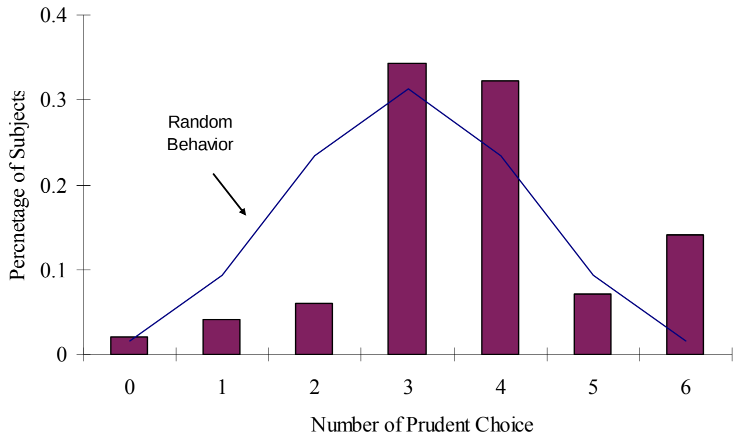
Prudence

There is evidence of prudence, although the degree is not overwhelming. Figure 4 plots the frequency of prudent behavior. Overall, 61% of the subject responses assigned the lottery to the state with the higher certain payoff.[16] Very few subjects were never prudent, just 2%, but only 14% were prudent on all six tasks. The number of prudent decisions is greater than would be

[15] One could argue that for subjects who are prudent in both stake levels the stakes were already sufficiently high in the low stakes case. Similarly, one could argue that the stakes remain too low for those who are not prudent at either stakes level. Thus, the people who do not respond to a change in the stakes are not necessarily inconsistent with a stakes effect.

[16] This percentage of is similar to that in the experiments by Tarazona-Gomez, who finds 63% of her subjects (not choices on particular tasks, but subjects) to be prudent in a somewhat more complicated experiment.

expected to occur if the subjects were making random choices (Kolmogorov-Smirnov statistic = 0.2225).



<u>Figure 4</u>. Distribution of the Number of Prudent Choices by Subjects

In five of the six tasks, there was no statistically significant difference between testing locations for Versions 1-4 and, thus, the data are combined for those tasks. Table 3 shows the percentage of subjects acting prudently. Prudence does not appear to be impacted by framing the certain state as a loss rather than a gain; in two of the four tasks more prudence is observed with a negative frame. However, as was the case with temperance, we cannot rule out a behavioral effect from playing with the house's money and seeking out the highest potential gain. Such a strategy would lead to the prudent choice of putting the zero-mean gamble together with the higher fixed-wealth outcome.

Based on a comparison of tasks 1 and 9 in Version 1, there is again some evidence of a stakes effect. More prudent behavior is observed when the items are a +/- $25 lottery and a $25 gain (loss) for sure than when the items are a +/- $5 and a $5 gain (loss). Approximately one third of the subjects changed their behavior when the stakes increased. Of these, almost 70% made more prudent choices with the higher stakes. There is no change in behavior due to increasing the size of the fixed amount while holding the lottery and the endowment constant; a comparison of Tasks 3, 5, and 9 in Version 1. Similarly, varying the relative size of the lottery and the fixed amount holding the expected value of the task fixed does not change behavior; a comparison of Tasks 7, 9, and 10 in Version 1. Finally, changing the stakes in the lottery for the same fixed amount does not change behavior, based upon comparisons of Tasks 3 and 7, as well as Tasks 5 and 10, in Version 1

Table 3. Prudent Behavior

Version 1 Task	Endowment	Item 1	Item 2	Percent Prudent in Versions 1 - 4	Percent Prudent in Version 5	p-value
1	$30.00	+/- $25	$25	71%	63%	0.4527
3	$12.50	$9	+/- $5	59%	79%	0.0692
5	$12.50	+/- $5	$1	61%	54%	0.5334
7	$10.50	$9	+/- $1	57%	58%	0.9312
9	$12.50	$5	+/- $5	60%	42%	0.1157
10	$14.50	+/- $9	$1	83% : 57%	42%	0.2428[x]

In task #10, 83% made the prudent choice at Arkansas but only 57% at Alabama. The p-value associated with the null hypothesis that the percentage was the same in the two locations against the two sided alternative was 0.02. Thus the percentages are reported separately for the two locations. The last column reports the p-value associated with testing the null hypothesis of no difference in the two proportions against the two sided alternative. [x] indicates that this p-value is based upon a comparison of Version 5 with the data from Versions 1-4 at the same location (Alabama), since there was a significant difference between the two locations for the original versions.

There is some evidence that the number of prudent choices and the number of temperate choices made by a subject are not independent. Figure 5 shows the percentage of subjects for each combination of prudent and temperate choices. The correlation between the number of temperate and prudent choices is -0.06, however, this correlation is not statistically significantly different from zero.[17]

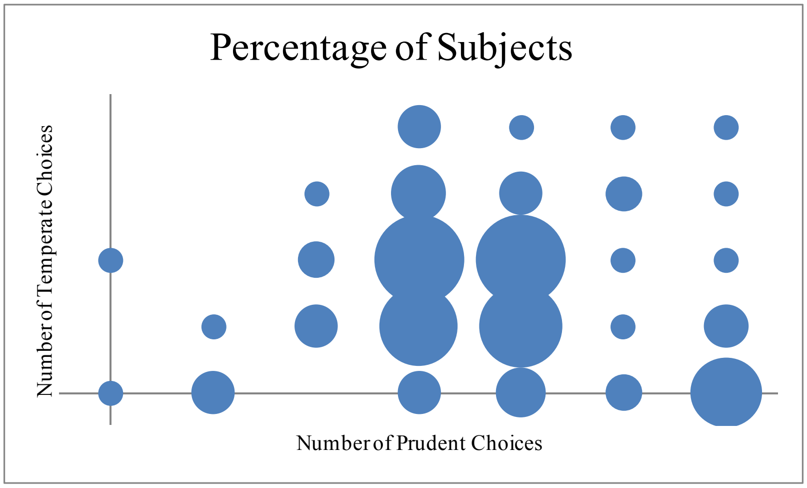


Figure 5. Number of Prudent and Temperate Choices by Subjects

[17] For independence, the chi-square statistic is 34.05 with 24 degrees of freedom (p-value = 0.0837). The insignificance of the correlation coefficient is based upon a t-test (t-value = -0.64 with 97 degrees of freedom).

5. Implications for Preferences

Eeckhoudt and Schlesinger (2006) make no claim that preferences should be either prudent or temperate in a normative or in a positive sense. They only define these behaviors and show their equivalences within an EU framework. So what does it imply when we support prudence but also support intemperance? For one, there is no reason a priori to expect that preferences need be always prudent or always imprudent. It is certainly within reason that preferences display prudence in some cases and imprudence in others. In other words, marginal utility might be locally convex for some wealth levels and locally concave for others. Analogous arguments apply for temperance.[18]

Our results also do not directly add to any list of arguments in support of EU or against EU as a choice-theoretic framework. However, taken at their face value, the results would rule out all of the commonly-used classes of utility functions. For example both constant relative risk aversion (CRRA) and constant absolute risk aversion (CARA) imply that preferences are temperate. In addition, one would need to rule out quadratic utility as well, since such preferences are well-known to depend only on the first two moments of the wealth distributions. Lesser known utility classes, such as the "strong one-switch utility" functions of Bell and Fishburn (2001) likewise need to be ruled out as they also always exhibit temperance.[19]

One model that could be consistent with prudence as well as with intemperance is the cumulative prospect theory model (CPT) of Tversky and Kahneman (1992). Since expected wealth is the same for both lottery choices, we might canonically view the so-called reference point as the expected level of wealth. Since the valuation function in their model is S-shaped, it would tend to devalue both high gains as well as high losses. However, the weighting function that is applied to the cumulative probabilities has an inverted S-shape, which would effectively increase the weight in both tails.

Consider first temperance and consider only the S-shaped valuation function, with a kink at the reference point to induce loss aversion. An outcome distribution with a higher kurtosis would typically do two things: increase the size of the tails and reduce the spread of probability mass that is closer to the mean (i.e. closer to the reference point). Given loss aversion, this "bunching" of probability mass near the mean would be welfare increasing. In addition, the S-shape implies that the fatter tails are not too bothersome. If we now consider the probability weighting, we have the opposite effect: this weighting tends to increase the importance of the fat tails. Whether

[18] We note, however, that if utility exhibits risk aversion and prudence at all wealth levels, that it is not possible for preferences to exhibit intemperance at every wealth level. See, for example, Menegatti (2001).
[19] These utility functions are the sum of a linear plus an exponential function of wealth.

or not preference exhibit temperance or not is thus dependent upon the parameters of the decision problem, as well as on the parameters of the CPT value function and the weighting function.

For prudence, we again obtain an ambiguous answer to the question as to whether CPT exhibits prudence or not. The S-shaped valuation function by itself would imply that a zero-mean risk is preferred at the lower wealth (in the domain of "losses"), since the valuation function is convex at these wealth levels. Hence preferences would be imprudent. However, the distortion of the probability to increase the weight in the tails of the distribution implies that these fair zero-mean gambles do not seem fair after the probability distortions. In particular: (*i*) an objectively fair bet in the domain of gains overweights the upside, making the bet seem favorable and (*ii*) the same objectively fair bet in the domain of losses overweights the downside, making the bet seem unfavorable. Once again the probability weighting works in the opposite direction of the valuation function. Hence, both prudence and imprudence can be theoretically consistent with CPT.[20]

Using parameters similar to Tversky and Kahneman (1992), we find that all six of our prudence tasks would show a preference for prudence under CPT. In a similar manner, we find that all four of the temperance tasks would show a preference for intemperance under CPT.[21] Obviously, these results could change with different lottery and wealth specifications. They could also change with different CPT parameters. Our point here is that it is at least possible to come up with preference models displaying both prudence and intemperance.

6. Concluding Remarks

In addition to risk aversion, higher orders of risk-preference behavior are important in analyzing behavior under uncertainty. For example, the link between prudence (a third-order effect) and precautionary saving is well known. Although less known, temperance (a fourth-order effect) also plays a key role in the analysis of behavior. Moreover, these effects often equate to a

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[20] We are aware of one paper, Ågren (2006), that examines both of these effects, but the results are restricted to inverse Gaussian distributions. Ågren uses parameters taken from Tversky and Kahneman (1992) and shows that CPT preferences are prudent. However, his results for kurtosis are mixed, with the decision maker liking both very high and very low levels of kurtosis.

[21] In particular, we used the weighting function $w(F) = F^{.65}[F^{.65} + (1-F)^{.65}]^{-(1/.65)}$, where F denotes the cumulative probability. We used the valuation function $v(x) = (x-r)^{.88}$ for $x > r$, and $v(x) = (-2.25)(r-x)^{.88}$ for $r \geq x$, where r denotes the reference point, i.e. the mean wealth in our lotteries.

preference for more positive skewness and against a higher kurtosis, when we restrict the distribution functions being compared.

In this paper, we report the results of an experiment that directly tested for prudence and for temperance. Although we find support for prudence, it is not overwhelming. We find no support for temperance. Indeed, to the contrary, preferences seem to be intemperate.

To what extent this behavior was the result of other psychological factors, such as playing with house money, is not apparent. Most economic research on decision making under uncertainty does not distinguish between the sources of outcomes. We do find mild evidence of a stakes effect for both prudence and for temperance. Of course, even though the relative sizes of the stakes in our experiment varied quite a lot, the highest dollar amounts are still not likely to have a lasting impact on most of the subjects and thus one would not expect a dramatic wealth effect.[22] However, Eeckhoudt and Schlesinger (2006) require that prudent and temperate people hold the specified preference relation no matter how trivial the stakes.

We have no other benchmark results, to which we can compare our data for temperance. For prudence, our numbers seem to support the findings of Tarazona-Gomez, who measures the strength of the prudence effect within an EU-based setting and finds that her subjects were mostly prudent, but not very much so. Our results also support the empirical conclusions of Dynan (1993), who finds evidence of very weak prudence, using an EU-based methodology.

We think our results have implications that are much broader than many people initially realize. For example, in an EU-framework, both CARA utility and CRRA utility are used with great frequency. Each of these utility forms always displays both prudence and temperance. But, to the extent that our results are not due to other behavioral effects, they would reject these classes of utility, since we find preferences to be somewhat intemperate. Likewise, the sometimes-used quadratic form of utility has both zero prudence and zero temperance, neither of which is supported by our experiment.

Similarly, non-expected utility theories should be cognizant of these higher-order risk effects. The literature has developed alternative concepts for risk aversion, such as ambiguity aversion, see Schmeidler (1989), and loss aversion, see Kahneman and Tversky (1979). However, we are not aware of any efforts to extend these higher-order risk affects.

[22] This is generally true for laboratory experiments studying risk aversion. See, for example, Deck et al. (2008) and Post et al. (2008). As an extreme stakes effect, one can note the Mega Millions lottery jackpot of March 6, 2007, which was $390 million, was split equally between two winners. Given that the net payout on a lottery ticket is usually around 50 cents on the dollar, we might conclude these two winners were risk lovers. Yet we doubt that either one of these two winners would have tossed a coin on the fair bet: "winner takes all."

Although we showed that our ten tasks would lead to the prudent choices or intemperate choices under CPT with parameters similar to Tversky and Kahneman (1992), not all individuals would be expected to have the exact same preferences. Indeed, these parameters for CPT are calibrated to fit the average data in Tversky and Kahneman (1992). In addition to varying the CPT parameters, there also are many variations in the functional forms used for both the value function and the weighting function. Most of these are analyzed in Stott (2006). Moreover, Kőszegi and Rabin (2006) have recently come up with alternative ways to incorporate the reference point into these types of models.[23]

Of course, there has not been much done in the way of experimentation for these higher-order risk affects. As such, we cannot compare the results of our experiment with others. What would happen with different subjects in the laboratory; or what would happen if our lotteries were embedded into field experiments? Perhaps more temperate behavior would show up in a different type of experiment.

Given their importance in predicting certain types of behavior, there is a need for future behavioral research to provide more insight into these higher-order risk effects. To the extent that such endeavors have findings similar to ours, it would call for newer theoretical work to help explain the resulting behavior and generate new testable hypotheses.

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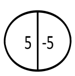
Appendix: Subject Directions, Comprehension Handout and Version 1

Experiment on Decision Making under Uncertainty: Higher-Order Effects

Instructions

You are participating in a research study on decision making under uncertainty. At the end of the study you will be paid your earnings in cash and it is important that you understand how your decisions affect your payoff. If you have questions at any point, please let a researcher know and someone will assist you. Otherwise, please do not talk during this study and please turn off all cell phones.

On the following sheets there is a series of 10 tasks. Once you have completed these sheets, <u>one</u> of the ten tasks will be randomly selected by rolling a 10 sided die to determine your payoff. Each task starts with a fixed amount of cash that includes the $5.00 participation payment that you are receiving and involves two additional items. The additional items will be cash or lotteries and a coin toss will determine if you receive these items. A lottery has 50% chance of having an amount of money added to your payoff and a 50% chance of that amount of money being subtracted from your payoff.



represents the lottery in which you could have US$ 5.00 added to or subtracted from your payoff. How much money you would receive from the lottery will be determined by a spinner that is half green and half red. If the spinner stops on green, the amount will be added to your payoff, but if it lands on red, the amount will be subtracted from your payoff. You are welcome to inspect the coin, die and spinner at any time.

In each task you determine if you prefer to receive the first additional item when the coin toss lands on *Heads* or *Tails*. You will also determine if you prefer to receive the second item on the *Same* or *Different* outcome of the coin toss as the first item. There is only one coin toss and you are deciding if you want the two items combined (so that you receive both or neither) or if you want the two items separated (so that you receive one or the other). If you receive two lotteries, there will be independent spins for each.

Your choice will not affect the expected value of the task, which is the average amount that you would be paid from going through the task many, many times. Please note that you cannot lose your own money or the $5.00 participation payment that you are receiving for completing this study.

PLEASE DO NOT CONTINUE UNTIL INSTRUCTED TO DO SO!

This page contains practice problems that will not impact your payoff in any way.

Practice # 1) You will receive $20 +

if the coin lands on *Heads* or *Tails* and $5.00 if the coin lands on the *Same* or *Different* outcome.

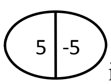
Suppose you made the indicated responses.
If your coin toss landed on Heads, your payoff would be ________.
If your coin toss landed on Tails and the spinner landed on Green, your payoff would be ________.
If your coin toss landed on Tails and the spinner landed on Red, your payoff would be _________.

Practice # 2) You will receive $20 +

if the coin lands on *Heads* or *Tails* and $5.00 if the coin lands on the *Same* or *Different* outcome.

Suppose you made the indicated responses.
If your coin toss landed on Heads, your payoff would be _________.
If your coin toss landed on Tails and the spinner landed on Green, your payoff would be _________.
If your coin toss landed on Tails and the spinner landed on Red, your payoff would be _________.

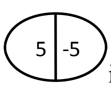
Practice # 3) You will receive $15 +



if the coin lands on *Heads* or *Tails* and $5.00 if the coin lands on the *Same* or *Different* outcome.

Suppose you made the indicated responses.
If your coin toss landed on Heads and the spinner landed on Green your payoff would be _________.
If your coin toss landed on Heads and the spinner landed on Red your payoff would be _________.
If your coin toss landed on Tails, your payoff would be _________.

Practice #4) You will receive $15 +



if the coin lands on *Heads* or *Tails* and


if the coin lands on the *Same* or *Different* outcome.

Suppose you made the indicated responses.
If your coin toss landed on Heads and the spinner landed on Green your payoff would be _________.
If your coin toss landed on Heads and the spinner landed on Red your payoff would be _________.
If your coin toss landed on Tails and the spinner landed on Green your payoff would be __________.
If your coin toss landed on Tails and the spinner landed on Red your payoff would be __________.

Once you have completed this sheet, please raise your hand so that an experimenter can check your responses and answer any questions you might have.

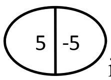
PLEASE DO NOT CONTINUE UNTIL INSTRUCTED TO DO SO!

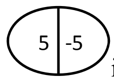
These pages contain the 10 decision tasks. One task will be randomly selected to determine your payoff.

Task #1)   You will receive $30.00 +

if the coin lands on *Heads* or *Tails* and $25.00 if the coin lands on the *Same* or *Different* outcome.

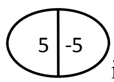
Task #2)   You will receive $15 +



if the coin lands on *Heads* or *Tails* and 

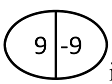
if the coin lands on the *Same* or *Different* outcome.

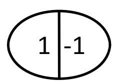
Task #3)   You will receive $12.50 +

$9.00 if the coin lands on *Heads* or *Tails* and 

if the coin lands on the *Same* or *Different* outcome.

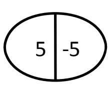
Task # 4)   You will receive $15 +



if the coin lands on *Heads* or *Tails* and 

if the coin lands on the *Same* or *Different* outcome.

Task #5)   You will receive $12.50 +



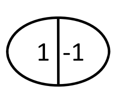
if the coin lands on *Heads* or *Tails* and $1.00 if the coin lands on the *Same* or *Different* outcome.

Task #6)   You will receive $55.00 +

if the coin lands on *Heads* or *Tails* and 

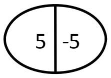
if the coin lands on the *Same* or *Different* outcome.

Task #7)   You will receive $10.50 +

$9.00 if the coin lands on *Heads* or *Tails* and 

if the coin lands on the *Same* or *Different* outcome.

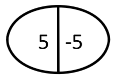
Task #8) You will receive $55.00 +



if the coin lands on *Heads* or *Tails* and 

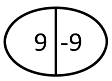
if the coin lands on the *Same* or *Different* outcome.

Task #9) You will receive $12.50 +

$5.00 if the coin lands on *Heads* or *Tails* and 

if the coin lands on the *Same* or *Different* outcome.

Task #10) You will receive $14.50 +



if the coin lands on *Heads* or *Tails* and $1.00 if the coin lands on the *Same* or *Different* outcome.

Please review your answers to verify that everything is marked the way you want it to be. Please raise your hand when you are done and an experimenter will approach you so that your payoff may be determined. Once you have rolled the die to determine which round will be used in calculating your payoff, you may not change your responses.

The remainder of this sheet is to be completed by an experimenter.

Number Rolled ________

Result of Coin Toss _______

Result of Spinner (as necessary) ____________

Payoff ____________

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