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**PROBABILITY WEIGHTING IN DIFFERENT  
DOMAINS: THE ROLE OF STAKES,  
FUNGIBILITY, AND AFFECT**

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## **Probability weighting in different domains: the role of stakes, fungibility, and affect**

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### **Abstract**

This paper reports the results of a laboratory experiment in which probability weighting functions for risky gains were elicited non-parametrically in over 500 incentivized subjects. I compare probability weights for monetary rewards to two less fungible domains involving vouchers for different types of consumption, inducing stronger or weaker (positive) emotions. The level of stakes was also manipulated. I find that the probability to win monetary rewards is weighted almost linearly in the high stakes condition, the probability to win vouchers associated with positive affect is underweighted and the probability to win affect-poor vouchers is strongly underweighted. Substantial underweighting also prevails in all three domains in the low stakes condition.

### **Keywords:**

prospect theory, probability weighting functions, fungibility, affect

### **JEL:**

D81

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## 1. Introduction

When making decisions under risks, humans may not weigh events in accordance with their (known) probability (Starmer, 2000). This is widely perceived as irrational, as it implies a violation of axioms considered as sound normative basis of decision making.

Several studies (Wu and Gonzales, 1996; Abdellaoui, 2000; Booij and van de Kuilen, 2006) have reported that the median decision maker appears to attach overly high weights to unlikely gains (in which case she may be risk-seeking), whereas intermediate and high probabilities are underweighted (risk-aversion prevails). This “inverse-S” probability weighting pattern, as it is referred to in literature based on Tversky and Kahneman’s (1992) (Cumulative) Prospect Theory (PT, Wakker, 2010) is sometimes portrayed as a seminal regularity of decision making under risk. Yet, several caveats apply.

First, essentially all papers report substantial heterogeneity. The median may be inverse-S, but a variety of other patterns will typically be observed. This makes low sample sizes of some (early and influential) studies a major problem. For example, the path-breaking study of Gonzalez and Wu (1999) used data from exactly ten individuals. Bleichrodt and Pinto (2000) and Abdellaoui (2000) had about 50 subjects each. Admittedly, Booij et al. (2010) had a large sample, representative of the Dutch society.

Second, several studies find other median and modal patterns (often these are convex probability weighting functions, PWF) or otherwise report results inconsistent with well-defined inverse-S. For example, van de Kuilen and Wakker (2011) used a new non-parametric technique that I shall also employ here and observed a convex probability weighting function for risky gains (pessimism).<sup>1</sup> This result was also obtained by Qiu and Steiger (2011), although they used the same method as Abdellaoui (2000). Harbaugh et al. (2002) reported choices between two-outcome gambles and their expectations. Studying 234 subjects in various age groups (ranging from 5 to 64 years) in the domain of gains they consistently found risk seeking for large probabilities and risk aversion for small probabilities—the exact opposite of the inverse-S.<sup>2</sup> Goeree et al. (2003) observed an analogous effect in subjects’ behavior in simple games. Blavatskyy (2010) reported the reverse of the common-ratio effect predicted by PT with inverse-S: many subjects switched to the safer option when (initially high) probabilities of both gambles were scaled down, in a clear violation of the inverse-S. Likewise, Birnbaum and Chavez (1997) as well as Humphrey and Verschoor (2004) found the reverse of the common-consequence effect predicted by PT with inverse-S and seemingly manifested in the famous Allais (1954) Paradox. Fehr-Duda et al. (2010) observed greater probability weights (making risky gambles generally more attractive) when decision concerned low rather than high winnings. Etchart-Vincent (2004, 2009) reported that probability weights depend on level and spacing of losses.

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<sup>1</sup> Their online appendix contains lists of studies reporting evidence in favor and against inverse-S extracted from Wakker’s annotated bibliography, <http://people.few.eur.nl/wakker/refs/webfrncs.doc>.

<sup>2</sup> All of these studies were incentivized, although stakes were relatively low.

Third, the majority of studies eliciting probability weights (particularly of those that find inverse-S), including the large study of Booij et al. (2010), are based on hypothetical answers. Clearly, a stark violation of the rational, normative benchmark should be subject to a stringent reality check.

Fourth, little is known about how probability weights might differ depending on the nature of rewards and how the differences (if any) could be explained. This is of great importance given that, on top of financial risks, an individual daily takes chances in many other walks of life. Should I cheat at exams if I am a student? Should I cross the street at red light? Should I ski off-piste? Should I engage in extra-marital flirts? Should I quit my job in the academia and launch my own business? While all of these activities might perhaps eventually have dire monetary consequences, they primarily entail other sorts of risks, associated with ethical integrity, health/physical safety etc. Studies find that willingness to take risks is only moderately correlated across different domains (Blais and Weber, 2006) but there are very few attempts to compare probability weights.

Berns et al. (2007) asked their subjects to make choices between gambles resulting in painful electric shocks (that were actually delivered). The PWF was not much different from what had typically been observed in studies with monetary losses. Bleichrodt and Pinto (2000) elicited probability weights for life years (how fortunate that their study was hypothetical!). Deviations from the linear benchmark seemed more pronounced than in most studies using monetary rewards. None of these studies involved a control treatment with cash payments. Recently, a difference depending on the reward domain was also reported by Abdellaoui and Kemel (2014)—probability weighting function was more elevated and less sensitive to probabilities for (real) delay time than for money.

A priori, there are good theoretical reasons to expect probability weights to be identical in all domains. Clearly, the normative benchmark is the identity function, never mind the nature of rewards. If, however, we observe deviations, predictions as to whether they will be identical in various reward domains depend on where these deviations are believed to come from in the first place. In the original formulation of the PT and perhaps in most of the extant literature, distorted weighting of probabilities is proposed to result from "diminishing sensitivity". In view of this psychophysical explanation, the same change in probability of an event is perceived as large when it occurs close to the limits of its admissible range—changing something impossible into possible or something certain into uncertain. By contrast, the perceptual apparatus is relatively insensitive in the middle of the scale. As a side note, this explains inverse-S but not convex probability weighting. It would seem that such effects should operate similarly in different domains, so that generally analogous weighting functions are predicted.

More recently, an alternative, emotional account has been proposed. Here, the shape of the probability weighting function is proposed to be mediated by emotions, which are said to respond to mere possibility of an event, rather than its likelihood. This is a route taken by Loewenstein et al. (2001). It is predicted in particular that favorable yet unlikely

events will be given more weight if they evoke strong positive emotions, such as hope and excitement.<sup>3</sup> Hypothetical experiments run by Rottenstreich and Hsee (1999) confirmed this conjecture: subjects showed extreme insensitiveness (over a very wide range of 1% to 99%) to changes in probability in "affect-rich" domains (such as a kiss from a movie star).

To the extent that it is (literally) vitally important and thus presumably emotionally engaging how many more years we might live, insensitivity to probability observed by Bleichrodt and Pinto (2000) could thus perhaps be explained (to be sure, life years clearly differ from (small to moderate) monetary stakes on several other dimensions as well). Similarly, substantial insensitivity to risk is often reported in the literature on health risks, such as poisoning (but see Hammitt and Graham, 1999). The prediction based on this approach would thus be that positive affect leads to higher weights of low-probability events and negative affect leads to lower weights for medium- or high probability events.

Another perspective that could shed light on differences in probability weighting functions elicited for different reward domains is that of substitutability. As Leclerc et al (1995) convincingly argued, money is unusually fungible; in other domains (such as time), planning may be more demanding “and because uncertainty makes planning difficult, [it] is especially aversive”. Leclerc and colleagues indeed (unlike Abdellaoui and Kemel, 2014) reported strong risk aversion for gambles whose consequences were expressed in waiting time. This observation may be related to findings on risk taking and evaluation periods (Gneezy and Potters, 1997)—people tend to accept risk more easily when several gambles are bracketed together rather than taken one by one. The general prediction here would thus be that less fungible domains lead to less elevated probability weighting function.

Several goals were laid out for the present study. First, I wanted to elicit probability weights in a large sample, to be able to account for subjects’ heterogeneity. Second, stakes were to be varied, in order to explore the role of incentives. Third and most importantly, I sought to investigate various reward domains. Some subjects played for the most fungible, monetary rewards. Others could obtain vouchers allowing a specific type of consumption only. These came in two types—evoking stronger or weaker (positive) emotions.

The most important findings are as follows. First, probability weights tend to be lower for less-fungible domains; indeed, when rewarded with vouchers, subjects show substantial pessimism. Second, affect-rich vouchers trigger higher probability weights than affect-poor ones. Both of these treatment effects are, however, severely reduced in the low stakes condition. Third, in all the treatments median probability weighting functions are (approximately) convex; I only observe the inverse-S pattern in about 15% of subjects.

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<sup>3</sup> There is also voluminous and rather equivocal psychological literature on the impact of (induced) positive vs. negative mood on willingness to take risks, see e.g. Halicka and Krawczyk (2013) for a short review.

## 2. The experiment

### 2.1 Online pilot

To identify domains that would be distinguished by emotional intensity I conducted an online pilot study. Subjects were asked to indicate for each of six types of vouchers, each worth PLN 200 (ca. 50 euro)

- a) What amount of cash would they consider equivalent
- b) How excited they would be about the possibility of receiving such a voucher

I aimed at finding a pair of vouchers that would differ substantially on the second dimension only. The pilot was run in September 2013 in a student subject pool and I collected 413 complete responses. I decided to use Sodexo leisure & recreation vouchers that can be used to pay in theatres, cinemas, daily spa centers etc. vs. local discount supermarket Stokrotka vouchers. Indeed, mean and median value were about 180 PLN in each case, whereas anticipated excitement (0-7 scale) was 5.46 (SD 1.48) for Sodexo and 4.63 (SD 1.91) for Stokrotka,  $p < .001$ .

### 2.2 Design

To elicit subjects' probability weighting function in a non-parametric way I applied the iterated Price List technique to the midweight method (van de Kuilen and Wakker, 2011). The experiment consisted of eight rounds. In the first two I identified outcomes equally spaced in utility (see Wakker and Deneffe, 1996), i.e. such  $x_0, x_1, x_2$  that  $u(x_2)-u(x_1) = u(x_1)-u(x_0) > 0$ , where  $u$  is a strictly increasing, continuous utility function (sometimes also called value function)  $u: \mathbb{R} \rightarrow \mathbb{R}$ . This was also the starting point of earlier non-parametric studies such as Abdellaoui (2000), van de Kuilen and Wakker (2011) and Abdellaoui and Kemel (2014).

To elicit equally spaced outcomes I let my subjects make a number of choices between risky options Left and Right presented in tables (see Figure 1 for a translated and trimmed screenshot). Option Left always involved the same lottery. For example, in Round 1 it would give a 75% chance for 50 PLN (ca. 12 euro) and 25% chance for 100 PLN which was to become my  $x_0$ . Option Right would always give a 75% for 30 PLN yet the higher outcome was different in each row, improving linearly as we go down the table.<sup>4</sup>

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<sup>4</sup> The choice of specific value of the higher outcome in option Right in the last row was to some extent arbitrary. We chose to make it equal to 250, i.e. 150 larger than in the first row. In this way a risk-neutral switching point was close to the middle (row 4) and values were round.

| Option Left                                                                                                | Option Right                                                                                               |
|------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------|
| 100 PLN for shopping in Stokrotka with prob. 25.0%<br>50 PLN for shopping in Stokrotka with prob. 75.0%    | 100 PLN for shopping in Stokrotka with prob.25.0%,<br>30 PLN for shopping in Stokrotka with prob. 75.0%    |
| 100 PLN for shopping in Stokrotka with prob. 25.0%,<br>50 PLN for shopping in Stokrotka with prob.75.0%    | 125 PLN for shopping in Stokrotka with prob.25.0%,<br>30 PLN for shopping in Stokrotka with prob.75.0%     |
| 100PLN for shopping in Stokrotka with prob.25.0%,<br>50 PLN for shopping in Stokrotka with prob. 75.0%     | 150PLN for shopping in Stokrotka with prob. 25.0%,<br>30 PLN for shopping in Stokrotka with prob.75.0%     |
| 100PLN for shopping in Stokrotka with prob. 25.0%,<br>50 PLN for shopping in Stokrotka with prob.75.0%     | 175PLN for shopping in Stokrotka with prob. 25.0%,<br>30 PLN PLN for shopping in Stokrotka with prob.75.0% |
| 100 PLN for shopping in Stokrotka with prob.25.0%,<br>50PLN for shopping in Stokrotka with prob.75.0%      | 200 PLN for shopping in Stokrotka with prob. 25.0%,<br>30 PLN for shopping in Stokrotka with prob. 75.0%   |
| 100 PLN for shopping in Stokrotka with prob. . 25.0%,<br>50 PLN for shopping in Stokrotka with prob. 75.0% | 225 PLN for shopping in Stokrotka with prob. 25.0%,<br>30PLN for shopping in Stokrotka with prob. 75.0%    |
| 100 PLN for shopping in Stokrotka with prob. 25.0%,<br>50 PLN for shopping in Stokrotka with prob. 75.0%   | 250 PLN for shopping in Stokrotka with prob.25.0%,<br>30 PLN for shopping in Stokrotka with prob. 75.0%    |

**Figure 1: Options in Round 1**

I was interested in the value of this higher outcome of option Right, at which the subject was indifferent between the two options—my  $x_1$ . Prospect theory assumes that (cumulative) probabilities are transformed into decision weights using a strictly increasing, continuous (*cumulative*) probability weighting function  $w:[0,1] \rightarrow [0,1]$  with  $w(0)=0$  and  $w(1)=1$  (identity function  $w(p)=p$  is the normative benchmark of Expected Utility Theory). Indifference would then mean that:

$$w(.25)u(x_0) + (1 - w(.25))u(50) = w(.25)u(x_1) + (1 - w(.25))u(30)$$

so that

$$u(x_1) - u(x_0) = \frac{(1 - w(.25))(u(50) - u(30))}{w(.25)}$$

Because a single point of switching between options Left and Right could reasonably be expected, I enforced such consistency, for example option Right disappeared in Rows 1-2 and option Left disappeared in Rows 4-7 if someone chose indifference in Row 3. If a subject indicated any indifference, the higher outcome of option Right that was deemed just as good as option Left was taken as  $x_1$ .<sup>5</sup> If a subject switched directly from Left to Right at some point, she would get a “second iteration”—a new table within the same round, where option Left and the lower outcome of option Right were unchanged and the higher outcome of option Right improved with each row – between that of the last row of the first iteration in which the subject preferred Left and the first in which she preferred Right. If, for example, in Table 1, a subject chose Left in Rows 1-3 and then Right in rows 4-7, the higher outcome of option Right would vary between 150 and 175 in her second iteration table. The value of  $x_2$  would then be inferred from choices made in the

<sup>5</sup> In the highly unusual case of more than one indifference we would take the mean.

second iteration in the same way as described before. In this way I was able pin down the point of indifference more precisely.<sup>6</sup>

In the second round, the probabilities and lower outcomes were unchanged. The higher outcome in option Left was, however, replaced by  $x_1$  elicited in the previous round. The higher values in option Right were changed accordingly. Again, if the subject is indifferent at some  $x_2$ , we get

$$w(.25)u(x_1) + (1 - w(.25))v(50) = w(.25)u(x_2) + (1 - w(.25))u(30),$$

$$u(x_2) - u(x_1) = \frac{(1 - w(.25))(u(50) - u(30))}{w(.25)} = u(x_1) - u(x_0),$$

so that  $x_0, x_1, x_2$  are indeed equally spaced. We can thus subsequently use them to learn the shape of the probability weighting function. In Round 3 option left involved getting  $x_1$  for sure. Under option Right either  $x_0$  or  $x_2$  would obtain, with increasing probability of the latter as one goes down the table (from zero to 100%). One immediately obtains the result that the probability at which the subject is indifferent has the weight of .5. In an analogous way (see van de Kuilen and Wakker, 2011 for details), values of  $w^{-1}(.75)$ ,  $w^{-1}(.875)$ ,  $w^{-1}(.25)$ , and  $w^{-1}(.125)$ , were elicited in rounds 4-7, with probability values elicited in previous rounds being used in option Left. Round 8 involved a consistency check in which option left would give  $x_2$  with probability  $w^{-1}(.25)$  and  $x_0$  otherwise, whereas option Right could bring  $x_1$  or  $x_0$ . Because utility difference was twice as large under Left as under Right, subjects were expected to switch at  $w^{-1}(.5)$ , which could be compared to the one elicited in Round 3.

In each round, subjects could also make use of a visual aid in the form of roulette wheels representing probabilities and outcomes of option Left and selected option Right (see Appendix A).

Once decisions in all the rounds were made, one round was picked at random and one decision made in this round was implemented (second-iteration decisions were proportionally less likely to be chosen, so that conditional on given round being picked, subjects were best off following their true preference). A random number generator (visually represented by a spinning roulette wheel) determined the outcome which was paid out immediately after the session.

The paid rounds were preceded by a practice round, with hypothetical resolution of risk resembling the real one that was to come after the last round.

### 2.3 Discussion of the design

Vouchers or gift certificates have frequently been employed in experiments, often in comparison with monetary gifts. The focus was typically on the propensity to consume (Abeler and Marklein, 2008; White, 2008; Milkman and Beshears, 2009; Felső, and Soetevent, 2013), so that we cannot learn much about risk posture. However, these

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<sup>6</sup> Gonzalez and Wu (1999) also used iterated price list with enforced consistency.

studies collectively provide a strong evidence that gift certificates are treated as much less fungible than cash by a substantial fraction of individuals.

The midweight method is relatively novel, so one could wonder whether it would be desirable to stick to more established ones. First, a parametric method could have been used. One disadvantage of such an approach is that one needs to make assumptions about the shape of the probability weighting function and the utility functions. Given the exploratory nature of my investigation (involving rewards that had not been used before), there was limited guidance as to whether families of functions found in the literature would provide a good fit. On the other hand, the disadvantage of all non-parametric methods is that questions are chained (linked), yet subjects cannot know this, a feature that some consider a mild form of deception (by omission), see Krawczyk (2013).

Second, one could use non-parametric methods based on a longer sequence of payoffs equidistant in utility such as those proposed by Bleichrodt and Pinto (2000) and Abdellaoui (2000). Their weakness from my viewpoint lies in the fact that, by their nature just mentioned, they are less efficient in eliciting probability weights in that more indifference curves need to be elicited per one point on the PWF.<sup>7</sup> The exact shape of the utility function for money may be important, but probably not so for a specific type of voucher. In particular, there is little theoretical reason to expect that these shapes will be identical for different vouchers (and money), so establishing that they are not would not be particularly interesting.

## 2.4 Treatments

Three main conditions were used: Sodexo, Stokrotka and Cash. They only differed in terms of the nature of rewards used. In the two voucher conditions, the vouchers were described in the instructions as they were in the pilot study. To make sure that subjects remembered the rewards were not in cash, the relevant voucher name appeared in each decision row, as shown in Table 1 and the screenshot in the Appendix. Because vouchers worth less than 10 PLN were not available, subjects could receive a few PLN in cash also in these treatments.

Two stakes levels were used. I will refer to the case of  $x_0=100$  discussed before as *high stakes*. Additionally, I used  $x_0=40$  (*low stakes*). The constant lower outcomes of option Left and Right as well as the range of the higher outcome under option Right in rounds 1 and 2 were adjusted accordingly—they were equal to 10, 20 and 60, resp.

Two different round orders were used: In half the sessions elicitation of the inverse of the PWF for the low probability weights .25 and .125 preceded elicitation for the high probability weights .75 and .875, i.e. the former took place in rounds 4 and 5, while the latter in rounds 6 and 7. The reverse was true in remaining sessions. No evidence of order effects were found, so this differentiation will not be discussed henceforth.

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<sup>7</sup> This is of particular importance given that we wanted sessions to be possibly brief, so that subjects do not forget the nature of rewards described at the end of instructions.

## 2.5 Subjects and procedures

The experiment was conducted in the Laboratory of Experimental Economics of the University of Warsaw. Subjects were recruited from the local subject pool and informed that rewards could take the form of vouchers rather than cash. A typical session would involve 20-24 subjects, all facing the same treatment.

In total, 26 sessions were conducted with 522 subjects. Ninety-nine (18.9%) of these were excluded from analysis because one or more of their choices contradicted the principle that a stochastically dominant gamble should always be strictly preferred (this corresponds to the case that left is not preferred in Row 1 of one of the tables or right is not preferred in Row 7 of one of the tables and as a result elicited value function or probability weighting function is not strictly increasing). The fraction of discarded observations might seem high but it is not unusual in such demanding tasks, e.g. van de Kuilen and Wakker (2011) excluded 17.9% of observations in their first experiment. The fraction did not differ substantially between treatments and exclusion does not qualitatively change the results. Large majority of subjects were undergraduate students. About half were male and half studied economics. Table 1 shows the number of non-discarded subjects in each of the six treatments.

Sessions lasted for about an hour and subjects earned about 114 PLN on average in the high stakes treatment, which would have otherwise taken them eight to ten hours given prevailing rates for typical students' jobs. In the Low stakes treatment average earnings were about 60 PLN.

**Table 1 Number of subjects per treatment**

|           | Low stakes | High stakes | Total |
|-----------|------------|-------------|-------|
| Cash      | 54         | 51          | 105   |
| Sodexo    | 60         | 112         | 172   |
| Stokrotka | 63         | 83          | 146   |
| Total     | 177        | 246         | 423   |

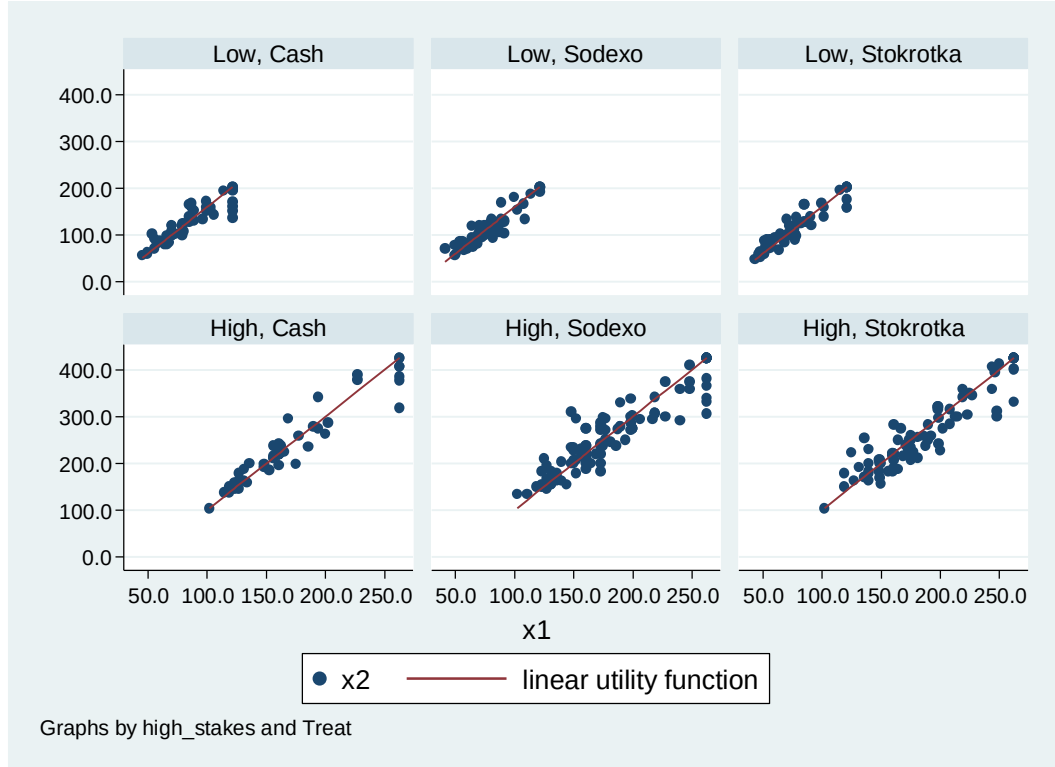
## 3. Results

### 3.1 Utility function

Table 2 shows values of  $x_1$  and  $x_2$ , by treatment (recall that  $x_0$  was 40 and 100 in low stakes and high stakes resp.). The values do not differ much depending on the type of reward, although entries for cash tend to be lowest those for Stokrotka—highest. Analyses using ANOVA as well as non-parametric tests showed no impact of stakes or treatment on convexity of the utility function. Overall, it was relatively close to linear in most subjects, especially under low stakes, as shown in Table 2 and Figure 1

**Table 2 Mean and median values of outcomes equidistant in utility, by treatment**

| Stakes             | Reward type | Mean $x_1$ | Median $x_1$ | Mean $x_2$ | Median $x_2$ |
|--------------------|-------------|------------|--------------|------------|--------------|
| Low ( $x_0=40$ )   | Cash        | 82.3       | 78.5         | 123.9      | 119.2        |
|                    | Sodexo      | 76.6       | 70.7         | 112.4      | 103.0        |
|                    | Stokrotka   | 75.2       | 70.2         | 111.3      | 100.4        |
| High ( $x_0=100$ ) | Cash        | 171.0      | 160.4        | 240.2      | 220.8        |
|                    | Sodexo      | 178.6      | 170.8        | 255.1      | 237.5        |
|                    | Stokrotka   | 186.6      | 175.0        | 266.1      | 250.0        |

**Figure 1 Scatter plots of  $x_1$  and  $x_2$ , by treatment**

### 3.2 Probability weighting function

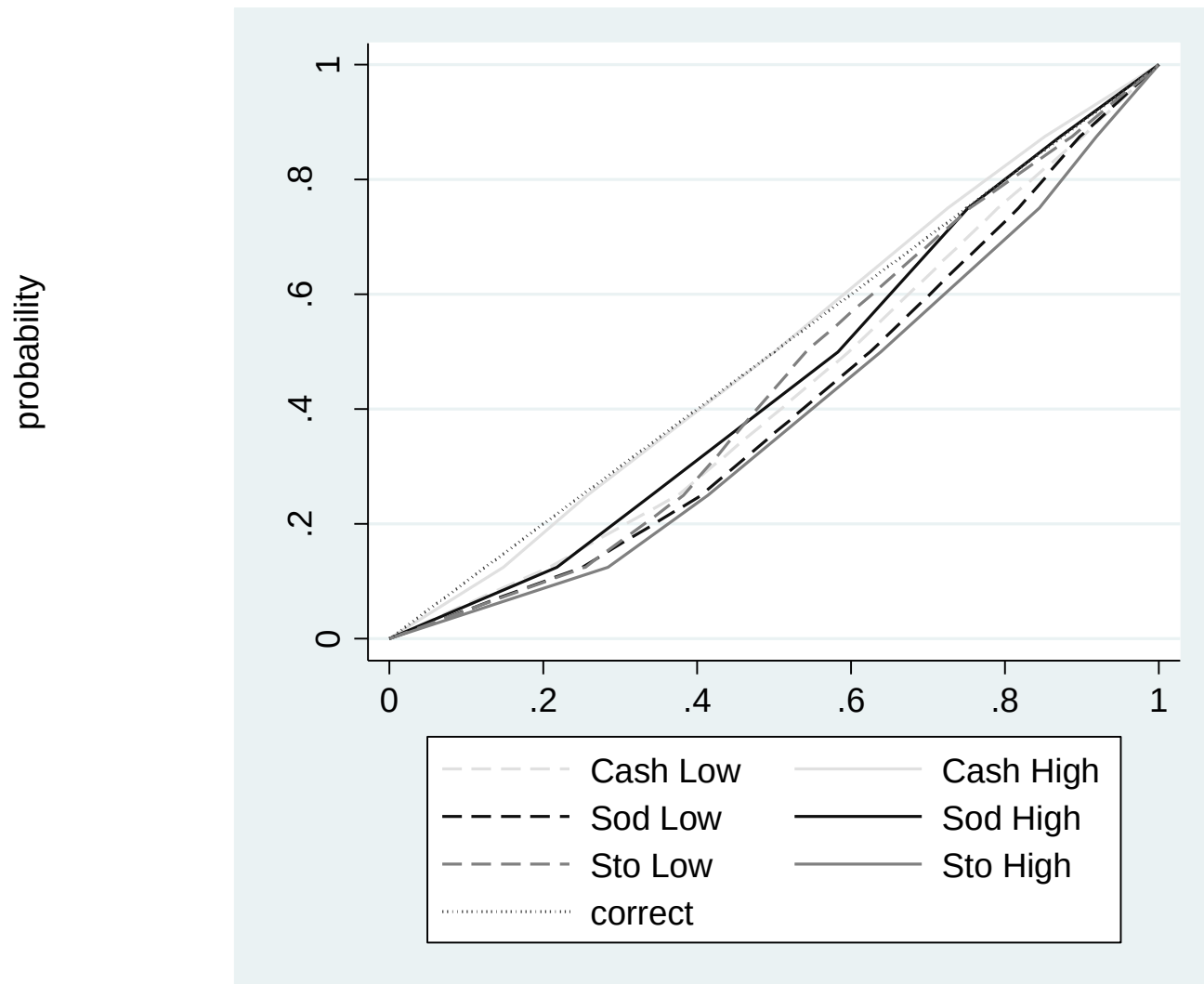
#### Reliability

As mentioned before, the value of  $w^{-1}(.5)$  was actually elicited twice, in rounds 3 and 8. While the latter was higher (.672 vs. .592,  $p < .01$ ), the two were highly correlated ( $\rho = .496$ ). Thus subjects showed some, albeit highly imperfect, consistency.

#### Shape of the probability weighting functions

Figure 2 shows median probability weighting functions in each of the six treatments (and Appendix B contains a table with mean and median values). A few observations are noteworthy. First, none of the curves exhibits the inverse-S pattern. Instead, median PWFs are roughly linear *within the investigated range* and often nearly convex globally. In other words, they deviate from the normative benchmark – except for the case of high monetary stakes, subjects tend to underweight probabilities. Indeed, the hypothesis that  $w(p) = p$  is generally rejected in nonparametric Wilcoxon tests ( $p < .01$ ), except for Cash-

high treatment and except for highest probabilities (.875 typically and .750 in some cases) for other treatments.



**Figure 2 Median PWFs, by treatment**

Probability weighting is thus treatment-specific: for high stakes there is no underweighting for Cash, some for Sodexo and even more for Stokrotka. For low stakes, differences between the three treatments are very small. To investigate treatment effects systematically and formally, I have conducted Mann-Whitney ranksum tests for each probability level separately.

**Table 3 Mann-Whitney tests of treatment effects in PWFs**

| Prob.       | cash vs. vouchers |         | Sodexo vs. Sto. |         |
|-------------|-------------------|---------|-----------------|---------|
| High stakes |                   |         |                 |         |
| .125        | -2.242            | (.0249) | -1.591          | (.1116) |
| .250        | -2.418            | (.0156) | -1.712          | (.0869) |
| .500        | -2.541            | (.0111) | -2.265          | (.0235) |
| .750        | -2.508            | (.0112) | -2.239          | (.0251) |
| .875        | -2.096            | (.0360) | -2.000          | (.0454) |
| Low stakes  |                   |         |                 |         |
| .125        | .170              | (.8650) | .066            | (.9476) |
| .250        | .343              | (.7315) | .822            | (.4109) |
| .500        | .767              | (.4430) | 1.182           | (.2371) |
| .750        | .615              | (.5383) | 1.422           | (.1551) |
| .875        | .656              | (.5116) | 1.166           | (.2435) |

Note: each test statistic followed by *p* value.

As can be seen in the upper part of Table 3 (High stakes), treatment made a difference at each probability level. More specifically, vouchers were more underweighted than cash, as expected. Of the two vouchers, Stokrotka resulted in lower weights than Sodexo, as hypothesized, although contrary to expectations, the difference was actually smaller for low probabilities. No difference was found for low stakes.

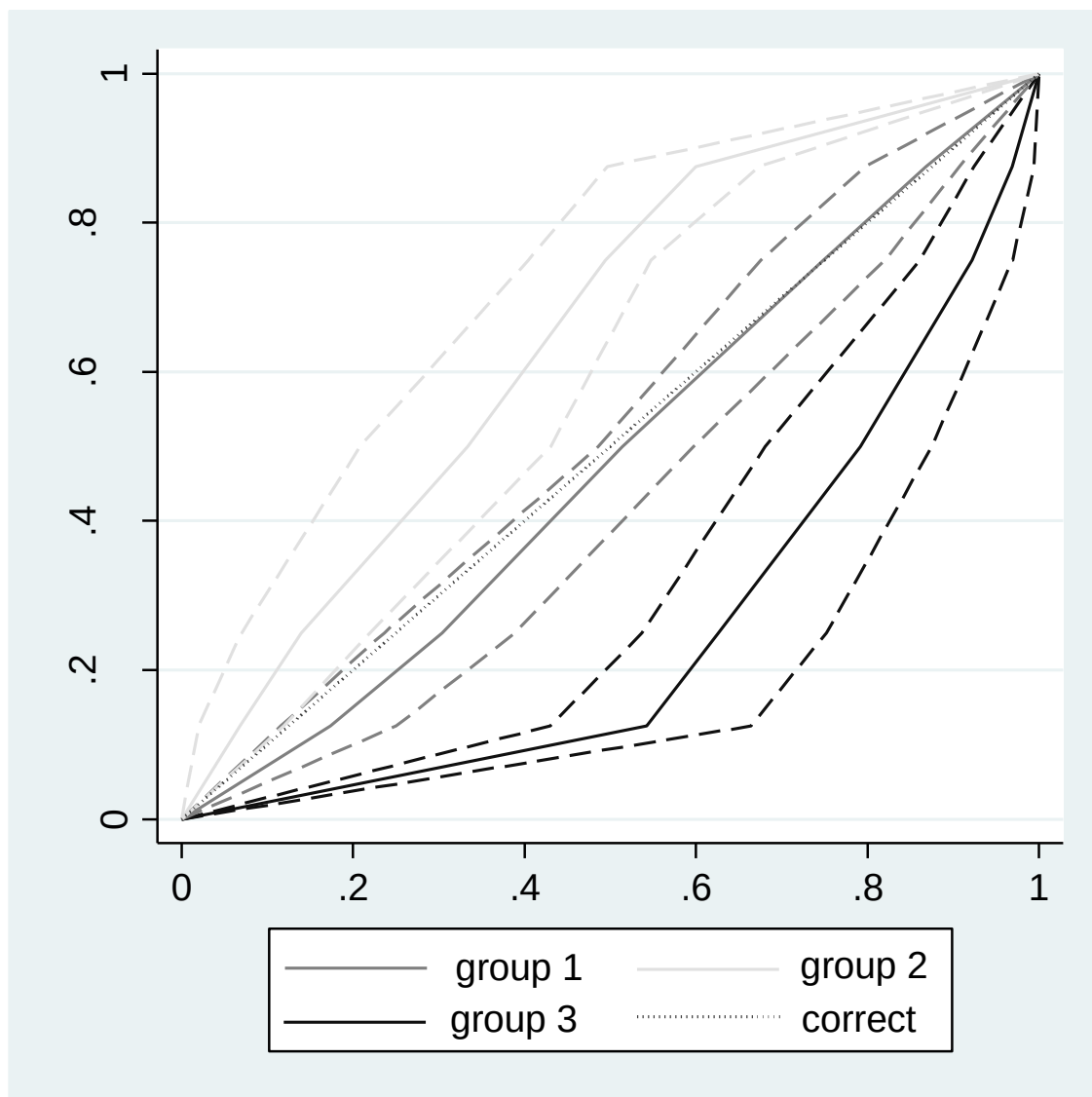
To shed light on determinants of probability weights, a multivariate regression with errors clustered on individuals was performed, see Table 4. With Stokrotka-High as base category, Cash High and Sodexo High have negative coefficients (corresponding to less underweighting). Estimates are stable in that they do not change much when I control for demographics. Subjects majoring in economics and (to a much larger extent) those declaring to be willing to take risks in life are less prone to underweight probabilities.

**Table 4 Probability weights: regression analysis**

| $w^{-1}()$                | (1)                           | (2)        |
|---------------------------|-------------------------------|------------|
| Cash Low                  | -0.0056                       | 0.0139     |
| Cash High                 | -0.0936***                    | -0.0814*** |
| Sodexo Low                | -0.0077                       | 0.0116     |
| Sodexo High               | -0.0508**                     | -0.0404*   |
| Stokrotka Low             | -0.0454                       | -0.0241    |
| Probability               |                               |            |
| .250                      | 0.1016***                     | 0.1016***  |
| .500                      | 0.2921***                     | 0.2921***  |
| .750                      | 0.4575***                     | 0.4575***  |
| .875                      | 0.5387***                     | 0.5387***  |
| Order: low1 <sup>st</sup> | -0.0023                       | -0.0061    |
| Male                      |                               | -0.0119    |
| Econ                      |                               | -0.0323*   |
| q_risk                    |                               | -0.0283*** |
| q_educ_mon                |                               | 0.0138     |
| q_income                  |                               | 0.0000     |
| q_year                    |                               | -0.0055    |
| _cons                     | 0.3355***                     | 0.3874***  |
| N                         | 2120                          | 2120       |
| R <sup>2</sup>            | 0.5112                        | 0.5277     |
| Legend:                   | *p< .1; ** p< .05; *** p< .01 |            |

### Types

As mentioned before, experiments often find substantial heterogeneity of subjects. A “theory-free” approach to subject classification is to conduct cluster analysis on elicited individual (inverses of) probability weights. Three distinct groups can be identified; quartiles of their (inverse) probability weighting function values are shown in Figure 3



**Figure 3 Median Probability Weighting Functions for the three clusters. Solid lines represent the median and dotted lines correspond to quartiles.**

Group 1, encompassing 47.6% of subjects shows roughly correct probability weighting. Group 3 (35.5% of subjects) underweights probabilities, especially low probabilities, while Group 2 (17.9%) overweights them. Table 5 shows that relatively many subjects rewarded with Stokrotka vouchers belong to the underweighting group, which corresponds to results shown earlier.

**Table 5 Tabulation of conditions and clusters**

| Reward type\Group | 1   | 2  | 3   | Total |
|-------------------|-----|----|-----|-------|
| Cash              | 51  | 21 | 33  | 105   |
| Sodexo            | 89  | 25 | 58  | 172   |
| Stokrotka         | 61  | 26 | 59  | 146   |
| Total             | 201 | 72 | 150 | 423   |

Another approach, based on categories discussed in previous literature would be to search for patterns of subadditivity. Following Bleichrodt and Pinto (200) a probability weighting function is called lower-subadditive if its slope on the first interval (here: PWF value of 0 to .125) is greater than the slope on the second interval (.125 to .250). A function that is concave for low probabilities will display lower-subadditivity—increasing the chance of earning the highest amount by, say, one percentage point will have less and less impact with each increment. This tendency corresponds to the *possibility effect*. By the same token, a function is called upper-subadditive if its slope on its last interval (here PWF value of .875 to 1) is greater than on the second-to-last (.750 to .875), which will result from the PWF being convex for high probabilities, causing *certainty effect*. A subject showing both types of subadditivity can be considered inverse-S. I find that only 21.3% of subjects were lower-subadditive, 60.0% were upper-subadditive and 14.7% combined the two, thus can be considered inverse-S. These values are similar to those reported by van de Kuilen and Wakker (2011), except that I have more upper-subadditive subjects. These fractions were not significantly affected by treatment.

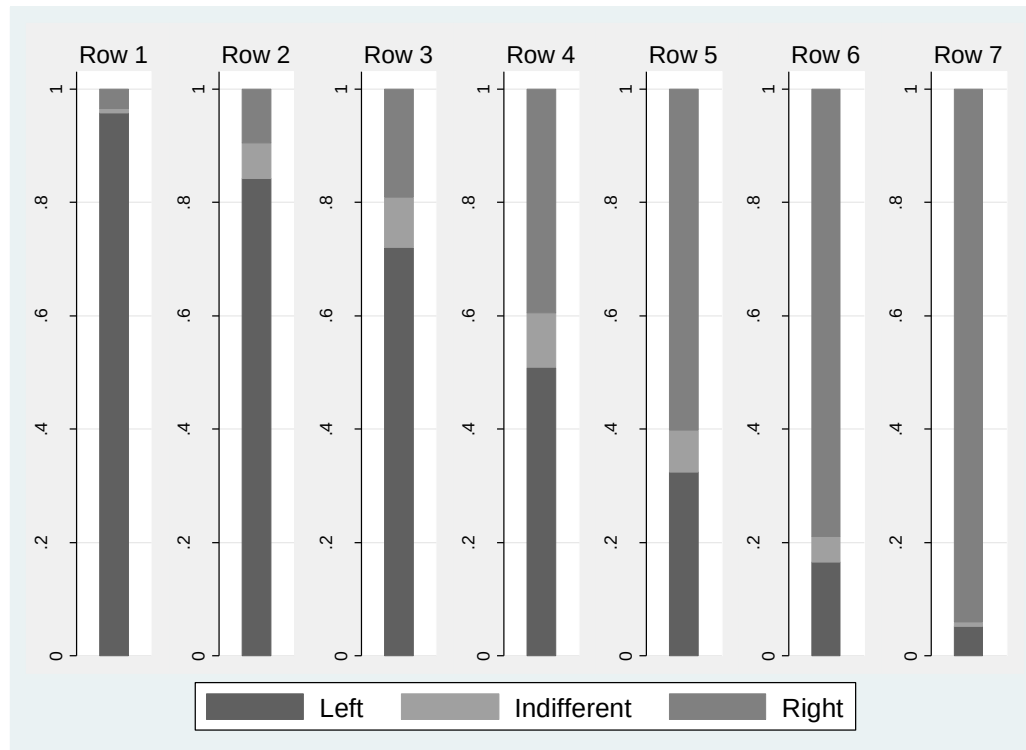
## 4. Discussion

### 4.1. The inverse-S

The fact that I do not observe an inverse-S pattern reported in many previous studies eliciting probability weights begs for an explanation (see also discussion in section 9 of van de Kuilen and Wakker, 2011). One feature that distinguishes my method from most of those used before is that I use tables rather than binary choices. As Andersen et al. (2006), among others, note, experimenter's choice of upper and lower bounds in the table may not be neutral. Subjects, being unsure what the “right” choice is, might simply have a tendency to switch in the middle. Else, they could infer from the contents of the table, what the experimenter considers a reasonable range, although Andersen and colleagues rightly remark that if “values are bounded by the laws of probability between 0 and 1 (...) this is less likely to be a factor”. In my case, one bound in the probability elicitation task was either 0 or 1, while the other was determined by very transparent stochastic dominance. In this sense, there was limited cue for subjects in this choice of range.

Additionally, subjects were told to consider each row separately and encouraged to do it in any order they wished. Also, the mechanism of disappearing options described before might have facilitated making decisions disregarding the specific range given in the table. For example, even if subjects shied away from clicking option Left, say, five times, it was enough for them to click it but once (in Row 5).

When we look at the distribution of choices of option Left/Indifferent/Right by row of the table (in the first iteration only, merging all probability elicitation Rounds 3-8), we see very little evidence that subjects felt compelled to switch exactly in the middle of the table (i.e. choose left in Rows 1-3 and Right in rows 5-7), see Figure 4. For example, as many as over 30% would still choose left in Row 5.



Note: this figure shows data for all the 522 subjects. The data for non-discarded subjects looks qualitatively similar, except of course that choices are uniform in Rows 1 and 7.

**Figure 4 Distribution of choices (first iteration)**

Furthermore, note that my results correspond closely to those of van de Kuilen and Wakker (2011), who used bisection instead of the iMPL tables.

Finally, we should ask whether the tendency to switch in the middle (if any) could explain departure from the inverse-S? Note that switching at Row 4 exactly would in my setting mean a perfectly linear probability weighting function,  $w(p)=p$ . One would thus suspect that this bias merely renders the inverse-S less pronounced. In fact, what we observe is a clear pattern of systematic probability underweighting, particularly for low probabilities.

Conversely, the tendency to switch in the middle of the table might very well explain the inverse-S finding reported in some earlier studies. Consider (Gonzalez and Wu, 1999). In their method subjects were asked to make choices such as those shown in Table 6.

**Table 6 Typical choices in (Gonzalez and Wu, 1999)**

| Gamble                             | Sure thing |
|------------------------------------|------------|
| $p\%$ for \$100; $(1-p)\%$ for \$0 | \$0        |
| $p\%$ for \$100; $(1-p)\%$ for \$0 | \$20       |
| $p\%$ for \$100; $(1-p)\%$ for \$0 | \$40       |
| $p\%$ for \$100; $(1-p)\%$ for \$0 | \$60       |
| $p\%$ for \$100; $(1-p)\%$ for \$0 | \$80       |
| $p\%$ for \$100; $(1-p)\%$ for \$0 | \$100      |

Clearly, even a mild tendency to switch somewhere close the middle of the table (here: between \$40 and \$60) would lead here to “overweighting” of low  $ps$  and “underweighting” of high  $ps$ .

Likewise, in (Bleichrodt and Pinto 2000) subjects were asked to pick  $x_j$  (number of years still to live) that would make them indifferent between 50/50 gambles A: (55 or  $x_{j-1}$  years) and B: (45 or  $x_j$  years) for  $j=0,1 \dots$  starting at  $x_0=0$ . In a personal interview subjects were first encouraged to admit that the first gamble is better for  $x_1=0$  and the second is better for  $x_1=45$ . Consider now an individual who is truly risk neutral but is compelled to switch “close to the middle”. For simplicity assume that the switching point will be the average of the two values – one corresponding to risk neutrality and the other corresponding to the midpoint of the range. In our example she will switch at  $(10+22.5)/2=16.25$ . This “drag to the middle” will be weaker in each subsequent step (actually, it will soon reverse). For example, in step two, the range will be  $(16.25;45)$ . Risk neutrality would dictate  $x_2=26.25$ , choosing the midpoint entails picking 30.625, so she will choose 28.4375. Note that  $(x_2-x_1)$  is smaller than  $(x_1-x_0)$  – a convex utility function is elicited, although the true one is linear. One can easily show more generally that the tendency to switch close to the midpoint of the range will result in overly convex utility function here.<sup>8</sup> The sequence is subsequently used to elicit probability weights and two different formulas are applied for low probabilities and high probabilities respectively, see equations (8) and (9) on page 1489. It is easy to verify that artificially increased value of an early element in the sequence ( $x_j$  and  $x_q$  in their notation) will tend to raise calculated weight of small probabilities and lower the weight of large probabilities, perhaps contributing to the inverse-S shape.

As mentioned before, yet another difference between my study and most of extant literature is that I used real and sizable incentives, while stakes could be extremely high in some previous studies, but merely hypothetical, which could exacerbate deviations from rationality. This seems consistent with my observations that probability weighting was closest to the normative benchmark for the case of high cash payments.

A subtle way in which the inverse-S may be self-fulfilling, in parametric studies such as (Gonzalez and Wu, 1999) at any rate, was recently suggested by Stewart et al. (2014). In their “decision-by-sampling” model individuals’ perception of differences between stimuli is shaped by their distribution in previous choices. Because researchers expect the PWF to be steep near zero and one, they try to measure it more carefully there, asking subjects to evaluate many gambles involving very low and very high probabilities. This exposition alone makes the subjects perceive changes in these ranges as more important than those in the middle of the scale, leading to inverse-S being “confirmed”.

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<sup>8</sup> Actually, only mildly concave shape of utility function of life years they observe seems quite counter-intuitive. It would seem that living for another 40 years is not even remotely twice as good as living for another 20 years when one takes into account discounting of future utility streams and worsening health, to name two obvious factors.

## 4.2 Further potentially problematic features

A potential concern about the validity of my results in general (not necessarily the absence of inverse-S) is associated with the fact that electronic randomization devices were used, rather than physical ones. This was so mostly because it was impractical to use dices given that all the subjects were playing for real, unlike in van de Kuilen and Wakker (2011) for example. One could argue that subjects suspected that my roulette wheels were biased, so that e.g. the lower of two possible outcomes would always obtain. First, such an approach should lead to complete insensitivity to probability, a behavioral pattern that could hardly be more remote from what we actually observed. Second, but a single subject made a remark in the post-experiment questionnaire that signaled mistrust in the devices used.

In theory, subjects could also realize that questions were chained and react strategically.<sup>9</sup> Not a single person made a remark in the questionnaire (administered after their payments were determined and displayed) that would give us any hint that she or he realized there were interdependencies that could be exploited. Note also that such strategic choices would involve switching at later rows than actually preferred, resulting in higher values of  $w^{-1}()$ . Yet, as mentioned before,  $w^{-1}(.5)$  elicited in Round 8 (which was announced to be the last one, thereby making strategic forward-looking misrepresentation of preference nonsensical) was quite a bit higher than the one obtained in Round 3.

## 5. Conclusions

This study confirms that probability weights may not be identical for all domains of risk taking. In particular, at least for substantial amounts, less fungible and less exciting rewards seemed to discourage gambling. Such findings can help us understand differences in willingness to take risks in various domains, some of which have been explained in terms of overweighting of low probabilities.

For example, the same person may be willing to overpay for car insurance and still indulge in gambling not so much because the former involves avoiding low probability losses and the latter endorsing low probability gains but because these activities involve different mental accounts. A family car is useful but perhaps not particularly exciting. It is also “discrete” and replacing it will be a time-consuming, perhaps tedious procedure. By contrast, cash labelled for entertainment is fungible and evokes excitement.

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<sup>9</sup> Wang, Filiba and Camerer (2010) list several ways, in which this problem could be addressed, should it ever seem to be present. See also Bardsley et al. (2010) p. 265, for a discussion of the distinction between theoretical incentive compatibility.

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## Appendix A INSTRUCTIONS

Welcome to the experiment in decision making. In this experiment you will receive a gift certificate, the value of which will depend on your choices as explained below. You will be told more about the gift certificates later on.

### SHORT SUMMARY OF INSTRUCTIONS

Click in each row of each table appearing on the screen the button corresponding to the option you like better (or button 'I' if you are indifferent). One of your choices will be played out for real.

To get the details, please read on.

### TASK

During this experiment you will be asked to make a number of choices between two options: 'Option Left' and 'Option Right'. To this end, you will see decision tables on the screen. An example of such a decision table is given below

| This is Round 0 |                                                                                                          |                                                                                                           |                                     |                                  |                                      |
|-----------------|----------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------|-------------------------------------|----------------------------------|--------------------------------------|
|                 | Option Left                                                                                              | Option Right                                                                                              | Your Decision                       |                                  |                                      |
| Row 1           | 600 PLN for shopping in Stokrotka with prob. 62.5%<br>300 PLN for shopping in Stokrotka with prob. 37.5% | 600 PLN for shopping in Stokrotka with prob. 62.5%<br>200 PLN for shopping in Stokrotka with prob. 37.5%  | <input type="button" value="Left"/> | <input type="button" value="I"/> | <input type="button" value="Right"/> |
| Row 2           | 600 PLN for shopping in Stokrotka with prob. 62.5%<br>300 PLN for shopping in Stokrotka with prob. 37.5% | 700 PLN for shopping in Stokrotka with prob. 62.5%<br>200 PLN for shopping in Stokrotka with prob. 37.5%  | <input type="button" value="Left"/> | <input type="button" value="I"/> | <input type="button" value="Right"/> |
| Row 3           | 600 PLN for shopping in Stokrotka with prob. 62.5%<br>300 PLN for shopping in Stokrotka with prob. 37.5% | 800 PLN for shopping in Stokrotka with prob. 62.5%<br>200 PLN for shopping in Stokrotka with prob. 37.5%  | <input type="button" value="Left"/> | <input type="button" value="I"/> | <input type="button" value="Right"/> |
| Row 4           | 600 PLN for shopping in Stokrotka with prob. 62.5%<br>300 PLN for shopping in Stokrotka with prob. 37.5% | 900 PLN for shopping in Stokrotka with prob. 62.5%<br>200 PLN for shopping in Stokrotka with prob. 37.5%  | <input type="button" value="Left"/> | <input type="button" value="I"/> | <input type="button" value="Right"/> |
| Row 5           | 600 PLN for shopping in Stokrotka with prob. 62.5%<br>300 PLN for shopping in Stokrotka with prob. 37.5% | 1000 PLN for shopping in Stokrotka with prob. 62.5%<br>200 PLN for shopping in Stokrotka with prob. 37.5% | <input type="button" value="Left"/> | <input type="button" value="I"/> | <input type="button" value="Right"/> |
| Row 6           | 600 PLN for shopping in Stokrotka with prob. 62.5%<br>300 PLN for shopping in Stokrotka with prob. 37.5% | 1100 PLN for shopping in Stokrotka with prob. 62.5%<br>200 PLN for shopping in Stokrotka with prob. 37.5% | <input type="button" value="Left"/> | <input type="button" value="I"/> | <input type="button" value="Right"/> |
| Row 7           | 600 PLN for shopping in Stokrotka with prob. 62.5%<br>300 PLN for shopping in Stokrotka with prob. 37.5% | 1200 PLN for shopping in Stokrotka with prob. 62.5%<br>200 PLN for shopping in Stokrotka with prob. 37.5% | <input type="button" value="Left"/> | <input type="button" value="I"/> | <input type="button" value="Right"/> |

Option Left

Option Right

value depends on the row

Show me the roulette wheel for row#

As illustrated by this screen-shot, in each row of each table there will be an Option Left and an Option Right. Both options yield prizes, depending on chance. For example, Option Left in the third row of the table shown here yields a prize of 600 with probability 62.5% and a prize of 300 PLN with probability 37.5%. Option Right on the third row of the table yields a prize of 800 PLN with probability 62.5% and a prize of 200 PLN with probability 37.5%.

For your convenience, prizes and probabilities will be represented also by a roulette wheel as depicted at the bottom of the table. We will further discuss this below.

During the experiment, we will ask you to choose between the options by selecting the option that you prefer in the 'Choice' column at the end of each row using the mouse. Thus, if you prefer Option Left in a row you should click the button labeled 'Left' in this column and if you prefer Option Right, you should click the button labeled 'Right'. If you cannot decide which of the options you prefer, you can click the middle button labeled 'I' (which stands for 'Indifferent').

You will have to make a choice in each row of every table that appears on the screen. However, to simplify your task, sometimes some options may disappear. To see why, note that while Option Left is identical in all the rows, option Right is better in row 7 than in row 6, where it is better than in row 5 etc. (and this will be the case of all the tables in the experiment). Suppose now for example that you prefer Option Right to Option Left in row 4 (where the probability of the higher outcome in Option Right, 625 euro, is 75%). You will then also surely prefer Option Right in rows 5 to 7. So if you click Right in row 4, buttons 'Left' and 'I' will disappear in rows 5 to 7. This will save you some time and reduce the probability of an error.

You can make your decisions in any order. If you make a mistake, you can always click the 'Start Again' button. After you have made all the choices, click the button 'Ready'.

### **ADDITIONAL TABLE WITHIN SAME ROUND**

It may be that we sometimes ask you to make some extra choices within the same round, to learn your preference more precisely. In these choices Option Right will be better than in the last row in which you preferred Option Left but worse than in the first row in which you preferred Option Right. In such an additional table you have to make your choices in the same way as in any other table.

### **VISUAL ASSISTANCE: ROULETTE WHEELS**

The roulette wheels which you can see at the bottom part of the screenshot correspond to the options Left and Right. The relative size of each colored section of the wheel corresponds (is proportional) to the probability of obtaining a given outcome. The wheel for Option Left is shown immediately on each screen. To see the wheel for Option Right you can type in the row number for which you want to see the wheel. Note that these roulette wheels are only meant as a tool to visualize the probabilities and possible prizes of both options; you can ignore them if you want.

### **PAYMENT**

Once you have made all your decisions, one row from one table will be randomly selected and announced by the computer for payment (the chances that a row from an additional table, should it ever appear, is selected, are proportionally smaller). You will obtain the option you preferred in this row (or a randomly chosen option if you were

indifferent) and it will be played out. A computerized roulette wheel will be used for this purpose – you will see the outcome on your screen.

You will receive a gift certificate of appropriate value, that is to say, in accordance with the chosen option and the outcome of the spin. If you declared being indifferent between the options in the selected row, the computer will randomly select Option Left or Option Right and that option will then be played out for real.

**Because one of your choices will actually be played out for real, it is important for your earnings that you make a careful decision in each row, always picking the option that you actually like better. If you hastily choose an option that you in fact like less, it might negatively affect your earnings.**

Before the relevant decisions you will make a choice in one trial table (round “0”). We will also show you in this round how randomization works. This round will have no impact on your earnings—the choices you make in this round as well as the results of the drawing will be purely hypothetical.

## VOUCHERS

**In today’s experiment you will be rewarded with vouchers that can be spent in any discount supermarket Stokrotka on food, household chemicals and the like. You cannot buy alcohol or cigarettes with them. These vouchers are to be spent in the store—you cannot redeem or sell them.**

If you have any questions, please raise your hand. If not, please click the button on the screen and wait for the experiment to continue.

## Appendix B: additional tables

**Table B1 Mean and median values of  $w^{-1}(p)$  under Low Stakes, by treatment**

| Treatment | .125  | .250  | .500  | .750  | .875  |
|-----------|-------|-------|-------|-------|-------|
| Cash      | 0.344 | 0.447 | 0.619 | 0.773 | 0.849 |
|           | 0.215 | 0.380 | 0.597 | 0.787 | 0.899 |
| Sodexo    | 0.315 | 0.431 | 0.618 | 0.790 | 0.870 |
|           | 0.251 | 0.405 | 0.625 | 0.818 | 0.898 |
| Stokrotka | 0.313 | 0.399 | 0.572 | 0.731 | 0.820 |
|           | 0.255 | 0.382 | 0.542 | 0.755 | 0.887 |
| Total     | 0.323 | 0.424 | 0.602 | 0.764 | 0.846 |
|           | 0.250 | 0.389 | 0.597 | 0.790 | 0.893 |

**Table B2 Mean and median values of  $w^{-1}(p)$  under Low Stakes, by treatment**

| Treatment | .125  | .250  | .500  | .750  | .875  |
|-----------|-------|-------|-------|-------|-------|
| Cash      | 0.229 | 0.327 | 0.520 | 0.707 | 0.810 |
|           | 0.148 | 0.257 | 0.500 | 0.726 | 0.852 |
| Sodexo    | 0.285 | 0.386 | 0.575 | 0.742 | 0.820 |

|           |       |       |       |       |       |
|-----------|-------|-------|-------|-------|-------|
|           | 0.218 | 0.341 | 0.583 | 0.752 | 0.872 |
| Stokrotka | 0.323 | 0.429 | 0.640 | 0.799 | 0.870 |
|           | 0.284 | 0.414 | 0.639 | 0.845 | 0.919 |
| Total     | 0.286 | 0.388 | 0.586 | 0.754 | 0.835 |
|           | 0.232 | 0.362 | 0.597 | 0.767 | 0.875 |



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