



## Experienced utility versus decision utility: Putting the ‘S’ in satisfaction

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### ABSTRACT

Recent research distinguishes an individual's decision utility, inferred from her observed choices, from her experienced utility, which more closely matches the notion of happiness. Using various estimation techniques, we test whether post-choice satisfaction (experienced utility), like decision utility in an experimental data set, is S-shaped with loss aversion around a given reference point. We also present a model which estimates the satisfaction function and reference point simultaneously. When pooling the data across individuals, we find an S-shaped satisfaction function in which the reference point depends on past payments, social comparisons, and subjective expectations. There is mixed evidence of loss aversion. At the individual level, there is substantial variation in satisfaction function shapes, although the S-shape is common. Though the two notions of utility are distinct, our findings imply that the two are related at a fundamental level.

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“[The Prospect Theory value function] represents the *decision utility* of the gains and losses associated with possible outcomes of the decision at hand; it is silent about the post-choice *experienced utility* of the reference situation . . . [I]nferences from decision utility to experienced utility should be made with great caution.” *Kahneman (1999, pp. 18–19, his italics)*

### 1. Introduction

The modern economist's notion of utility differs dramatically from that of utilitarian Jeremy Bentham and his contemporaries. To these earlier thinkers, utility was the sum of experienced pleasures minus pains. This hedonic view of utility fell out of favor in the early twentieth century when critics argued that pleasures and pains could not be measured.<sup>2</sup> Economists instead redefined utility to be a representation of preferences revealed through observed behavior and commenced the reconstruction of economic theories.<sup>3</sup> It was concluded that theories of experienced pleasures and pains

were not only scientifically problematic, they were also unnecessary because utility conceived as consistent choice or revealed preference was sufficient for constructing economic theories and evaluating policies.<sup>4</sup>

Though this behaviorist view of utility still dominates economics, Kahneman and others have recently sparked a renewed interest in a notion of utility corresponding to hedonic experience (e.g., see *Kahneman et al., 1997*). “Experienced utility” is not only measurable, they argue, but also of fundamental importance for both understanding behavior and selecting public policies because, as shown in various studies, experienced utility (enjoying) differs from decision utility (wanting or desiring) in significant ways. For example, *Tversky and Griffin (2000 [1991])* report evidence that realized outcomes such as payments matter more for decisions while contextual factors such as comparisons matter more for judgements of hedonic experience, *Loewenstein and Adler (1995)* find that subjects incorrectly predict the extent to which their post-choice satisfaction adapts, and *Schwarz and Strack (1999)* review evidence that judgements result from cognitive processes that depend on non-choice related factors (also see *Loewenstein and Ubel, 2008*).

This paper confronts the caution expressed in the epigraph. We explore whether the S-shape property of empirically estimated decision utility functions is also found in experienced utility. This S-shape represents *Kahneman and Tversky's (1979)* surprising yet ubiquitous finding that individuals are generally risk averse when

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<sup>2</sup> This shift in economic thinking was initiated by *Robbins (1932)* and is tied to skepticism in the early twentieth century about the possibility of interpersonal comparisons of utility (see *Fleurbaey and Hammond, 1998*).

<sup>3</sup> For modern treatments of utility, see *Fishburn (1987)* or *Mas-Collel et al. (1995)*. *Stigler (1950a,b)* summarizes some developments of the use of the word “utility” in economics.

<sup>4</sup> However, *Mandler (1999)* describes problems that persist in the new theories.

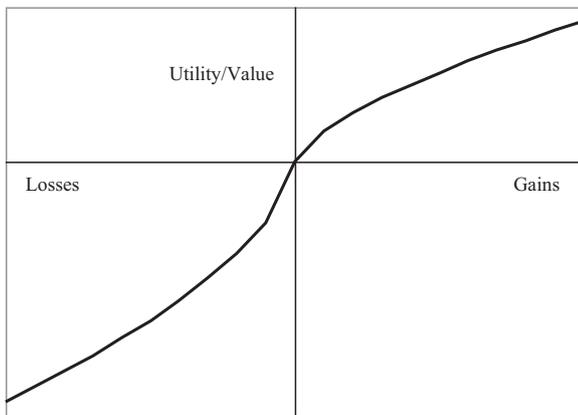


Fig. 1. An S-shaped function with loss aversion.

making decisions about gains but risk loving when making decisions about losses. Fig. 1 depicts such a function that is concave in gains but convex in losses. Although not all individuals' choices over gambles exhibit the S-shape, the S-shape is modal and therefore provides a benchmark for understanding how outcomes are valued (Luce, 2000). The S-shaped value function assumed in Prospect Theory (Kahneman and Tversky, 1979; Tversky and Kahneman, 1992) provides perhaps the best known example of a theory inspired by the empirically derived S-shape.

This paper asks two questions: Is experienced utility S-shaped? If so, what determines the reference point that separates gains from losses? The reference point is often taken to be the status quo wealth position, a natural assumption in the context of gambles with monetary gains and losses as the possible outcomes. Yet, Kahneman and Tversky (1979: 277, 286) initially acknowledged that the reference point will more generally depend on hedonic adaptation, expectations, social comparisons, or other contextual factors. Previous research has examined various candidates as factors that influence the reference point; e.g., the social utility function literature focuses on social comparisons (see Suls and Wheeler, 2000), the goal literature focuses on subjective expectations (see Pervin, 1989), and the adaptation literature focuses on past experience (see Frederick and Loewenstein, 1999). Because these factors have generally been studied separately, it is not known which are relatively more important when all are present. Even though “[t]he most basic problem of hedonic psychophysics is the determination of the level of adaptation and aspirations that separates positive from negative outcomes” (Kahneman and Tversky, 1984: 349), “[h]ow multiple reference points are integrated is an open question” (Camerer and Loewenstein, 2004: 17). This open question applies both to decision utility and experienced utility.

Our paper is an empirical one that uses unique data from a previous experimental study (McBride, 2010) to estimate the shape of the post-choice *satisfaction function* and its associated reference point. A key characteristic of these data is that they contain measures of three factors believed to affect an individual's reference point: past outcomes, expected outcomes, and outcomes of potential comparison groups. We conduct a series of non-parametric and parametric regressions to let the data reveal the underlying relationship between an outcome, reference point, and satisfaction. Many satisfaction functions, when estimated by individual, are S-shaped, though this is not the modal shape. Thus, similar to what Luce (2000) concludes with respect to decision theory value functions, the S-shape should be understood as one of the various possible shapes observed in a heterogeneous population. When pooling all individuals' observations, we find that the shape of the satisfaction function depends on the factor selected as the reference point: it is S-shaped when using the expectations and social

comparison as the reference point but is not always S-shaped when using past outcomes as the reference point. When simultaneously estimating a reference point function, we find strong evidence of an S-shape, though the evidence on loss aversion is mixed. We also find that the reference point depends on all three factors. Overall, we find strong evidence in favor of an S-shaped satisfaction function, and, as we suggest later, this evidence suggests that experienced utility and decision utility are fundamentally related even though they are conceptually distinct.

For a comprehensive treatment of the resurgent interest in experienced utility, see Kahneman et al. (1999) edited volume.<sup>5</sup> See Kahneman and Thaler (2006) for a brief and more recent discussion. Kahneman et al. (1997) provide a formal normative theory of experienced utility, which provides a useful distinction between it and decision utility. Because this work is relatively recent, it is not surprising that there have been very few studies that examine whether experienced utility is S-shaped. Galanter (1990) uses magnitude scaling to find evidence that reported feelings of hypothetical monetary losses and gains are S-shaped. Vendrik and Woltjer (2007) use reported life satisfaction as a proxy for experienced utility and the predicted income of one's social comparison group as one's reference income to find that satisfaction is concave (not S-shaped) in annual income. Layard et al. (2008) also use reported happiness to proxy for experienced utility and find happiness to be concave in income.<sup>6</sup>

Our study differs from these three last mentioned studies in important ways. While Galanter (1990) asks respondents to rate happiness associated with hypothetical monetary gains and losses, the experimental data we draw from have subjects rate an experience related to actual monetary payments. Thus, the subjects' responses more closely approximate the feeling of an actual experience, while Galanter's data are better described as representing predicted experienced utility, which is known to suffer a variety of biases (Loewenstein and Schkade, 1999; Kahneman and Thaler, 2006). The data we use also differ in that they contains multiple reference point factors, thereby allowing us to estimate how subjects calculate reference points. The survey data used by Vendrik and Woltjer (2007) and Layard et al. (2008) capture the subjectively perceived value of life experience, and their rejection of the S-shape in life satisfaction (happiness) and income survey data is an important finding in the happiness literature. However, there are reasons why we might not predict an S-shape in the life-as-a-whole context. For example, individuals with income well below that of their comparison group may be living near or below subsistence, and such individuals may be very risk averse in income instead of risk seeking. The experimental data used here are from a context much closer to the gambles setting (short time-frames, lower payments, etc.) in which are found S-shaped decision utility. That we find evidence of S-shape satisfaction in the gambles setting implies that the life-as-a-whole context contains factors that work against those that generate the S-shape. Vendrik and Woltjer also assume that the predicted income of a comparison group is the reference point, while we consider how multiple factors into a reference point. Layard, Mayraz, and Nickell do not consider reference points.

Finally, we acknowledge that experienced utility, to the extent that it is a meaningful concept, is the result of complex cognitive

<sup>5</sup> See Clark et al. (2008) for a more recent survey on the closely related research on relative income and happiness.

<sup>6</sup> Though of a different vein, interested readers may also consider Brandstätter (2000), Loewenstein et al. (1989), and Messick and Sentis (1985). Rablen (2008) defines a value function to be the difference between *ex ante* decision utility and *ex post* experienced utility, which he calibrates to an S-shape. Koszegi and Rabin (2006) provide a model of preferences that depend on a reference point.

and emotional processes, and our study looks at one particular aspect of it, namely, the immediate feeling or assessment of an actual experience and not the long-term subjective experienced utility.

## 2. Hypotheses

Drawing from the decision theory literature, we posit two immediate hypotheses about the shape of the experienced utility function to be tested with our experimental data.

**Hypothesis 1.** Experienced utility  $h(y|r)$  is S-shaped.

**Hypothesis 2.** Experienced utility  $h(y|r)$  exhibits loss aversion.

As mentioned above, the literature on reference points has identified three particular factors at work in reference point determination. The first is that individuals adapt to past payments, i.e., that higher past payments increase one's current reference point. The second is that higher payments within one's comparison group lead to an increase in one's reference point. The third is that the higher an individual's expected payment, the higher the reference point. Our third hypothesis follows.

### Hypothesis 3.

- (a) The reference point is increasing in past payment.
- (b) The reference point is increasing in comparison payment.
- (c) The reference point is increasing in expected payment.

There currently is no unifying theory of how different reference factors aggregate into a single reference point. Without any particular guidance, we here propose a benchmark hypothesis.

**Hypothesis 4.** The reference point is a weighted average of past payment, comparison payment, and expected payment.

## 3. Experimental data

This paper uses the data McBride's (2010) experiment. We provide here a brief description of the experiment and refer the reader to his original paper for more details.

After entering the experimental computer lab,<sup>7</sup> each subject sits at a computer terminal, receives verbal instructions, participates in one practice round, and participates in 25 real rounds. In each round, each subject plays the Matching Pennies game against a randomly selected computer "partner-type." There are five possible partner-types:

- 20% heads – 80% tails
- 35% heads – 65% tails
- 50% heads – 50% tails
- 65% heads – 35% tails
- 80% heads – 20% tails.

The computer reports the partner-type to the subject which informs the subject of the probability distribution used by the computer to select the opponent's coins in that round. The choice of partner-type is i.i.d. across subjects and time so that in any given round some subset of the subjects will be matched with a 20–80 type, another subset will be matched with a 35–65 type, and so on. After being told the partner-type, the subject chooses heads or tails for each of five coins, and the computer randomly and independently selects heads or tails according to the partner-type

<sup>7</sup> The experiment was conducted at the California Social Science Experimental Laboratory (CASSEL) located at UCLA.

		Computer	
		Heads	Tails
Subject	Heads	1	0
	Tails	0	1

Fig. 2. The matching pennies game.

distribution. For example, in a given round, the subject might be matched with a 35–65 partner-type, choose (heads, heads, tails, tails, tails) for its five coins, then learn that the computer randomly selected (tails, tails, heads, tails, tails) for the partner. If the subject's first coin and the computer's first coin match (either both are heads or both are tails), then the subject wins the coin, and so on for the other coins. Fig. 2 depicts the subject's payoff matrix for a single coin choice. With five coin choices, a subject can win 0, 1, 2, 3, 4, or 5 coins in any given round.

After the computer partner's choices are made, the computer reports to the subject the coin choices made by the computer and the number of coins won by the subject. The subject is also told the average number of coins won by others (not including herself) in that round by partner type; i.e., she is told the average of all those matched with a 20–80 partner-type, the average of all those matched with a 35–65 partner type, and so on.

Immediately after being told the outcome of a round (i.e., the number of coins won and, depending on the treatment, information about others' coins won), the subject is asked, "How satisfied are you with the result of this round?" The subject then reports her satisfaction on a scale of 1–7, with 1 signifying "very dissatisfied," 4 signifying "satisfied," and 7 signifying "very satisfied."<sup>8</sup> The form of this question matches the convention used in happiness and life satisfaction surveys (Schwarz and Strack, 1999). Although answers to these subjective questions suffer from various imperfections, it is widely held that these data meaningfully capture relevant aspects of happiness or satisfaction.<sup>9</sup>

After all subjects report their satisfaction levels, the next round begins. Subjects are randomly assigned a new, possibly different, partner-type. The selection of partner-types is independent across subjects. Coin choices are independent across subjects and across coins within a round for a given subject. Information on partner-types, coin choices, and payments from prior rounds remains on the computer screen. The experiment session ends after all 25 rounds have been completed. At the experiment's end, each subject was paid a \$5 show-up payment plus actual US dollars for their coins received according to an exchange rate of 8 coins for 1 dollar. The experiment used 36 subjects and lasted approximately 1 h.

<sup>8</sup> This type of question has been used to gather satisfaction or subjective well-being (i.e., happiness) data in experiments (e.g., Charness and Grosskopf, 2001) and surveys (e.g., Ferrer-i-Carbonell and Frijters, 2004). The term satisfaction is thought to entice a more cognitive response than the term happiness, which is thought to be more emotive. The income-happiness literature uses the terms interchangeably because they appear empirically equivalent (e.g., the title of Van Praag and Ferrer-i-Carbonell's (2004) book includes both terms). We suspect that the terms would yield similar results in this experiment, yet future experiments must verify that conjecture. We use satisfied in the question in the unlikely case that satisfy does prompt a more cognitive, thoughtful response.

<sup>9</sup> See Diener (1984) for an extended discussion of happiness and satisfaction questions. See Krueger and Schkade (2008) for a recent analysis of the statistical validity and interpretation of these questions.

We note that McBride's experiment was not designed to test the specific questions that we ask.<sup>10</sup> However, we argue that examining these data is a valuable undertaking. The hypotheses we seek to test could and, arguably, should, if they are general enough, find supporting evidence across multiple settings including McBride's experiment. The fact that his experiment does not generate ideal data for us does not invalidate our study; most empirical studies in economics do not use ideal data. Our paper is an empirical one that happens to use pre-existing experimental data; it is not an experimental paper. Moreover, scientific understanding is not reached via a single finding in support or in refutation of a theory and hypothesis but rather by a collection of results from many studies. Our study should be understood as one that fits within this wide net, and additional studies will, of course, be necessary for a more complete picture. Finally, though the data are not ideal, they do have many features conducive to our study, and this is why we chose to use his data. We mention four particularly important features of the data.

First, the data include multiple reference point factors—past payments, expected payments, and others' payments—thought to affect an individual's assessment of well-being. The subject's past payments and that subject's information about others' payments are displayed on the subject's monitor. The subject's expected payment can be inferred from the partner-type. If the subject acts to maximize her expected payment, she will choose all heads when paired with an 80–20 or 65–35 type, all tails when paired with a 35–65 or 20–80 type, and anything when paired with a 50–50 type. These optimal actions yield expected payments for the round of 4 against the 80–20 and 20–80 types, 3.25 against the 65–35 and 35–65 types, and 2.5 against the 50–50 type. If subjects act to maximize their expected payments, then these expected payments are valid proxies for subjects' subjectively perceived expected payments. Also note that the past payments, expected payments, and others' payments are all reported in the same units, so we can directly compare coefficients in my regressions to make specific statements about the relative magnitude of each factor's impact on satisfaction. The social comparison payment for a given subject in a given round is the average payment of all other subjects matched with the same partner-type in that round.

Second, the payment structure facilitates the interpretation of the results. The payment range is 0–5, thus yielding six possible payment outcomes, while the satisfaction rating is on a seven category scale. Because the scale and payment range are not the same, subjects will be less inclined to associate a particular monetary payment with a "natural" satisfaction report. For example, if the satisfaction scale was 0–5 like the payment range, and a subject received payment 3, she might automatically associate a payment 3 with satisfaction 3. Under this design, the satisfaction report requires more of a subjective assessment and any non-linearity in the responses can contain meaningful information.

Third, the optimal decision to maximize expected payments is a simple one. As described above, the expected payment maximizing choice depends on the partner-type, is easy for the subject to deduce, and is incentivized because outcomes correspond to take-home monetary amounts. As will be seen below, the large majority of individual coin choices do correspond to expected payment maximization, which supports our use of the expected payment to capture a subject's subjectively perceived expected payment.

Finally, the satisfaction data arising from the experiment are clearly post-choice. The satisfaction question is asked after the

outcome of the choice. Moreover, it is asked in manner designed to get at the quality of the outcome.

#### 4. Econometric methodology

##### 4.1. Econometric issues and estimation strategy

There exist various econometric methods for estimating a satisfaction function, yet there is no single best method given the constraints of the data. Three particular issues stand out. First, the dependent variable is discretely ordinal and not cardinal. Technically speaking, concavity in gains and convexity in losses are psychological conditions that can exist whether or not they are cardinally measurable (Mandler, 1999), yet we in this paper are concerned with empirically identifying such properties. As such, we must be interested in satisfaction as a cardinal property and thus must confront the limitation of having only ordinal data. Second, conducting formal statistical tests of the hypotheses requires that we impose a parametric structure on the satisfaction function, but imposing such structure limits the possible shapes that the estimated function can take. Third, previous studies find that subjective reports of satisfaction or happiness exhibit significant individual-level fixed effects due to personality or genetic traits (Ferrer-i-Carbonell and Frijters, 2004), yet adequately controlling for fixed effects is not possible in all regression frameworks. It is possible for OLS but is problematic in discrete dependent variable contexts.

Economists typically use ordered probit or ordered logit regressions when working with ordinal data. Because these regressions condition on the ordinal properties of the dependent variable by assuming an underlying latent variable function, neither their estimates nor the estimates of the underlying latent variable function have a cardinal interpretation (see Vendrik and Woltjer, 2007 and references therein). Thus, these regressions do not allow us to make statements about the shape of the satisfaction function. With this in mind, previous researchers in the economics of happiness have assumed that the ordinal response data have cardinal meaning, e.g., Vendrik and Woltjer (2007) and Layard et al. (2008). We also make this assumption.<sup>11</sup>

An argument can be made for assuming cardinality with our data. First, it makes interpretation of the results straightforward and can allow for formal statistical tests. Second, having many response categories—more than there are possible payment outcomes—suggests that any non-linearity in responses may reflect non-linearity in satisfaction. One might think that a player who receives the lowest or highest possible payment would give the lowest or highest possible satisfaction response, respectively. However, when there are more response choices than payment outcomes, any non-linearity in the reported satisfaction can be more easily manifested. Third, there is evidence that ratings scales like those in our data provide what psychophysicists call linear judgement functions. The idea is that an underlying stimulus (e.g., payment) produces a psychological sensation (e.g., level of satisfaction) that the subject must then judge for placement on the reporting scale (e.g., satisfaction report). Some research indicates that the judgement process is linear for category scales (see Marks and Algorn, 1998: 137). For our study, this implies that any

<sup>11</sup> It could be argued that Bayesian techniques can actually bridge the gap between assuming a cardinal interpretation of the dependent variable and treating it as strictly ordinal. To explore this possibility, we estimated ordered probit regressions using Bayesian methods. We discuss this methodology and results in a technical appendix that is available from the authors upon request. We note briefly here that we did find an S-shape using expected payment and comparison payment but not past payment. However, as explained in that appendix, giving the results a cardinal interpretation is problematic.

<sup>10</sup> His primary motivation was identifying which of the three factors (previous payment, comparison payment, past payment) has the largest affect on satisfaction. He did not consider the curvature of the satisfaction function.

non-linearity in responses results from non-linearity in underlying psychological satisfaction and not the actual reporting of satisfaction.

With our cardinality assumption in place, our strategy to confront the other econometric issues mentioned above is to estimate satisfaction functions under a variety of methods and assumptions and look for an emergent pattern. The basic equation of interest is

$$h_{it} = f(d_{it}) + \varepsilon_{it},$$

$$d_{it} = y_{it} - r_{it},$$

where, for subject  $i$  in round  $t$ ,  $h_{it}$  is the reported happiness,  $d_{it}$  is the difference between the monetary payment  $y_{it}$  and the reference point  $r_{it}$ , and  $\varepsilon_{it}$  is a random disturbance term. We first estimate non-parametric spline regressions at both the individual level and with pooled data. These regressions allow for maximum flexibility in functional shape while assuming a particular reference point. We then estimate two types of parametric regressions: non-linear power form regressions and fixed effects OLS regressions. The power form regressions allow for formal statistical tests and for the explicit estimation of a reference point function, but they do not account for individual fixed effects. The fixed effects OLS regressions control for fixed effects and allow for higher order polynomials, but they do not allow for explicit reference point estimation.

#### 4.2. Spline regressions

One option available to allow for a flexible functional form is a cubic spline regression. In general, splines are functional forms fit onto a sub-segment of the data. These subsegments are specified by  $k$  knot points  $\xi_1, \dots, \xi_k$ , which can be chosen *a priori*, or determined analytically through the data.<sup>12</sup> Within each subsection, separate regression parameters are estimated. For cubic smoothing splines, the functional representation is,<sup>13</sup>

$$h_{it} = \alpha_i + \beta_{11}(d_i - x_i) + \beta_{12}(d_i - x_i)^2 + \beta_{13}(d_i - x_i)^3 \quad \forall d_i \text{ s.t. } x_i < d_i < x_{i+1}. \quad (1)$$

We can estimate Eq. (1) by OLS and use linear predictions to calculate the expected satisfaction. These predictions are then plotted against the scaled payment variable to map out the shape. We also calculate and plot confidence intervals for the spline functions using the standard error of prediction based on the estimation of Eq. (1). Simply, the interval is the prediction plus or minus the 1.96 times the estimated standard error.

As with Prospect Theory, the inflection point in the satisfaction function corresponds to the reference point. Choice of the reference point is a non-trivial matter because it is a central variable for theory. This data set provides us with three possible reference points exogenously given. The first is the payment received by player  $i$  in the previous round  $t - 1$  (PREVPAY). The second is the expected payment that player  $i$  should receive based on the partner type (EPMAX). The third reference point is the average payment received by all other subjects (excluding player  $i$ ) in the round who have the same partner type (TYPEAVG). The independent variable in the spline equation is the difference of the payment

received and one of the reference points mentioned. We note that there exists the possibility that the true reference point is some weighted average of PREVPAY, EPMAX and TYPEAVG,

$$r_{it} = g_0 + g_1 \text{PREVPAY}_{it} + g_2 \text{EPMAX}_{it} + g_3 \text{TYPEAVG}_{it},$$

where the  $g$  coefficients are unknown *a priori* and can be estimated. For the spline analysis, we do not attempt to employ any unobserved weighted average as the reference point, but we do employ the weighted average for our power regressions.

#### 4.3. Power form non-linear regressions

The power form is a functional form widely used in the economics and psychology literature because multiple studies find that it well represents subjects' choices (Luce, 2000: 80). Assuming  $d_{it}$  maintains the definition given earlier, the power functional form is

$$h_{it}(d_{it}) = \begin{cases} \beta_1 d_{it}^\alpha, & d_{it} \geq 0, \\ \beta_2 (-d_{it})^\alpha, & d_{it} < 0, \end{cases} \quad (2)$$

where  $h_{it}(d_{it}) \geq 0$  if  $d_{it} \geq 0$  and  $h_{it}(d_{it}) < 0$  if  $d_{it} < 0$ .

If the function is S-shaped, then we must have

$$\beta_1 > 0, \quad (3)$$

$$\beta_2 < 0, \quad (4)$$

$$0 < \alpha < 1. \quad (5)$$

The advantage of assuming the coefficient  $\alpha$  is identical for gains and losses is that it makes testing for loss aversion very simple, i.e., we need only test that

$$|\beta_1| < |\beta_2|. \quad (6)$$

Of course, the coefficient  $\alpha$  could differ for gains and losses as discussed below.

One benefit of the power form regression is that it allows us to not only choose an exogenous reference point but to also model an unobserved reference point that is a function of PREVPAY, EPMAX and TYPEAVG. Let  $y_{it}$  be the current monetary payment define  $\hat{r}_{it}$  be the estimate of the unobserved reference point

$$\hat{r}_{it} = g_0 + g_1 y_{it-1} + g_2 \text{EPMAX}_{it} + g_3 \text{TYPEAVG}_{it}. \quad (7)$$

Dropping the  $d_{it}$  notation temporarily so that the inequality constraints can be easily represented, we can thus write the satisfaction function for  $i$  in time  $t$  as

$$h_{it} = \begin{cases} \beta_1 (y_{it} - \hat{r}_{it})^\alpha - 4, & y_{it} \geq \hat{r}_{it} (\text{PREVPAY}_{it}, \text{EPMAX}_{it}, \text{TYPEAVG}_{it}), \\ \beta_2 (\hat{r}_{it} - y_{it})^\alpha - 4, & y_{it} < \hat{r}_{it} (\text{PREVPAY}_{it}, \text{EPMAX}_{it}, \text{TYPEAVG}_{it}). \end{cases} \quad (8)$$

The minus 4 normalizes the boundary between satisfaction and satisfaction to 0. For the S-shape and loss aversion, we need conditions (4)–(7) to hold as before.

We assume that any error comes in the satisfaction directly and not through the reference point calculation. These assumptions yield the following non-linear least squares regression:

$$\hat{r}_{it} = g_0 + g_1 \text{PREVPAY}_{it} + g_2 \text{EPMAX}_{it} + g_3 \text{TYPEAVG}_{it} \quad (9)$$

$$h_{it} = \begin{cases} \beta_1 (y_{it} - \hat{r}_{it})^\alpha - 4 + \varepsilon_{it}, & y_{it} \geq \hat{r}_{it}, \\ \beta_2 (\hat{r}_{it} - y_{it})^\alpha - 4 + \varepsilon_{it}, & y_{it} < \hat{r}_{it}. \end{cases} \quad (10)$$

Notice that the power function shape (parameters  $\beta_1$ ,  $\beta_2$ , and  $\alpha$ ) are estimated simultaneously with the reference point function parameters ( $g_0$ ,  $g_1$ ,  $g_2$ , and  $g_3$ ). This fact is important because it allows the maximization procedure to identify the reference point that best matches the inflection point of the S-shape should it have an S-shape. The estimation procedure imposes some meaningful structure on the reference point by tying it to the three factors

<sup>12</sup> It is common to use percentiles or evenly spaced interval values as knot points. However, since knot point choice is not crucial to our analysis, we remain agnostic about our knot points.

<sup>13</sup> The spline representation presented here does not delve into the continuity and differentiation conditions required for the cubic smoothing spline. Briefly, these conditions require that the spline be continuous at the knot points, so as to smooth the entire curve across all the data windows.

**Table 1**  
Observations by payment and reported satisfaction.

		Payment						Total
		0	1	2	3	4	5	
Reported Satisfaction	7	0	0	1	10	47	<b>120</b>	178
	6	0	0	0	4	<b>117</b>	1	122
	5	0	0	1	38	51	0	90
	4	1	3	9	<b>96</b>	39	7	155
	3	0	4	33	58	4	0	99
	2	0	5	<b>65</b>	28	1	0	99
	1	<b>11</b>	<b>50</b>	44	15	0	1	121
Total		12	62	153	249	259	129	864
Mean		1.25	1.35	2.10	3.67	5.62	6.78	4.24
Increase in Mean			0.10	0.74	1.57	1.95	1.16	

Note: 900 observations used for Treatment C with 36 total subjects.

thought to affect judgements instead of just allowing the procedure to identify any reference point for each observation. Also note that, more in line with our understanding of reference points, this setup assumes that the reference point factors ( $PREVPAY_{it}$ ,  $EPMAX_{it}$ ,  $TYPEAVG_{it}$ ) impact satisfaction via their effects on the reference point. The factors will thus shift the entire function horizontally instead of vertically. This regression also allows for direct testing of loss aversion because we can formally test conditions (4)–(7).

We also conduct our estimation allowing the exponent term to differ for relative gains and losses, i.e.,

$$h_{it} = \begin{cases} \beta_1(y_{it} - \hat{r}_{it})^{\alpha_1} - 4 + \varepsilon_{it}, & y_{it} \geq \hat{r}_{it}, \\ \beta_2(\hat{r}_{it} - y_{it})^{\alpha_2} - 4 + \varepsilon_{it}, & y_{it} < \hat{r}_{it}. \end{cases}$$

The S-shape now arises when the following conditions hold:  $\beta_1 > 0$ ,  $\beta_2 < 0$ ,  $0 < \alpha_1 < 1$  and  $0 < \alpha_2 < 1$ . Testing for loss aversion is not as simple as checking  $|\beta_1| < |\beta_2|$  because differences in  $\alpha_1$  and  $\alpha_2$  are relevant. Instead, loss aversion requires checking the predicted happiness at each estimated point. That is, if  $\hat{h}_{it}(d)$  is the predicted happiness at point  $d$ , then loss aversion arises when

$$|\hat{h}_{it}(d)| < |\hat{h}_{it}(-d)| \quad \text{for } d > 0.$$

#### 4.4. Fixed-effects OLS regressions

Given the setup of the data, the observations include individuals who report satisfaction for multiple rounds. It is natural to suppose that there is some unobservable characteristic that affects the reported satisfaction with the outcome and that is heterogeneous across individuals. For example, some individuals playing the game may have a higher level of baseline happiness. Controlling for these individual effects (these are the fixed effects because they are assumed to not change over the course of the game play) can be accomplished through differencing, or individual dummy variable identification, which strategy we use here. We also cluster the standard errors at the level of the individual. We model our estimation as

$$h_{it} = f(d_{it}) + c_i + \varepsilon_{it},$$

using the previously defined  $d_{it}$ . The term  $c_i$  is the unobserved individual level characteristic controlled for by dummy variables. To allow for the emergence of an S-shaped satisfaction function, we

approximate the function  $f(d_{it})$  in the fixed-effects OLS model with polynomial expansions of orders one, three, and five<sup>14</sup>:

Order 1:  $f(d_{it}) = \beta_1 d_{it}$

Order 3:  $f(d_{it}) = \beta_1 d_{it} + \beta_2 d_{it}^2 + \beta_3 d_{it}^3$

Order 5:  $f(d_{it}) = \beta_1 d_{it} + \beta_2 d_{it}^2 + \beta_3 d_{it}^3 + \beta_4 d_{it}^4 + \beta_5 d_{it}^5$ .

The polynomial expansions capture any higher order curvature in reported satisfaction. The order one expansion is included in the analysis for comparison purposes with the order 3 and order 5 expansions.

## 5. Results

### 5.1. Summary statistics

Table 1 summarizes the payment and reported satisfaction data. Each cell in the table displays the number of subjects who reported the satisfaction level of the vertical axis when receiving the payment amount on the horizontal axis. The mean reported satisfaction, reported below each payment–satisfaction combination in the table, increases as the payment increases. The modal reported satisfaction for each payment amount (boxed) is also (weakly) increasing in payment. A cursory glance at both the mean and modal reported satisfaction suggests an S-shape because the reported satisfaction in either case increases at an accelerating rate at lower payments and that rate decreases at higher payment levels. A similar S-shape is found in the plotted figures in Fig. 3. Fig. 3(a) plots the average reported satisfaction by payment level, and Fig. 3(b)–(d) plots the average reported satisfaction by payment level using the three different reference point factors, respectively.

Table 2 presents evidence on the validity of the EPMAX measure. Roughly 90% of all coin choices are consistent with the assumption that subjects acted to maximize their expected payoffs. The percentage of times that a subject’s five-coin decision in a round matches expected payment maximization is much lower, probably a reflection of a misunderstanding of independence. However, the large majority are consistent, thus suggesting that the expected payment proxy is a valid proxy of a subject’s actual expected payment.

<sup>14</sup> We estimated polynomial expansions of orders two and four as well, to check the sensitivity of the results. A polynomial of Order 2 constrains the functional form from exhibiting an S shape, and was left out. The Order 4 coefficient for each reference point was not statistically significant.

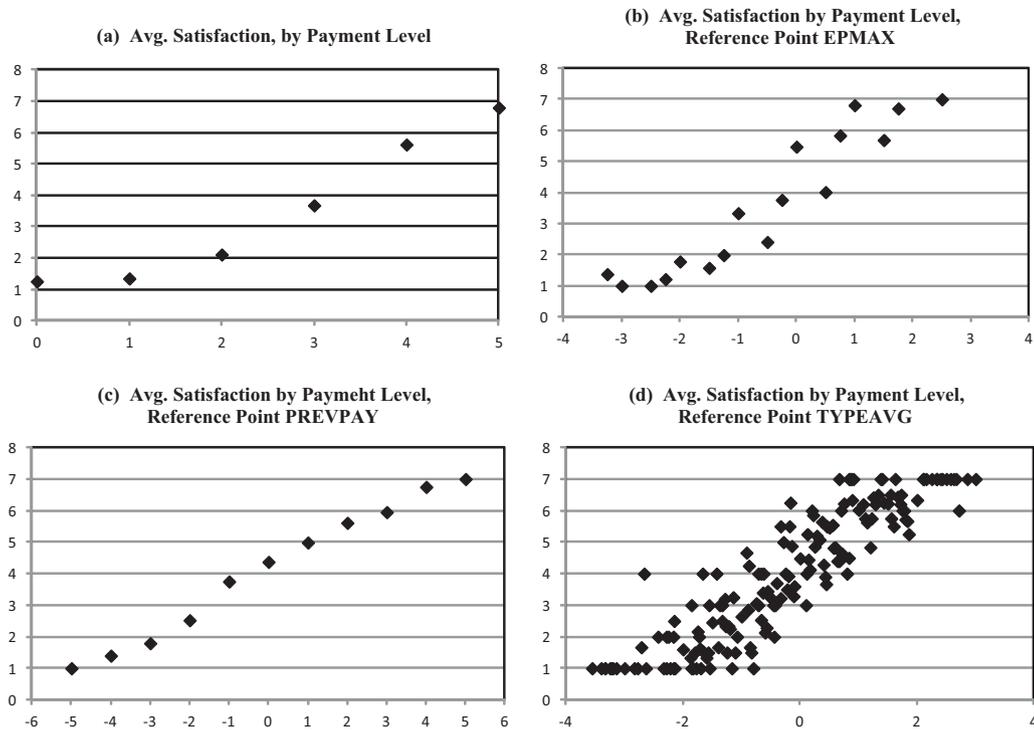


Fig. 3. Average satisfaction by payment level.

Table 2

Percent of decisions consistent with expected payoff maximization.

	Percent of coin choices consistent with expected payoff maximization	Percent of subject-rounds in which all five coin choices consistent with expected payoff maximization	Percent of subjects who always chose consistently with expected payoff maximization
Pooled	93%	73%	25%
Expected payment 2.5	100%	100%	100%
Expected payment 3.25	86%	58%	25%
Expected payment 4.0	94%	78%	53%

Note: 900 observations used for Treatment C with 36 total subjects.

5.2. Non-parametric regression results

We first use non-parametric spline techniques to estimate three satisfaction functions for each individual, one for each of the three reference factors. Visual inspection then allows us to classify each function as either S-shaped, linear, convex, concave, with multiple inflection points, or other; formal statistical tests are not possible due to the flexible estimation structure. Table 3 summarizes what we observed. The S-shape is the modal shape when using the previous payment as the reference points: 13 out of 36 individual functions show the S-shape, 9 exhibit multiple inflections, 7

are linear, and so on. The S-shape is not modal when using the expected payment (only 7 out of 36) or comparison payment (only 9 out of 26) as the reference point; however, the S-shape does appear frequently. Moreover, we note that this classification is fairly strict. We have 25 observations per individual, and with more observations per individual, we suspect that some of those functions classified as multiple inflection, which comprise the largest category, would likely become S-shaped as the function's smoothness would increase.

Fig. 4(a)–(c) plots the satisfaction functions and 95% confidence intervals estimated via non-parametric splines when pooling

Table 3

Number of subjects by estimated nonparametric function shape.

Reference point	S	Multiple inflections	Linear	Concave	Convex	Other	Total
Previous payment							
Number of subjects	13	9	7	3	1	3	36
Percent of subjects	36%	25%	19%	8%	3%	8%	
Expected payment							
Number of subjects	7	14	0	9	6	0	36
Percent of subjects	19%	39%	0%	25%	17%	0%	
Comparison payment							
Number of subjects	9	13	9	1	2	2	36
Percent of subjects	25%	36%	25%	3%	6%	6%	

Note: Results obtained from cubic spline regressions with five knots.

**Table 4**  
Power form non-linear regression results.

	(1)	(2)
Reference point function		
$g_0$ (constant)	2.66** (0.11)	2.81** (0.11)
$g_1$ (previous payment)	-0.04** (0.01)	-0.03** (0.01)
$g_2$ (expected payment)	0.07* (0.03)	0.04 (0.03)
$g_3$ (comparison payment')	0.10** (0.03)	0.07** (0.03)
Power form function		
$\alpha$ (exponent)	0.61** (0.04)	-
$\alpha_1$ (gain exponent)	-	0.73** (0.07)
$\alpha_2$ (loss exponent)	-	0.48** (0.07)
$\beta_1$ (gain coefficient)	1.87** (0.05)	1.74** (0.07)
$\beta_2$ (loss coefficient)	-1.71** (0.06)	-1.84** (0.08)
Observations	864	864
Adjusted $R^2$	0.75	0.75
W-test: $\beta_1 = -\beta_2$	2.87*	0.52
Test: $\alpha_1 = \alpha_2$	-	5.20*
Joint test: $\beta_1 = -\beta_2, \alpha_1 = \alpha_2$	-	7.81*
Test: $g_0 = 0$	514.85**	665.31**
Test: $g_1 = g_2 = g_3 = 0$	25.42**	9.56*
Test: $g_0 = 0, g_1 + g_2 + g_3 = 1$	525.35**	665.36**

Note: The dependent variable in each regression was reported satisfaction. Each regression used the last 24 rounds of the experiment session. Standard errors are listed in parentheses.

\* Significance at 5% level.

\*\* Significance at 1% level.

the data. Each estimated function used a different one of the three candidate reference points. When using expected payment or comparison payment as the reference point, we find clear evidence of the S-shape. It is not S-shaped when using previous payment; it is fairly linear but slightly concave. That the individual functions with previous payment are frequently S-shaped but the pooled function is nearly linear means that the individual-level non-linearities are cancelled out in the pooled regression. We do not have a compelling explanation for this. However, if the reference point depends on all three factors, then the S-shape may best represent the data overall given its frequent appearance.

5.3. Power form results

Table 4 presents results from two non-linear least squares regressions that estimate coefficients of a power form. Regression 1 assumes that the exponent is the same regardless of whether or not the payment is larger than the reference point. Regression 2 allows for the exponent term to be different, depending on whether or not the payment is larger than the reference point. Fig. 5 displays the two regressions graphically.

To test the first hypothesis (S-shape), we look at exponent coefficient  $\alpha$ . A value for the exponent term bounded by zero and one produces an S-shape, though values approaching unity force linearity on the shape. Regression 1 yields  $\alpha = 0.61$ , which is statistically significant, confirming an S-shape. Regression 2 allows the exponent to differ for relative gains and losses. When the payment is greater than the reference point, the estimate  $\alpha_1$  is 0.73 and is statistically significant. When the payment is less than the reference point, the estimate of  $\alpha_2$  is 0.48 and is also statistically significant. All estimates confirm the S-shape. We reject the hypothesis that

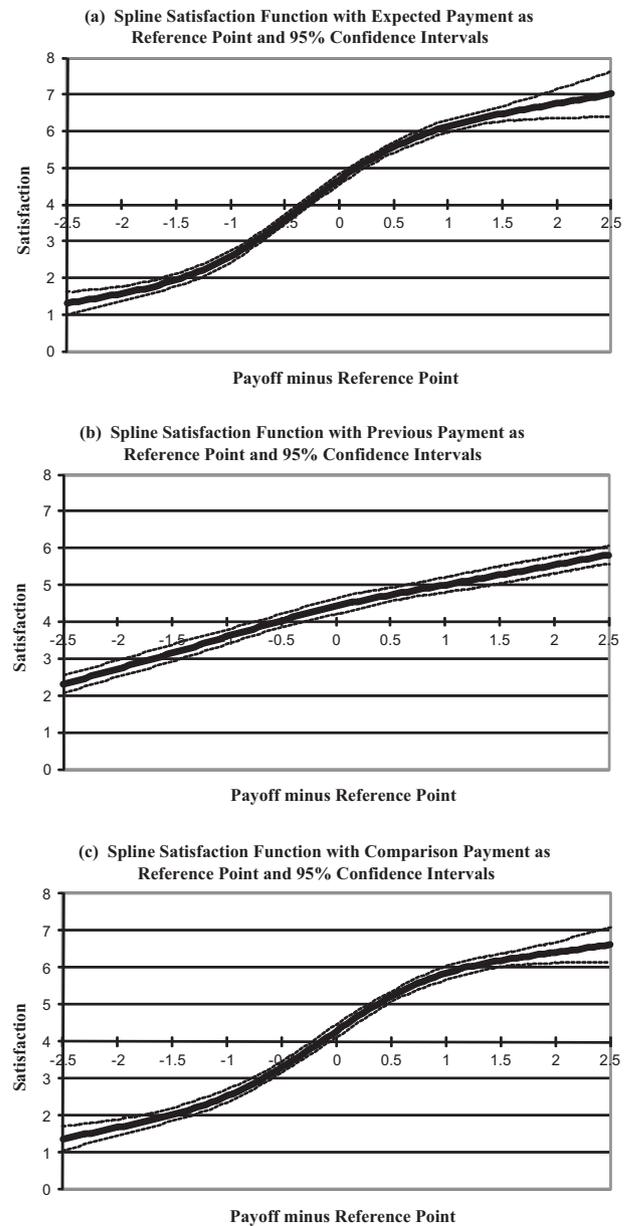


Fig. 4. Spline satisfaction functions.

$\alpha_1 = \alpha_2$  at the 5% level; the concavity in relative gains is not as sharp as that for relative losses. Fig. 5 clearly illustrates the S-shape.

For the second hypothesis (loss aversion), we test the equivalence of  $\beta_1$  and  $\beta_2$  in regression 1. If  $\beta_1 = \beta_2$  in regression 1, then a one unit loss relative to the reference point has the same magnitude change in utility as a one unit gain. Loss aversion requires that a change in satisfaction be larger for losses than for gains. We find, under the assumption of a common value of  $\alpha$ , that  $\beta_1$  differs statistically from  $\beta_2$ , yet, the difference is not in the direction as expected. Loss aversion would imply  $|\beta_1| < |\beta_2|$  in regression 1, but we find  $|\beta_1| > |\beta_2|$ , though the level of statistical significance is not high. When estimating separate  $\alpha$ 's in regression 2, we do find  $|\beta_1| < |\beta_2|$ , however we must now consider the different exponent estimates  $\alpha_1$  and  $\alpha_2$  when checking for loss aversion. A visual inspection of the regression 2 in Fig. 4 shows that there is not loss aversion for small gains or losses but that there is loss aversion for larger gains and losses. Thus, evidence of loss aversion is mixed.

For the third hypothesis (reference point effects), we consider the coefficients  $g_0, g_1, g_2,$  and  $g_3$  estimated for the reference point function. In both regressions, we find significant evidence that the three coefficients on the reference point factors ( $g_1, g_2,$  and  $g_3$ ) are jointly significant. Consistent with Hypothesis 3, the expected payment and comparison payment have statistically significant positive effects on the reference point in the first regression. Both work the same direction in the second regression, though the effect of an increase in comparison payment is now not statistically significant. Contrary to the hypothesis, the previous payment has a negative effect on the reference point. Larger values in the previous round reduce the perceived reference point. As explained by McBride (2010), this could be due to a short-term positive glow effect from receiving a high payment that lasts into the next round. In words, a subject who receives a high payment in round  $t$  might have a temporary happy feeling that lasts into the next round.

To test the fourth hypothesis (weighted reference point factors), we test if  $g_0 = 0$  and  $g_1 + g_2 + g_3 = 1$ . The  $F$ -statistics in the last row of Table 4 strongly reject this hypothesis even at the 1% level in each regression. The reference point is not a simple weighted average of the three reference point factors. Instead, there is a large fixed component. Moreover, the expected payment and comparison payments have a much larger impact than the previous payment which, as mentioned above, works in an opposite direction.

5.4. Fixed-effect OLS regression results

Table 5 displays the results of various fixed-effects OLS regressions: three order 1 polynomial regressions, three order 3 polynomial regressions, and three order 5 polynomial regressions. For each order, we estimated a regression using each different reference point factor as the reference point. Various test statistics are reported at the bottom of the table. Consider the order 3 regressions. For the expected payment and comparison payment reference points, the coefficients for each polynomial order are significant, confirming the need for higher order polynomials. In contrast, the order 3 coefficient for the previous payment reference point is not significant at the 10% level. However, when tested jointly with the second order coefficient, the null hypothesis is

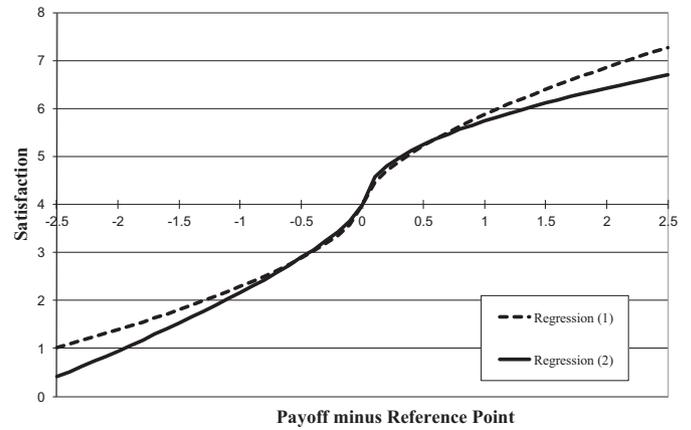


Fig. 5. Power regression function.

rejected and the order 3 specification should be included. Under previous payment and comparison payment reference points, the order 5 regressions do not show significant order 4 coefficients, even when order 5 effects appear to be marginally significant, but there are such effects under previous payment. For the order 5 regressions, we conduct two joint tests: the first to test the restrictions on the order 4 and 5 coefficients, while the second is the joint significance test on all regression coefficients. We find that under previous payment and comparison payment reference points, the coefficients for orders 4 and 5 are jointly insignificant, indicating that an order 3 polynomial model would be sufficient to capture the curvature, though the order 5 polynomial specification is necessary when previous payment is used as the reference point.

Fig. 6 plots the estimated satisfaction function for each of these regressions. We see the clear S-shape under expected payment and comparison payment. The higher order curvature estimated in the polynomial regressions produce S-shapes as predicted in these cases. The S-shape does not appear under previous payment; instead it is a mirrored S-shape with concavity in losses and convexity in gains.

Table 5  
Fixed-effects OLS polynomial regression results by reference point.

Reference point	Order 1 polynomial			Order 3 polynomial			Order 5 polynomial		
	Exp. payment	Comp. payment	Prev. payment	Exp. payment	Comp. payment	Prev. payment	Exp. payment	Comp. payment	Prev. payment
Constant	4.49*** (0.013)	4.24*** (0.0000)	4.23*** (0.00004)	4.59*** (0.042)	4.28*** (0.036)	4.33*** (0.047)	4.62*** (0.071)	4.29*** (0.065)	4.43*** (0.069)
Payment – Reference Point	1.49*** (0.007)	1.33*** (0.066)	0.70*** (0.034)	1.87*** (0.095)	1.63*** (0.099)	0.72*** (0.055)	1.97*** (0.140)	1.77*** (0.146)	0.67*** (0.063)
(Payment – Reference Point) <sup>2</sup>	– (0.042)	– (0.029)	– (0.017)	–0.13*** (0.013)	–0.06** (0.082)	–0.032* (0.039)	–0.21* (0.016)	–0.08 (0.010)	–0.11*** (0.002)
(Payment – Reference Point) <sup>3</sup>	– (0.021)	– (0.015)	– (0.004)	–0.13*** (0.053)	–0.08*** (0.058)	–0.001 (0.014)	–0.20*** (0.005)	–0.17*** (0.005)	0.01 (0.0006)
(Payment – Reference Point) <sup>4</sup>	–	–	–	–	–	–	0.02 (0.016)	0.01 (0.010)	0.005*** (0.002)
(Payment – Reference Point) <sup>5</sup>	–	–	–	–	–	–	0.01* (0.005)	0.01* (0.005)	–0.006 (0.0006)
Observations	900	900	864	900	900	864	900	900	864
R <sup>2</sup>	0.61	0.56	0.33	0.63	0.57	0.33	0.63	0.58	0.33
Test: all coefficients = 0	370***	405***	422***	182***	220***	169***	162***	144***	237***
Test: $\beta_2 = \beta_3 = 0$	–	–	–	21.01***	15.98***	2.54*	–	–	–
Test: $\beta_4 = \beta_5 = 0$	–	–	–	–	–	–	1.71	2.10	5.92***

Note: The dependent variable in each regression was reported satisfaction. Robust standard errors clustered by individual are listed in parentheses.

\* Significance at 10% level.  
 \*\* Significance at 5% level.  
 \*\*\* Significance at 1% level.

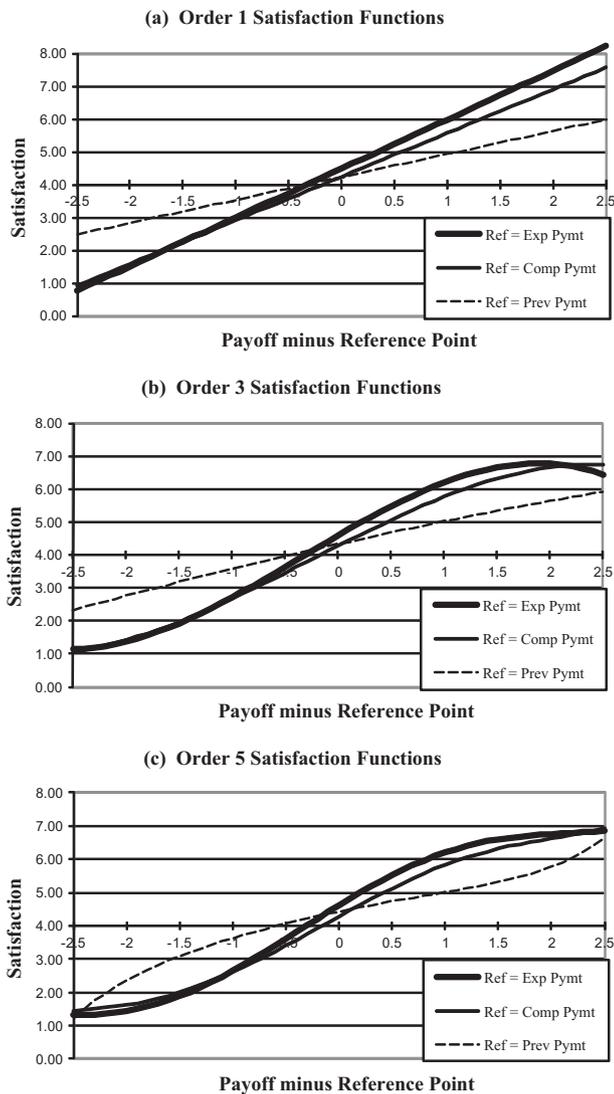


Fig. 6. Fixed-effects OLS polynomial satisfaction functions.

To assess the robustness of this result, we partitioned the data into two subsamples. The first subsample included all subject-rounds in which the subject choose all five coins consistent with expected payoff maximization, while the second subsample included subject-rounds in which the subject did not act consistently with expected payoff maximization.<sup>15</sup> We find a much stronger S-shape in the first sample when using expected payment and comparison payment as the reference point (results not shown). We cannot be sure why this specific pattern is found, yet there is an interpretation consistent with our overall emerging picture. Subjects who act consistently with expected payoff maximization have more accurate expectations about their payoffs, and the expected payoff maximization and comparison payment reference point factors would more accurately reflect those subjects' self-perceived reference point. If true, then the second subsample underestimates the S-shape that exists in those subjects' actual satisfaction functions. This interpretation lends added credence

to the overall conclusion that subjects have S-shaped satisfaction functions. It also suggests that a different experiment design in which a more accurate measure expectations were obtained for all subjects would yield a sharper S-shape. Such could be the case, for example, if the subjects did not choose their coins but instead were just given the outcome of the lottery.

### 5.5. Discussion

Consistent with Hypothesis 1, we find an emerging pattern from our empirical analysis that satisfaction is well-represented by an S-shaped satisfaction function. This is true especially when using expected payment or comparison payment as reference point; it is less true when using previous payment as the reference point. When estimating a reference point function in our power regressions, we find that expected payment and comparison payment have the anticipated effects on reference points but previous payment does not. Thus, two out of the three parts of Hypothesis 3 are verified. Hypothesis 4 is rejected: the reference point is increasing faster in expected payment and comparison payment than it is decreasing in previous payment. How to assess Hypothesis 4 is less clear because the evidence of loss aversion is mixed. Overall, however, the S-shape fits the data well in most of our regressions.

Why do we find the S-shape? One possible two-part explanation goes as follows. First, decision utility and experienced utility are fundamentally related via underlying psychophysical processes as suggested in Section 2. Second, the differences that do exist between decision utility and experienced utility increase in prominence as the time between the decision and the reporting of the experience. Because the time between the making of a decision and the reporting of satisfaction in the experimental data is fairly short (usually a matter of seconds), any difference between decision utility and experienced utility would be minimized. This conjecture could be tested by running additional experiments that vary the length of time between the decision and satisfaction report.

This logic situates our paper somewhere between empirical estimations of the decision utility functions on one end of the spectrum and Vendrik and Woltjer's (2007) and Layard et al.'s (2008) results on the other end. Decision utility is derived from observed decisions. Life satisfaction, on the other hand, is a reflective assessment of one's overall life situation and reflects the outcomes of a large number of life decisions (e.g., whether or not to go to college, accept a job offer, marry, etc.). That the cited studies found a concave (not S-shaped) life satisfaction function would thus reflect a difference between decision utility and experienced utility that arises over time in the context of the reflective life satisfaction question. The satisfaction with an experiment payment in McBride's data is much closer to the actual decision made. Any indirect linkage, psychophysical or not, between decision and experienced utility would be stronger in our setting.

Why is the evidence for loss aversion mixed? One possibility is that the distribution of realized payments is heavily skewed, with the mean payment 3.24 much closer to the highest possible payment 5 than the lowest possible payment 0. Suppose that 3.24 best represents the reference point, that a subject who receives a payment of 5 achieves her highest possible satisfaction and would report satisfaction 7, and that a subject who receives a payment of 0 achieves her lowest satisfaction and would report satisfaction 1. Then a relative gain of 1.76 (equals  $5 - 3.24$ ) yields an increase in satisfaction of 3 (from 7 to 4), while a relative loss of  $-3.24$  (equals  $0 - 3.24$ ) yields a change in satisfaction of  $-3$  (from 1 to 4). Having reference points closer to the highest possible category implies a smaller range of relative gains which, according to the interpretation of the reporting scale, are spread over a larger reporting

<sup>15</sup> Any coin choice by a subject matched with a 50–50 partner-type is consistent with expected payoff maximization, and there is no way to separately identify the subjects matched with 50–50 partners who were actively trying to maximize expected payoffs from those who were not. For this reason, we took a conservative approach and included them in the second subsample.

range. This leads to a steeper function in gains than losses not due to psychophysical processes but due to distribution of payments.

## 6. Conclusion

This paper uses various econometric techniques to estimate experimental subjects' reported satisfaction functions. We find strong evidence that an S-shape best represents subjects' satisfaction responses, and we suggest that this shape could arise from psychophysical processes similar to those that generate S-shaped decision utility. We do not find compelling evidence of loss aversion, but we do find a role for various factors in the formation of subjects' reference points. Expected payments and comparison payments work to raise reference points as predicted but previous payments do not.

Future work has many avenues to pursue in building on this work. One direction is to explicitly account for time in a subjects' satisfaction function: How does the shape of experienced utility change over time? Do people become less sensitive to comparisons or expectations? Another direction is to further examine how reference points are determined: Which other reference point factors should be considered in a theory of reference point determination? A competing theory called range-frequency explicitly incorporates the properties of the distribution of stimuli into its account of how subjects rate those stimuli. Future work should compare the range-frequency theory with the theory presented here to determine which better fits the data. Work along these lines will yield a more complete understanding of how people subjectively experience the outcomes of their many economic decisions.

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