The predictive capabilites of the ITCH-model: Experimental evidence of model fit with perceived losses

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Abstract

In this paper we try to examine the ability of a particular heuristic model (ITCH model) in predicting intertemporal decisions with perceived losses. We performed a survey with four treatments and 16 MEL questions were presented to 50 individuals. Results shown that the ITCH model predictions are as good for losses and gains and outperform the traditional discounting models. However, there is no clear difference in predictive accuracy between ITCH and Hyperbolic models. Additionally, in the results presented there is no evidence of hyperbolic discounting in the ITCH model.

Introduction

In the recent decades substantial research has been devoted to model situations where economic agents are faced with decisions of allocation of resources over time. The research has shown that decisions depend on several aspects which are not addressed in Expected Utility Theory (Thaler 1981; Rabin and Thaler 2001; Rubinstein 1988). Literature within the field of experimental economics' provides evidence that exponential discounting and traditional utility-maximizing reasoning does not fully explain intertemporal choices (Gintis 2000; Estle et al. 2006).

Empirical research have identified several effects that appear to influence agents' decision process. One of the effects that has been found is that the subjects' perception of whether the decision is between gains or losses seem to have an effect on how the subject discount the allocations, i.e. the gain-loss-asymmetry, and to have a significant impact on the decision (Kahneman and Tversky 1984). Furthermore, some experiments have found that the decision depends on how the question is phrased, more precisely the order of the options presented. When subjects are faced with choosing between the two timings of allocations t or $t+s$ compared to subjects that have to choose between $t+s$ or t, even though the difference is the same, the subjects express different preferences in the two settings, also known as the Speedup-Delay effect. Additionally, the absolute amount involved in the decision seems to have an effect on the discount rate, this is often referred to as the absolute magnitude effect. Larger absolute amounts seem to suffer less proportional discounting (Loewenstein and Prelec 1992). One last departure from the traditional models is the Common Difference effects, in which a time difference t might have a different effect when the subjects is faced with decision *today plus time* t compared to *one year in the future plus time* t.

Loewenstein and Prelec have proposed a theoretical model to address these issues, their proposal was to assume that intertemporal choices are defined as deviations from a consumption

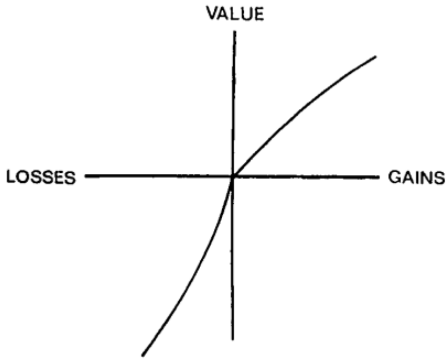

Figure 1: Original figure of loss aversion, published at "Prospect Theory: An Analysis of Decision under Risk" (Kahneman and Tversky 1984)

benchmark (Loewenstein and Prelec 1992). On a broader basis, either single or multiple reference points can play a central role in tradeoff models of allocations (Scholten and Read 2010).

This paper's objective is to look closer at gain-loss asymmetries in intertemporal decisions. Kahneman and Tversky first investigated the psychological and cognitive explanations (Kahneman and Tversky 1984) to later propose a reference dependent model which, supported by empirical evidence, assumes that losses have a greater impact in preferences than gains (Tversky and Kahneman 1991). The proposed explanation was that those differences were due to loss aversion and mental accounting (Thaler et al. 1997). The former stands for the higher aversion when lotteries are framed in losses rather than in gains, and the latter refers to the period of time the agent takes as reference to evaluate the outcome of the investment.

Neuroeconomics has also contributed to enlighten the field of intertemporal choices. This research field has provided evidence that legitimizes more subjective discount-models (Kable and Glimcher 2007) and higher risk aversion when decisions concerns losses (Tom et al. 2007). Furthermore, evidence shows that in repeated choices the history of outcomes matters: agents seem to take riskier decisions after having experienced higher losses (Gehring and Willoughby 2002).

Therefore, empirical evidence shows the necessity of finding new methods to predict agents' behavior in intertemporal choices. Neither the classical Expected Utility Theory, the broadly used Hyperbolic or Quasi-Hyperbolic models seem to be optimal to predict subjects' behavior (Abdellaoui, Attema, and Bleichrodt 2010). In the attempt to identify the drawbacks of the Hyperbolic discounting model, the Decreasing Impatience (DI) model was introduced (Prelec 2004). This perspective recognizes that agents would be willing to initially employ costly commitment devices to ensure the realization of the desired outcome in a later stage.

Taking into account the shortcomings of these models, several heuristic models have been proposed that better suit the empirical findings. Heuristic models are an alternative approach to explain intertemporal decisions in which the decision is based on simple rules that compare alternative choices. Several heuristic models have been proposed and have shown promising abilities to explain intertemporal choices, among others the Difference-ratio-interest-finance-time (DRIFT) model (Read, Frederick, and Sholten 2013) and the Intertemporal Choice Heuristic (ITCH) model (Marzilli et al. 2015). The latter model structures the agents' decision process on simple computations involving the absolute and relative difference in time and money of allocation options. In fact, this psychological approach acknowledges that individuals employ a weighted multifactor comparison in *Money-earlier-or-later* (MEL) decisions. This model has achieved a higher explanatory power of individual choices than the currently used models as shown in (Marzilli et al. 2015).

The previous authors focused on settings in which the agents had to choose to receive different amounts of money. Oppositely, the purpose of this article is to test the performance of the model when the agent is faced with perceived losses options. The ITCH-model can be expressed in the following way:

$$P(LL) = \Lambda\left(\beta_I + \beta_{xA}(x_2 - x_1) + \beta_{xR}\frac{x_2 - x_1}{x*} + \beta_{tA}(t_2 - t_1) + \beta_{tR}\frac{t_2 - t_1}{t*}\right)$$

Where Λ is the cumulative logistic distribution function. The estimated function takes on the value 1 when it predicts that the later and larger (LL) option is chosen and 0 when it predicts that the earlier option is chosen. The subindex R and A stand for "Relative" and "Absolute", x and t refers to money and time and *1* and *2* for the earlier and latter option, accordingly. Finally, (x*, t*) represent the arithmetic average of the two options ($x* = (x_1 + x_2)/2$, $t* = (t_1 + t_2)/2$) and can be thought as a reference point.

Within the heuristic framework a more in-depth study allows to identify several classes of models (Eduard Brandstätter and Hertwig 2006). Though, only the lexicographic approach is supported by empirical evidence in choices under uncertainty. One specific type of ordered decision process is the priority heuristic which describes risk aversion with gains and losses when probabilities are high and low respectively, and risk seeking with low chances of gains and high chances of losses.

To compare the different models we used cross-validation, a contemporary statistical method of comparing different models (Kohavi 1995). Cross-validation is an unbiased out-of-sample technique in which a fraction of the data is used for training and the remaining data is used to test the estimated models predictive capabilities. Compared to others testing methods within a sample using standard measures of fit, the cross validation gives us a more reliable instrument of comparison.

Experiment design

The experiment was originally designed in *oTree* (Chen, Schonger, and Wickens 2016)[1] [2] with random assignment for the 4 different treatments, but due to technical issues the survey was performed through 4 different Google Forms[3], one for each treatment. The surveys were sent to friends and families, and responses from 50 subjects [4] were collected.

The questions in the surveys were whether the subjects preferred some amount of money at one point in time or a larger amount at a later point in time. There were 16 questions with different amounts of money and points of time (available in Appendix 1). To ensure that the responses were unaffected by the order of the questions, the sequence of questions was randomized.

The experiment involved four different treatments across subjects:

[1]The code can be accessible through this URL: https://git.io/vbjga

[2]We acknowledge Li Yutong for her help in the programing of the Otree experiment and for providing her code on the balanced randomization of treatments.

[3]https://www.google.com/forms/about/

[4]Descriptive statistics of the sample can be found in Appendix 3

- Gain-Delay
- Gain-Speedup
- Loss-Delay
- Loss-Speedup

One independent survey was displayed for each treatment. The pivotal difference between treatments was whether the subject perceived to be dealing with a situation of loss or gain. The subjects faced gain-framed questions to investigate whether the results from (Marzilli et al. 2015) could be reproduced.

The questions that involved gains were formulated as traditional MEL tasks. The treatment in which subjects faced a perceived loss was employed to investigate if the ITCH-model is able to predict the subject's behavior when losses are involved. In order to examine potential loss-aversion in the subjects, an initial endowment was provided. Given this endowment the subjects could face a greater loss in closer proximity in time or a smaller loss at a future time. Subjects' final payoffs were equivalent for both gains and losses treatments, the only difference was the framing of the question.

Both main treatments (gains and losses) were also differentiated in whether the later and higher amount was given as the first option or latter option (speedup and delay framing, accordingly). The purpose of this distinction was to account for the significant effect it caused in previous ITCH estimation results (Marzilli et al. 2015) [5].

To incentivize truthful responses participants knew that a random subject and answer would be drawn, this subject would receive the amount at the point of time that the subject chose in the selected question. The intent was to render each answer potentially payoff relevant and to incentivize agents to consider each option carefully. Therefore, the strategy method was employed to elicit agents' preferences in each possible scenario.

Data processing and results

To investigate the explanatory abilities of the model we used a Logit regression in which the outcome variable was 1 if the larger and later option was chosen and 0 if not. The ITCH-model represented earlier was used, the values we used in our questions for absolute time and amount and relative time and amount can be found in Appendix 2.

A comparison of the models was carried using cross-validation [6]. This approach allows to obtain real out-of-sample error statistics from each model. Using this out-of-sample approach we are able to compare the different models. First, a total of 100 estimations was performed for each model on a random section of 75% of the sample and then the remaining 25% of the sample was used for predictions. Finally, the absolute error of all the estimated predictions of each model was calculated. The mean absolute error is illustrated in Figure 2.

[5] From Marzilli et al. 2015 data and estimation method it can be calculated that β_{xR} is significantly lower and β_I is significantly higher for speedup framing if we compare to delay framing. Finally, there was not such difference in our results.

[6] The full R code is available in: https://git.io/vNfB8. We would like to thank the authors of (Marzilli et al. 2015) for making their code and data publicly available (https://git.io/vNfS5) which allowed us to fully analyze their research and to use part of it as a basis for our code.

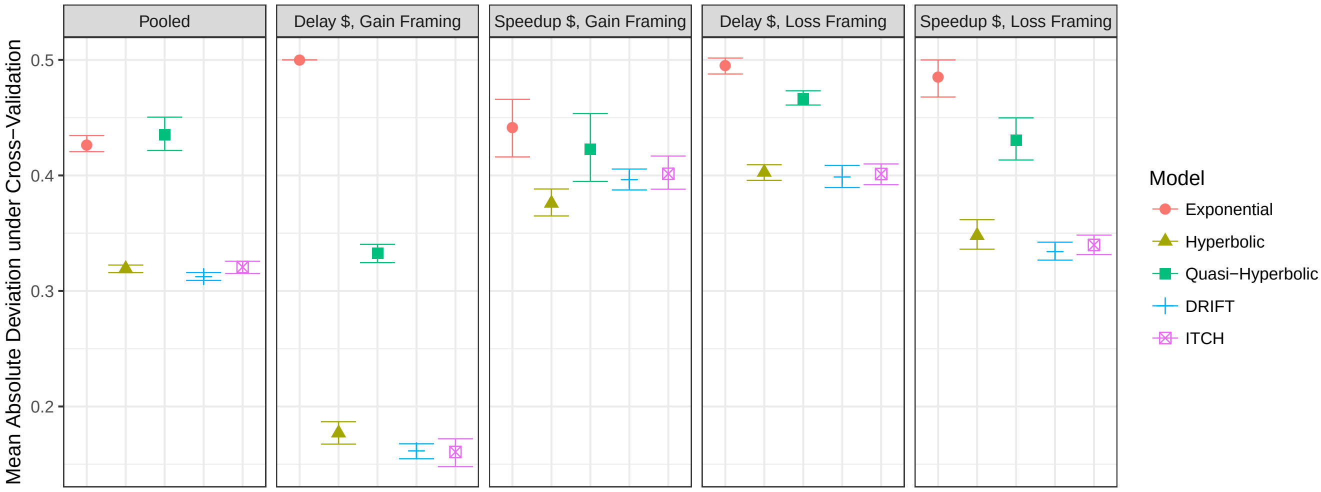

Figure 2: Predictive accuracy relevant models and treatments in terms of out-of-sample Mean Absolute Deviation. The bars illustrate the 95% confidence interval of the cross-validated errors. All models mathematical definitions can be found at Appendix 4.

The ITCH model performed better in all framings in predicting the choices of the subjects compared to the exponential model. However, it was found that the Hyperbolic model performed far better than in Marzilli et al. paper (Marzilli et al. 2015). Furthermore, the DRIFT and hyperbolic models performed better in our sample. Our results, contrary to the ones obtained by Marzilli et al., lead to the conclusion that the hyperbolic and DRIFT models performs just as well as the ITCH-model and, in some framings, even better.

For the delay gain framing results shown that the mean absolute deviation of the ITCH model is as low as 0.15. The other framings seem to have a similar deviations that is between 0.34 and 0.4. On the one hand, in the speedup treatment the ITCH predicts better the decisions with the perceived loss. On the other hand, in the delay treatment the ITCH gives a better prediction in the gains treatment. Therefore, there is no clear difference between the models' ability to predict losses or gains. This might also be caused by the small variance in the fairly limited number of questions asked and the reduced sample size.

Figure 3 illustrates the estimated parameters for the ITCH model. Presumably, an increase in the absolute and relative difference between the two amounts increases the probability of choosing the latter option, and an increase in the relative and absolute time decreases the probability of choosing the latter option. The intercept coefficient can be interpreted as treatment-specific effects on the probability.

Estimated parameters of the different treatments are similar to each other, whereas the Gain-Delay treatment deviates from the others in some of the estimated parameters. As above, there is not a clear difference between the two main treatments: perceived loss and gain. This could mean that the ITCH model fits well to actual intertemporal decisions regardless of whether there are perceived losses or gains. However, this could also be caused by our relatively small sample, such that potential differences in the parameters in different framings are not revealed.

Using the pooled data as an example we can say that β_{xA} being positive, as in our results, is interpreted as the Absolute Magnitude Effect, that can be produced by a concave utility

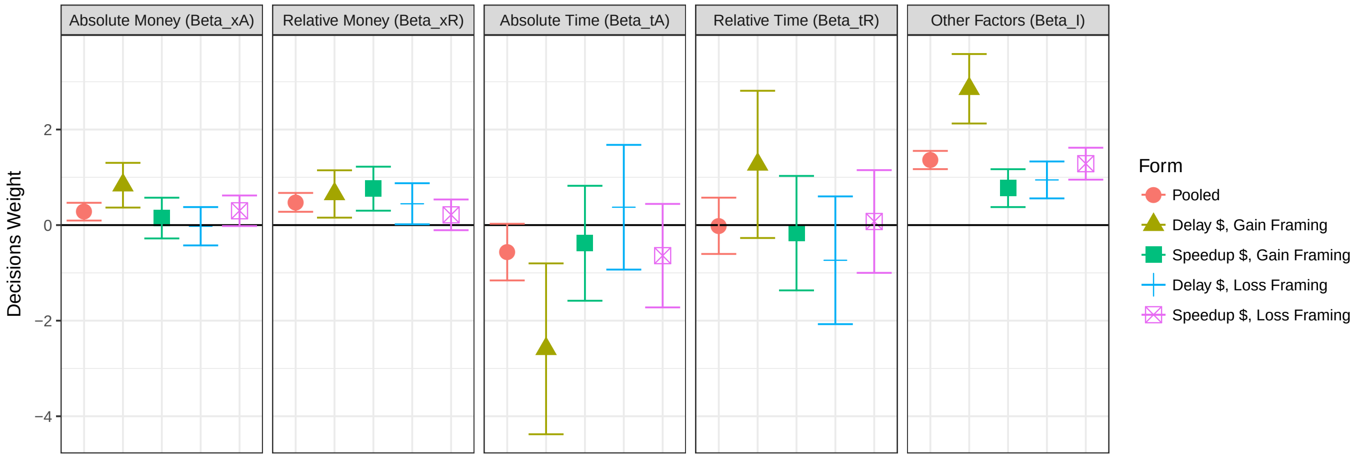

Figure 3: Estimated coefficients or weights for the ITCH model with their 95-percent confidence interval. One for each experimental condition and one estimated with the pooled data from all conditions.

function. Given that relative time decreases with a delay in both t_1 and t_2 a negative β_{tR} could be interpreted as the effect of decreasing impatience or hyperbolic discounting (Marzilli et al. 2015). Our data is non-conclusive in this last hypothesis, even when pooled.

As seen in Figure 1 there is loss aversion when the psychological value is higher for losses, this cannot be inferred from the estimated coefficients. In case of loss aversion the money difference in losses would have a stronger effect on the decision than in gains (Kahneman and Tversky 1984). This difference would make the relative and absolute money coefficients (β_{xR} and β_{xA}) larger for losses than for gains, which is not observed in the results. This absence of loss aversion could also be caused by lack of variance in questions and the relatively small sample.

However, the time coefficients seem to have higher variance and counterintuitively, the estimate is positive in some cases. Many of the time-coefficients are not significant at a 5%-level. This is likely to be caused by the lack of variance in the questions but it might also be related to potential biases in preferences in the limited subject pool.

Conclusions

The conclusions that can be drawn form our experiment are limited due to the small subject group and small variance in the questions. Taking into consideration these limitations the results can, however, be interpreted. First, we have seen that the ITCH model performs far better than the traditional exponential model. Second, we have also found that the ITCH models' ability to predict is barely affected by whether the subjects was faced with a loss or a gain. Third, it cannot be concluded which model is more efficient when the ITCH-model's ability to predict individual choices is compared to that of the hyperbolic model.

Given the shortcomings of the exponential models' ability to predict intertemporal decisions many other frameworks have been proposed. Constructing the discounting models based on principles found in empirical research seems to improve significantly our ability to understand and predict agents' behavior. To further develop these models seems crucial to improve the economist ability to predict intertemporal decisions of economic agents.

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Appendix 1: Experiment Script

Welcome.

In this survey you will be asked 16 questions. In each question you have to choose between two options: receive a certain amount of money at one point in time, or a different amount of money at another point in time. At the end of the experiment there will be a random lottery which decides one winner whose reward depends on her/his answers. All the answers are recorded. This game is completely anonymous.

Take into account that the time it is counted from today, the day you submit the answer.

Treatment AG: Absolute Gains

(a) 5€ in two weeks vs. 10€ in six weeks.

(b) 4€ in two weeks vs. 6€ in six weeks.

(c) 13€ in two weeks vs. 20€ in six weeks.

(d) 5€ in two weeks vs. 15€ in six weeks.

(e) 4€ in two weeks vs. 12€ in six weeks.

(f) 1€ in two weeks vs. 4€ in six weeks.

(g) 7€ in two weeks vs. 14€ in six weeks.

(h) 8€ in two weeks vs. 10€ in six weeks.

(i) 5€ in two weeks vs. 15€ in three weeks.

(j) 5€ in two weeks vs. 15€ in four weeks.

(k) 5€ in two weeks vs. 15€ in five weeks.

(l) 5€ in three weeks vs. 15€ in five weeks.

(m) 13€ in two weeks vs. 20€ in three weeks.

(n) 13€ in two weeks vs. 20€ in seven weeks.

(o) 13€ in four weeks vs. 20€ in seven weeks.

(p) 13€ in two weeks vs. 20€ in five weeks.

Treatment SG: Speed up Gains

(a) 10€ in six weeks vs. 5€ in two weeks.

(b) 6€ in six weeks vs. 4€ in two weeks.

(c) 20€ in six weeks vs. 13€ in two weeks.

(d) 15€ in six weeks vs. 5€ in two weeks.

(e) 12€ in six weeks vs. 4€ in two weeks.

(f) 4€ in six weeks vs. 1€ in two weeks

(g) 14€ in six weeks vs. 7€ in two weeks.

(h) 10€ in six weeks vs. 8€ in two weeks.

(i) 10€ in three weeks vs. 5€ in two weeks.

(j) 10€ in four weeks vs. 5€ in two weeks.

(k) 10€ in five weeks vs. 5€ in two weeks.

(l) 10€ in five weeks vs. 5€ in three weeks.

(m) 20€ in three weeks vs. 13€ in two weeks.

(n) 20€ in seven weeks vs. 13€ in two weeks.

(o) 20€ in seven weeks vs. 13€ in four weeks.

(p) 20€ in five weeks vs. 13€ in two weeks.

Treatment AL: Absolute Losses

(a) You have an endowment of 15€: lose 10€ in two weeks vs. lose 5€ in six weeks.

(b) You have an endowment of 10€: lose 6€ in two weeks vs. lose 4€ in six weeks.

(c) You have an endowment of 33€: lose 20€ in two weeks vs. lose 13€ in six weeks.

(d) You have an endowment of 20€: lose 15€ in two weeks vs. lose 5€ in six weeks.

(e) You have an endowment of 16€: lose 12€ in two weeks vs. lose 4€ in six weeks.

(f) You have an endowment of 5€: lose 4€ in two weeks vs. lose 1€ in six weeks.

(g) You have an endowment of 28€: lose 14€ in two weeks vs. lose 7€ in six weeks.

(h) You have an endowment of 18€: lose 12€ in two weeks vs. lose 10€ in six weeks.

(i) You have an endowment of 15€: lose 10€ in two weeks vs. lose 5€ in three weeks.

(j) You have an endowment of 15€: lose 10€ in two weeks vs. lose 5€ in four weeks.

(k) You have an endowment of 15€: lose 10€ in two weeks vs. lose 5€ in five weeks.

(l) You have an endowment of 15€: lose 10€ in three weeks vs. lose 5€ in five weeks.

(m) You have an endowment of 33€: lose 20€ in two weeks vs. lose 13€ in three weeks.

(n) You have an endowment of 33€: lose 20€ in two weeks vs. lose 13€ in seven weeks.

(o) You have an endowment of 33€: lose 20€ in four weeks vs. lose 13€ in seven weeks.

(p) You have an endowment of 33€ lose 20€ in two weeks vs. lose 13€ in five weeks.

Treatment SL: Speed up Losses

(a) You have an endowment of 15€: lose 5€ in six weeks vs lose 10€ in two weeks.

(b) You have an endowment of 10€: lose 4€ in six weeks vs lose 6€ in two weeks.

(c) You have an endowment of 33€: lose 13€ in six weeks vs lose 20€ in two weeks.

(d) You have an endowment of 20€: lose 5€ in six weeks vs lose 15€ in two weeks.

(e) You have an endowment of 16€: lose 4€ in six weeks vs lose 12€ in two weeks.

(f) You have an endowment of 5€: lose 1€ in six weeks vs lose 4€ in two weeks.

(g) You have an endowment of 28€: lose 7€ in six weeks vs lose 14€ in two weeks.

(h) You have an endowment of 18€: lose 10€ in six weeks vs lose 12€ in two weeks.

(i) You have an endowment of 15€: lose 5€ in three weeks vs lose 10€ in two weeks

(j) You have an endowment of 15€: lose 5€ in four weeks vs lose 10€ in two weeks

(k) You have an endowment of 15€: lose 5€ in five weeks vs lose 10€ in two weeks

(l) You have an endowment of 15€: lose 5€ in five weeks vs lose 10€ in three weeks.

(m) You have an endowment of 33€: lose 13€ in three weeks vs lose 20€ in two weeks.

(n) You have an endowment of 33€: lose 13€ in seven weeks vs lose 20€ in two weeks.

(o) You have an endowment of 33€: lose 13€ in seven weeks vs lose 20€ in four weeks.

(p) You have an endowment of 33€: lose 13€ in five weeks vs lose 20€ in two weeks.

Appendix 2: Explanation of ITCH-values

The parameters are:

- $x_2 - x_1$: difference between the two amounts specifying the amounts
- €: the computed difference on the amount
- $\frac{x_2 - x_1}{x^*}$: the relative difference on the amounts respected to the mean
- ρ: the computed relative difference on the amount
- $t_2 - t_1$: difference between the two periods of time specifying the periods
- weeks: the computed difference on time
- $\frac{t_2 - t_1}{t^*}$: the relative difference on time respected to the mean
- δ: the computed relative difference on time

Table 1: Parameters

	$x_2 - x_1$	€	$\frac{x_2 - x_1}{x^*}$	ρ	$t_2 - t_1$	weeks	$\frac{t_2 - t_1}{t^*}$	δ
a	10-5	5	10-5/7,5	0.67	2-6	4	2-6/1,5	2.67
b	6-4	2	6-4/5	0.40	2-6	4	2-6/1,5	2.67
c	20-13	7	20-13/16,5	0.42	2-6	4	2-6/1,5	2.67
d	15-5	10	15-5/10	1.00	2-6	4	2-6/1,5	2.67
e	12-4	8	12-4/8	1.00	2-6	4	2-6/1,5	2.67
f	4-1	3	4-1/2,5	1.20	2-6	4	2-6/1,5	2.67
g	14-7	7	14-7/10,5	0.67	2-6	4	2-6/1,5	2.67
h	10-8	2	10-8/9	0.22	2-6	4	2-6/1,5	2.67
i	10-5	5	10-5/7,5	0.67	3-2	1	3-2/0,5	2
j	10-5	5	10-5/7,5	0.67	4-2	2	4-2/1	2
k	10-5	5	10-5/7,5	0.67	5-2	3	5-2/1,5	2
l	10-5	5	10-5/7,5	0.67	5-3	2	5-3/1	2
m	20-13	7	20-13/16,5	0.42	3-2	1	3-2/2,5	0.4
n	20-13	7	20-13/16,5	0.42	7-2	5	7-2/4,5	1.11
o	20-13	7	20-13/16,5	0.42	7-4	3	7-4/5,5	0.55
p	20-13	7	20-13/16,5	0.42	5-2	3	5-2/3,5	0.86

Appendix 3: Descriptive statistics of subjects

Table 2: Gender and age

Age	Male participants	Female participants
18	0	1
21	6	6
22	3	9
23	3	8
24	3	0
25	1	1
26	0	1
27	1	0
28	1	0
39	1	0
47	1	0
49	0	2
55	0	1
69	0	1
Sum	20	30

Table 3: Monthly income of subjects in euros

Below 1200	From 1201 to 1800	From 1801 to 2500	From 2501 to 3500	Above 3500
19	8	7	4	12

Appendix 4: Mathematical definition of the used models

Heuristic Models

Intertemporal choice heuristic (ITCH):

$$U(x_2, t_2) - U(x_1, t_1) = \beta_I + \beta_{xA}(x_2 - x_1) + \beta_{xR}\frac{x_2 - x_1}{x*} + \beta_{tA}(t_2 - t_1) + \beta_{tR}\frac{t_2 - t_1}{t*}$$

Difference-Ratio.Intrest-Finance-Time model (DRIFT):

$$D = \beta_1 z(x_2 - x_1)$$

$$R = \beta_2 z\left(\frac{x_2 - x_1}{x_1}\right)$$

$$I = \beta_3 z\left(\left(\frac{x_2}{x_1}\right)^{\frac{1}{(t_2 - t_1)}} - 1\right)$$

$$T = \beta_4 z(t_2 - t_1)$$

$$U(x_2, t_2) - U(x_1, t_1) = \beta_1 + D + R + I + T$$

Discounting Models

Exponential discounting model:

$$U(x_2, t_2) - U(x_1, t_1) = x_2 e^{\kappa t_2} - x_1 e^{\kappa t_1}$$

Hyperbolic discounting model:

$$U(x_2, t_2) - U(x_1, t_1) = x_2\frac{1}{1 + \kappa t_2} - x_1\frac{1}{1 + \kappa t_1}$$

Quasi-hyperbolic discounting model:

$$U(x_2, t_2) - U(x_1, t_1) = \left\{ \begin{array}{lll} x_2\delta_a^{t_2} & if & t_2 = 0 \\ x_2\delta_a^{t_2}\delta_b & if & t_2 > 0 \end{array} \right. - \left\{ \begin{array}{lll} x_2\delta_a^{t_1} & if & t_1 = 0 \\ x_2\delta_a^{t_1}\delta_b & if & t_1 > 0 \end{array} \right.$$