

# Hypobolic Discounting and Willingness-to-Wait

David Eil\*

University of California, San Diego

March, 2011

This Version: November 8, 2011

## Abstract

Experimental and field research has shown that individuals often exhibit time inconsistent preferences. Often this is in the direction of “hyperbolic” or quasi-hyperbolic discounting. That is, individuals have a steeper discount rate for a given delay length when that delay comes sooner. This paper presents an experiment that tests this hypothesis with a novel choice task. Instead of being asked how much money today makes them indifferent between some amount later, subjects are asked how long they would be willing to wait to be indifferent between some amount sooner and some larger amount later. In this new task, many subjects exhibit “hypobolic” discounting, the opposite of the standard finding. This result does not appear to be a consequence of payout risk. The result suggests that hyperbolic discounting may be subject to the framing of choices, and therefore not purely an aspect of preferences.

*JEL classification:* D81, D90

*Keywords:* Uncertainty.

---

\*University of California at San Diego, Department of Economics, 9500 Gilman Drive, La Jolla, CA 92093; deil@ucsd.edu. I would like to thank Vincent Crawford for continued guidance, as well as Nageeb Ali, James Andreoni, Uri Gneezy, Craig McKenzie, Justin Rao, and Charles Sprenger for helpful comments and support.

# 1 Introduction

Recent theoretical and empirical work has devoted significant attention to self-control problems and time inconsistency of preferences. Theoretical work generally takes hyperbolic discounting as an assumption and explores the implications of such preferences for individual behavior (O’Donoghue and Rabin, 1999, 2001; Laibson, 1997) and market outcomes (DellaVigna and Malmendier, 2004). The predictions of these models, such as procrastination of costly activities, are familiar to us all. Further, some field evidence seems to support the idea that some individuals realize their self-control problems, and have demand for costly commitment devices (DellaVigna and Malmendier, 2006). Finally and most relevant to this paper, experimental evidence involving choices over dated monetary payoffs have found that subjects have preferences more consistent with hyperbolic discounting than the standard exponential discounting model (Thaler, 1981). In their thorough and influential survey, Frederick, Loewenstein and O’Donoghue (2002) review the experimental and field evidence for hyperbolic discounting, and note that across studies, the estimated discount rate tends to decline as a function of the time horizon involved in the study.

Meier and Sprenger (2010) and Meier and Sprenger (2007) provide a clean and well executed example of such an experiment. Using a multiple price list, the experiment elicits each subject’s willingness to pay (WTP) in today’s dollars for \$50 in one month, their WTP in today’s dollars for \$50 in six months, and finally their willingness to pay in six months from now’s dollars for \$50 in seven months. A significant minority of subjects exhibit a steeper discount rate in the first task than the second or the third. This evidence suggest that the subjects engage in hyperbolic discounting, or present bias.

This paper replicates the findings in Meier and Sprenger (2010), but also has subjects perform a complementary task. In this task, instead of eliciting a subject’s WTP for some future payment, we elicit the subject’s willingness to wait (WTW) for the larger of two payoffs. That is, the amount of delay that a subject would be willing to accept in order to choose a later, higher payoff over a sooner, lower one. Since hyperbolic discounting assumes that the discounting is less steep for later dates, hyperbolic discounters should increase their WTW by more than an exponential discounter would when the later, high payoff is raised. Instead, we find the opposite. In the extreme, some subjects exhibit the same WTW for a later payment of \$48 over a sooner payment of \$25 as they do when choosing between the same sooner payment of \$25 and a later payment of \$34.

This suggests that while people do endow the present with special significance, the hyperbolic discounting model does not accurately capture the nature of this significance. Instead, subjects use rules of thumb to answer questions involving dated experimental payoffs. After replicating the finding of hyperbolic discounting in the traditional experimental task, we conduct an experiment to exploit these rules of thumb, and induce subjects to display “hypobolic” discounting instead. Clearly subjects cannot be simultaneously hyperbolic and hypobolic discounters. There are intransitivities in choice within subject across the two different frames of the task. As a result no utility function whose arguments are only payoff amounts and their dates is capable of representing the choices of these subjects.

## 2 Hyperbolic Discounting: Theory and Evidence

The discounted utility model, first introduced by Samuelson (1937), remains the dominant paradigm within economics. In this model, an individual at time  $t$  evaluates a stream of consumption  $(c_t, \dots, c_T)$  as:

$$U^t(c_t, \dots, c_T) = \sum_{k=0}^{T-t} D(k)u(c_{t+k})$$

An additional common assumption is that of exponential discounting:  $D(k) = \delta^k$ . Under this assumption,  $\frac{D(s+k)}{D(s+l)} = D(k-l)$ , so that the relative values of two dated payoffs depends only on the length of time *between* the two, not how far into the future they are. The delay to the first payoff,  $s$ , does not matter, only the delay from the first to the second,  $k-l$ .

Hyperbolic discounting holds when  $\frac{D(s+k)}{D(s+l)}$  is increasing in  $s$ . A given delay length seems more important the closer to the present it is. For a given amount of time between payments, the sooner payment will appear more attractive the closer to the present it gets. For this reason, hyperbolic discounting is also referred to as “present bias”. A widely used special case is the  $\beta\delta$  model, where  $D(k) = \beta\delta^k$ , which loads all of the effect on the first period into the future (Strotz, 1955; Phelps and Pollak, 1968; Laibson, 1997). Under this model,  $D(k) = \beta\delta^k$  for all  $k > 0$ , while still equaling 1 for  $k = 0$ . That is, the individual discounts the first period especially steeply, at the rate  $\beta\delta$ , but thereafter is an exponential discounter with a discount factor of  $\delta$ .

Experiments often elicit discount factors by what Frederick et al. (2002) call “choice tasks”. Specifically, subjects are presented with a series of choices between some payoff at time  $t$ , and a larger payoff at a later time  $t+k$ . I shall use  $x_s$  to denote a payoff of amount  $x$  arriving at a delay length of  $s$  months from the date of the choice, so that  $x_0$  is a payment given “immediately”,  $x_1$  is a payment arriving in one month, etc.. Typically these choices are presented as an ordered list (a “multiple price list” (MPL)), with either the sooner or the later payment fixed, and the unfixed payment starting out at a clearly undesirable (desirable) amount and then increasing (decreasing). At some point in the list, the subject should switch choices. The experimenter concludes that their true indifference point lies somewhere in between the rows in the MPL where they switched.

Finally, the experimenter calculates the discount factor implied by the choices of the subject, assuming the subject evaluates options using a discounted utility model and a linear utility function. Under these assumptions, if a subject reveals that they are indifferent between  $x_t$  and  $x_{t+k}$ , then their discount factor is estimated to be  $\hat{\delta}_{t,t+k} = \left(\frac{x_t}{x_{t+k}}\right)^{\frac{1}{k}}$ .

Findings of hyperbolic discounting involve comparing  $\hat{\delta}_{t,t+k}$  for different values of  $t$  and  $k$ . Clearly, if the individual is truly an exponential discounter, the eliciting discount factor should not depend on  $t$  or  $k$ . For a hyperbolic discounter,  $\hat{\delta}_{t,t+k}$  should be increasing in both  $t$  and  $k$ .

As an example that clearly exhibits this practice, Meier and Sprenger (2010) uses two comparisons to classify individuals as exhibiting present bias, corresponding to increases in

$t$  and  $k$ . The first is to compare  $\hat{\delta}_{0,1}$  to  $\hat{\delta}_{6,7}$ . That is, the delay between payments  $k$  is fixed at one month, but the delay to the first payment,  $t$ , is increased by six months across the two choice tasks. If the individual were truly  $\beta\delta$  discounter, then  $\hat{\delta}_{0,1} = \beta\delta$ , while  $\hat{\delta}_{6,7} = \delta$ .  $\hat{\delta}_{0,1} < \hat{\delta}_{6,7}$  then indicates a  $\beta$  less than one, or present bias. Mapping this back to the behavior in the choice task, it means that subjects express a higher willingness to pay for money in seven months when paying using money in six months, than their willingness to pay for money in one month when paying in today's money. This is the comparison Meier and Sprenger (2010) uses for the bulk of their analysis.

A secondary way Meier and Sprenger (2010) classifies individuals as present biased involves comparing  $\hat{\delta}_{0,1}$  and  $\hat{\delta}_{0,6}$ . Here, the date of the sooner payment is kept fixed at the date of the experiment, while the delay to the second payment is manipulated across the two tasks. Again fitting this to a  $\beta\delta$  model,  $\hat{\delta}_{0,1} = \beta\delta$ , while  $\hat{\delta}_{0,6} = \beta^{\frac{1}{6}}\delta$ . Therefore  $\hat{\delta}_{0,1} < \hat{\delta}_{0,6}$  indicates  $\beta < \beta^{\frac{1}{6}}$ , or  $\beta < 1$ . Again looking at what this means for choice behavior, it means that given the amount that an individual is willing to pay today for an amount of money in a month, they don't move their willingness to pay enough for the same amount of money six months from now. The amounts that their willing to pay today for the two different dated payoffs are too similar. As shown above, when the econometrician tries to fit a  $\beta\delta$  model to this behavior, he finds that  $\beta < 1$ .

Fitting the data to a  $\beta\delta$  model assumes not only that the present is special, but that is special in a particular way. This is an assumption that Rubinstein (2003) objects to:

I agree that the hyperbolic discounting approach does capture the psychological phenomenon that the present is given special treatment and as such it is a very interesting exercise. However, the approach goes much farther than simply assigning a special role for the present. It assumes the maximization of a utility function with a specific structure and as such misses the core of the psychological decision-making process.

The experiment in this paper makes an attempt to disentangle the special role of the present from the  $\beta\delta$  model in particular.

## 3 Experiment

### 3.1 Motivation

If the choices of subjects in the experiments described above represent true preferences, then they should exhibit the same behavior in choice tasks that are designed to elicit the same parameters of the utility function, only using a different sequence of choices. Specifically, instead of fixing a later payment and the date of the sooner and later payment, and then varying the amount of the sooner payment until the subject's indifference point is found, I fix the date of the sooner payment and the amounts of the sooner and later payment, and

vary the date of the later payment until the subject’s indifference point is found. While the first task elicits the subject’s willingness to pay in today’s dollars for a payment in the future, my task elicits the subject’s willingness to wait, or the amount they will pay in the currency of delay, for a higher payment later.<sup>1</sup>

In previous experiments eliciting willingness to pay information, a subject was identified as having present bias if their willingness to pay for a future payment moves by too little when that payment is pushed farther into the future. When providing willingness to wait, a subject with  $\beta\delta$  preferences should instead increase their willingness to wait for a later payment by *more* than an exponential discounter when that later amount increases. In particular, suppose that a subject says that they are indifferent between \$25 today and \$34 in  $k_1$  periods. We can then estimate that her per-period discount factor is  $\hat{\delta} = (\frac{25}{34})^{\frac{1}{k_1}}$ , assuming she is an exponential discounter with a linear utility function. What delay length  $k_2$  would then make her indifferent between \$25 today and a delayed payment of \$48? It would be the  $k_2$  that solves:

$$\begin{aligned} 25 &= \hat{\delta}^{k_2} 48 \\ k_2 &= \frac{\ln 25 - \ln 48}{\ln \hat{\delta}} \\ &= \frac{\ln 25 - \ln 48}{\frac{1}{k_1}(\ln 25 - \ln 34)} \\ \frac{k_2}{k_1} &= \frac{\ln 25 - \ln 48}{\ln 25 - \ln 34} \\ &\approx 2.12 \end{aligned}$$

An exponential discounter should therefore approximately double their willingness to wait when the later payment moves from \$34 to \$48. Now suppose that the subject were instead a  $\beta\delta$  discounter. Then our original estimate of  $\delta$ ,  $(\frac{25}{34})^{\frac{1}{k_1}}$ , is actually equal to  $\beta^{\frac{1}{k_1}}\delta$ . Since we were ascribing *all* of the discounting over those first  $k_1$  periods to  $\delta$ , we will overestimate the amount of discounting that will occur over subsequent periods. Therefore when the amount of the later payment is raised, it will take more periods to decay the present value of the later payment back to \$25 than we would have expected under the assumption of exponential discounting. That is, the  $k_{2,\beta}$  that makes the subject indifferent between the \$25 now and the \$48 in  $k_{2,\beta}$  periods is not the  $k_{2,\beta}$  that solves:

$$25 = \hat{\delta}^{k_{2,\beta}} 48$$

---

<sup>1</sup>In some respects this is time preferences analog of the “uncertainty equivalent” in Andreoni and Sprenger (2010b). They alter the standard risk preferences task of asking for the certain amount that makes a subject indifferent between that amount and a given gamble to instead ask what probabilities on the payoffs in lottery A makes the subject indifferent to that lottery and lottery B. In effect I do the same thing here, finding indifference points in the “weights” on the payoffs (here, discount factors instead of probabilities) instead of amounts of the payoffs.

Instead, it's the  $k_{2,\beta}$  that solves:

$$\begin{aligned}
 25 &= \beta \delta^{k_{2,\beta}} 48 \\
 &= \beta^{1-\frac{1}{k_1}} \hat{\delta}^{k_{2,\beta}} 48 \\
 k_{2,\beta} &= \frac{\ln 25 - \ln 48 - \frac{1-k_1}{k_1} \ln \beta}{\ln \hat{\delta}}
 \end{aligned}$$

For a  $\beta$  of one, this reduces to  $k_2$ . For  $\beta$  less than one, the present biased case,  $k_{2,\beta} > k_2$ . This shows again that a present biased subjects can be identified as those whose willingness to wait increases too much in response to an increase in the amount of the later payment. If subjects are present biased in the  $\beta\delta$  sense, subjects should therefore be more than doubling their willingness to wait for \$48 compared to their willingness to wait for \$34.

## 3.2 Methods

The experiment was conducted at the experimental lab at the University of California at San Diego using 33 undergraduate subjects across two sessions in May 2010. The experiment lasted about 15 minutes, and followed a separate, independent experiment on risk preferences. Subjects were paid in Amazon.com gift certificates, emailed to them on the date of payment. Subjects were told at the beginning of the experiment that all payments would be in Amazon.com gift certificates. Thereafter payoffs were simply referred to by their dollar amounts. Each subject completed six paper-and-pencil MPLs, to be described below. In each session, one row out of one of the MPLs was randomly selected for payment, and three subjects from each session were paid. Four subjects selected ended up with the \$25 immediate payment, while two received a \$34 payment two years from the date of the experiment. To engender credibility in the payments, subjects were given receipts indicated when and in what amount they should receive their payments, as well as contact information for redress in the event of nonpayment.

The first three MPLs correspond to the type of willingness-to-pay tasks used in Meier and Sprenger (2010). Each list is a series of binary choices. Option A is always some fixed payment at a fixed time. For the Willingness to Pay tasks, Option B is a future payment of a fixed date but varying amount. For the Willingness to Wait tasks, Option B is a future payment of a fixed amount but a varying date. Table 1 summarizes the lists presented to the subjects.

Table 1: Six Multiple Price Lists used in Experiment

	Option A (fixed)	Option B	Range of Option B Values
Willingness to Pay Tasks			
Task 1	\$25 today	\$X in one month	\$25-\$56
Task 2	\$25 today	\$X in six months	\$25-\$62
Task 3	\$25 in six months	\$X in six months	\$25-\$56
Willingness to Wait Tasks			
Task 4	\$25 today	\$34 in K months	15 days-30 months
Task 5	\$25 today	\$48 in K months	15 days-48 months
Task 6	\$25 in six months	\$34 in K months	6 months 15 days - 36 months

For most of the results that follow, for each MPL, I take the worst Option B that the subject selects, and take that as their indifference point between Option A and Option B. This is not fully accurate, however, as the true indifference point lies between the worst Option B chosen and the best Option B not chosen. Later in the discussion I expand the analysis to consider these points. Similarly, for some subjects, it is impossible to identify a  $\beta$  and a  $\delta$  separately because they always choose either the sooner or the later payment. These subjects are dropped from the analysis. The tables indicate for each set of tasks how many subjects remained.<sup>2</sup>

### 3.3 Results

Table 2 presents the average discount factor from each task, calculated as  $(\frac{x_t}{x_{t+k}})^{\frac{1}{k}}$  when a subject has exhibited indifference between the payments  $x_t$  and  $x_{t+k}$ .

Table 2: Mean Estimated Discount Factors from Each Task

Task 1	.83
	.14
Task 2	.95
	.04
Task 3	.87
	.14
Task 4	.87
	.15
Task 5	.86
	.17
Task 6	.80
	.22

<sup>2</sup>Commonly in MPLs a number of subjects have to be dropped because of “multiple switching”, or intransitivities within one choice sheet. None of the subjects in this experiment did this.

Consistent with earlier experiments, the discount factor does increase in the WTP when the delay to the later payment is increased (comparing task 1 and task 2), as well as when the delay to the first payment is increased (comparing tasks 1 and 3). However, in the WTW tasks, the estimated discount factor decreases when the amount of the later payment is increased (comparing tasks 4 and 5). The estimated discount factor for task 6 (with the sooner payment is in six months, the later payment varying in delay) is especially low. However this is due entirely to four subjects who chose the sooner payment in every case, perhaps due to not understanding that the sooner payment was in six months, not immediately. None of these subjects appeared so impatient on any other task. Without these subjects, the mean discount factor for task 6 would be .88.

Using any two tasks gives two indifference conditions that can be used to solve for a  $\beta$  and a  $\delta$ . Table 3 presents the  $\beta$  and  $\delta$  that can be calculated from the “shift k” pair of tasks, 1 and 2, and the “shift t” pair of tasks, 1 and 3.

Table 3: Preference Parameters Implied by Different Pairs of WTP Responses

	“Shift k” (Tasks 1 and 2)	“Shift t” (Tasks 1 and 3)
Median $\beta$	0.86	1
	<i>0.14</i>	<i>0.16</i>
% $\beta < 1$	85	42
Median $\delta$	0.99	0.94
	<i>0.04</i>	<i>.14</i>
N	29	29

Following the pattern of the aggregate discount factors from table 2, may subjects exhibit present bias. Almost all subjects exhibit present bias in the “shift k” pair of tasks, not increasing their willingness to pay in future dollars for the today payment by as much as an exponential discounter would.

Table 4 presents the results from the Willingness to Wait tasks. These are also grouped into two pairs, “Shift \$”, using tasks 4 and 5, and “Shift t” using tasks 4 and 6. As discussed above, present biased types should have a WTW that *more* than doubles when the dollar amount of the later payment increases. They should also have a WTW that decreases from task 4 to task 6.

Table 4: Preference Parameters Implied by Different Pairs of WTW Responses

	“Shift \$” (Tasks 4 and 5)	“Shift t” (Tasks 4 and 6)
Median $\beta$	1.35	1.07
	-	33.78
% $\beta > 1$	71	60
Median $\delta$	0.82	0.89
	0.87	.22
N	29	29

Note that median estimates of  $\beta$  for these tasks is greater than one. The typical subject exhibits “future bias”. I report the medians, and cannot report the standard deviation for the  $\beta$  estimated using tasks 4 and 5, because 3 of the 29 subjects did not change their willingness to wait at all between the two tasks, leading to a  $\beta$  estimate of  $\infty$ . Generally, subjects do not increase their willingness to wait disproportionately between the two tasks, as hyperbolic discounting would predict. Instead, many subjects report a willingness to wait for \$48 that is very close to their willingness to wait for \$34.

## 4 Discussion

### 4.1 The Present and Rules of Thumb

The above results suggest that while people are not exponential discounters, and do make decisions differently when a present payment is involved, they do not always make decisions as  $\beta\delta$  discounters. Instead, thinking about their decisions as executing rules of thumb that in fact maximize no utility function may better describe behavior.

In particular, consider a subject thinking about task 1 and task 2. In each task, the subject is choosing between an amount today and an amount later. These are the salient facts of the tasks to the subject. The difference in the date of the later payment seems trivial, so the subject gives a similar answer. Likewise when comparing tasks 4 and 5, the subject is choosing in each case between an amount today and an amount later. Again, the slight difference in the amount of the later payoff seems unimportant. What’s important is the salience of today for less versus later for more, which is common to both tasks. Except here, giving a similar answer violates the  $\beta\delta$  model for exactly how the present is special.

This change in the shape of the discounting function in reaction to the type of task faced by the subject is irreconcilable with any utility function. In particular, each task consists of a number of binary choices. Although they are presented in sequence and each is used by the experimenter to identify one particular indifference condition, they are in fact independent. The effect of WTW vs. WTP tasks therefore indicates that an individual binary choice is affected by the surrounding binary choices to which it is compared. In this sense the results here support findings in Sprenger (2010), which suggests that subjects use fixed options in a list as reference points. Here, not only are fixed options on the same page used as reference

points, but past choices on tasks that the subject views as similar affect current decisions.

## 4.2 Concave Utility

While the amounts in the experiment are small enough that rational lifetime-utility-maximizing subjects should have linear utility (Rabin, 2000), in practice subjects likely do not have linear utility over the payoffs. This assumption biases estimates of discount factors if utility is instead concave. Estimates of present bias may also be affected. Intuitively, for WTP tasks 1 and 2, present bias says that when you shift out the delay until the later payment, the subject does not change by a large enough amount their indifference point in the later amount. If utility is concave, then the indifference point in later *utility* has moved even less.

While this may also bias the estimate of  $\beta$ , not all forms of concavity are enough to make an exponential discounter look like a hyperbolic discounter.<sup>3</sup> Still it is important to note that two studies that attempt to control for the curvature of the utility function, Andersen, Harrison, Lau and Rutström (2008) and Andreoni and Sprenger (2010a), find no evidence of present bias.

Willingness to Wait tasks suffer a similar problem. Present bias would here entail the willingness to wait moving by “too much” when the amount of the later payment is increased. If utility is concave, then the utility of the later payment has been increased by less than the amount of the later payment, so the increase in the willingness to wait is still more disproportionate. But likewise when we see that the willingness to wait has moved “not enough”, some of this could be attributed to the fact that the payoffs have moved not as much as one would assume under linear utility. Therefore some of the observed “future bias” in the WTW tasks could be attributed to concavity of the utility function.

## 4.3 Front End Delay

The issue of what constitutes the “present” is an important one in this literature. It is desirable to equate transactions costs and risks across the two different kinds of payments, but at the same time it is impossible to promise credibly that you will find the subject wherever they are at some later date and hand them cash, as you can in the lab the day of the experiment. Andreoni and Sprenger (2010a) institutes a “front end delay” by placing all payments, even  $t = 0$  payments, in subjects’ mailboxes. They find no evidence of present bias. It is not entirely clear whether this is because their procedures equate transactions costs, or because even a check placed in the mailbox that afternoon is not truly a  $t = 0$  payment. Andersen et al. (2008) also institutes a front end delay and also finds little evidence

---

<sup>3</sup>For example, consider an individual with CRRA utility. Take first the example of the WTP tasks. Assuming a  $\beta\delta$  model, tasks 1 and 2 give indifference conditions  $u(x_0) = \beta\delta u(x_1)$  and  $u(x_0) = \beta\delta^6 u(x_6)$ . Solving for  $\beta$  gives  $\beta = \frac{u(x_0)u(x_6)^{\frac{1}{6}}}{u(x_1)^{\frac{1}{6}}}$ . The estimated  $\hat{\beta}$  under the assumption of linear utility will be  $\frac{x_0 x_6^{\frac{1}{6}}}{x_1^{\frac{1}{6}}}$ , while the true  $\beta$  will be  $\hat{\beta}^\alpha$ . However for all positive  $\alpha$ ,  $\hat{\beta} < 1$  if and only if  $\beta < 1$ . Similar calculations pertain for the WTW tasks. Thus, it requires a particular kind of concavity, likely implying increasing relative risk aversion, for concavity of the utility function to create the illusion of hyperbolic discounting.

of present bias. However, Meier and Sprenger (2010) finds present bias in spite of front end delay.

By sending Amazon.com gift certificates instead of giving cash on the spot, my experiment also uses some front end delay. However, as I still find evidence of present bias in the WTP tasks, which are paid using the same mechanism, it could not be the front end delay that drives the finding of future bias in the WTW tasks.

#### 4.4 Payment Risk

One of the main reasons for instituting front end delay is to equate payment risk between the sooner and later payments. However it may be that even with front end delay, subjects have a view of payment risk that is not exponential. That is, they may view payments more than, say, a year into the future as being much less likely to be paid than payments 10 or 11 months into the future. Since, for an expected discounted utility maximizing subject, the weight placed on the payoff in a given period is the discount factor times the probability that the payoff will be realized, it may be that what we think might be hyperbolic discounting is in fact payment risk that is increasing later into the time horizon of the payoffs.

To investigate this possibility, I calculated the implied  $\beta$  only for subjects whose WTW to wait in Task 4 is four months or less. This means that the horizons for Tasks 4 and 5 cover roughly the same time period as WTP tasks 1 and 2. The mean implied  $\beta$  for these subjects is 1.72. 64 percent of these subjects exhibit future bias. The mean implied  $\beta$  for the same subjects in the WTP task was 0.79. Therefore it seems unlikely that the shape of the beliefs about payment risk drive the asymmetry in the shape of the estimated discount function between the WTP and WTW tasks.

#### 4.5 Interval Values

The preceding analysis assumed that the subject was indifferent between Option A and the worst Option B that they preferred to Option A. In reality, their indifference point lies somewhere between the worst Option B they chose and the best Option B they did not choose. Since the analysis above relies on comparisons between responses in different tasks, not their absolute levels, this is not a problem unless there are systematic differences across tasks in where the subject's indifference point lies within the interval of possible points.

However we can see what the analysis would look like when making the most pessimistic assumptions on the data. For example, when comparing the WTP tasks 1 and 2, present bias was identified as having not a big enough difference in indifference points across the two tasks. To minimize that, I assume that the true indifference point on task 1 is the best Option B not chosen. The difference between this and the worst Option B chosen in task 2 is the biggest possible difference between the true indifference points in each task. Likewise for the WTW tasks 4 and 5, I found that subjects were not moving their indifference point by enough to be exponential discounters. Here again for task 4, I will assume that the true indifferent point is the best Option B not chosen.

These assumptions do not affect the conclusions drawn from the data. Still, 82 percent of the subjects are estimated to be present biased in the WTP tasks, and 54 percent of the subjects are estimated to be future biased in the WTW tasks. The median estimated  $\beta$  in the WTP tasks is still below 1 at 0.9. The median  $\beta$  in the WTW tasks is still above 1 at 1.08. Thus it does not seem that the specifics of which points are included in the price lists are driving the results.

## 5 Conclusion

Introspection and experimental evidence both indicate that people treat the present differently than other periods. The  $\beta\delta$  model represents a convenient way of capturing this intuition, as it leads to much of the behavior that is associated with time inconsistency, and nests the standard exponentially discounted utility model as a special case.

The experimental results in this paper suggest that the  $\beta\delta$  model does not fully capture the ways in which the present is special. While hyperbolic and quasi-hyperbolic discounting make a clear prediction that WTW should increase disproportionately as the amount of the later payment goes higher, instead I observe the opposite.

It may be that the salience of the present induces the subject to give similar answers to questions that involve relative valuations of a payment today and a payment in the future. Subjects are not as sensitive to other parameters of the question, such as the payment amounts or the exact date of the later payment, as they should be according to the standard model. This heuristic produces responses that look like quasi-hyperbolic discounting in WTP tasks. In WTW tasks however, the same heuristic leads to responses that look like hyperbolic discounting. This behavior presents more difficulty in modeling, as it cannot be produced by a model that does not consider the context of each question. At the least, however, the results here suggest that hyperbolic discounting is sensitive to question context, if not entirely a result of it.

## References

- Andersen, S., G.W. Harrison, M.I. Lau, and E.E. Rutström, “Eliciting risk and time preferences,” *Econometrica*, 2008, 76 (3), 583–618.
- Andreoni, J. and C. Sprenger, “Estimating time preferences from convex budgets,” Technical Report, National Bureau of Economic Research 2010.
- and —, “Uncertainty Equivalents: Linear Tests of the Independence Axiom,” Technical Report, Working Paper 2010.
- DellaVigna, S. and U. Malmendier, “Contract Design And Self-Control: Theory And Evidence\*,” *Quarterly Journal of Economics*, 2004, 119 (2), 353–402.

- and –, “Paying not to go to the gym,” *American Economic Review*, 2006, 96 (3), 694–719.
- Frederick, S., G. Loewenstein, and T. O’Donoghue**, “Time discounting and time preference: A critical review,” *Journal of Economic Literature*, 2002, 40 (2), 351–401.
- Laibson, D.**, “Golden Eggs and Hyperbolic Discounting\*,” *Quarterly Journal of Economics*, 1997, 112 (2), 443–477.
- Meier, S. and C. Sprenger**, *Impatience and credit behavior: Evidence from a field experiment*, Federal Reserve Bank of Boston, 2007.
- and –, “Present-biased preferences and credit card borrowing,” *American Economic Journal: Applied Economics*, 2010, 2 (1), 193–210.
- O’Donoghue, T. and M. Rabin**, “Doing it now or later,” *The American Economic Review*, 1999, 89 (1), 103–124.
- and –, “Choice and Procrastination\*,” *Quarterly Journal of Economics*, 2001, 116 (1), 121–160.
- Phelps, E.S. and R.A. Pollak**, “On second-best national saving and game-equilibrium growth,” *The Review of Economic Studies*, 1968, 35 (2), 185–199.
- Rabin, M.**, “Risk aversion and expected-utility theory: A calibration theorem,” *Econometrica*, 2000, pp. 1281–1292.
- Rubinstein, A.**, “Economics and Psychology? The Case of Hyperbolic Discounting\*,” *International Economic Review*, 2003, 44 (4), 1207–1216.
- Samuelson, P.A.**, “A note on measurement of utility,” *The Review of Economic Studies*, 1937, 4 (2), 155–161.
- Sprenger, C.**, “An Endowment Effect for Risk: Experimental Tests of Stochastic Reference Points,” 2010.
- Strotz, R.H.**, “Myopia and inconsistency in dynamic utility maximization,” *The Review of Economic Studies*, 1955, 23 (3), 165–180.
- Thaler, R.**, “Some empirical evidence on dynamic inconsistency,” *Economics Letters*, 1981, 8 (3), 201–207.