Can We Really Observe Hyperbolic Discounting?*

Jesús Fernández-Villaverde

University of Pennsylvania, NBER, and CEPR

Arijit Mukherji

University of Minnesota

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Abstract

This paper proposes a new, more robust experiment to test for the presence of hyperbolic discounting. We motivate the experiment by pointing out the problems in interpreting the existing evidence caused by uncertainty. In the design of our experiment, we control for uncertainty by exploiting the demand of hyperbolic discounting agents for commitment. The experiment offers two choice sets, the second being a strict subset of the first. Exponential discounters (possibly weakly) prefer the largest one. Hyperbolic discounters, in contrast, (strictly) prefer the second set because its design makes it equivalent to a commitment technology. The experiment is conducted on a sample of undergraduate students. We find that 13 percent of students opt for the smaller choice set. Our results suggest that hyperbolic discounting might be less prevalent than implied by previous experiments.

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*Department of Economics, 160 McNeil Building, 3718 Locust Walk, Philadelphia, PA 19104-6297. E-mail: jesusfv@econ.upenn.edu. We thank Colin Camerer, V.V. Chari, Juan Carlos Conesa, John Dickhaut, Carlos Garriga, Tom Holmes, Karsten Jeske, Narayana Kocherlakota, Jing Li, and seminar participants at several institutions for useful comments. However, we owe our biggest debt of gratitude to David Levine. Arijit departed some time ago for a much better place. All remaining errors are, consequently, the responsibility only of Jesús.

1. Introduction

Over the last three decades, researchers have presented experimental and field evidence of present-bias in intertemporal choice (Frederick *et al.*, 2002). A typical experiment in the literature runs as follows. When confronted with the choice between two payments that are close in time, for example, \$10 today *versus* \$11 tomorrow, many agents prefer \$10 today and demonstrate an incredibly high discount rate (in this case, $7.79 \exp(-16)$ on an annual basis). However, most agents choose \$11 in 101 days over \$10 in 100 days, even if the distance between both payments is still one day.

A popular approach to account for this phenomenon is hyperbolic discounting, the hypothesis that individuals discount the future at a greater rate in the short run than in the long run. A feature of hyperbolic discounting is that it induces time-inconsistent choices as defined by Strotz (1956): if individuals have the opportunity to revise their plans in the future, they will deviate from the decisions made in the past.

We make two points in this paper. First, we raise a problem when we interpret the evidence on present-bias: the presence of uncertainty. When we face a payment today against a payment tomorrow, uncertainty's role is asymmetric. Uncertainty matters when we evaluate the payment tomorrow, but it does not when we assess the payment today, since the realizations of all shocks are already known. However, when the decision involves two future payments, uncertainty is relevant for both of them. Thus, both choice problems are not equivalent. We show how a small degree of uncertainty generates the observed behavior in a standard model with exponential discounting. We make this argument within the context of exponential discounting, not because we find it the most plausible model of discounting, but because it is the simplest environment in which we can do so. We can generalize the argument to many periods if the uncertainty about the future grows at a decreasing rate, i.e., there is much more additional uncertainty regarding the day after tomorrow versus tomorrow, than the additional uncertainty in 101 days versus 100 days (Halevy, 2005).

The point is relevant because operationalizing choice problems in the laboratory may introduce uncertainty in subtle ways and change the behavior of the experimental subject. A simple example is the prior of the agent with respect to default by the experimenter. Even a very low prior probability that the experimenter will not honor her promise tomorrow (either by explicit default or by an appeal to the "fine print" of the instructions of the experiment) will induce the agent to select the payment today despite the steep monetary penalty that such option fetches.

If uncertainty can cause the choices reported in experiments, the evidence of present-bias is not necessarily evidence in favor of hyperbolic discounting. The second point of the paper is, then, to propose an experiment to test for the presence of hyperbolic discounting that controls for uncertainty using commitment devices. Hyperbolic discounting agents who are aware of their preferences (the so-called *sophisticated* hyperbolic discounters, the most common model in the literature) will demand commitment devices that lock them into consumption patterns that overcome their inconsistency problem. This prediction suggests a test to detect sophisticated hyperbolic discounting: Do agents take commitment devices when they are offered one?

We exploit this observation by offering agents two choice sets, the second being a strict subset of the first. Exponential discounters, our control benchmark, (possibly weakly) prefer the largest one. Hyperbolic discounters, in contrast, (strictly) prefer the second set because its design makes it equivalent to a commitment technology that defeats time inconsistency. We conduct the experiment on a sample of undergraduate students at the University of Minnesota. We find that 13 percent of students opted for the smaller set while 87 percent chose the larger set.

We interpret this 13 percent as evidence of self-control problems in a significant share of the population. Our finding motivates the theoretical investigation of this phenomenon. However, it provides a somehow more nuanced view of the quantitative importance of hyperbolic discounting than the evidence coming from previous studies, which, without controlling for uncertainty, documented that between 40 and 60 percent of agents (and often higher shares) behaved as hyperbolic discounters.

Our evidence is also pertinent to other behavioral models that rationalize present-bias. Examples of alternative frameworks include Bénabou and Pycia (2002), Benhabib and Bisin (2005), Fudenberg and Levine (2005), Gul and Pesendorfer (2001 and 2004), or Rubinstein (2003) among others. Our finding suggests that the type of behavior those paper attempt to capture might be far less pervasive than previously thought. However, the 13 percent of our population that demand commitment devices more than justifies the study of intertemporal choice models, including sophisticated hyperbolic discounting.

There are two caveats in our evidence. First, our experiment cannot distinguish between sophisticated hyperbolic discounting and other models of present-bias. Benhabib *et al.* (2006) design experiments to accomplish this goal. Second, our experiment cannot tell whether the students who choose flexibility did so because they are exponential discounters or because they are *naive* hyperbolic discounters, i.e., they are agents that repeatedly fail to understand their time-inconsistency problems. On the other hand, while our paper does not show any evidence against naive hyperbolic discounting, it does not provide any evidence in favor of it either, as the subjects' choices can be accounted for by the standard model of exponential discounting and uncertainty.

We structure the paper as follows. We present in section 2 a simple model of dynamic choice with uncertainty. We describe our experiment in section 3. We report the experimental results in section 4. We compare our results with those in the literature in section 5. We conclude in section 6. An appendix includes the instructions of the experiment.

2. A Model with Uncertainty

We present in this section a model with uncertainty and exponential discounting. As explained in the introduction, we do so, not because we find it the most empirically relevant model of discounting (see Frederick *et al.*, 2002, for a catalogue of the empirical failures of exponential discounting) but to illustrate our argument regarding the importance of uncertainty in intertemporal choice. The exponential discount model is just the simplest environment in which we can formalize our argument.

Consider an economy with a continuum of agents of measure 1. Each agent has preferences over consumption sequences that are representable by a utility function of the form:

$$\max_{\{c_t\}_{t=0}^{\infty}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U\left(A_t c_t\right)$$

where c_t is the consumption at period t, β is the discount factor, and $A_t \in (0, \infty)$ is an idiosyncratic shock to preferences, revealed at the beginning of each period before consumption decisions are made. The preference shock is independent across time and follows a L_2-distribution P over the Borel σ-field of subsets of $\Re_+$, ϕ, such that $P(\Upsilon) > 0$ for all sets $\Upsilon \subseteq \phi$. $\mathbb{E}_0$ is the conditional expectation operator with respect to P and evaluated at time 0. We assume that the population follows a law of large numbers (Uhlig, 1996). The period utility function satisfies the usual properties: $U(\cdot) \in C^2$, $U'(\cdot) > 0$, $U''(\cdot) < 0$ for all c_t in $\Re_+$. Furthermore, $U(\cdot)$ is bounded below at 0.

Given these assumptions, the following lemma holds:

Lemma 1. *$\int U(A_t c_t)\, dP$ is bounded for all c_t in $\Re_+$.*

Proof. Since P is L_2, for a given c_t, $\int A_t c_t dP < \infty$. Since $U''(\cdot) < 0$, by the Hyperplane Separation Theorem, there are some constants a and b such that $U(A_t c_t) \leq a A_t c_t + b$. Then $\int U(A_t c_t)\, dP \leq a \int A_t c_t dP + b < \infty$. ■

From Lemma 1, the maximization problem is well defined and the usual theorems in choice theory follow. Then, we can show how agents in this economy behave differently when faced with apparently similar situations. In particular, we study the case when agents encounter the following two choice problems:

1. Consume c' units of the good in n periods or c'' units of the good in $n+1$ periods.

2. Consume c' units of the good today or c'' units of the good tomorrow.

We assume these consumption units are non tradable (and thus there is no possibility of insurance among agents) and that the agent does not have any other source of income. The following proposition is direct.

Proposition 2. *All the agents will prefer the same option in choice problem 1.*

Proof. First note that, for every agent, the utility of consuming at time n is given by $\beta^n \int U(A_n c')\, dP$, while the utility of consuming at time $n+1$ is given by $\beta^{n+1} \int U(A_{n+1} c'')\, dP$. By Lemma 1, both expressions are bounded constants, and by the assumption that shocks are independent, they have the same value for all agents regardless of the value of A_0. Thus, all agents will opt for consumption in the same period. ■

Without loss of generality, we assume that the consumption units in choice problem 1 are such that:

$$\beta \int U(A_{n+1} c'')\, dP > \int U(A_n c')\, dP$$

Then, all agents will wait until period $n+1$, as observed in the experiments cited in the introduction. Now, we can prove the next proposition.

Proposition 3. *Different agents will take different options in choice problem 2.*

Proof. For every agent, the utility of consuming at time 0 is $U(A'c')$ where A' is the realization of the preference shock at time 0, while the utility of consuming at time 1 is $\beta \int U(A_1 c'')\, dP$.

Since from our assumptions $U(\cdot)$ is invertible, there exists an A^*:

$$A^* = \left(U^{-1}\left(\beta \int U(A_1 c'')\, dP\right)\right) / c'$$

such that all agents with $A' \geq A^*$ will opt for consumption in period 0 and all agents with $A' \leq A^*$ will wait until period 1.

Again, by assumption, both $P([A^*, \infty)) > 0$ and $P((0,\ A^*)) > 0$. By the law of large numbers, those measures coincide with the population measures and, then, with the share of realized choices. ■

Propositions 1 and 2 show that, under uncertainty, the behavior of agents is different when the choice deals only with the future than when the problem involves both the present and the future. The intuition for the result is straightforward. In choice problem 2, the agent knows the utility from consuming today. If the current shock A is high enough, she would prefer to consume immediately, even if the quantity of the good is substantially lower than the quantity she will obtain by waiting one period. In fact, A does not need to be too high because she is risk-averse. In choice problem 1, since both alternatives are in the future, uncertainty is integrated out on both sides of the comparison, and the only relevant issue is the relation between the discount factor and the difference in the quantities of the good.

To gauge the quantitative importance of our argument, we present a numerical example. We consider a modified CRRA utility function:

$$U = \frac{(A_t c_t + \varepsilon)^{1-\sigma} - 1}{1-\sigma}$$

where $\varepsilon > 0$ is a real number that bounds below the utility function but is small enough to be numerically irrelevant. The shock A_t is distributed as $\log A_t \sim \mathcal{N}(1, \theta_A)$. We fix β at 0.9999 (equivalent to a 0.96 annual discount factor if we use days as our time units) and to keep figures from the standard example, we set c' equal to 10 and c'' equal to 11.

Then, for $\sigma = 2$ and $\theta_A = 0.25$, 52 percent of agents prefer to consume today and all of them prefer consumption in $n+1$ over consumption in n. As shown in figure 1, even if the variance of the preference shock is reduced, a sizable part of the population will keep this choice. For instance, with a variance of 0.04, 36 percent of the population still opts for current consumption. If we use higher risk aversions, like those reported by Barsky *et al.* (1997), the results are clearer. For $\sigma = 3$ and $\theta_A = 0.25$, 64 percent of the agents choose present consumption. Even with a variance as low as 0.01, this share is still 32 percent. For comparison purposes, Ainslie and Haendel (1982) found that 33 percent of subjects made inconsistent choices when faced with real payoffs.

Is this a fair example? Are these variances of the shocks plausible? It is hard to judge. However, it seems reasonable to defend the hypothesis that preferences suffer shocks over time. A simple explanation takes the utility function as a function that produces services for the self and is subject to random shocks. For example, the ability to appreciate a movie depends on elements such as the theater's temperature or the number of people in the room. Another justification is to see the utility function as the reduced form of a more complex problem where the capacity to enjoy a good depends on many factors that the economist does not want to model explicitly. Variations in those omitted factors appear as preference shocks. No matter the justification behind them, our bottom line is simple: small shocks to the utility function can account for the experimental findings on present-bias even within the context of exponential discounting.

3. An Alternative Experiment

The difficulty in interpreting the existing evidence on intertemporal choice under the presence of uncertainty raises the need to collect further data. There are many routes to do so, from case studies (DellaVigna and Malmendier, 2005) to micro data (Huang *et al.*, 2006). We focus, instead, on the original source of empirical evidence regarding hyperbolic discounting: experiments on individual intertemporal choice. Given our discussion in section 2, we design a new, more robust experiment to detect hyperbolic discounting. We consider four points in the design. First, we look for a simple experiment that subjects can easily understand. Second, all the implicit costs for every alternative are equalized so they do not distort the choice. Third, we ensure that random shocks to preferences influence the choices symmetrically. Fourth, we use goods without outside intertemporal markets.

With these points in mind, we propose the following experiment involving minutes of access of undergraduates to video games (the use of video games has also been suggested by Millar and Navarick, 1984). The agents are presented with two alternatives:

- Option A: Get 180 minutes of access to video games that can be played in the laboratory on three consecutive days after some specified date in the future. So, if the specified date is n, the students can use the minutes in $n+1$, $n+2$, and $n+3$. The distribution of time is constrained by the experiment to be 60 minutes on the first day, 60 minutes on the second, and 60 minutes on the last day. Subjects must go to the laboratory for the experiment on all three days and sign an attendance sheet.

- Option B: Get 180 minutes of access to video games that can be played in the laboratory on three consecutive days after the same specified date in the future. So, if the specified date is n, the students can use the minutes in $n+1$, $n+2$, and $n+3$. The subjects are free to distribute that time as they wish over the three days, but they should come to the laboratory for the experiment on all three days and sign an attendance sheet.

We analyze how an exponential discounting agent and a sophisticated hyperbolic discounting agent will evaluate both alternatives. Our comparison with exponential discounting is motivated by the desire to have the classical framework as the control benchmark.

The case of the exponential discounting agent is simple. She will always choose option B, regardless of the degree of uncertainty associated with preference shocks. Since she is able to design dynamically consistent plans, option B provides the utility derived from solving the value function problem:

$$V^B(A_t, M_t, t) = \max_{c_t} u(A_t c_t) + \beta \int V^B(A_{t+1}, M_{t+1}, t+1)\,dP,\ t \in \{n+1, n+2\}$$

$$V^B(A_{n+3}, M_{n+3}, n+3) = u(A_{n+3} M_{n+3})$$

$$s.t.\ M_{t+1} = M_t - c_t,\ M_{t+1} \geq 0$$

$$M_{n+1} = 180$$

where the states are the shock A_t, the remaining minutes to be consumed M_t, and the period t. The solution of this problem, $\int \beta^{n+1} V^{B*}(A_{n+1}, 180, n+1)\,dP$, is at least as high as the utility of option A, $V^A = \sum_{t=n+1}^{n+3} \beta^t \mathbb{E}_0 U(A_t 60)$, since the agent can always replicate, by herself, the second alternative (the solution of an unconstrained problem is at least as high as the constrained one). In addition, in a generic case, she can rearrange the consumption stream to account for the discount factor and the uncertainty, and then:

$$\int \beta^{n+1} V^{B*}(A_{n+1}, 180, n+1)\,dP > \sum_{t=n+1}^{n+3} \beta^t \mathbb{E}_0 U(A_t 60)$$

i.e., in the presence of uncertainty, flexibility has a positive option value.

Which option will a hyperbolic discounting agent prefer? To analyze her choice, we need additional structure. We assume, as in Phelps and Pollack (1968), that the total utility of consuming at times $n+1$, $n+2$, and $n+3$, evaluated at 0 is represented by:

$$\mathbb{V}_0 = \mathbb{E}_0 \left[U(c_0) + \delta \sum_{t=n+1}^{n+3} \beta^t U(c_t) \right]$$

and that the period utility function, as in the example in the last section, is:

$$U = \frac{(A_t c_t + \varepsilon)^{1-\sigma} - 1}{1-\sigma}$$

where $\log A_t \sim \mathcal{N}(1, \theta_A)$. We use the bold $\mathbb{V}$ to denote the value function of the hyperbolic discounting agent and distinguish it from the regular V of an exponential discounting agent.

The utility under option A is simply:

$$\mathbb{V}_0^A = \delta \sum_{t=n+1}^{n+3} \beta^t \int \frac{(A_t 60 + \varepsilon)^{1-\sigma} - 1}{1-\sigma} dP$$

To compute the utility under option B, we find the Nash Equilibrium in the game of the agent against herself (Laibson, 1997). Using backward induction and the response functions of future selves, we find the consumption path for W total minutes available at the beginning of period $n+1$:

$$c_{n+1} = \frac{k'}{1+k'}W$$
$$c_{n+2} = \frac{k}{(1+k')(1+k)}W$$
$$c_{n+3} = \frac{1}{(1+k')(1+k)}W$$

where k and k' are functions of A_n, A_{n+1}, and A_{n+2}. The utility of the self at present time is then:

$$\mathbb{V}_0^B = \delta\beta^{n+1}\int_{A_1}\frac{\left(\frac{A_1 k'}{1+k'}W\right)^{1-\sigma}-1}{1-\sigma}dP + \delta\beta^{n+2}\int_{A_1,A_2}\frac{\left(\frac{k}{1+k'}\frac{A_2}{1+k}W\right)^{1-\sigma}-1}{1-\sigma}dP + \delta\beta^{n+3}\int_{A_1,A_2,A_3}\frac{\left(\frac{A_3}{(1+k')(1+k)}W\right)^{1-\sigma}-1}{1-\sigma}dP$$

This expression shows the presence of two different forces with opposite effects. First, the self-control problem reduces utility with respect to the exponential discounting problem. Second, the lack of flexibility in option A increases the utility of option B even for hyperbolic discounters. Since this integral does not have an analytic solution, we use numerical methods to evaluate it for $\beta = 0.999$, $\delta = 0.6$, and different values of θ_A and σ (including those in our example in section 2). We found that, in general, we will have $\mathbb{V}_0^B > \mathbb{V}_0^A$. Exceptions occur when the variance of the preference shock and the risk aversion are extremely high, but those are precisely the cases where standard theory explains the observed preference for present consumption.

The intuition behind the design of the experiment is simple. Hyperbolic discounters will trade off the flexibility of option B for the commitment of option A, since they are aware of their self-control problem. However, the exponential discounters, since they do not face time inconsistency, will always prefer to keep flexibility available. The experiment embodies the idea of Gul and Pesendorfer (2001) that a hyperbolic discounter may prefer a reduced set of alternatives to a bigger one, since the smaller set is a commitment technology that increases its welfare. We also see the experiment as parallel to the analysis in Laibson (1994), where agents with self-control problems like to have access to a "binding automaton," a commitment device that restricts the freedom of choice of future selves.

We conclude this section by summarizing the properties of the experiment:

1. It generates different behavioral predictions for exponential and for hyperbolic discounters with little external structure.

2. It controls for hidden cost: both alternatives require that all subjects travel all three days to the laboratory, and the cost is independent of the amount of minutes played each day.

3. It controls for uncertainty: moving all relevant payoffs into the future removes any possible asymmetry between the alternatives.

4. It eliminates outside markets for the consumption good being offered. Even if subjects can play video games elsewhere, there is no mechanism to exchange the minutes in the experiment with the outside alternatives.

5. It allows for a nice dual interpretation. If the subjects do not like the consumption good, they will see the 180 minutes as work time. A hyperbolic discounter would tend to procrastinate (instead of overindulge), and to avoid having too many minutes at the last moment of the experiment, she would also prefer option A as a way of locking herself into working early.

4. Empirical Results

We conducted the proposed experiment with undergraduate students at the University of Minnesota. We recruited volunteers from three sections in intermediate microeconomics and one section in accounting. Students arrived at the laboratory on Monday, April 10, 2000, and received instructions, which are reproduced in the appendix. These instructions concluded with a short quiz five questions to check that the subjects understood the details of the experiment. After subjects had read the instructions and received answers to any questions they had, they completed their choice between option A (60 minutes each day to play video games on computers in the laboratory, two weeks later, on the 24th, 25th, and 26th of April) and option B (a total of 180 minutes to play video games on computers in the laboratory, two weeks later, on the 24th, 25th, and 26th of April, to be allocated as they wished on those three days). After subjects completed their choices they were paid \$5. We reminded subjects that, even if they preferred to not use any of their allocated time on a specific day under option B, they were required to visit the laboratory and sign in on each of the days, and if they completed all stages of the experiment they would be paid an additional \$30 on the 26th of April, regardless of whether they had chosen option A or B.

Two weeks later subjects came to the laboratory and were given access to the computers with the video games installed, according to the choices they have made on the 10th of April. Four different video games were installed on each computer of the laboratory. We selected the games from *Amazon.com*'s top-sellers list a week before the experiment to offer a popular and diverse choice of games. We monitored subjects' use of time to ensure that they did not exceed the time limits corresponding to the selected options. Subjects were paid $30 in cash on the 26th of April. The pay of $10 per hour of participation in the experiment was at least $1 above the prevailing hourly wage for on-campus jobs. The experiment days, in late April were outside of mid-term or finals weeks, making it unlikely that many students would be seriously time constrained on some of the days.

A total of 23 subjects read the instructions and completed the choice form between option A and option B. Twenty of the 23 subjects (87 percent) selected option B, flexibility in minutes allocation, and the remaining 3 (13 percent) selected option A, commitment to 60 minutes per day.

We assessed those choices as strong evidence that *most* subjects prefer not to use commitment devices. However, there is also strong evidence that *some* subjects prefer to use commitment devices. We conducted exit interviews at the end of the experiment. One of the subjects who chose option A mentioned explicitly that she preferred that option because it was a commitment device. That answer suggests to us that students understood the trade-off they were facing. Using the principle of irrelevance of stopping rules, and given our results, we decided to stop the experiment at that point and not proceed with additional batches of students (El-Gemal and Palfrey, 1996).

On a more formal basis, we conduct a Bayesian inference exercise. Given the existence of two different alternatives, the likelihood function is given by a binomial distribution on the share of the population that has exponential discounting p:

$$\mathcal{L}\left(x|\,p\right) = \binom{n}{x} p^{x}\left(1-p\right)^{n-x}$$

To complete our model, we need a prior. A uniform prior on the percentage of subjects with hyperbolic discounting is a plausible and natural belief. In addition, uniforms are conjugate priors for the binomial model and the posterior is distributed as a Beta with parameters $x+1$, $n-x+1$:

$$P\left(y\right) = \frac{\Gamma\left(n+2\right)}{\Gamma\left(x+1\right)\Gamma\left(n-x+1\right)} y^{x+1}\left(1-y\right)^{n-x+1}$$

Given the results of the experiment, our posterior distribution is a Beta with mean 0.84 and standard deviation 0.07, moments that support the presence of sophisticated hyperbolic discounting among a nontrivial share of the population. A graphical view of our empirical results is included as figure 2, which plots our prior, our posterior, and the likelihood function (up to a constant factor). We see our choice of prior as being non-informative. To illustrate that point, note that the maximum likelihood estimate of p is 0.87 with an asymptotic standard error of 0.03. Consequently, the interpretation of the results from a classical perspective is nearly identical.

Finally, we analyzed the patterns of time allocation across the three days of the experiment by students who chose flexibility. We did not find any clear pattern. Most students nearly perfectly smoothed time use; some followed decreasing patterns, some increasing, and some preferred to settle for hump profiles.

5. Comparison with Previous Results

Our empirical results suggest that the evidence in favor of sophisticated hyperbolic discounting might be weaker than previously claimed in the literature. Beyond our experimental design that provides commitment devices, several differences in our framework may account for the alternative outcomes.

First, our experiment involved real rewards. Most experiments presented in the literature involve only hypothetical choices. Out of the 34 experimental papers cited by Frederick *et al.* (2002) in table 1 of their paper, 25 use hypothetical choices. This issue raises the problem of the robustness of the findings under real payoffs: individuals may not have any incentive to give a reasonable answer or to spend mental resources to think about their true preferences. There is mixed evidence and a fair degree of controversy about the interpretation of experiments with hypothetical payoffs.

Second, our experiment precludes outside trading opportunities. In an economy with financial markets, the relevant parameter for intertemporal choice problems involving money (or other goods that can be easily traded) is not the discount factor but the interest rate since, thanks to financial intermediation, agents can rearrange their cash flow into an optimal consumption stream (Fuchs, 1982). If we assume that access to financial markets is limited, the relevant quantity is no longer the discount factor but the (unobservable) ratios of marginal utilities evaluated at the constrained consumption levels. Again, the existing experimental evidence involving money lacks a clear interpretation.

Even, if for the sake of the discussion, we forget about the existence of markets, the handful of experiments with real payoffs offer by themselves much weaker evidence in favor of hyperbolic discounting than is sometimes argued. Ainslie and Haendel (1982) found that around a third of subjects prefer a present monetary payoff when confronted with a 25 percent interest rate over three days. They comment that this choice was made despite the fact that the subjects have very little money available. We interpret that fact as a problem of the test, not as a reinforcing mechanism: the standard intertemporal choice model has very different predictions when liquidity constraints are binding. Holcomb and Nelson (1992) found weak evidence in favor of hyperbolic discounting when they asked undergraduate students if they preferred immediate or delayed payoffs. In the classical example of the choice between a quantity of money today and a different quantity tomorrow (with a daily interest rate of 1.5 and 3.0 percent), between 80 percent and 47 percent of subjects chose the immediate payoff, well within what can be accounted with a model of exponential discounters with uncertainty if we do not allow for financial markets.

Horowitz (1992) tested for time consistency in the choice of risky assets. He found important differences in choice over time, but they were not systematic nor did they imply a change at the aggregate level. Further, one could point to three features of his experiment: the amount of the payment was small (the expected value was between $1 and $2), subjects were not reminded of their own original choices when they made their second choice, and there could have been uncontrolled changes in the financial position of subjects in the interim. Horowitz (1991) tried to elicit directly the discount rate through a second-price auction of a bond. The very odd behavior of the subjects (they paid more for a two-month bond than for a one-month bond) points out important experiment design problems, some of which could be attributed to the subjects' lack of familiarity with the institution. Kirby (1997) also used the idea of auctioning bonds of future payments and found more robust evidence in favor of hyperbolic discounting. However, he did not provide any procedure to distinguish between possible anomalies in the auction itself and in the intertemporal choice problem. In fact, for the numbers of bidders that he uses (3 or 4), Kagel, Levin, and Harstad (1995) have found that bidders earn positive average profits, making it difficult to elicit the true values for the agents of the bond and weakening his evidence in favor of hyperbolic discounting.

Finally, Pender (1996) studied choices between payments of rice among low-income rural residents of South India. He documented higher discount rates in the seven-month horizon than in the twelve-month horizon. He argues, however, that hyperbolic discounting models have problems rationalizing the evidence. This last observation returns us to an observation we made in the introduction. Evidence of present-bias in intertemporal choice does not directly lead to support for hyperbolic discounting. Instead, many other behavioral models are compatible with the existing experimental evidence. It is important, then, to empirically distinguish among them.

6. Conclusion

Do we observe hyperbolic discounting? At this point, we believe the evidence is not as one-sided as is sometimes claimed. It is a robust fact that people choose present goods more frequently than implied by a simple full-information model with exponential discounting. However, many factors, such as uncertainty, may account for that observation even within the (otherwise problematic) framework of exponential discounting. Also, we have shown that most agents do not seem to be eager to embrace commitment devices, as implied by the sophisticated hyperbolic discounting model.

Our conclusion is extremely cautious. Present-bias is a feature of many agents' choice in some intertemporal problems. It is not clear from the evidence, however, that sophisticated hyperbolic discounting is the best way to capture that bias. Alternatives based on the role of uncertainty, fixed costs of decision-making, framing effects, dynamic self-control preferences, dual-self, planner-doer, or procedural approaches might fit the data better. Also, those alternatives may provide a better foundation for welfare analysis. We eagerly await the insights that further experiments and neuroeconomics may be able to provide in the near future about how individuals discount over time (see the fascinating evidence in McClure *et al.*, 2004, regarding the two neural systems engaged in intertemporal choices).

7. Appendix: Instructions for Individual Choice Experiment

1. General

You are about to participate in an experiment in the economics of individual choice. Various research foundations have provided the funding for this project. If you follow these instructions carefully, you will earn $30 just for playing games on the computer.

Please do not talk during the experiment. If you have any questions, raise your hand and an experimenter will assist you.

The experiment consists of your choosing between two options, A and B, and meeting all of the requirements of the option that you have chosen. These requirements are described in section 2 below.

Once you have completed all of the requirements of the option that you have chosen, you will be paid an additional $30 in cash. If you fail to complete all of the requirements of the option that you have chosen, you will not be paid any amount. Note that this payment does NOT depend on whether you chose B or A, but depends only on completing the requirements of the option that you have chosen. Also, the payment does NOT depend on what other subjects in this experiment choose. Just choose the option that you like the most.

2. The Options

You will have 180 minutes to play different games on the computers installed in the lab in 3-114 in the Carlson School of Management building from Monday to Wednesday in the week of 24th April to 26th April. Your choice concerns how you want to distribute these minutes.

Option A

If you choose option A), you will have 60 minutes on Monday 24th April, 60 minutes on Tuesday 25th April and 60 minutes on Wednesday 26th April. You can come in any time from 10 a.m. to 5 p.m. (from 24th April to 26th April) and then use your 60 minutes for the appropriate day in the lab.

You do have to attend on all three days. You should also sign your name on a control sheet, so we can verify that you have attended on all three days.

At the end of your last 60 minutes on Wednesday, if you have attended all three days as required, you will be paid $30 in cash.

Option B

If you choose option B), you can decide how you want to distribute a total of 180 minutes over the three days, Monday 24th April, Tuesday 25th April and Wednesday 26th April. You can come in any time from 10 a.m. to 5 p.m. (again, from 24th April to 26th April) to the lab.

You do have to attend on all three days. You should also sign your name on a control sheet, so we can verify that you have attended on all three days. So for example, you could choose to play 100 minutes on Monday, 0 on Tuesday and 80 on Wednesday, but on Tuesday you need to come to the lab, sign the sheet and then leave if you want to play for 0 minutes on that day.

At the end of your session on Wednesday, if you have attended all three days as required, you will be paid $30 in cash.

Your choice

After you have read the instructions, you will make your choice - between Option A and Option B - TODAY. Once you have made your choice TODAY, you CANNOT change your choice.

3. The Games

The lab in which you will participate in the experiment has a network with many computers. Each computer has three or more games installed on it. During your playing time, regardless of whether you have chosen Option A or Option B, you are free to change from one game to the other, if you wish.

4. The Experimental Lab

The lab is located on the 3rd floor of the Carlson School of Management Building in room 3-114. The lab will be open for this experiment 10 a.m. to 5 p.m. during the period 24th to 26th April. During this time, you may choose to attend at any time according to your schedule. If you have any questions about the experiment at any time, you may contact either Professor Mukherji by telephone (624-9825) or e-mail (amukherji@csom.umn.edu) or Jesús Fernández-Villaverde by telephone (204-5492) or e-mail (jesusfv@econ.umn.edu).

5. Before we begin

If you have any question regarding the experiment, ask them NOW. To ensure that you understand the instructions, please answer the following questions. An experimenter will check your answers when you are finished.

a) My payment will NOT depend on the choice of option A) or B) but in following the requirements of the option that I have chosen.

True False

b) For both options A and B, I need to come to the lab three times.

True False

c) I am allowed to change options when I want.

True False

d) Every time I go to the lab, I need to sign my name on a control sheet.

True False

e) I can play any of the games in the computer without any limitations except time.

True False

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Figure 1: Share of Population Choosing Consumption Today

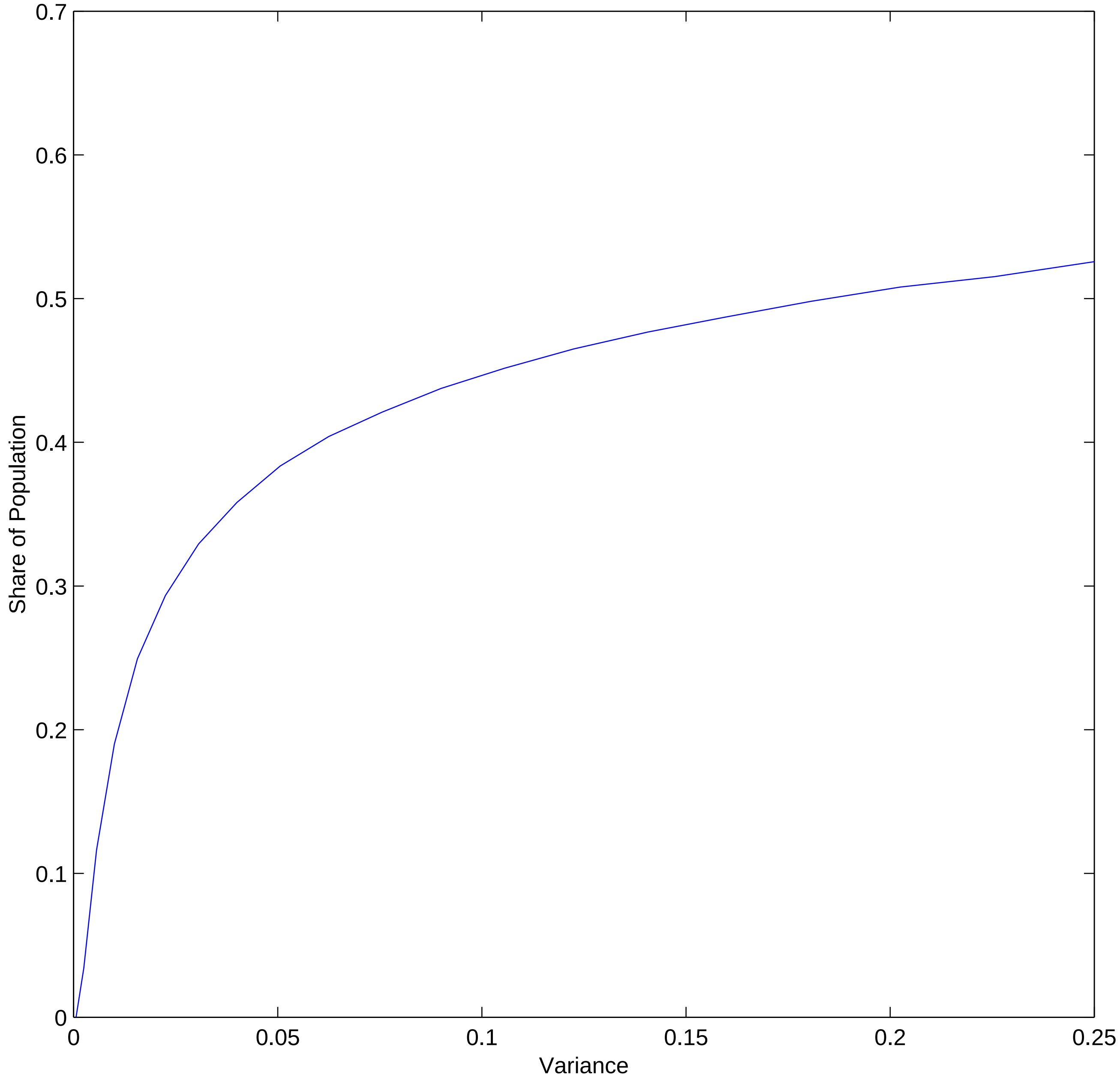

Figure 2: Prior, Posterior and Likelihood