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EXPLAINING ANOMALIES IN INTERTEMPORAL CHOICE: A MENTAL ZOOMING THEORY*

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Abstract

I present a theory that can explain hyperbolic discounting and magnitude effects in intertemporal choice. This approach builds on theories of narrow framing and reference dependence and expands these theories in a novel way by examining hidden mental zooming in base consumption adjustment in decisions regarding intertemporal prospects of varying magnitudes and time horizons. Data from a field experiment were used to assess the theory with an incentive-compatible multiple price list approach involving magnitude levels of 5x, 10x and 20x the basic magnitude level with time horizons of one, three, six and 12 months. Without zooming adjustments in base consumption, very strong hyperbolic and magnitude effects were found, and present bias could not explain the hyperbolic effects. The mental zooming model provides an effective rational explanation of what appear to be significant intertemporal anomalies in the data. *JEL* codes: D03, D91, C93.

Key words: Intertemporal choice, hyperbolic discounting, magnitude effects, mental zooming theory, field experiment.

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I. INTRODUCTION

Anomalies in inter-temporal choice include hyperbolic discounting, quasi-hyperbolic discounting (present bias) and magnitude effects (Chung and Herrnstein 1967; Thaler 1981; Ainslie 1991; Loewenstein and Prelec 1992; Laibson 1997) and represent deviations from the well-known discounted utility model (Samuelson 1937).

Hyperbolic discounting is among the peculiar behavioral observations that has fascinated economists and is one of the most common persistent irrational behaviors that leads to inter-temporally inconsistent behavior with potential negative externality effects. Although behavioral and experimental economics have revealed many forms of irrational and inconsistent behavior, hyperbolic discounting may be among the behaviors with the strongest negative long-run effects due to the high weight given to present and near-future outcomes at the expense of outcomes further in the future (Laibson 1997). Hyperbolic discounting may lead to overspending, underinvestment, resource degradation and poverty traps that require policy action. One may even speculate about whether the current inability to mobilize nations for global collective action to address the challenge of global warming is partly due to hyperbolic discounting and therefore may not be a pure collective action problem (Karp 2005).

Although hyperbolic discounting has been accepted as a widespread behavioral characteristic, there have been few convincing attempts to explain this phenomenon beyond the immediate pleasure and addiction motives that may explain present bias or quasi-hyperbolic discounting. However, the phenomenon stretches beyond the quasi-hyperbolic functional form and therefore requires a wider and deeper explanation. The aim of this paper is to provide this explanation, testing a new theory with experimental data.

My theory builds on the concept of “narrow framing,” which was first discussed by Kahneman and Lovallo (1993) and relates to the more general concept of “decision framing” that was introduced earlier by Tversky and Kahneman (1981). My theory is also inspired by Google Earth, a visual aid that illustrates the process of mental mapping and zooming in towards a more specific and narrow area. Using this tool, one chooses a geographical area to zoom in on and the degree to which one zooms in. As one zooms in, new details appear, and the frame becomes much narrower. As one dives deeper towards the details, one loses sight of the larger landscape and can focus much more clearly on the details within the narrow frame. My theory is that mental zooming in relation to various types of decisions works in the same way. In many situations, the brain functions as a mental zooming device, narrowing its focus to specific issues that it fails to evaluate holistically. In some contexts, narrow framing (Barberis, Huang and Thaler 2006) and choice bracketing (Read et al. 1999) are more specific outcomes of the zooming behavior of the brain. This theory is therefore a more general attempt to explain specific patterns of systematically inconsistent inter-temporal choices.

Narrow framing, combined with first-order risk aversion, has been used to explain why many people turn down independent favorable small gambles (Barberis, Huang and Thaler 2006; Rabin and Thaler 2001) in a behavioral pattern that is consistent with limited asset integration, as observed in risk preference experiments (Binswanger 1980; Wik et al. 2004). New independent gambles are evaluated more or less in isolation from the pre-existing wealth of the decision-maker. Rabin (2000) demonstrated that the levels of risk aversion revealed in small gambles lead to unrealistically high levels of risk aversion in large gambles with asset integration and that standard utility functions cannot explain the high levels of risk aversion observed in small gambles.

Similarly, in inter-temporal choices, magnitude effects in the form of systematically lower discount rates associated with the prospect of larger monetary gains appear to be an accepted empirical regularity[1] with few convincing explanations. Referred to as the "increasing proportional sensitivity property" (Prelec and Loewenstein 1991), this phenomenon cannot be explained by the functional form of the utility function.

The main contribution of this paper is that it illustrates how the zooming theory can explain both hyperbolic discounting and magnitude effects, two puzzling phenomena that are observed as forms of "irrational behavior" in time preference experiments. I am unaware of any other explanations for these phenomena. Furthermore, my theory is a theory of partial asset integration that is consistent with experimental evidence from risk and time preference experiments, in which asset endowments exhibit weak but significant correlations with risk and time preference estimates.

Section two of the paper reviews the literature on anomalies in intertemporal choice, in particular hyperbolic discounting and magnitude effects, including attempts to explain thees phenomena. Section three outlines the zooming theory with partial asset integration. Section four describes field experiments used to obtain data to test the theory. Section five uses both the standard theory and the new zooming theory to demonstrate and discuss the predictive power of the new theory. A final section concludes.

[1] See Frederick, Loewenstein and O'Donoghue (2002) for a review of early studies and Andersen et al. (2010) for a more recent review.

II. LITERATURE REVIEW

The literature review is divided into two parts. The first part reviews the literature on hyperbolic discounting and magnitude effects in intertemporal choice, including theories and tests that have attempted to explain these phenomena. The second part reviews the literature that presents evidence of limited asset integration, theories of narrow framing and tests of these theoretical efforts to explain these forms of "irrational" behavior.

II.A. Hyperbolic Discounting and Magnitude Effects

Research has revealed that both animals and humans behave as if their discount functions are approximately hyperbolic (Chung and Herrnstein 1967; Loewenstein and Prelec 1992; Ainslie 1992; Laibson 1997), with quasi-hyperbolic discounting explained by present bias and liquidity constraints. Whereas present bias may be caused by addiction or demand for immediate gratification, hyperbolic discounting is less well understood and less well documented. Behavior as described by a hyperbolic discount function is regarded as a form of systematically irrational behavior that leads to time-inconsistent decisions. However, although hyperbolic discounting functions have provided a convenient way to model behavior, such behavior is not theoretically explained by hyperbolic discount functions.

Following Loewenstein and Prelec (1992), I start with a general utility function in which time and money are separable:

1) $$u(x,t) = F\left(v(x)\phi(t)\right)$$

where $v(x)$ is the value function, $\phi(t)$ is the discount function and F is a monotonically increasing transformation that may be dropped based on a distributivity condition. Under the assumption of additive time-separable utility, the intertemporal utility function may be reformulated as follows:

2) $$U\left(x_1,t_1;\ldots x_n,t_n\right)=\sum_{i=1}^{n}v\left(x_i\right)\phi\left(t_i\right)$$

As a special case, the exponential discounted utility model of Samuelson (1937) uses the simple single discount rate:

3) $$U\left(x_i,t_i\right)=\sum_{t=1}^{n}u\left(x_t\right)e^{-\delta t_i}$$

where δ is the continuous time (constant) discount rate. Loewenstein and Prelec (1992) demonstrated the stationarity property of a utility function with constant base consumption

4) $$u\left(c+x\right)\delta^{t}+u\left(c\right)\delta^{t'}=u\left(c\right)\delta^{t}+u\left(c+y\right)\delta^{t'}$$

by dividing through by δ^{t}:

5) $$u\left(c+x\right)-u\left(c\right)=\left(u\left(c+y\right)-u\left(c\right)\right)\delta^{t'-t}$$

They then elaborated upon the various anomalies of intertemporal choice: for example, the common difference effect, the absolute magnitude effect, gain-loss asymmetry and delay-speedup asymmetry. On this basis, most attempts to model dynamically inconsistent behaviors due to the common difference effect have attacked the discount function with representations such as that of Ainslie (1975), who formulated $\phi\left(t\right)=1/t$ to explain animal behavior, and the generalized hyperbola formulated by Harvey (1986):

6) $$\phi\left(t\right)=\left(1+\alpha t\right)^{-\delta/\alpha},\ \alpha,\delta>0$$

where α determines the degree of departure from constant discounting, with $\phi(t)=e^{-\delta t}$ as the limiting case as $\alpha \to 0$.

The issue of whether respondents really valued prospects in relation to a constant base consumption level when comparing different prospects therefore escaped the attention of researchers, who focused more on identifying discount functions that satisfied the "empirical matching law" and usually associated the reference point with the status quo situation of the respondents in their assessments of, for instance, gains versus losses (Loewenstein and Prelec 1992).

In the present paper, I limit myself to the analysis of choices with prospects of gain, both to keep the analysis simple and because framing effects in relation to gains versus losses have been studied extensively, whereas the implicit or hidden framing of base consumption associated with changing time horizons and magnitudes has largely escaped researchers' attention.

Laibson (1997) suggested a quasi-hyperbolic discounting function based on Phelps and Pollak (1968):

7) $$U_t = E_t\left(u(c_t) + \beta \sum_{\tau=1}^{T-t} \delta^{\tau} u(c_{t+\tau}) \right)$$

where $\beta < 1$ captures the present bias or quasi-hyperbolic discounting, which may be distinguished from generalized hyperbolic discounting, in which discount rates decline with the length of the time period, unlike δ in this model.

Dasgupta and Maskin (2005) link hyperbolic discounting to uncertainty and the possibility that decision-makers may switch from a dynamic optimum to a static survival strategy when uncertainty rises. They argue that such uncertainty does not entail preference reversals and that hyperbolic discounting may be regarded as fully rational.

The magnitude effect may be illustrated as follows:

8) $$\frac{u(x_{t+s})}{u(x_t)} < \frac{u(\alpha x_{t+s})}{u(\alpha x_t)} \text{ for } \alpha > 1, s > 0, x_{t+s} > x_t > 0, u(\cdot) \text{ represents utility}$$

Named the "increasing proportional sensitivity" property by Prelec and Loewenstein (1991), this property is not captured by standard utility functions. Chapman (1996) finds that the magnitude effect is reduced under a monetary utility function that lacks this property.

Thaler (1981), who finds strong magnitude effects, hypothesizes that these effects are explained by self-control problems. He also observes that both hyperbolic and magnitude effects can be explained by a fixed cost of waiting. However, the experiments that he conducts do not include such fixed costs, which must therefore be psychic.

Andersen et al. (2010), in their review of the literature on magnitude effects, emphasize that most studies that identify magnitude effects use hypothetical questions and do not satisfy the quality standards of experimental economics. Loewenstein and Prelec (1992) state that the magnitude effect cannot be due to the curvature of the utility function because the effect tends to be stronger for small amounts. However, Andersen et al. (2010) question this argument. Another explanation could be that there is a fixed cost or minimum amount that is needed before a delay in receiving a given amount becomes salient (Benhabib, Bisin and Schotter 2010). This threshold would result in a decreasing magnitude effect as amounts increase. Using data from an experiment with real payouts for a sample of adults in Denmark, Andersen et al. (2011) find a significant magnitude effect after controlling for the concavity of the utility function, while the use of a linear utility function results in a smaller magnitude effect. The researchers find that their estimated magnitude effect is much lower than in earlier studies and that it disappears when they include only prospects for which both points in time are delayed. They point to a potential weakness of earlier studies that find magnitude effects: such studies do not use delayed front-end payments, and a difference between the fixed transactions costs for immediate and delayed payments may thus explain the magnitude effect. A possible limitation of the Andersen et al. (2011) study is that they use only two magnitude levels, DKr 1500 and DKr 3000, which implies only a doubling of the magnitude. My experiments include magnitudes that are five, 10 and 20 times the smallest magnitude, with varying delays in the initial point in time and with real payments. I can therefore test whether fixed transaction costs related to delayed payments can eliminate the magnitude effect, as suggested by the findings of Andersen et al. (2011), and I can test my mental zooming theory in the magnitude dimension.

II.B. Limited Asset Integration and Framing Theories

Limited asset integration was first revealed in risk preference experiments conducted by Binswanger (1980) in India, experiments that were later replicated in other countries (for example, in Zambia by Wik et al. (2004)). The respondents exhibited risk-averse behavior when confronted with favorable small gambles that should have led them to behave in a risk-neutral manner if their decisions and wealth outcomes had been integrated with their total wealth. The respondents were much more sensitive to changes in game levels than to variations in final wealth. Rabin (2000) has shown that this behavior cannot be explained by standard utility functions and expected utility theory.

Tversky and Kahneman (1981) introduced the more general concept of "decision framing," which they illustrated by introducing the same decision problem from a gain versus loss perspective, demonstrating that behavior changes in response to framing. The concept of "narrow framing" was first used by Kahneman and Lovallo (1993), who observed that decision-makers "*tend to isolate the current choice from future opportunities and neglect statistics of the past in evaluating current plans*" (ibid., p. 17).

Reasons for narrow framing may relate to the need to simplify decision problems and execute decisions, as comprehensive and "holistic" evaluation is cognitively more demanding and time consuming. People therefore utilize "narrow framing", "mental accounting" (Thaler 1985; 1999) and "choice bracketing" (Read et al. 1999) as simplifying decision-making tools. Read et al. (1999) discuss factors that affect whether people bracket narrowly or broadly, including cognitive limitations, the way choices are framed in terms of narrowness or division into several and smaller tasks, and motivational framing as a form of broader bracketing.

Kõszegi and Rabin (2006) expanded the theory of status quo bias and reference-dependent preferences by proposing an endogenous reference point that is determined, via rational expectations, by the economic environment and by the recent experiences of the decision-maker. The researchers claim that using an expected reference point rather than the status quo as a reference point induces better predictions when these reference points differ. Unobservable reference points therefore explain how apparently "irrational behavior" may result from rational decisions. My mental zooming theory of hyperbolic discounting and magnitude effects in inter-temporal decisions follows a similar line of reasoning but expands on how decision-makers adjust their reference points to the prospects with which they are confronted.

Kõszegi and Rabin (2013) introduced a model of economic choice in which the individual focuses more on attributes that differ more starkly and hence tends to overweight such attributes. They applied the model to intertemporal choice and showed that the model leads to present bias and time inconsistency in situations in which the future effect is distributed over many dates and in which the effects of multiple decisions accumulate. The theory implies that present bias is lower when costs are less dispersed or when the number of decisions with cumulative effects is smaller.

I distinguish between the explicit framing that researchers impose on experiments as part of the design of such experiments—framing that may even vary over alternative treatments—and the implicit framing that respondents undertake when they are confronted with alternative decision problems. Kahneman (2003, p. 1459) discussed the passive acceptance of framing conditions that may occur in some situations and that allows researchers to introduce explicit framing treatments. My focus in this paper is on possible "hidden" framing effects that may occur when individuals make choices in certain types of experiments involving risk and time. Such "hidden framing" may explain various forms of puzzling and apparently "irrational" responses, such as "endowment effects" (which may be eliminated through the introduction of an appropriate set of controls (Plott and Zeiler 2005; 2007)), limited asset integration (as observed in experiments on risk preferences) and, as I propose here, hyperbolic discounting and magnitude effects in time preference experiments. My theory states that people gradually adjust the framing of their reference points ("mental zooming"), whereas earlier theories have focused on either "narrow" or "wide" framing or bracketing. In the next section, I propose that such mental zooming is used to assess prospects that involve choices between alternative amounts of money received at different points in time. My theory builds on the earlier framing and reference-dependent theories that I have reviewed above but also has unique attributes that have escaped the attention of earlier theorists.

III. A THEORETICAL MODEL WITH MENTAL ZOOMING

I begin with an additively time-separable intertemporal utility function with exponential discounting as the benchmark model. I assume that respondents have concave utility functions within given time periods (Andersen et al. 2008). I focus exclusively on "gains only" situations so that I can ignore "gain-loss" asymmetries. The hyperbolic and magnitude anomalies that I seek to explain are evident in experiments with gains only and therefore are not a direct effect of gain-loss asymmetries.

Respondents are given the choice between two prospects, M_A at time t_1 and M_B at time t_2, where $t_1 \geq 0$ and $t_1 < t_2$. Decision-makers must choose between U_A and U_B:

9)
$$\begin{aligned} U_A &= \left(\left(e^{-\delta(t_1-t_0)}u\left(y_1+M_A\right)\right)+\left(e^{-\delta(t_2-t_0)}u\left(y_2\right)\right)\right) \\ U_B &= \left(\left(e^{-\delta(t_1-t_0)}u\left(y_1\right)\right)+\left(e^{-\delta(t_2-t_0)}u\left(y_2+M_B\right)\right)\right) \end{aligned}$$

where δ is the continuous time discount rate and where y is background consumption. Present bias may occur if $t_1=0$, as immediate temptation may affect decisions, transaction costs may be perceived as lower for immediate payments than for delayed payments, or the level of uncertainty regarding immediate payment may be lower than that associated with delayed payments (Coller and Williams 1999; Andersen et al. 2008).

The zooming theory with limited asset integration assumes that the prospects offered at two different points in time are integrated to varying degrees with decisions regarding other endowments of the decision-maker. This concept can be illustrated in a simple way based on equation (5) above:

$$10)\qquad u\left(c\left(P^*\right)+x\right)-u\left(c\left(P^*\right)\right)=\left(u\left(c\left(P^*\right)+y\right)-u\left(c\left(P^*\right)\right)\right)\delta^{t'-t}$$

where base consumption is assumed to be a function of the prospect characteristics P^*. Using a daily wage rate (y) as the "starting reference point" for short-term prospects makes it possible to model zoom-adjusted base consumption as follows:

$$11)\qquad c\left(P^*\right)=y\left(P^*\right)=yf\left(t_2-t_1,M_B\right)$$

The degree of this type of asset integration depends on the length of the time horizon and the magnitude of the prospects. A higher level of asset integration, "zooming out", occurs over longer time horizons and for larger amounts, whereas for shorter time intervals and smaller amounts, a lower level of asset integration is needed. Thus, in the latter case, the decision is "zoomed in", becoming more myopic and less holistic because the problem may be more trivial or of a more short-term nature. The novel contribution of this theory is therefore the notion that the decision-maker automatically adjusts the framing of the decision problem to the most relevant scale to simplify the decision-making process (hidden mental zooming). In zooming in on a narrower set of factors and excluding other issues, the individual faces a simplified problem that can be evaluated more quickly, which, in turn, will expedite decision-making. This conclusion implies that the base consumption levels (y_1, y_2) are functions of the time period and of the magnitudes of the prospects. If this theory is correct, zoom-adjustment of the base consumption level should eliminate hyperbolic and magnitude effects in time preference experiments, and decisions should appear rational in the zoom-framing perspective, as in other theories of reference-dependent preferences (Kõzegi and Rabin 2006; 2007).

Given that reference consumption levels are unobservable, I assume that for the period in question, a base consumption level and investment levels that are similar in magnitude to those upon which the decisions are based are appropriate starting points. This is similar to assumptions made by other researchers, e.g., Andersen et al. (2008; 2011). The structural model may therefore simply be reformulated as follows to capture zooming adjustment with partial asset integration:

12)
$$U_A = \left(\left(e^{-\delta(t_1-t_0)}u\left(y_1 f\left(t_2-t_1, M_B\right)+M_A\right)\right)+\left(e^{-\delta(t_2-t_0)}u\left(y_2 f\left(t_2-t_1, M_B\right)\right)\right)\right)$$
$$U_B = \left(\left(e^{-\delta(t_1-t_0)}u\left(y_1 f\left(t_2-t_1, M_B\right)\right)\right)+\left(e^{-\delta(t_2-t_0)}u\left(y_2 f\left(t_2-t_1, M_B\right)+M_B\right)\right)\right)$$

where base consumption at each point in time represents the unobservable zooming level, which, according to my mental zooming theory, is a function of the length of the time interval and the magnitude of the amount at the far end that is under consideration in each choice set. Larger amounts and longer time horizons imply wider framing and zooming out because these decisions are more momentous and therefore “require” a more holistic treatment that implies a higher level of asset integration.

Another aspect of equation 12 is that it focuses on the utilities of prospects, where utility is a function of incomes received under alternative prospects. Following Andersen et al. (2008), respondents are risk-averse and have utility functions with diminishing marginal utility. Neglect of this property could lead to the overestimation of discount rates. Diminishing marginal utility is also relevant in more narrow framing perspectives, as diminishing marginal utility also affects short-term consumption. Indeed, I argue that it is narrow framing that leads to diminishing marginal utility in short-term decision-making, which tends to be consumption-oriented. More long-term and larger decisions tend to be investment-oriented and are associated with consumption over longer periods of time. For the sake of simplicity, in testing the theory, I have used utility functions with constant elasticity of marginal utility. In addition, I vary this elasticity to assess the sensitivity of the results of such variations.

In testing whether the model can explain hyperbolic discounting and magnitude effects, I expect that these effects will be eliminated or will become very small when zooming adjustment of base consumption is included in the analysis of the experimental data, with time horizon and magnitude effects included among the (randomized) experimental treatments. I therefore use such data to test the "explanatory power" of the theory. There are, however, three important unobservable components that require attention: a) the determinants of the appropriate initial base consumption; b) the determinants of the functional form of the zooming adjustment to the length of the time horizon; and c) the determinants of the functional form of the zooming adjustment to the magnitude effect. My theory states that the base consumption level is an increasing function of both the length of the time horizon and the magnitude of the far end monetary payment (with less narrow framing for larger, longer-term decisions). Andersen et al. (2008) chose the daily wage rate as the base consumption level in their time preference experiments in Denmark. I have used the same daily wage rate as a starting point for decisions with a short time horizon (one month). If mental zooming is similar to visual zooming and if the observable area adjusts similarly to the mentally observed "area", it may be relevant to test this adjustment to the mental "area" as if the brain translates the visual area using the same scale as the mental "area". For example, when one visually zooms in using Google Earth, reducing the distance from the earth to half the initial distance reduces the visually observable area to one quarter if the angle of vision is constant and the radius of the observable area is reduced by half. When base consumption is included in a non-linear utility function, the same non-linear adjustment to time and magnitude frames occurs if these frames are included in linear form. I therefore start with this type of linear adjustment in the consumption space of base consumption to time and magnitude frames in a logarithmic utility function, assessing the effects of deviating from it. Because I do not have a theory that indicates which functional form is more appropriate, I resort to testing alternative functional forms empirically. Because the unobservable base consumption level and degree of zooming may vary across individuals, I test for the general tendency in the data. Some individuals may be more prone to high levels of asset integration; thus, they may make more holistic decisions and exhibit greater "rationality." In contrast, others may zoom in more narrowly and may thus exhibit greater myopia and "irrationality" in their decisions. I use experimental data to "experiment" with different base consumption levels and the functional form of the zoom adjustment in the two dimensions of time and magnitude.

My theory may explain quasi-hyperbolic discounting or present bias as an instance of extremely narrow framing of base consumption that, in the limit, reduces to a purely static decision that ignores future outcomes. This may occur as a break or a switch from the more continuous framing adjustment that is implied by my mental zooming theory to a purely static/myopic corner solution.

IV. Experimental Design and Implementation

Using a multiple price list (MPL) design, field experimental data from representatives gathered from a random sample of rural households in Malawi were used to examine anomalies in intertemporal choice and to test whether the hidden mental zooming theory might explain these phenomena. The treatments used included three front-end timing treatments, four endpoint timing treatments and four magnitude level treatments. The front-end timing treatment included present timing, a one-week delay and a one-month delay, specifications that allowed for separate testing of quasi-hyperbolic versus hyperbolic discounting. The end-point timing treatments included one-month, three-month, six-month and 12-month delays. The magnitude levels, which were fixed for the end points, were 1,000 MK[2], 5,000 MK, 10,000 MK and 20,000 MK. Although other researchers have used MPLs with amounts offered in increasing order (Pender 1996; Andersen et al. 2011), such a design can lead to substantial censoring in developing country settings (Pender 1996; Yesuf and Bluffstone 2009). I therefore chose to fix the future amount and ordered the smaller current/near future amounts in decreasing order. This strategy allows for much higher discount rates without any censoring problems. Even given this design, however, we encountered individuals with extremely high discount rates that were outside the range of our standardized lists. For these individuals, we extended the lists on an individual basis until a switch point was identified. Fixing the future amount of each prospect is also a convenient way to test my zooming theory. The simple design of the intertemporal choice prospects in the MPLs is presented (example of the prospects) in the Appendix. The basic treatment variations are presented in Table I.

<TABLE I APPROX HERE>

There are 44 unique possible combinations, as the 1 month-1 month combination is irrelevant. We further reduced the number of treatments to 27 but retained the “middle ground” treatments that were considered most relevant to the analysis of input demand decisions, which

[2] MK=Malawi Kwacha, 1 US$= 284 MK at the time of the experiments (August 2012).

the experiments were designed to illuminate, and which are typically made 3-6 months before a crop is harvested. The amounts that smallholder households typically spend on farm inputs are also in the range of 5,000 to 20,000 MK. We preferred to compare two future points in time in most treatments (20) but included a sufficient number of treatments (7) involving the comparison of the present time with a future point in time to test for present bias. The numbers in parentheses in Table 1 indicate how many of the treatments contained each treatment level.

The treatments were randomized across households. Each household was confronted with 9 of the 27 series, so that all 27 series were distributed across three household representatives in each village.

The time preference experiments were run jointly with risk preference and input demand experiments. The order of these experiments was randomized, which enabled us to test for the order effects of the experiments.

In each series, using ten cards from a card deck, the starting point was randomized by the experimental enumerator to minimize starting point bias. After receiving an answer for this random task, the enumerator was told to go to the end point of the series in the direction in which a switch point was expected, where the direction depended on whether the respondent chose the near future (current) amount or the far future amount. If the respondent chose the near future amount, the bottom task in the series would be chosen. If the respondent then switched to the far future amount, the enumerator would move to the series in the middle between the two previously tested series and then continue to quickly narrow in on the switch point. There were cases in which a switch point was not identified before the bottom of the series was reached. The enumerator then added rows by offering even smaller near future (current) amounts until a switch point was detected. In analyzing the data, we tested for starting point bias by creating a variable that interacted the starting point dummy with the row number that had been randomly chosen as the starting point in that series.

Four well-trained Malawian MSc-graduates in economics were recruited as experimental enumerators. They were first trained by the author in the classroom for one day and then tested the experimental formats on one another after being introduced to the designs. Next, they were involved in the field testing of the designs an out of of the sample location, also with close follow-up by the author. After some modifications to the design and refinements of the method of conducting the interviews, an implementation plan was established. Within each district, several villages (typically four per district) were sampled. The experiments required one day in each village, and one district was completed in one week. A suitable school within the village (in most cases) or in close proximity was identified as the field laboratory. A classroom was typically chosen, and tables and chairs were organized in each corner of the room so that each enumerator could interview a respondent without being disturbed by the others. The respondents sat with their backs to the center of the classroom. Those who had not yet participated in the experiments waited at sufficient distances outside the classroom and were unable to observe the activities taking place inside. Those who had completed all experiments received their payments (in cash and in kind) and were asked to return to their homes and avoid speaking with anyone outside the classroom who had not yet participated in the experiment. The enumerators conducted all three types of experiments while randomizing their order and rotating the respondents among themselves.

Due to the limited literacy and numeracy of the respondents, the enumerators had to spend time explaining the details to them and teaching them the concepts of probability and random choice that were required for them to participate in the more cognitively challenging risk preference experiments. We decided not to provide the respondents with information about the implied annual discount rates in the intertemporal choice tasks, as most of the respondents were unfamiliar with the concept of an annual discount rate.

All of the respondents received pay-outs in the risk preference and input demand experiments, whereas each respondent had a 10% probability of receiving a pay-out in the time preference experiments based on a random draw of a card from ten cards. For a winner, a new card would be drawn to identify one of the nine series he or she had completed, and another card would be drawn to determine the task in that series. Their choice during that task determined whether they would receive the near future payment or the far future payment. The organizer of the survey, who were from the University of Malawi, took responsibility for ensuring that proper payments were made on the appropriate dates. The fact that the households belonged to a panel that had been visited and interviewed many times during the preceding six years gave the respondents reason to trust that they would in fact receive the future payments.

V. Methods and Data Analysis

The Utility differential from equation (12) is specified as

13) $$\nabla U = U_A / (U_A + U_B)$$

capturing the probability that prospect A is chosen. A further extension of the estimation of the above models includes stochastic errors. More specifically, I applied the Luce specification, which was also used by Holt and Laury (2002) in estimates of risk preferences and by Laury et al. (2012) in estimates of time preferences:

14) $$\nabla U = U_A^{1/\mu} / \left(U_A^{1/\mu} + U_B^{1/\mu} \right)$$

where μ is the stochastic (Luce) error. We use the simple logarithmic constant relative risk aversion (CRRA) utility function with relative risk aversion $r = 1$ as the base model, which leads to lower estimates of discount rates than when risk aversion is ignored (Andersen et al. 2008).

The logarithmic function is conservative in that it implies a higher degree of risk aversion than that observed by Holt and Laury (2002) in their estimates of risk aversion among students in the US and that observed by Andersen et al. (2008) in their joint estimations of risk and time preferences in Denmark. Although some findings indicate that poor people tend to be more risk averse than others –such that they exhibit decreasing relative risk aversion (DRRA) relative to wealth and increasing partial risk aversion (IPRA) relative to game levels (Wik et al. 2004; Yesuf 2004) – Binswanger (1980) and Mosley and Verschoor (2005) find no significant association between risk aversion and wealth.

Based on the prospects presented and the utility function, a log-likelihood function is constructed for the maximum likelihood estimation of relevant parameters such as the discount rate (δ), the noise parameter (μ), treatment (prospect) characteristics (Z_i) and respondent characteristics (X_j):

15) $$\ln L\left(\delta, \mu; Choice_{ij}, Z_i, X_j\right) = \sum_j ((\ln \Phi(\nabla U) \mid Choice_{ij} = 1) + (\ln \Phi(1 - \nabla U) \mid Choice_{ij} = 0))$$

The choice of exponential discounting enables us to test for deviations from this specification with our randomized treatments and makes it possible to assess whether the zooming theory can explain hyperbolic discounting and magnitude effects. Significant time horizon and magnitude treatment effects in the baseline estimates without zooming adjustments in base consumption serve as a starting point for the test of the zooming theory. Constant base consumption in the baseline models is set at the average daily wage rate, i.e., 300 MK. This may be an appropriate base consumption level for decisions pertaining to relatively short periods of time (for example, less than one month) but may provide too narrow a frame for longer-term decisions or decisions involving larger amounts than are consumed over short periods.

The sensitivity analyses of zooming adjustment in this study included varying the elasticity of marginal utility, the functional form of the magnitude adjustment and the functional form of the time horizon adjustment. Risk preference experiments were conducted on the same households using the Holt and Laury (2002) MPL under two approaches. The first approach involved hypothetical real-world framing of the choice between different varieties of the main staple crop (maize) given alternative states of nature (drought or no drought). The second approach employed the same design structure but included monetary outcomes and real payouts. These experiments yielded average rates of relative risk aversion of 1.3 in the hypothetical experiments involving crop varieties and 0.8 in the experiments involving real monetary payouts using a CRRA utility function. Accordingly, the time preference experiments used utility functions with elasticities of marginal utility of -0.8, -1.0, and -1.3, with the logarithmic utility function as a reasonable base model.

The elasticity of adjustment of base consumption to the time horizon and the magnitude of future payments varied from 0.5 to 2.0 in consumption space, and the results were compared with those for models that employ the usual approach, i.e., with constant base consumption and where the discount function is adjusted instead (e.g., Loewenstein and Prelec 1992).

Table II presents the results of tests of alternative zooming adjustments of base consumption. In the first test, zooming adjustment is just made for the length of the time horizon by multiplying base consumption by the length (number of months) of the time horizon (linear zooming in the time horizon). The second and third zooming adjustments combined linear adjustment for the length of the time horizon with linear adjustment for the magnitudes of the fixed future amounts normalized, alternatively, by the lowest and second lowest future amounts. Additional zooming adjustments were used to assess nonlinear (concave) magnitude adjustments. A concave adjustment for magnitude and a convex adjustment for time horizon in consumption space within the logarithmic utility function were found to provide a reasonably good fit. The stability of such non-linear zooming adjustments across sites or sample populations is, however, a question that requires further investigation.

<TABLE IIAPPROX HERE>

VI. Results and Discussion

I start by examining the estimation results using a standard continuous time exponential discounting utility function with constant base consumption set at the average local daily wage rate (the baseline model). The elasticity of marginal utility is set to unity (with a logarithmic utility function). The results for this structural model are presented in Table III, and the predicted discount rate distributions by time horizon are shown in Figure I. The model demonstrates very strong hyperbolicity and magnitude effects. The discount rate varies from 150% for a one-month time horizon to implausible negative values for a 12-month time horizon.

As a first step towards testing my zooming theory, to adjust base consumption to the time frame of the prospects, I have made base consumption a linear function of the number of months of the time horizon in the second model in Table III, assuming that respondents zoom out and integrate their prospect decisions into a larger base consumption level when the prospects are more long-term. The predicted discount rate distributions by length of time horizon are presented in Figure II. We observe that the variation in discount rates across time periods is reduced and that most of the distribution of the discount rates for the 12-month horizon has non-negative values. Figure III shows the predicted magnitude effects for the same model with linear adjustments in base consumption to the time horizon only. Although the size difference in discount rates between the time horizon treatments was reduced by more than 60%, as seen in Table III, the size difference in the magnitude effects increased by approximately 20%.

<TABLE III APPROX. HERE>

<FIGURE I APPROX. HERE>

<FIGURE II APPROX. HERE>

<FIGURE III APPROX. HERE>

The zooming theory also states that the base consumption level or degree of asset integration implies the zooming of base consumption to the amounts in the prospects under consideration. A set of models was run that tested the joint zooming of base consumption in time horizons and magnitudes of prospects. The first two models are linear in time horizon and magnitude in consumption space but differ with respect to the normalization of the magnitude effect, where the first model is normalized by the smallest amount (1,000 MK) and the second model is normalized by the second smallest amount (5,000 MK). Under the first model, the magnitude effect was reversed, as it was for longer time horizons. The second model, which gives less weight to the magnitude adjustment, yielded discount rates that were close to each other in the treatments with three-, six- and 12-month horizons and with magnitudes of 5,000, 10,000 and 20,000 MK, whereas the smallest amounts and time horizons were associated with significantly higher discount rates. A similar result was found in the third model in Table IV, where base consumption was adjusted to the square root of the magnitude in combination with linear adjustment in the time horizon, implying a weaker adjustment to magnitudes than to the time horizon. Figures IV and V show the discount rate distributions predicted by the zooming model for the time horizon and magnitude treatments. The model appears to perform well in both dimensions with respect to eliminating time horizon and magnitude effects, except for the smallest magnitudes and shortest time horizons, which may be associated with a discontinuous shift towards very narrow framing.

<TABLE IV APPROX. HERE>

<FIGURE IV APPROX. HERE>

<FIGURE V APPROX. HERE>

The experiments included treatments with the initial point either delayed or current to test for present bias (quasi-hyperbolic discounting). Tables III and IV reveal significant present bias in the form of higher discount rates when the near point in time is the present. Figures VI and VII show the model’s prediction of discount rates when the initial point is the present and when the initial point is delayed for larger amounts (10,000 MK) and three- and 12-month horizons (Figure VI) as well as for smaller amounts (1,000 MK) and three- and six-month horizons

(Figure VII). The extent of the present bias appears to be larger for smaller amounts and does not become insignificant after the zooming adjustment in base consumption.

<FIGURE VI APPROX. HERE>

<FIGURE VII APPROX. HERE>

A final set of models with quadratic zooming in the time horizon and square-root zooming in the magnitude in the consumption space for three different elasticities of marginal utility (EMU) is presented in Table V. The least concave utility function has an EMU that equals -0.8, and the most concave utility function has an EMU that equals -1.3, in addition to the standard logarithmic utility function used in the earlier model specifications. The zooming adjustment in base consumption is held constant in the consumption space in the three models to illustrate how variations in the curvature of the utility function affect the estimated average discount rates and zooming adjustment through the utility function.

<TABLE V APPROX. HERE>

<TABLE VI APPROX. HERE>

The average predicted rates by time horizon and magnitude are presented in Table VI, where the time horizon rates are for 10,000 MK treatments with delayed initial payment and where the discount rates for alternative magnitudes are for all time horizons with delayed initial payment. Tables V and VI demonstrate that mental zooming adjustments in base consumption may well explain both “hyperbolic discounting” and magnitude effects. Figures VIII and IX illustrate the predicted discount rate distributions for the model with logarithmic utility in Tables V and VI. Table VI also clearly shows how sensitive the discount rate estimates are to variations in assumptions about the curvature of the utility function, whereas the mental zooming theory appears to be quite robust to variations in the curvature of the utility function. Adjusting base consumption may therefore be theoretically more appropriate than adjusting the discount function to the time horizon or the magnitudes of decision prospects. However, this supposition should be further tested with alternative data sets.

<FIGURE VIII APPROX. HERE>

<FIGURE IX APPROX. HERE>

VII. CONCLUSION

As stated by Loewenstein and Prelec (1992), no simple theory can hope to account for all motives that influence a particular decision. In this paper, I have proposed a zooming theory that may contribute to a deeper understanding of certain anomalies in intertemporal choice: hyperbolic discounting and magnitude effects. “Hyperbolic discounting” is an observed “fact” that has largely eluded theoretical explanation, except in the case of the quasi-hyperbolic discounting associated with the satisfaction of immediate needs or self-control problems that cause extremely narrow framing of decisions and lead to ignorance of future consequences. Doubt about the existence of these phenomena has arisen because they have been mostly identified in hypothetical experiments that do not meet the quality standards of experimental economics (Andersen et al. 2011). Based on an incentive-compatible field experiment with prospects characterized by alternative time horizons and magnitudes, I demonstrate that these phenomena are highly significant and cannot be explained by present bias/quasi-hyperbolic discounting.

I then demonstrate the relevance of my theory of mental zooming as hidden or implicit framing through the adjustment of base consumption to the characteristics of the prospects under evaluation as a possible rational explanation for these intertemporal choice anomalies. My theory builds on other cognitive framing theories that help to explain phenomena such as limited asset integration and high levels of risk aversion in small-stakes risky choices. Quasi-hyperbolic discounting may be an extreme form of such mental zooming adjustment in intertemporal choice. To my knowledge, this is a novel contribution to the literature on time discounting. Hyperbolic discounting functions were derived as an "empirical matching law without a theory." I propose that we replace the matching law with a theory of mental zooming that provides a logical and plausible explanation for the same phenomenon, and I have demonstrated the theory's empirical fit with the data using a field experiment. Future research should aim to further test the theory by examining more explicit questions about how respondents integrate their decisions with their background consumption and/or by more explicitly framing the background consumption that respondents should consider when making their decisions. Furthermore, it will be important to test the theory in different environments to assess the conditions for its dominance versus more holistic modes of framing intertemporal prospects to which respondents may switch.

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TABLE I.

TREATMENTS IN TIME PREFERENCE EXPERIMENTS

Treatment type	Treatment levels
Front end point in time	Current(7), 1 week delay(13), 1 month delay(7)
End point in time	1 month(5), 3 months(11), 6 months(6), 12 months(5)
Future amount level	1000MK(6), 5000MK(6), 10000MK(9), 20000MK(6)

Note: MK=Malawian Kwacha

TABLE II.

MODELS WITH ALTERNATIVE BASE CONSUMPTION ZOOMING FOR TIME HORIZON AND MAGNITUDE OF FUTURE OFFERS

Zooming model	Base consumption adjustment
1	MK 300*far future time months
2	MK 300*far future time months*far future amount/1000
3	MK 300* far future time months*far future amount /5000)
4	MK 300*1.5* far future time months*sqrt(far future amount /5000)
5	MK 10*(far future time months)^2*sqrt(far future amount/5000)

TABLE III.

TIME PREFERENCE MODELS WITHOUT AND WITH ZOOMING ADJUSTED (FOR TIME HORIZON) BASE CONSUMPTION

	Baseline model without zooming adjustment	Zooming adjustment model 1
Future amount: Baseline=1000MK		
Future amount: 5000MK	-0.569****	-0.666****
Future amount: 10000MK	-0.773****	-0.908****
Future amount: 20000MK	-0.819****	-1.023****
Far future point in time: Baseline=1 month		
3 months	-0.995****	-0.423****
6 months	-1.398****	-0.514****
12 months	-2.096****	-0.728****
Dummy for front end point=current	0.122***	0.083**
Dummy for front end point=1 month	0.111**	0.079*
Experienced drought shock in 2011/12, dummy	0.259*	0.261*
Random starting point dummy*Task number	-0.029****	-0.021****
Constant	1.825****	1.603****
Luce error constant	0.061****	0.037****
Prob. > F	0.000	0.000
Number of observations	31631	31631

Note: Maximum likelihood models with logarithmic utility functions with Luce error. Baseline model where the base consumption level=MK300. Zooming adjustment model 1, where the base consumption level=MK300*Months time delay. Models were corrected for inflation(20% continuous time discount rate). Significance levels: *: 10%, **: 5%, ***: 1%, ****: 0.1%.

TABLE IV.

MODELS WITH ALTERNATIVE ZOOMING ADJUSTMENT OF BASE CONSUMPTION

	Zooming adjustment models		
	2	3	4
Future amount: Baseline=1000MK			
Future amount: 5000MK	0.127	-0.214***	-0.249***
Future amount: 10000MK	0.292****	-0.294****	-0.323****
Future amount: 20000MK	0.424****	-0.268****	-0.310****
Far future point in time: Baseline=1 month			
3 months	-0.387****	-0.461****	-0.423****
6 months	-0.255***	-0.499****	-0.434****
12 months	0.907	-0.594****	-0.413***
Dummy for front end point=current	0.174***	0.179***	0.172***
Experienced drought shock in 2011/12, dummy	0.268*	0.285*	0.286*
Present bias*Shock interaction	-0.121*	-0.114	-0.111
Dummy for front end point=1 month	0.090*	0.099**	0.096*
Random starting point dummy*Task number	-0.009*	-0.019****	-0.018****
Constant	0.948****	1.101****	1.194****
Luce error constant	0.014****	0.035****	0.030****
Prob. > F	0.000	0.000	0.000
Number of observations	31631	31631	31631

Note: Maximum likelihood models with logarithmic utility functions with Luce error. Models where the base consumption level is adjusted as shown in Table II. Significance levels: *: 10%, **: 5%, ***: 1%, ****: 0.1%.

TABLE V.

SENSITIVITY TO ALTERNATIVE UTILITY FUNCTIONS (ELASTICITIES OF MARGINAL UTILITY)

	Utility function		
	u=y^0.2	u=ln(y)	u=y^(-0.3)
Future amount: Baseline=1000MK			
Future amount: 5000MK	-0.146*	-0.067	-0.228**
Future amount: 10000MK	-0.213****	-0.116*	-0.392****
Future amount: 20000MK	-0.152**	-0.024	-0.368****
Far future point in time: Baseline=1 month			
3 months	-0.602****	-0.364****	-0.516****
6 months	-0.653****	-0.244***	-0.379****
12 months	-0.695****	-0.106	-0.360***
Dummy for front end point=current	0.096**	0.099***	0.128***
Dummy for front end point=1 month	0.103**	0.101**	0.100*
Random starting point dummy*Task number	-0.022****	-0.025****	-0.031****
Experienced drought shock in 2011/12, dummy	0.241*	0.241	0.277
Tool endowment index	-0.014	-0.012	-0.013
Farm size in ha, gps measured	-0.056*	-0.057*	-0.057
Enumerator dummies	Yes	Yes	Yes
District dummies	Yes	Yes	Yes
Constant	0.940****	0.271	0.102
Luce error constant	0.095****	0.061****	-0.085****
Prob. > F	0.000	0.000	0.000
Number of observations	31631	31631	31631

Note: Base consumption adjustment = 10*(far future time months)^2*sqrt(far future amount/5000). Maximum likelihood models with alternative utility functions with Luce error. Inflation corrected models, adjusted with 20% (continuous time discount rate). Significance levels: *: 10%, **: 5%, ***: 1%, ****: 0.1%.

TABLE VI.

PREDICTED AVERAGE DISCOUNT RATES FOR MODELS WITH VARYING ELASTICITY OF MARGINAL UTILITY

	Utility function		
Length of time period, months	u=y^0.2	u=ln(y)	u=y^(-0.3)
1	1.035	0.541	0.074
3	0.484	0.212	-0.392
6	0.441	0.344	-0.249
12	0.379	0.442	-0.251
All	0.514	0.364	-0.248
Future amount, MK			
1000	0.823	0.434	0.166
5000	0.624	0.379	-0.079
10000	0.514	0.364	-0.248
20000	0.640	0.420	-0.201
All	0.619	0.392	-0.133

Note: The table shows predicted discount rates in 100% units for models in Table 5. The discount rates for alternative time horizons are for 10000 MK treatments with delayed initial payment and the discount rates for alternative magnitudes are for all time horizons with delayed initial payment.

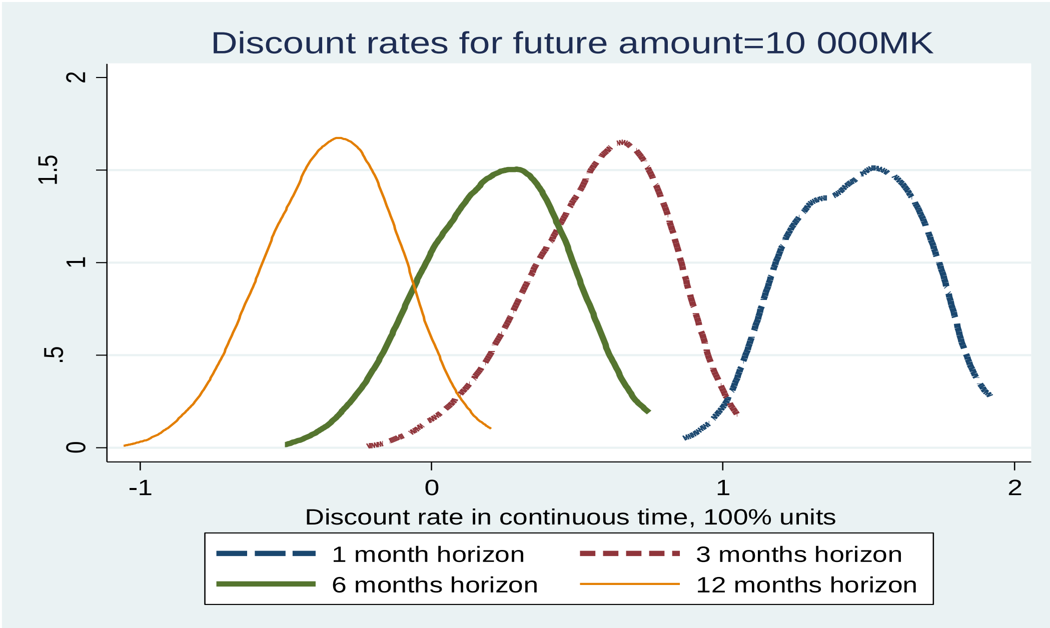

FIGURE I.

Predicted Discount Rate Distributions for 10000 MK Series with 1, 3, 6 and 12 Months Future Horizons and Delayed Initial Period with Constant Base Consumption=MK300.

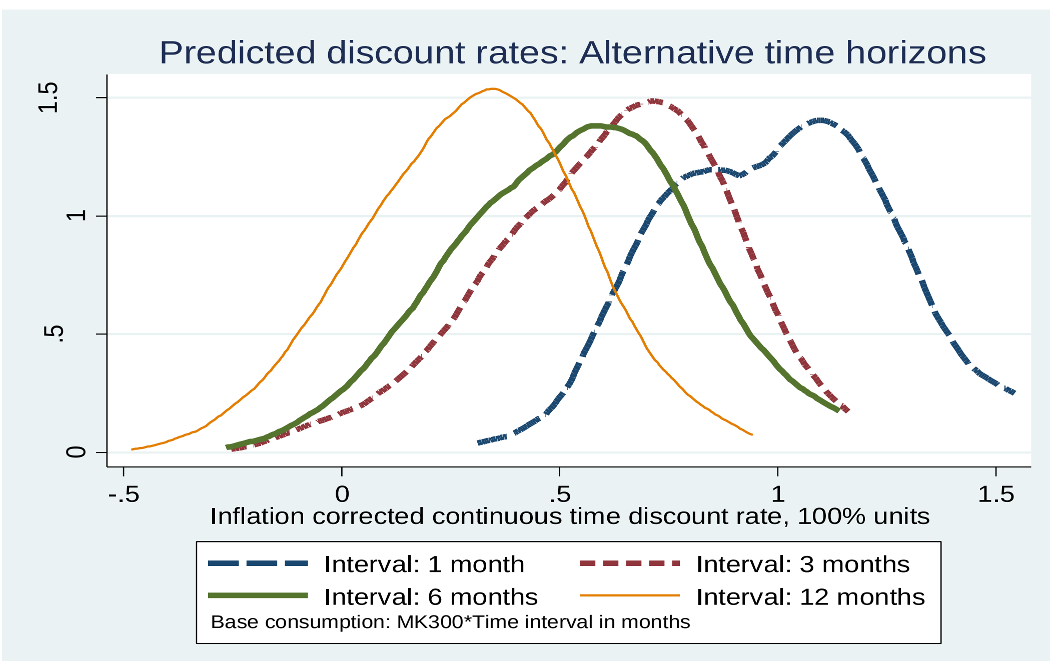

FIGURE II.

Predicted Discount Rate Distributions for 10000 MK Series with 1, 3, 6 and 12 Months Future Horizons with Zooming Model 1.

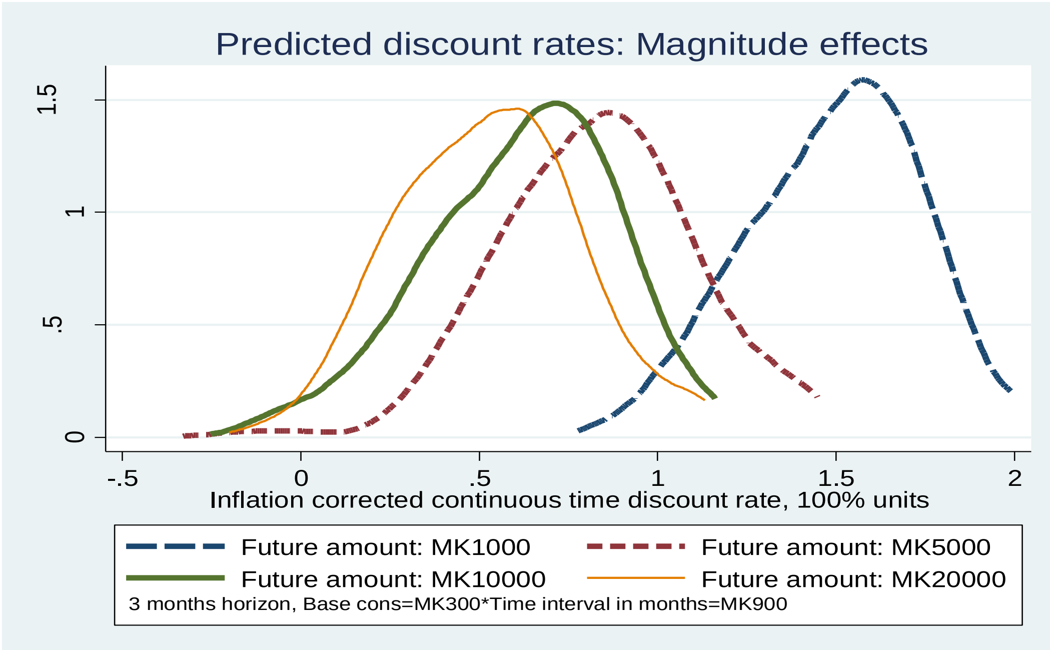

FIGURE III.

Predicted Discount Rates for Alternative Future Amounts (Magnitude Effects), with 3 months horizon, Zooming Model 1 (Base Consumption only Adjusted for Time Horizon).

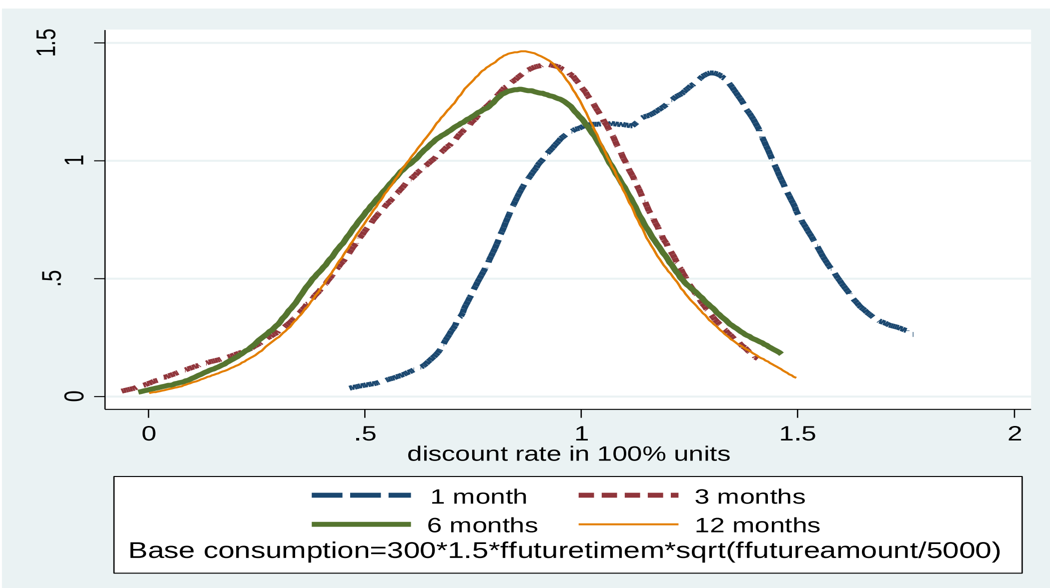

FIGURE IV.

Predicted Discount Rates for Alternative Time Horizons with Zooming Adjustment Model 4, with MK10000 Series

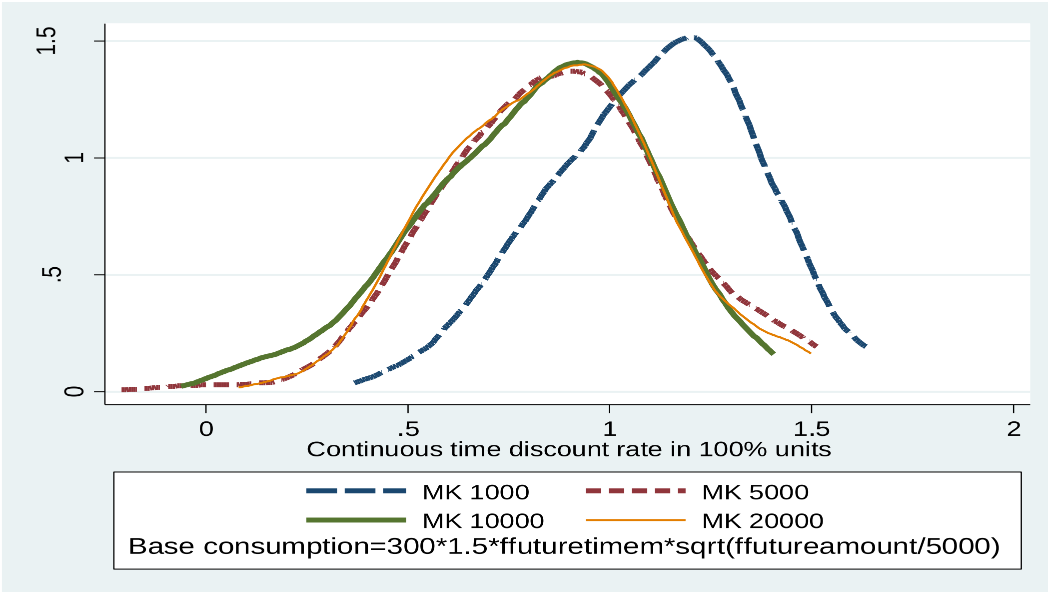

FIGURE V.

Predicted Discount Rates for Alternative Future Amounts with Zooming Adjustment Model 4

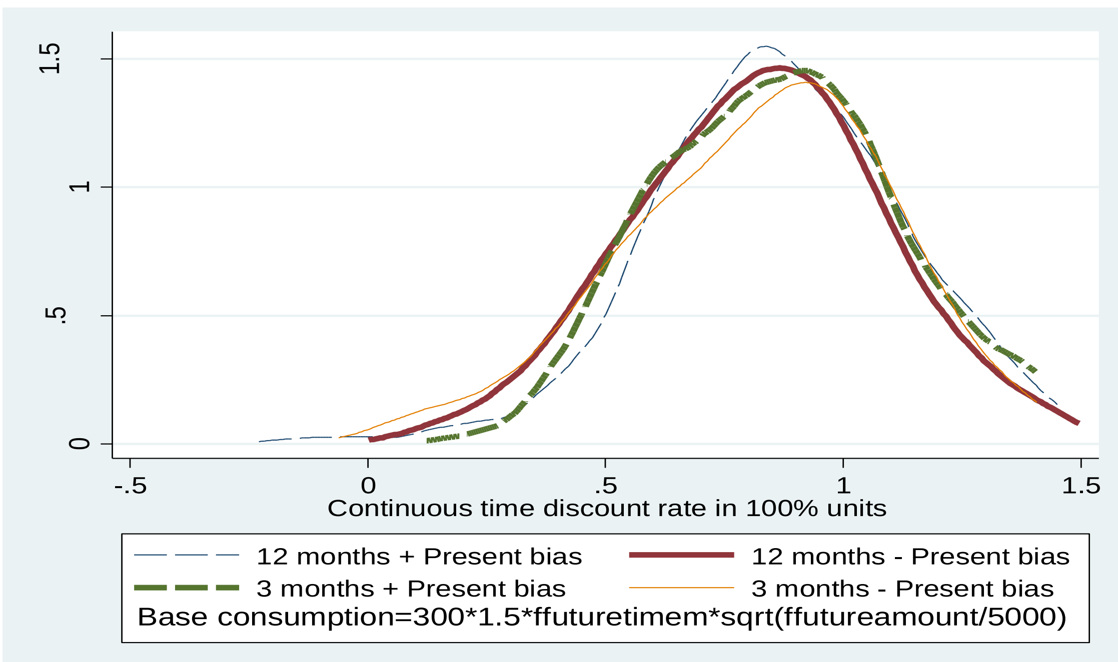

FIGURE VI.

Predicted Discount Rates with and without Initial Time Delay (Present Bias) with Zooming Adjustment Model 4, MK 10000 series with 3 and 12 Months Horizon

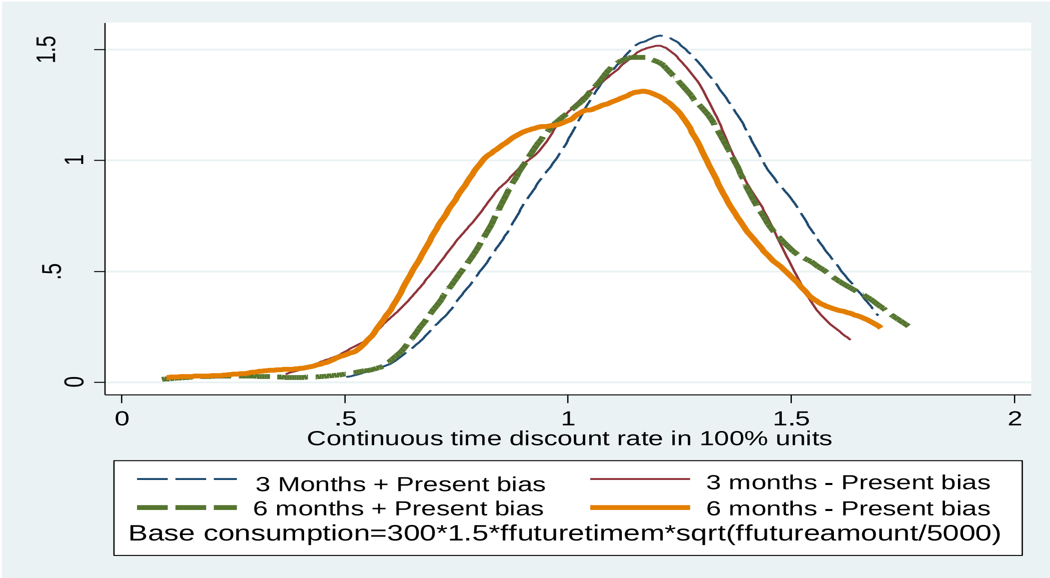

FIGURE VII.

Zooming Adjustment and Present Bias for Small Amounts (1000 MK), Zooming Adjustment Model 4 with 3 and 6 Months Horizon with and without Initial Delay (Present Bias).

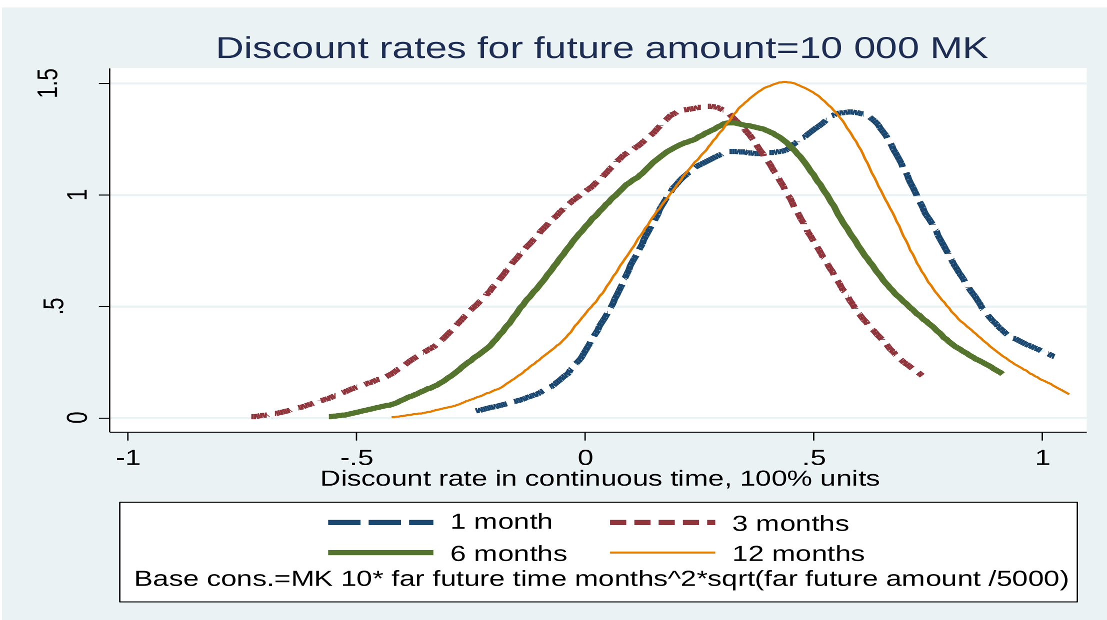

FIGURE VIII.

Predicted Discount Rates for Alternative Time Horizons for Zooming Model 5 (Quadratic Adjustment in Time Horizon and Square Root Adjustment in Magnitude and Logarithmic Utility)

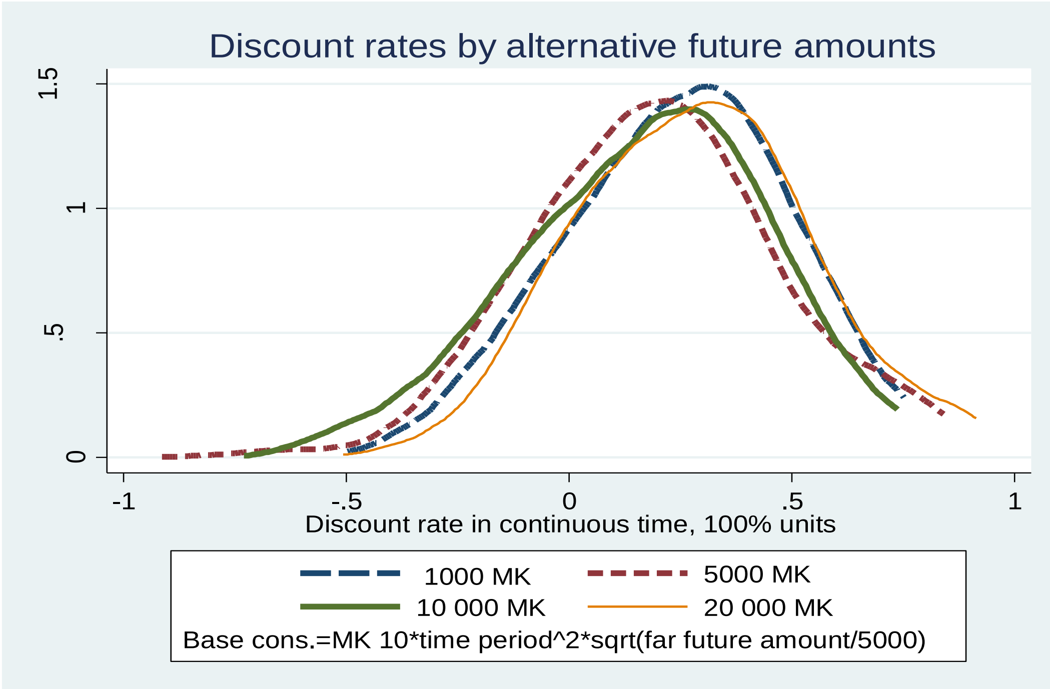

FIGURE IX.

Predicted Discount Rates for Alternative Future Amounts, Zooming Adjustment Model 5 with Logarithmic Utility