

Janssens, Wendy; Kramer, Berber; Swart, Lisette

Working Paper

Be patient when measuring Hyperbolic Discounting: Stationarity, Time Consistency and Time Invariance in a Field Experiment

Tinbergen Institute Discussion Paper, No. 15-097/V

Provided in Cooperation with:

Tinbergen Institute, Amsterdam and Rotterdam

Suggested Citation: Janssens, Wendy; Kramer, Berber; Swart, Lisette (2015) : Be patient when measuring Hyperbolic Discounting: Stationarity, Time Consistency and Time Invariance in a Field Experiment, Tinbergen Institute Discussion Paper, No. 15-097/V, Tinbergen Institute, Amsterdam and Rotterdam

This Version is available at:

<https://hdl.handle.net/10419/125098>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.

TI 2015-097/V
Tinbergen Institute Discussion Paper



Be patient when measuring Hyperbolic Discounting: Stationarity, Time Consistency and Time Invariance in a Field Experiment

Wendy Janssens
Berber Kramer
Lisette Swart

*Faculty of Economics and Business Administration, VU University Amsterdam, and Tinbergen
Institute, the Netherlands.*

Tinbergen Institute is the graduate school and research institute in economics of Erasmus University Rotterdam, the University of Amsterdam and VU University Amsterdam.

More TI discussion papers can be downloaded at <http://www.tinbergen.nl>

Tinbergen Institute has two locations:

Tinbergen Institute Amsterdam
Gustav Mahlerplein 117
1082 MS Amsterdam
The Netherlands
Tel.: +31(0)20 525 1600

Tinbergen Institute Rotterdam
Burg. Oudlaan 50
3062 PA Rotterdam
The Netherlands
Tel.: +31(0)10 408 8900
Fax: +31(0)10 408 9031

Duisenberg school of finance is a collaboration of the Dutch financial sector and universities, with the ambition to support innovative research and offer top quality academic education in core areas of finance.

DSF research papers can be downloaded at: <http://www.dsf.nl/>

Duisenberg school of finance
Gustav Mahlerplein 117
1082 MS Amsterdam
The Netherlands
Tel.: +31(0)20 525 8579

Be Patient When Measuring Hyperbolic Discounting: Stationarity, Time Consistency and Time Invariance in a Field Experiment

Wendy Janssens* Berber Kramer† Lisette Swart*

August 6, 2015

Abstract

Most evidence of hyperbolic discounting is based on violations of either stationarity or time consistency as observed in choice experiments. These choice reversals may however also result from time-varying discount rates. Hyperbolic discounting is a plausible explanation for choice reversals only if violations of stationarity and time consistency overlap. Our field experiment examines the extent to which this is the case. At different points in time, the same participants allocated a future gift over sooner-smaller and later-larger rewards with varying front-end delays. We find that most violations of time consistency do not coincide with violations of stationarity. This is surprisingly similar to what an earlier experiment on stationarity, time invariance and time consistency finds using a different design among a different type of participants (Halevy, *Econometrica*, 2015). Random noise in decision-making alone does not explain this finding, given that we find a significant association between changes in household wealth and violations of stationarity and time consistency. We conclude that when incomes fluctuate, one can only identify hyperbolic discounting by eliciting violations of both stationarity and time consistency through a longitudinal design for the same subject pool.

Keywords: Time preferences, present bias, temporal stability

JEL Codes: C93; D03; D14; D90; G02.

*Tinbergen Institute and Department of Economics, VU University Amsterdam, w.janssens@vu.nl and l.swart@vu.nl

†Markets, Trade and Institutions Division, International Food Policy Research Institute (IFPRI), b.kramer@cgiar.org. An earlier version circulated under the title ‘Time Inconsistent Behavior Under Incomplete Markets: Results from a Fields Experiment in Nigeria.’ We gratefully acknowledge funding from the PharmAccess Foundation and VU University Amsterdam (VU-IRPP Grant). We thank Prof. Akande, Dr. Osagbemi, Dr. Ameen and Dr. Olawale for excellent data collection. Gary Charness, Chris Elbers, Jan Willem Gunning, Glenn Harrison, Shachar Kariv and Charles Sprenger provided valuable comments, as well as participants in seminars at the Tinbergen Institute, VU University Amsterdam, IFPRI, CEAR at Georgia State University, Risk Preferences and Decisions under Uncertainty workshop in Berlin, Experimental Methods in Policy conference 2015 in Curaçao, BEELAB conference in Florence, Royal Holloway University in London, M-BEES 2013 conference in Maastricht, MIEDC 2014 in Minnesota, CSAE Conference 2014 in Oxford, Spring School in Behavioral Economics in San Diego and TIBER14 in Tilburg.

1 Introduction

Everyday choices, whether decisions to borrow, invest or perform a tedious task, involve intertemporal trade-offs. The timing of these decisions can matter significantly. When asked far in advance, someone may prefer to invest towards increased future consumption, but when asked again right before investing the money, she may change her mind and opt for sooner but lower consumption. Such dynamic choice reversals or violations of time consistency are often assumed to result from hyperbolic discounting, meaning that implicit discount rates are lower for tradeoffs in the more distant future than for tradeoffs in the near future (Frederick, Loewenstein and O'Donoghue, 2002).

Empirical evidence of hyperbolic discounting is however mostly based on violations of stationarity¹ and more specifically on observations of present bias in (cross-sectional) static choice experiments. Someone may prefer for instance \$110 in 31 days over \$100 in 30 days, but \$100 now over \$110 tomorrow (Green, Fristoe and Myerson, 1994; Kirby and Herrnstein, 1995). Although this is the easiest and hence most common way to test for hyperbolic discounting, such a violation of stationarity may also reflect future uncertainty or anticipated changes in economic incentives (Read, Frederick and Airoldi, 2012).²

This paper analyzes to what extent *stationarity* and *time consistency* overlap by means of a field experiment in rural Nigeria. We build on Halevy (2015) and correlate experimentally measured violations of time consistency not only to violations of stationarity, but also to violations of *time invariance*. Time invariance is violated when observed subjective discount rates change over time, meaning that for instance one month ago a person chose

¹Violations of stationarity refer to people making different decisions when asked at a certain point in time about different payment dates. Violations of time consistency on the other hand refer to people making different decisions about the same payment dates when asked at different points in time. Note that violations of stationarity and time consistency do not necessarily imply any form of irrationality.

²Violations of stationarity may also result from a lack of trust regarding not receiving future payments or uncertainty around future preferences and states. Experiments use small front-end delays to minimize the influence of these confounding factors (Harrison, Lau and Rutström, 2005).

\$110 one day later over \$100 the same day, but today chooses \$100 the same day over \$100 tomorrow. This difference may be due to noise, changes in underlying preferences, or changes in the economic environment. In this way, time variance offers a second yet often neglected reason for violations of stationarity and time consistency. Crucially, hyperbolic discounting is a plausible explanation for time-inconsistent behavior only when violations of both stationarity and time consistency occur among the same participants.

To elicit violations of time consistency, stationarity, and time invariance, the experiment elicited three intertemporal allocations using convex time budgets (Andreoni and Sprenger, 2012a) in a longitudinal design adopted from Giné et al. (2014). Participants distributed a future gift over a sooner-smaller and a later-larger reward. Sooner and later rewards arrived ‘tomorrow’ and ‘in one month’ for the first allocation, ‘in two months’ and ‘in three months’ for the second allocation, and ‘tomorrow’ and ‘in one month’ again for a third allocation made two months later. The third allocation concerned the same calendar dates as the second allocation, but since it was asked two months later, the sooner payment date was ‘tomorrow’, similar to the first allocation.

The experiment elicited these three allocations for 240 participants. Within-subject comparisons of the first and second allocation, elicited on the same day with varying front-end delays (‘tomorrow’ and ‘in one month’ versus ‘in two months’ and ‘in three months’), yield data on violations of stationarity. Differences between the second and third allocation, choices elicited at different points in time regarding the same calendar dates, are interpreted as violations of time consistency. Finally, comparing the first and third allocation, elicited on different days but both framed as an allocation over ‘tomorrow’ and ‘in one month’, yields violations of time invariance. In theory, if time invariance is satisfied, a hyperbolic discounter will violate both stationarity and time consistency. Violating either stationarity or time consistency alone must be related to a violation of time invariance.

In the experiment, violations of time consistency and stationarity often do not overlap. While 43.4 percent of participants violates time consistency, only 24.2 percent violates *both* time consistency and stationarity. Moreover,

nearly half of this subsample violates time consistency and stationarity in different directions with one present-biased violation and one future-biased violation. Random noise in decision making alone cannot explain our findings; we show that time consistency and stationarity violations are correlated with changes in households' background wealth between the two decision moments. Thus, testing for hyperbolic discounting requires a longitudinal design measuring both stationarity and time consistency.

This paper makes three unique contributions to the literature. First, the experimental design links violations of time consistency and stationarity to violations of time invariance. To our best knowledge, Halevy (2015) is the only existing choice experiment doing so, but using a different design (multiple price lists in a laboratory experiment instead of convex time budgets in a field experiment) and subject pool (undergraduate students in economics instead of a rural population in Nigeria). Despite these differences, our experiments find surprisingly similar percentages of participants who violate time consistency, stationarity and time invariance.

Beyond replicating Halevy's findings in the field, our paper sheds light on the role of background wealth as an explanation for why stationarity and time consistency do not always overlap. Other experimental studies either analyze violations of stationarity (e.g. Coller and Williams, 1999; Harrison, Lau and Williams, 2002) or of time consistency (e.g. Sayman and Öncüler, 2009; Read, Frederick and Airoldi, 2012) without linking the two. Studies that do analyze the link between stationarity and time consistency do not test to what extent violations are related to violations of time invariance (Giné et al., 2014; Augenblick, Niederle and Sprenger, 2015).

Second, discrepancies between stationarity and time consistency imply that the patience level of participants changes over time. As such, our longitudinal design relates to the literature on the temporal stability of time preferences. Identifying temporal stability (or time invariance) requires a longitudinal design in which the experimental methodology and the subject pool are fixed (Frederick, Loewenstein and O'Donoghue, 2002). The main field experiment with such a design and incentivized decisions elicited preferences for a sample of 203 participants in two consecutive years (Meier and

Sprenger, 2015). They find that any temporal instability observed at the individual level can be explained by random noise.

By contrast, Krupka and Stephens (2013) use a panel with hypothetical choices collected during a period of high inflation and find that elicited discount rates are correlated to economic factors such as the inflation rate and household income, suggesting that temporal instability of expressed time preferences is not purely random. This is more consistent with our findings, and we show that this results in non-overlapping violations of time consistency and stationarity.

Third, this study analyzes intertemporal allocations of monetary rewards for individuals in a context with limited access to credit. In a context without credit constraints, allocations involving monetary rewards are potentially influenced by the interest rate at which participants can save and borrow outside the experiment (Chabris, Laibson and Schuldt, 2008). When access to financial markets is restricted, changes in consumption are likely to follow small changes in income very closely (Halevy, 2014), so that intertemporal allocations of monetary rewards are more likely to express participants' time preferences rather than an external interest rate.

Giné et al. (2014) carried out a similar experiment with credit-constrained participants. Although our papers bear many similarities, we differ in two important respects. To start, Giné et al. (2014) focus on the link between stationarity and time consistency, and do not (report data to) test whether the link between these two concepts is stronger than the link with time invariance. In addition, while Giné et al. (2014) analyze the relation between shocks and violations of time consistency, we correlate violations of time consistency as well as stationarity with changes in background wealth, independent of whether the household reports these changes as a shock to household wealth.

This paper is structured as follows. The next section outlines a conceptual framework to interpret the relation between stationarity, time consistency, and time invariance. Section 3 describes the experiment. Section 4 presents our results and discusses potential behavioral mechanisms. Section 5 concludes.

2 Conceptual Framework

To show why violations of stationarity as measured in most (cross-sectional) time preference experiments do not necessarily overlap with time inconsistent behavior, this section first outlines the types of intertemporal allocations considered in the experiment. We then describe how one can infer violations of stationarity, time consistency and time invariance from these allocations. The section concludes by discussing the implications of hyperbolic discounting in this framework.

Consider a consumer allocating a gift of g vouchers over two future payment dates. She allocates x vouchers to a later date, denoted p_L , and the remaining $g - x$ vouchers to a sooner date, p_S . Each voucher allocated to the later date is worth v_L . Vouchers allocated to the sooner date are worth v_S and are never worth more than vouchers allocated to the later date, $v_S \leq v_L$.

Allocations are made at the start of two distinct rounds, at decision moments τ_1 and τ_2 . The consumer allocates her vouchers between a sooner and later payment date in the first round, $\{p_{1S}, p_{1L}\}$, and between a sooner and later payment date in the second round, $\{p_{2S}, p_{2L}\}$. In both rounds, the sooner payment date immediately follows the decision moment associated with that round, τ_1 and τ_2 , respectively. This yields the three intertemporal allocations $x_{1,1}$, $x_{1,2}$ and $x_{2,2}$ depicted in Figure 1.

The first allocation, $x_{1,1}$, is made at the start of the *first* round (at $t = \tau_1$) regarding the payment dates during the *first* round, $\{p_{1S}, p_{1L}\}$, which are both in the near future. The second allocation, $x_{1,2}$, also concerns a choice made at the *first* decision moment, but concerns the payment dates during the *second* round, $\{p_{2S}, p_{2L}\}$, which are in the distant future. The third allocation, $x_{2,2}$, is made at the start of the *second* round and concerns the payment dates during the *second* round, $\{p_{2S}, p_{2L}\}$. This allocation hence concerns the same payment dates as the second choice, but these payment dates are again in the near future, as in the first choice.

Building on Halevy (2015), Table 1 illustrates how these three allocations combined elicit violations of time consistency, stationarity, and time invariance. Stationarity is violated when otherwise similar intertemporal

choices (with respect to the delay between p_S and p_L) depend on the front-end delay, i.e. the amount of time between the decision moment and the sooner payment date. In our experiment the delay between payment dates is the same across allocations. We therefore observe a violation of stationarity when the two first-round decisions $x_{1,1}$ and $x_{1,2}$ are not identical, i.e. $x_{1,1} \neq x_{1,2}$.

A violation of time invariance implies that the timing of the *decision moment* influences the intertemporal choice when the front-end delay remains the same. In other words, in an otherwise similar choice, a person becomes more or less patient depending on when she takes the decision. This can result from random noise in decision-making, changes in wealth or changes in the underlying structural time preferences. The experiment therefore tests whether the first-round allocation over first-round payment dates, $x_{1,1}$, differs from the second-round allocation over second-round payment dates, $x_{1,1} \neq x_{2,2}$.

Time consistency is violated when a person's allocation between two payment dates at fixed points in time is affected by the time span between the decision moment and the two payment dates. In our experiment, we observe a violation of time consistency when first-round allocations regarding the second-round payment dates, $x_{1,2}$, are not the same as second-round allocations regarding the same payment dates, $x_{1,2} \neq x_{2,2}$.

Summarizing, violations of stationarity occur when first-round choices for the first- and second-round payment dates are different ($x_{1,1} \neq x_{1,2}$); violations of time invariance when the choices regarding the near-future payment dates differ between the first and second round ($x_{1,1} \neq x_{2,2}$); and violations of time consistency when choices regarding the second-round payment dates differs between the first and second round ($x_{1,2} \neq x_{2,2}$).

These three violations are closely linked. It is straightforward to show that if one of them occurs, we must observe at least one other violation (for a proof, see Halevy, 2015), i.e. violations do not occur in isolation. An individual's allocations $\{x_{1,1}, x_{1,2}, x_{2,2}\}$ can hence be categorized into one of five collectively exhaustive groups:

1. $x_{1,1} = x_{1,2} = x_{2,2}$. In this group, choices are identical regardless of front-end delay and decision moment, thereby satisfying time consistency, stationarity and time invariance.
2. $x_{1,1} \neq x_{1,2} = x_{2,2}$. In this group, allocations for second-round payment dates do not depend on the decision moment, thereby satisfying time consistency, $x_{1,2} = x_{2,2}$. However, these two allocations differ from the first-round allocation regarding first-round payment dates, $x_{1,1}$, violating stationarity and time invariance.
3. $x_{1,1} = x_{1,2} \neq x_{2,2}$. In the first round, this group makes identical decisions independent of the timing of payment dates, thereby satisfying stationarity, $x_{1,1} = x_{1,2}$. However, in the second round, this group chooses a different allocation, violating time consistency and time invariance.
4. $x_{1,1} = x_{2,2} \neq x_{1,2}$. In this group, allocations regarding near-future payment dates do not depend on when the decision is made, thereby satisfying time invariance, $x_{1,1} = x_{2,2}$. This group however chooses a different allocation regarding distant-future payment dates, violating stationarity and time consistency.
5. $x_{1,1} \neq x_{1,2} \neq x_{2,2}$. In this group, individuals choose different allocations in each type of choice, thereby violating time consistency, stationarity, and time invariance.

Thus, as long as time invariance is satisfied (Groups 1 and 4), a violation of stationarity coincides with - and can be interpreted as - a violation of time consistency. However, when time invariance is violated, the two do not necessarily coincide, and a violation of stationarity cannot be interpreted as a violation of time consistency (Groups 2, 4 and 5).

To illustrate how these concepts relate to hyperbolic discounting, assume a two-period discounted utility framework with time-separable utility and - for tractability - quasi-hyperbolic discounting (also referred to as $\beta\delta$ -

discounting, Laibson, 1997).³ When time invariance is satisfied, the three voucher allocations, $x_{1,1}$, $x_{1,2}$ and $x_{2,2}$, optimize the following three target functions:

$$\max_{x_{1,1}} u(g - x_{1,1}; \omega_S) + \beta \delta u(x_{1,1}; \omega_L) \quad (1)$$

$$\max_{x_{1,2}} \beta u(g - x_{1,2}; \omega_S) + \beta \delta u(x_{1,2}; \omega_L) \quad (2)$$

$$\max_{x_{2,2}} u(g - x_{2,2}; \omega_S) + \beta \delta u(x_{2,2}; \omega_L) \quad (3)$$

where $u(\cdot)$ represents instantaneous utility and ω_S and ω_L an individual's background wealth and preferences at the time of the sooner and later payment dates, respectively. Further, $0 < \delta < 1$ represents a discount factor for the later relative to the sooner payment date⁴ and $0 < \beta \leq 1$ a present-bias parameter by which all instantaneous utilities for future payments are discounted.

Since background wealth and preferences ω_S and ω_L are stable over time, the first-round allocation regarding first-round payment dates equals the second-round allocation regarding second-round payment dates, $x_{1,1} = x_{2,2}$, and time invariance is not violated. If $\beta \neq 1$, allocations will violate both stationarity ($x_{1,1} \neq x_{1,2}$) and time consistency ($x_{1,2} \neq x_{2,2}$). That is, under the assumption of time invariance combined with (quasi-)hyperbolic discounting, $\beta < 1$, a violation of stationarity implies a violation of time consistency and vice versa.

However, if an individual's states ω_S and ω_L vary over time and across the three decisions, this conclusion no longer holds. If changes in states from the first to the second round are anticipated, stationarity is violated ($x_{1,1} \neq x_{1,2}$) even among exponential discounters who are not present or future biased, $\beta = 1$. Because of the anticipated nature of changes in states,

³Strictly speaking, quasi-hyperbolic discounting distinguishes the present (today) from the future (tomorrow and any later day). Given that our soonest payment takes place the next day, we need to assume that tomorrow will still be considered as the (extended) present by the participants, so that $\beta = 1$ for payments tomorrow. This will be the case when adopting a more general hyperbolic discount function.

⁴ δ needs to follow an exponential distribution to ensure that it is constant across the three equations.

these individuals will not violate time consistency, $x_{1,2} = x_{2,2}$. On the other hand, if changes from the first to the second round are unanticipated, exponential discounters violate time consistency, $x_{1,1} \neq x_{1,2}$, but not stationarity, $x_{1,1} = x_{1,2}$. In that case, violations of time consistency and time invariance will coincide. In other words, neither a violation of stationarity nor of time consistency in itself can be interpreted as unambiguous evidence of hyperbolic discounting.

We may observe violations of time invariance in particular in low-income areas where people have limited access to financial instruments for two reasons. First, households in resource-poor areas are generally exposed to large uninsured risks, resulting in frequent expenditure shocks and volatile incomes (Dercon, 2002). As this can shift the poor's wealth and expectations, their subjective discount rates are likely to fluctuate over time, resulting in violations of time invariance. Second, recent theories on the psychology of poverty suggest that scarcity can reduce decision-making quality by making households focus on the present (Mullainathan and Shafir, 2013). A financial shock creating scarcity may hence temporarily increase present bias, amplifying violations of time invariance. In low-income settings, the overlap between violations of time consistency and stationarity may therefore not be as strong as they are in a context with less volatile incomes and expenditures.

In conclusion, when time invariance may be violated, one can only infer hyperbolic discounting from observing both time consistency and stationarity, which requires longitudinal designs with allocations at different decision moments for payment dates at different points in time (Halevy, 2015). Since a longitudinal design is more costly, the majority of existing time preference experiments elicit only violations of stationarity, using cross-sectional designs with one decision moment regarding different payment dates. Systematic violations of time invariance due to predictable or unpredictable changes in the economic environment may confound the conclusions from these experiments, and this paper sheds light on the severity of the potential misclassification.

3 Experimental methods and procedures

3.1 Design

To test whether violations of time consistency empirically overlap with violations of stationarity, we conducted an artefactual field experiment in rural Nigeria. The experiment elicited participants' intertemporal allocations using Andreoni and Sprenger (2012a)'s convex time budget method. Participants received ten vouchers to divide between two future payment dates, with the later date exactly one month after the sooner date. Vouchers allocated to the later payment date were always worth 200 NGN.⁵ Vouchers allocated to the sooner payment date were worth either 200, 150, 120 or 100 NGN.

Participants allocated their budgets between the two payment dates in three different incentivized scenarios: (i) a first-round allocation dividing the ten vouchers between payment dates soon after the first round, 'tomorrow' and 'one month from now' (yielding choice $x_{1,1}$); (ii) a first-round allocation dividing the vouchers between payment dates in a more distant future, '2 months from now' and '3 months from now' (yielding $x_{1,2}$); and (iii) a second-round allocation conducted two months later for the same payment dates, and hence framed again as 'tomorrow' and 'one month from now' (yielding $x_{2,2}$). Thus, within subjects, we varied (a) the delay between the decision moment and the payment dates; and (b) the timing of the decision moment itself. As such, the experiment elicits measures of stationarity, time invariance and time consistency, as drawn in Table 1.

Note that in choices regarding the near future, the earliest payment date was tomorrow. Due to this front-end delay, we are unable to identify pure quasi-hyperbolic discounting, which assumes structurally different discounting of the present versus the future. We opted for a small delay before the first payment for two reasons. First, paying participants the same day was logistically difficult. Second, delaying the payment by one day helped avoid possible confounds such as differential transaction costs between pay-

⁵At the time of the experiment, 100 NGN (Nigerian Naira) was worth approximately 0.62 USD.

ment dates or trust issues (Chabris, Laibson and Schuldt, 2008). Sozou (1998) showed that the perceived risk of default of the experimenter differs between immediate payments and any future payments, but that the perceived difference in risk between different payment moments in the future is negligible. An increasing number of studies therefore avoids immediate payments and we followed this approach (for additional references and a detailed discussion, see Andreoni and Sprenger, 2012*a*).

3.2 Procedures

Participants were recruited from a sample of farming households in Kwara State, Nigeria, who were interviewed weekly about their health and finances from March 2012 to May 2013.⁶ Figure 2 illustrates a timeline of this experiment. In March 2012, a baseline survey collected individual characteristics for all household members. In April 2012, we conducted the first round of the experiment. Enumerators visited the households and interviewed all adult household members in private following a script with the experimental instructions (see Appendix A).⁷ They first elicited choices regarding the second-round payment dates, framed as payments ‘in three months’ versus ‘in two months’ from now, followed by a break with survey questions. After this intentional break, which served to reduce potential efforts to appear consistent across choices, enumerators elicited choices regarding the first-round payment dates, framed as payments ‘in one month’ from now versus ‘tomorrow’.⁸

Allocations regarding first- and second-round payment dates were both made for the four different values of vouchers allocated to the sooner date.

⁶This is the Health and Financial Diaries study implemented by the Amsterdam Institute for International Development in collaboration with the PharmAccess Foundation and the University of Ilorin Teaching Hospital (Janssens et al., 2013).

⁷We targeted the household head, their spouses, and other adult household members not enrolled in school.

⁸To enhance understanding of the time preference games, enumerators used a wooden board with two bowls representing the sooner and the later payment date, and small vouchers that people had to divide over the two bowls. The order of the questions was not randomized. Order effects are expected to be limited, since Andreoni and Sprenger (2012*a,b*) and Giné et al. (2014) do not find any evidence of order effects.

To ensure incentive compatibility, we randomly selected one of these allocations for each participant for actual payout. To retain a large enough sample for the second round, the probability of selecting a choice regarding second-round payment dates was 0.9.⁹ Participants did not know the exact probabilities. They were told that the computer would randomly select one question and that this would be one of the eight questions they were about to answer.

The ten percent of participants for whom a first-round choice was selected for payment received their payments according to their initial allocation. By contrast, those who were to be paid during the second round were revisited unexpectedly two months later, in June, just before their ‘sooner’ payment date. They received the opportunity to revise their earlier choice that was selected for payment. The enumerator clearly showed them their initial choice given the selected voucher values for second-round payment dates, $x_{1,2}$, and asked them to indicate their preferred allocation once more. They were paid according to this new allocation rather than the initial choice. Participants were reassured that they could leave their allocation as it was or change it; they could choose whatever allocation they preferred.

On payment dates, enumerators returned to every participant with a payout on that day and exchanged vouchers valid on that particular day for cash. The experimental design allowed participants to earn between 1,000 and 2,000 NGN, and they earned 1,862 NGN on average. These stakes are fairly high, as the maximum possible payment of 2,000 Naira is equivalent to approximately three days of work among the employed participant sample. Further, concerns about a lack of participant trust in receiving the experimental pay-outs are limited, as participants were part of a larger ongoing study for which they were being interviewed by the same research team on a regular basis.

⁹This probability was less than 1 to ensure incentive compability of choices regarding first-round payment dates.

3.3 Description of the participant sample

The experiment targeted 303 individuals who participate in the baseline survey in March 2012. Of those, 293 persons (96.7 percent) participated in the first round of our experiment. For 256 participants (87.4 percent of first-round participants), the experiment selected a choice regarding payment dates following the second round, and among them, 240 (93.8 percent) participated in the second round. For the remaining sixteen first-round participants, we did not observe second-round allocations because a few participants moved away from the study area, and one participant had passed away. His family members were hence mourning and did not participate in the second round either.

Table 2 presents summary statistics for all participants in the experiment. Columns (1) and (2) show the number of observations and the mean for all 293 participants who completed the first round of the experiment.¹⁰

The average age of the participants is just over 40 years of age and around forty percent of participants are male. The vast majority of participants is muslim, married, and a little more than half of them are married polygamously. Three quarters live in a village rather than in one of the main towns; a household takes care of on average five children; and the majority of participants never entered the formal school system.

The two predominant sources of income among participants are farming (36.9 percent) and business (39.6 percent). Since businesses are often related to farming, participants' financial situation depends heavily on the agricultural season. The experiment was conducted in the period between planting and harvest. At baseline, less than ten percent of the farmers expected to harvest before July, when the later payment date of the second round was due. Since households incur expenditures to harvest their produce and generally do not plan to sell their harvest right away, the harvest time may well be a cash-constrained period.¹¹ Households whose livelihoods depend

¹⁰We do not present standard deviations because all variables, apart from four (age, the number of children and two financial balances) are binary indicators.

¹¹Farmers often prefer to wait selling their harvest until supply is lower and prices have increased.

on the farming season may well take this into account when planning their allocations regarding second-round payment dates.

The idea that farmers became more cash-constrained in the course of the experiment is consistent with measures of household wealth at the start of both rounds, calculated as the balance of all financial assets and liabilities (the sum of current bank account balances, formal and informal savings, loans and credits receivable, subtracted by outstanding credits and loans). In the period of the experiment, household wealth decreased by a sizable 10,000 NGN from the first to the second round, which is 17 percent of households' net wealth at baseline, and five times the maximum experimental payout of 2,000 NGN.

This paper restricts the sample in the main analysis to participants for whom all three choices depicted in Figure 1 were elicited. For the 16 dropouts and the randomly selected participants who were not revisited for the time preference game in the second round, we cannot observe violations of time invariance or time consistency. Columns (3) to (5) compare the 240 participants who were revisited during the second round with the full sample and confirm that attrition from the first to the second round was not driven by observable characteristics. The only variables that differ significantly between the full sample and the revisited sample are household size and financial wealth at baseline.¹² Revisited participants were wealthier in the first round. This difference was no longer significant in the second round, mostly because wealth in the full sample dropped less than in the revisited subsample. We can attribute this only in part to the experimental earnings of the non-revisited participants who were selected for pay-out in the first round.

A large body of literature discusses the possible effects of limited understanding on conclusions drawn from time preference experiments (see for example Andreoni and Sprenger, 2012*a*). If a participant does not fully understand the task or its implications, her decisions will not accurately represent her underlying time preferences. Enumerators devoted a significant

¹²Reported significance levels are based on a *t*-test with standard errors clustered at the household level.

amount of time to explain the convex time budget task. To test whether poor understanding can nevertheless have introduced noise in the allocations, leading to violations of stationarity, time consistency or time invariance, we test a simple monotonicity condition. When the return on waiting increases, participants should never allocate *fewer* vouchers to the later payment date.

To test whether participants satisfied this monotonicity concept, we compare allocations when sooner vouchers are worth (1) 100 NGN vs. 120 NGN, (2) 120 NGN vs. 150 NGN, and (3) 150 NGN vs. 200 NGN; for both near-future ($x_{1,1}$) and distant-future ($x_{1,2}$) allocations. Using these six comparison pairs, 219 of the 240 participants in the final sample (91.3 percent) never violate monotonicity. Further, of the 1,440 pairs (6 pairs times 240 participants), 1410 pairs (97.9 percent) satisfy monotonicity, suggesting similar levels of understanding as university students participating in Andreoni and Sprenger (2012a), and better understanding than more comparable participants in Giné et al. (2014). Following Chakraborty et al. (2015), Appendix Table C1 tests for demand monotonicity by number of interior versus corner allocations. The percentage of choice sets violating demand monotonicity never exceeds 11.5 percent and does not increase in the number of interior choices in a choice set. Thus, demand monotonicity violations are not a major concern in our data.¹³

4 Results

This section describes the experimental results, starting with a description of how participants allocate their future gift over time. Next, we exploit our within-subject design to identify how frequently violations of time consistency overlap with violations of stationarity. Finally, this section analyzes whether violations of time invariance that account for this discrepancy can be explained by random noise or by other, more systematic, factors includ-

¹³Chakraborty et al. (2015) perform three additional tests to analyze the internal and external consistency of data from convex time budgets: they test for the weak axiom of revealed preferences, wealth monotonicity, and impatience monotonicity. We do not have experimental variation to perform these three tests.

ing changes in participants’ wealth and features of the experimental design. This section focuses on allocations for which all three choices ($x_{1,1}$, $x_{1,2}$ and $x_{2,2}$) given the randomly selected value of vouchers allocated to the sooner payment date are observed.

4.1 Description of choices

Figure 3 plots the cumulative distribution of the number of vouchers allocated to the later payment date and Table 3 presents corresponding summary statistics. In this and subsequent tables, reported p-values are based on a t -test for differences in means with standard errors clustered at the household level. Panel (a) illustrates how the return on waiting, varied between subjects, affects allocations in the experiment. Panel (b) presents the distribution by type of choice, which was varied within subjects.

Panel (a) of Figure 3 illustrates the cumulative distributions when vouchers allocated to the *sooner* payment date (‘sooner vouchers’) are worth 200 NGN, 150 NGN, 120 NGN or 100 NGN. Since vouchers allocated to the *later* payment date are worth a fixed 200 NGN, the return on waiting decreases in the value of sooner vouchers. Thus, for participants whose sooner vouchers are worth 200 NGN, the return on waiting is the lowest. They allocate most vouchers to the sooner payment date, leaving on average 2.54 vouchers for the later date (see Panel (a) in Table 3). Participants whose sooner vouchers are worth 150 NGN have a higher return on waiting and allocate on average nearly five additional vouchers to the later date ($p < 0.01$). Compared to this subsample, participants with vouchers worth 120 NGN allocate an additional 1.22 vouchers to the later date ($p < 0.01$). Reducing the value of sooner vouchers to 100 NGN does not significantly increase the number of vouchers allocated to the later date any further.¹⁴

Panel (b) shows allocations by type of choice. The solid line describes

¹⁴Allocations for sooner vouchers worth 200 NGN (with no return on waiting) thus seem to a different pattern than allocations where sooner vouchers are worth less than 200 NGN (yielding a positive return on waiting). We replicated all tables presented in this paper for the sample excluding sooner vouchers worth 200 NGN (available upon request). Omitting participants with sooner vouchers worth 200 NGN results in qualitatively similar patterns to the ones presented in this section.

first-round choices when the payment dates are in the near future, ‘tomorrow versus in one month’ ($x_{1,1}$). The dashed line describes first-round choices with payment dates in the distant future, ‘in two months versus in three months’ ($x_{1,2}$). The dotted line represents the choice elicited during the second round nearly two months later, framed again as an allocation regarding payment dates in the near future ($x_{2,2}$). The distributions of the two first-round choices $x_{1,1}$ and $x_{1,2}$ are very similar; in first-round choices regarding the near future, $x_{1,1}$, participants allocate on average 7.27 (out of ten) vouchers to the later payment date, while they allocate on average 7.30 vouchers to the later payment date in choices regarding the more distant future, $x_{1,2}$ (see Table 3). We fail to reject the hypothesis that $x_{1,1} = x_{1,2}$ ($p = 0.853$) and hence the aggregate data satisfy stationarity.

By contrast, second-round choices for payment dates in the near future, $x_{2,2}$, are different from the two first-round allocations, $x_{1,1}$ and $x_{1,2}$. The average number of vouchers allocated to the later payment date in the second-round choice is on average 5.57, which is significantly lower than both choices made in the first round ($p < 0.01$). Because participants tend to revise their first-round allocations for the distant-future payment dates in the second round, we reject the hypothesis that $x_{1,2} = x_{2,2}$ ($p < 0.01$), implying a violation of time consistency in the aggregate. Moreover, given that allocations regarding near payment dates are not constant across the two rounds, we reject the hypothesis that $x_{1,1} = x_{2,2}$ ($p < 0.01$), implying an aggregate violation of time invariance regarding payments in the near future.

Our analyses omit two types of first-round choices that do not have a second-round equivalent: choices for voucher values that were not selected for payment, and choices made by participants who were not revisited during the second round (because they were selected to be paid during the first round, or because the participant dropped out of the study). Also for these non-selected first-round choices and non-revisited participants, we cannot reject stationarity (see Appendix Table C2). This reinforces the conclusion drawn from Table 2 that attrition does not bias our results.

We conclude that the aggregate data violate time consistency and time

invariance, but not stationarity. This implies that individual choice patterns will also violate time consistency and time invariance, while stationarity may or may not be satisfied. Thus, time-inconsistent behavior appears to be linked more closely to violations of time invariance than stationarity, and the overlap between violations of time consistency and stationarity appears limited.

4.2 Classification of participants

Stationarity in the aggregate data is necessary but not sufficient for individual-level stationarity. We may observe aggregate stationarity simply because some participants choose present-biased allocations whereas others choose future-biased allocations that cancel each other out on average. Figure 4 therefore indicates the proportion of participants with a violation of time consistency (represented by the grey shaded bar), a violation of stationarity (represented by the bar with horizontal lines), and violations of time invariance (represented by the bar with vertical lines).

The left bar shows that 43.8 percent of the participants violates time consistency ($x_{1,2} \neq x_{2,2}$). Although we do not observe violations of stationarity, in the aggregate data, the middle bar indicates that stationarity is violated ($x_{1,1} \neq x_{1,2}$) by an almost similar percentage of participants as time consistency. It may hence appear that the two violations largely occur among the same group of participants. However, as discussed earlier, this is not necessarily the case when choices also violate time invariance ($x_{1,1} \neq x_{2,2}$): we may then observe violations of stationarity without observing violations of time consistency and vice versa. Indeed, the right bar indicates that choices regarding near-future payment dates change from the first to the second round for more than half (58.0 percent) of all participants.

The figure also illustrates why, despite very similar percentages of participants that violate stationarity and time consistency, only time consistency is violated at an aggregate level. The figure divides violations of stationarity and time consistency into present-biased violations (the lower areas marked ‘PB’) and future-biased violations (the upper areas marked ‘FB’).

Present-biased violations of stationarity and time consistency occur when a participant allocates more vouchers to the later date in choices regarding *distant-future* payment dates, $x_{1,2} > x_{1,1}$ and $x_{1,2} > x_{2,2}$. Future-biased violations of stationarity and time consistency, on the other hand, occur when a higher number of vouchers is allocated to the later date in choices regarding *near-future* payment dates, $x_{1,2} < x_{1,1}$ and $x_{1,2} < x_{2,2}$. While over 70 percent of time-inconsistencies are present-biased, present-biased violations account for only 55 percent of non-stationarities.

Figure 5 divides all participants into one of the five collectively exhaustive groups discussed in Section 2. Again, violations of time consistency are represented by grey shading, violations of stationarity by horizontal lines, and violations of time invariance by vertical lines. This figure illustrates that nearly half of all violations of time consistency - 19.6 out of 43.8 percent - coincide with a violation of time invariance, without stationarity being violated. Likewise, among the 43.3 percent of participants who violate stationarity, 19.2 percent violates time invariance without violating time consistency. Only 24.2 percent of participants violates both stationarity and time consistency.

Table 4 describes in more detail how well stationarity and time consistency overlap. The first column of Panel A defines violations the same way as Table 1 does: any difference between two allocations results in a violation of stationarity, time consistency or time invariance. The proportions summarized here are hence the same as the proportions shown in Figure 5. The correlation between violations of stationarity and time consistency is 0.212, which is substantially lower than the correlations between violations of stationarity and time invariance, or time consistency and time invariance, which are 0.548 and 0.541, respectively.

The model presented in Section 2 predicts that hyperbolic discounters violate stationarity and time consistency in a present-biased direction. These violations can however move in opposite directions when time invariance is violated. To analyze how often present-biased violations of stationarity and time consistency overlap, Panel B presents statistics for present-biased violations only, treating future-biased violations of stationarity (or

time consistency) as an observation satisfying stationarity (or time consistency). Similarly, Panel C specifically analyzes future-biased violations, treating present-biased violations of stationarity (or time consistency) as an observation satisfying stationarity (or time consistency).

The first column of Panel B shows that only 10.4 percent of all participants violates both stationarity and time consistency in a present-biased direction. The correlation between present-biased violations of stationarity and time consistency is 0.131, which is again substantially lower than both the correlation between present-biased violations of stationarity and time invariance (0.517) and the correlation between present-biased violations of time consistency and time invariance (0.738).¹⁵ In Panel C, only a small share of the participants violates both time consistency and stationarity in a future-biased direction, but more than twenty percent violates either stationarity or time consistency in a future-biased direction.

Columns (2) - (5) explore whether a trembling hand or the presence of corner allocations can account for the limited overlap between time consistency and stationarity. Column (2) relaxes the definition of stationarity, time consistency and time invariance violations to allocations differing by at least two vouchers to investigate the effects of a trembling hand. Column (3) excludes all participants who selected two or more identical corner allocations in which participants allocate all vouchers to one of the two payment dates, since these reveal participants' preferences only weakly: their preferred allocations may violate time consistency, stationarity, or time invariance, but this is not observed.¹⁶ As a final robustness check, Column (4) assumes that choices involving two identical corner allocations (i.e. all

¹⁵The second correlation compares present-biased violations of stationarity to violations of time invariance where participants become *more* patient. A participant who allocates 6 vouchers to 'in one month' (and the remaining 4 to 'tomorrow') and 8 vouchers to 'in 3 months' (and the remaining 2 to 'in 2 months') violates stationarity in a present-biased direction. If this person is time consistent (i.e. allocates 8 vouchers to the later payment date in the second-round choice), she becomes *more* patient. Following a similar line of reasoning, the correlation of present-biased violations of time consistency and time invariance on the other hand compares present-biased violations of time consistency to violations of time invariance where participants become *less* patient.

¹⁶Violations of stationarity, time consistency and time invariance are defined in the same way as Column (1).

choices from which we cannot infer whether a concept is violated) do in fact represent a violation. In this way, the results represent an upper bound to the number of violations. These robustness checks show qualitatively similar patterns as Column (1).

An important question is to what extent these findings differ from Halevy (2015)'s findings, the only existing experiment that relates time-inconsistent behavior to violations of stationarity and time invariance. There are large differences in methodology and subject pool between Halevy's study and our own: Halevy (2015) used a multiple price list, while we use a convex time budget method with visual aids, and Halevy's sample consisted of undergraduate students at the University of British Columbia in Canada while the participants in our experiment are adults living in poor households in rural Nigeria. Figure 6 shows the percentage of participants classified in each of the five groups in our sample and in that of Halevy (2015).

Interestingly, the percentages of participants belonging to the different groups is remarkably similar between the two studies. In both studies, the largest group of participants is the one where stationarity, time consistency and time invariance are all satisfied (Group 1). Furthermore, both studies find similar percentages of participants violating stationarity but not time consistency (Group 2), and of participants violating time consistency but not stationarity (Group 3). The group of participants that violates both time consistency and stationarity, but not time invariance (Group 4), is the smallest in both studies. Finally, the group of participants that violates all three concepts (Group 5) includes approximately twenty percent of participants in both studies. Thus, despite differences in design and subject pool between the two experiments, violations of time consistency, stationarity and time invariance arise in very similar ways.

In sum, our experiment provides evidence that violations of time consistency and stationarity often do not coincide. Violations of time invariance correlate much better with violations of stationarity and time consistency. To the extent that time consistency and stationarity do not overlap, observed behavior may well be driven by other mechanisms than hyperbolic discounting. These mechanisms do not necessarily need to be systematic.

The remarkable similarity with Halevy’s findings, combined with the stark differences in the experimental designs, raises the question whether the observed patterns simply result from random noise in decision-making that expresses itself in similar ways in very different experiments. The remainder of this section sheds light on this question.

4.3 Behavioral mechanisms I: Random noise in decisions

One possible reason for observed violations of time invariance may simply be noise. A trembling hand may explain why participants change their allocation regarding near-future payment dates from the first to the second round. This will also result in violations of stationarity and time consistency, so that a nonzero correlation between any two violations can result at least partially from random noise.

We therefore compare our experimental findings with simulated predictions from a model in which violations of time invariance are driven only by random noise in decision-making.

Columns (2) - (15) in Table 5 present the outcomes for the simulation, which can be directly compared to the actual outcomes in our experiment shown in Column (1). Due to the large number of corner allocations, the maximum likelihood estimates yield a convex utility function, $\rho < 0$. Since this assumption is disputable, Columns (2) to (9) first present simulation results for parameter estimates under the condition that utility is linear ($\rho = 0$). Columns (2) - (5) and (10) - (12) assume exponential (rather than hyperbolic) discounting, $\beta = 1$, so that any violation of stationarity or time consistency is driven solely by noise. Columns (6) - (9) and (13) - (15) assume quasi-hyperbolic discounting, $\beta < 1$. As a result, violations of time invariance are still driven by noise alone, while violations of stationarity and time consistency may result either from noise or from present bias. Finally, for each model, the simulations are repeated assuming three different levels of noise, μ .

The bottom row shows the correlation between violations of stationarity and time consistency. The *actual* correlation in our experiment is 0.21,

which is high compared to the simulated correlations in Columns (2) to (15). It does, however, not always fall outside the simulated confidence intervals. The correlation is furthermore mostly driven by the occurrence of future-biased choice reversals: when only present-biased violations are taken into account the *actual* correlation is in fact significantly lower than all of the simulated correlations. We therefore conclude that random noise alone cannot account for the low correlation between (present-biased) violations of stationarity and time consistency.

4.4 Behavioral mechanisms II: Changes in wealth

Alternatively, time consistency and stationarity may not overlap because households' financial situation changed from the first to the second round. Households' net wealth declined on average by 10,000 NGN, or five times the value of the experimental payment. This potentially increases subjective discount rates from the first to the second round, resulting in a violation of time invariance and either stationarity (if participants anticipate the decline in wealth) or time consistency (if the decline in wealth comes as a surprise). To investigate whether such changes play a role, we exploit variation in households' financial balances to assess whether violations of stationarity and time consistency correlate with changes in household wealth. Specifically, we estimate the following logit model for individual i in household h :

$$\begin{aligned} Pr(\mathbb{1}_{ih}(x_{t,t} \neq x_{1,2} \cup x_{s,s} = x_{1,2}) | Gain_h, Loss_h, Z_{ih}) = & \quad (4) \\ \Lambda(\beta_0 + Gain_h \beta_1 + Loss_h \beta_2 + \mathbf{z}_{ih} \beta_3), s \neq t & \end{aligned}$$

where $\mathbb{1}_{ih}(x_{t,t} \neq x_{1,2} \cup x_{s,s} = x_{1,2})$ is an indicator signaling whether an individual violates stationarity but not stationarity when $t = 1$ and $s = 2$, or time consistency but not stationarity when $t = 2$ and $s = 1$ and $\Lambda(x)$ is the logit function $\Lambda(x) = \frac{\exp(x)}{1 + \exp(x)}$. $Gain_h$ and $Loss_h$ are dummy variables indicating that between the first and second round, a household's net wealth increased by more than 33,580 NGN or decreased by more than 27,750 NGN, the highest and lowest quartile of changes in household wealth, respectively,

and \mathbf{z}_{ih} is a vector of control variables.¹⁷

Table 6 presents the marginal effects of wealth gains and losses on the probability of violating stationarity without violating time consistency, and the probability of violating time consistency without violating stationarity.¹⁸ Columns (1)-(3) test whether gains and losses relate to violations of time consistency but not stationarity, while Columns (4)-(6) relate gains and losses to violations of stationarity but not time consistency. In Columns (1) and (4), any difference between $x_{t,t}$ and $x_{1,2}$ is treated as a violation, i.e. $x_{2,2} \neq x_{1,2} = x_{1,1}$ and $x_{1,1} \neq x_{1,2} = x_{2,2}$. By contrast, Columns (2) and (5) zoom in on present-biased violations, $x_{2,2} < x_{1,2} \leq x_{1,1}$ and $x_{1,1} < x_{1,2} \leq x_{2,2}$, and Columns (3) and (6) on future-biased violations, $x_{2,2} > x_{1,2} \geq x_{1,1}$ and $x_{1,1} > x_{1,2} \geq x_{2,2}$.

Column (1) relates changes in wealth to violations of time consistency that occur in the absence of stationarity violations. In other words, the dependent variable is a dummy variable equal to one if and only if a participant makes the same two choices in the first round but revises the choice regarding second-round payment dates when revisited in the second round, $x_{1,1} = x_{1,2} \neq x_{2,2}$. Marginal effects are small and not statistically significant and the same holds for Column (3), which focuses on future-biased violations. By contrast, in Column (2), large gains significantly reduce the probability that a participant violates time consistency in a present-biased direction without also violating stationarity, providing a first suggestion that the wedge between time consistency and stationarity is systematic rather than random.

Columns (4) - (6) relate changes in wealth to violations of stationarity when participants satisfy time consistency. In Column (4), participants who experience a large gain in household wealth are more likely to make different choices in the first round regarding the first- and second-round payment dates, without revising their choices when revisited in the second round. Col-

¹⁷ \mathbf{z}_{ih} includes nine regional dummies, age, gender, the number of children living in the household, the level of education, a person's main source of income, and a dummy to indicate whether a person violates the monotonicity condition.

¹⁸The full results from the logit model are shown in Appendix Table C3.

umn (5) shows that this effect is mostly driven by present-biased violations. Nonetheless, losses in household wealth are associated with present-biased revisions of the allocation regarding second-round payments dates in Column (6). The significant effect of changes in wealth on violations of either type suggests that a discrepancy between time consistency and stationarity cannot be attributed solely to random noise in decision-making.

Table 6 also sheds light on the extent to which wealth changes driving a wedge between stationarity and time consistency are foreseen. On the one hand, when changes in wealth are *unanticipated*, gains and losses will not affect first-round allocations, because participants are not aware of any upcoming changes in background wealth yet at the time of the first decision moment. Instead, participants revise their allocations in the second round. Unanticipated wealth changes therefore lead to violations of time consistency, but not stationarity.

On the other hand, if a change in wealth is *anticipated*, a participant can take it into account when making the first-round choices and consequently there will be no need to adjust the allocation in the second round. Anticipated wealth changes will therefore lead to violations of stationarity, but not time consistency. Table 6 finds stronger marginal effects of gains and losses on the probability of violating stationarity than on the probability of violating time consistency. This can be interpreted as a sign that participants anticipated changes in background wealth.

In sum, significant correlations of wealth changes and non-overlapping violations of stationarity and time consistency indicate that the discrepancy between time consistency and stationarity is not purely random. Rather, our findings suggest that a number of participants anticipated lower wealth in the second compared to the first round, causing these participants to violate stationarity in a future-biased direction.

4.5 Behavioral Mechanisms III: Experimental Factors

Finally, we discuss whether key features of the experimental design may have caused discrepancies between violations of stationarity and time consistency.

A first potential limitation is that intertemporal allocations are elicited using convex time budgets, which have been questioned to yield valid choice patterns (Chakraborty et al., 2015). Our design does not include multiple price lists and does not vary experimental wealth or the delay between the sooner and the later payment date, so that we cannot test the weak axiom of revealed preferences, or test for wealth and impatience monotonicity, robustness checks proposed by (Chakraborty et al., 2015). Nevertheless, we showed in Section 3.3 that only few participants violate demand monotonicity, suggesting they have understood the convex time budget task. Further, convex time budgets have been shown to have equal or better predictive validity compared to double multiple price lists (Andreoni, Kuhn and Sprenger, 2015), supporting the validity of our method to elicit violations of time consistency and stationarity.

A second factor potentially biasing time preference experiments is a lack of trust in the experimenters among participants (Thaler, 1981; Chabris, Laibson and Schuldt, 2008; Sprenger, 2015). Participants who do not trust experimenters to return with their money on future dates will make different decisions for allocations where ‘today’ is one of the payment dates than for allocations with only only future payment dates, regardless from whether this person is a hyperbolic discounter. To avoid this we only included payment dates in the future, so that the soonest payment date is no longer immediate. Several recent studies adopt this approach and fail to reject stationarity at the aggregate level, suggesting that this indeed does eliminate changes in trust as a potential confound (e.g. Sprenger, 2015; Giné et al., 2014; Andreoni and Sprenger, 2012*a*). Further indications that limited levels of trust have not influenced participants’ allocations follow from the observation that even when there is no return on waiting (i.e. sooner vouchers are worth 200 NGN so that they do not ‘lose’ any money by allocating vouchers to the sooner date) participants allocate some vouchers to the later date in the first-round choice regarding near-future payment dates, as shown in Table 3. Participants thus appear to have trusted the experimenter to hold on to their money, suggesting that discrepancies between stationarity and time consistency violations are not driven by a lack of trust.

Decision fatigue or limited attention spans offer a third potential reason for the lack of overlap between violations of stationarity and time consistency in our experiment. In the second round, participants only had to allocate their vouchers once, while they were presented with eight different choices in the first round. As a result, participants may have paid more attention to their choice in the second round than they did in their first-round choices. Hoddinott, Hoel and Schwab (2014) find that when participants become fatigued, they behave more impatiently. Thus, if fatigue were a problem in our sample, we would expect participants to choose less patient allocations in their last decisions in the first round. However, the last first-round choices were near-future allocations. As shown in Table 3, participants actually do not behave more impatiently in these choices compared to their first set of choices, which concerned the distant-future payment dates. Fatigue does not explain why time consistency and stationarity do not overlap.

A fourth possible confound is that participants were interviewed about their cash inflows and outflows on a weekly basis for the larger project the experiment was embedded in, potentially increasing awareness of a present bias among hyperbolic discounters. In other words, hyperbolic discounting may have presented itself in a more sophisticated way during the second round than during the first round, affecting second-round choices, $x_{2,2}$. To test whether frequent interviewing affected the level of participants' financial sophistication, the project randomly selected a number of control households to be interviewed only at baseline and during an endline survey one year later. Table 7 compares respondents interviewed with high frequency with the control group in terms of a number of financial planning variables measured at baseline and endline. Financial planning improved among all respondents, also those in the control group, and we do not observe stronger improvements in financial planning for participants interviewed on a weekly basis. It is hence unlikely that frequent interviewing explains the discrepancy between violations of stationarity and time consistency.

A fifth factor potentially weakening the correlation between stationarity and time consistency is the elicitation method of the second-round choice. In the second round of the experiment, participants are shown their first-

round allocation for the distant future and asked whether they would like to revise this choice. This procedure, adopted from Giné et al. (2014), could potentially increase the probability of observing time-consistent choices that nevertheless violate stationarity and time invariance. Comparing our results to Halevy (2015) (who did not present the second round as a revision and did not show participants their first-round allocations during the second round), we observe a similar proportion of participants who satisfy time consistency but violate stationarity and time invariance. We hence conjecture that presenting the second-round choice as a revision does not confound our results.

Finally, the limited presence of formal financial institutions, like banks, in the region where our research was conducted may also have influenced our findings. Participants in our experiment do not have the formal financial instruments to save or borrow against future payments at a fixed, salient interest rate. Therefore, participants cannot engage in financial arbitrage using their experimental payments. Hence we do not need to censor subjective discount rates by the market interest rate (Cubitt and Read, 2007; Chabris, Laibson and Schuldt, 2008; Andersen, Harrison and Lau, 2014).

In sum, limited trust in the experimenters, decision-making fatigue that was potentially more present in the first compared to the second round, increased awareness of a present bias from the first to the second round, and presenting the second-round choice as a revision do not seem to drive our results. We conclude that violations of stationarity and time consistency often do not overlap, and this can be explained partly by changes in participants' financial situation.

5 Conclusion

An increasing number of scholars is interested in eliciting experimental measures of hyperbolic discounting. Most studies do so by means of a (cross-sectional) static choice experiment in which participants choose whether to receive a sooner-smaller or later-larger payment, with payment dates in either the near future or in a more distant future. Such experiments elicit

violations of *stationarity*. Alternatively, one can elicit violations of *time consistency* by means of a longitudinal design in which participants choose at different points in time whether to receive a sooner-smaller versus later-larger payment, keeping the payment dates fixed. Both violations of time consistency and stationarity are commonly interpreted as evidence for hyperbolic discounting. These violations may however also be driven by violations of *time invariance*, meaning that participants express different preferences regarding near-future payment dates depending on when they make their decisions. Hyperbolic discounting can be inferred from stationarity or time consistency violations only when participants choose identical allocations for near-future payment dates independent of the timing of these decisions.

A field experiment in rural Nigeria analyzed to what extent violations of time invariance drive a wedge between violations of stationarity and time consistency. Using convex time budgets, participants were asked during a first round to allocate vouchers between ‘tomorrow’ and ‘one month from now’, between ‘two months from now’ and ‘three months from now’, and during a second round two months later to allocate vouchers between ‘tomorrow’ and ‘in one month from now’, the same calendar dates as in the second choice. A difference between the first and the second choice is labeled a violation of stationarity; a difference between the second and the third choice is labeled a violation of time consistency; and a difference between the first and the third choice is labeled a violation of time invariance.

Although 43.4 percent of participants violate time consistency and a similar 43.8 percent violate stationarity, these violations are mainly attributed to violations of time invariance. The correlation between stationarity and time consistency is weak. Only 10.4 of participants violates both stationarity and time consistency in a present-biased direction and could be qualified as hyperbolic discounters.

These findings are very similar to results from a laboratory experiment with undergraduate students at the University of British Columbia in Vancouver (Halevy, 2015). Motivated by the question whether random noise in decision-making could yield this striking similarity, we subsequently investigate potential reasons for why time consistency and stationarity do not

overlap. We find that random noise alone cannot explain their low correlation. This conclusion is further reinforced by the observation that changes in wealth predict violations of time consistency and especially stationarity. Thus, when income or expenditures fluctuate over time, systematic changes in wealth can drive a wedge between stationarity and time consistency. In that case, one cannot infer hyperbolic discounting from observing either a stationarity or a time consistency violation.

At the aggregate level, participants violate time consistency and time invariance but not stationarity. The finding that stationarity is not rejected in the aggregate is in line with many recent studies with monetary rewards that carefully take into account trust issues (e.g. Sprenger, 2015; Giné et al., 2014; Andreoni and Sprenger, 2012*a*; Augenblick, Niederle and Sprenger, 2015; Carvalho, Meier and Wang, 2014). Increasing participants' trust in the experimenter is one explanation for why aggregate-level stationarity is satisfied. Our study provides a second explanation for the finding of aggregate stationarity. Participants who anticipate losses in wealth are more likely to violate stationarity in a future-biased direction, which offsets present-biased violations among other participants. As a result, we cannot reject the hypothesis that stationarity is satisfied on an aggregate level.

This study has direct implications for the design of studies that aim to elicit empirical measures of hyperbolic discounting. In order to identify hyperbolic discounters, experiments need to measure both violations of time consistency and of stationarity, unless violations of time invariance can be ruled out. We suggest one channel through which time preferences may change over time, but more research is needed on the (in)stability of time preferences, and econometric techniques can be used to control for them if the instability is driven by random noise.

Our findings have important implications for the design of commitment devices. Choice reversals in one-time experiments have often led to the conclusion that time inconsistent behavior is driven by present bias, and that people need commitment devices and other nudges to be able to commit to their earlier plans (Ashraf, Karlan and Yin, 2006; Bryan, Karlan and Nelson, 2010; Thaler and Benartzi, 2004). Such commitment devices tie individuals

to the mast, but for those individuals who did not anticipate a change in their financial circumstances, this may actually harm their welfare. In an area with large fluctuations in income and expenditures, commitment is not necessarily welfare-improving.

References

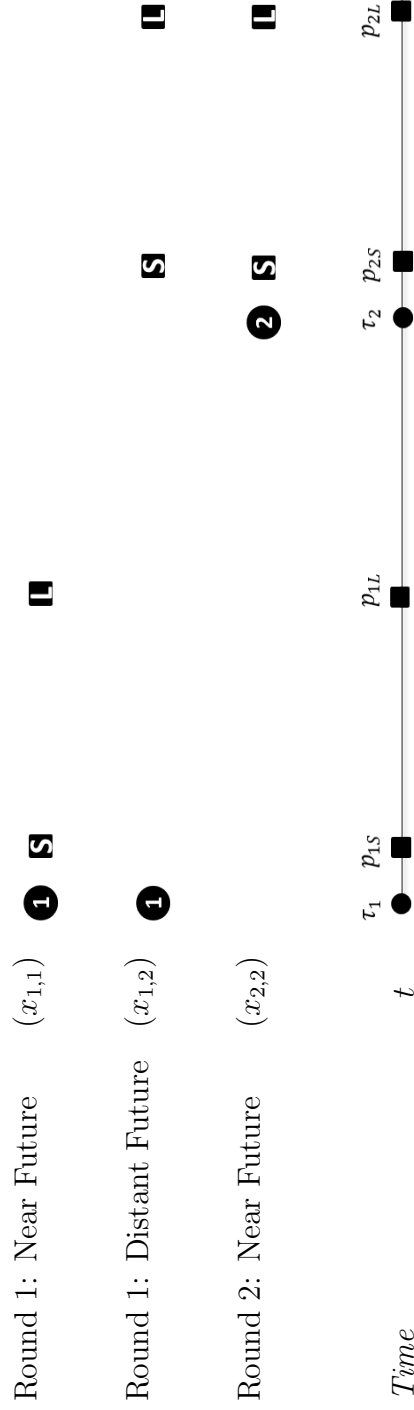
- Andersen, Steffen, Glenn Harrison, and Elisabet Lau, Morten and Rutström.** 2014. “Discounting behavior: A reconsideration.” *European Economic Review*, 71: 15–33.
- Andreoni, James, and Charles Sprenger.** 2012a. “Estimating time preferences from convex budgets.” *American Economic Review*, 102(7): 3333–3356.
- Andreoni, James, and Charles Sprenger.** 2012b. “Risk preferences are not time preferences.” *American Economic Review*, 102(7): 3357–3376.
- Andreoni, James, Michael Kuhn, and Charles Sprenger.** 2015. “On measuring time preferences.” *Forthcoming in Journal of Economic Behavior and Organization*.
- Ashraf, Nava, Dean Karlan, and Wesley Yin.** 2006. “Tying Odysseus to the mast: Evidence from a commitment savings product in the Philippines.” *Quarterly Journal of Economics*, 121(2): 635–672.
- Augenblick, Ned, Muriel Niederle, and Charles Sprenger.** 2015. “Working over time: Dynamic inconsistency in real effort tasks.” *Quarterly Journal of Economics*, 130(3): 1067–1115.
- Bryan, Gharad, Dean Karlan, and Scott Nelson.** 2010. “Commitment devices.” *Annual Review of Economics*, 2(1): 671–698.
- Carvalho, Leandro, Stephan Meier, and Stephanie Wang.** 2014. “Poverty and economic decision making: Evidence from changes in financial resources at payday.” *Unpublished manuscript*.
- Chabris, Christopher, David Laibson, and Jonathon Schuldt.** 2008. “Intertemporal choice.” *Palgrave Dictionary of Economics*.
- Chakraborty, Anujit, Evan Calford, Guidon Fenig, and Yoram Halevy.** 2015. “External and Internal Consistency of Choices made in Convex Time Budgets.” *Unpublished manuscript*.

- Coller, Maribeth, and Melonie Williams.** 1999. "Eliciting individual discount rates." *Experimental Economics*, 2(2): 107–127.
- Cubitt, Robin, and Daniel Read.** 2007. "Can intertemporal choice experiments elicit time preferences for consumption?" *Experimental Economics*, 10(4): 369–389.
- Dercon, Stefan.** 2002. "Income risk, coping strategies, and safety nets." *World Bank Research Observer*, 17(2): 141–166.
- Frederick, Shane, George Loewenstein, and Ted O'Donoghue.** 2002. "Time discounting and time preference: A critical review." *Journal of Economic Literature*, 40(2): 351–401.
- Giné, Xavier, Jessica Goldberg, Dan Silverman, and Dean Yang.** 2014. "Revising commitments: Field evidence on the adjustment of prior choices." *Unpublished manuscript*.
- Green, Leonard, Nathanael Fristoe, and Joel Myerson.** 1994. "Temporal discounting and preference reversals in choice between delayed outcomes." *Psychonomic Bulletin and Review*, 1(3): 383–389.
- Halevy, Yoram.** 2014. "Some comments on the use of monetary and primary rewards in the measurement of time preferences."
- Halevy, Yoram.** 2015. "Time consistency: Stationarity and time invariance." *Econometrica*, 83(1): 335–352.
- Harrison, Glenn.** 2008. "Maximum likelihood estimation of utility functions using STATA." *UCF Working Paper 06-12*.
- Harrison, Glenn, Morten Lau, and Elisabet Rutström.** 2005. "Dynamic consistency in Denmark: A longitudinal field experiment." *Unpublished Manuscript*.
- Harrison, Glenn, Morten Lau, and Elisabet Rutström.** 2013. "Identifying time preferences with experiments: Comment." *CEAR Working Paper*.

- Harrison, Glenn, Morten Lau, and Melonie Williams.** 2002. “Estimating individual discount rates in Denmark: A field experiment.” *American Economic Review*, 92(5): 1606–1617.
- Hoddinott, John, Jessica Hoel, and Benjamin Schwab.** 2014. “Self-control fatigue, cognitive function, and the expression of time preference: Experimental results from Ethiopia.” *Unpublished Manuscript*.
- Janssens, Wendy, Berber Kramer, Marijn Van der List, and David Pap.** 2013. “Financial and Health Diaries: A yearlong weekly panel of farming households in Nigeria and Kenya.” *Unpublished raw data*.
- Kirby, Kris, and Richard Herrnstein.** 1995. “Preference reversals due to myopic discounting of delayed reward.” *Psychological Science*, 6(2): 83–89.
- Krupka, Erin, and Melvin Stephens.** 2013. “The stability of measured time preferences.” *Journal of Economic Behavior and Organization*, 85: 11–19.
- Laibson, David.** 1997. “Golden eggs and hyperbolic discounting.” *Quarterly Journal of Economics*, 112(2): 443–477.
- Meier, Stephan, and Charles Sprenger.** 2015. “Temporal stability of time preferences.” *Review of Economics and Statistics*, 97(2): 273–286.
- Mullainathan, Sendhil, and Eldar Shafir.** 2013. *Scarcity: Why having too little means so much*. Macmillan.
- Read, Daniel, Shane Frederick, and Mara Airoidi.** 2012. “Four days later in Cincinnati: Longitudinal tests of hyperbolic discounting.” *Acta Psychologica*, 140(2): 177–185.
- Sayman, Serdar, and Ayse Öncüler.** 2009. “An investigation of time inconsistency.” *Management Science*, 55(3): 470–482.
- Sozou, Peter.** 1998. “On hyperbolic discounting and uncertain hazard rates.” *Proceedings of the Royal Society of London*, 265(1): 2015–2020.

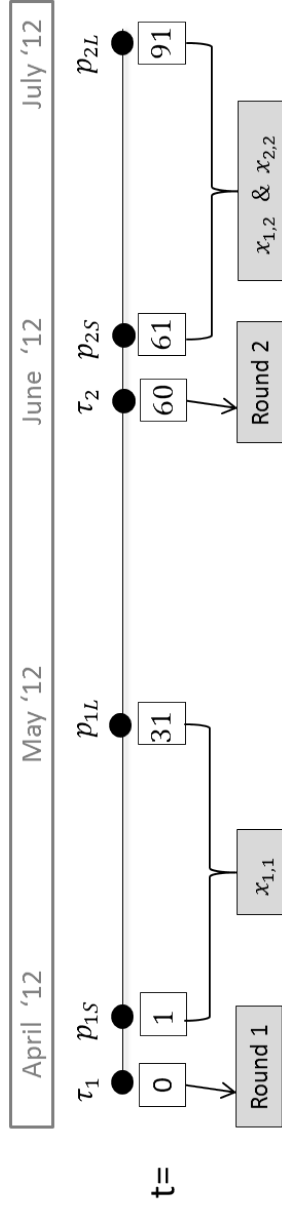
- Sprenger, Charles.** 2015. “Judging experimental evidence for dynamic inconsistencies.” *American Economic Review*, 105(5): 280–285.
- Thaler, Richard.** 1981. “Some empirical evidence on dynamic inconsistency.” *Economics Letters*, 8(3): 201–207.
- Thaler, Richard, and Shlomo Benartzi.** 2004. “Save more tomorrow: Using behavioral economics to increase employee saving.” *Journal of Political Economy*, 112(1): 164–187.

Figure 1: Three Types of Intertemporal Choices



Circles represent two different decision moments, $t = \tau_1$ for a first round and $t = \tau = 2$ for a second round. During these decision moments, people allocate g vouchers to a sooner and a later payment date. Squares represent the payment dates at which consumers can choose to receive the future gift. The sooner date is labeled 'S', and the later date is labeled 'L'. These payment dates are either in the period following the first round (for the first choice, $x_{1,1}$) or in the period following the second round (for the second and third choice, $x_{1,2}$ and $x_{2,2}$). The first and third choice concern payout dates in the near future. For the second choice, made in the first round regarding the payment dates in the second round, payout dates are in the distant future.

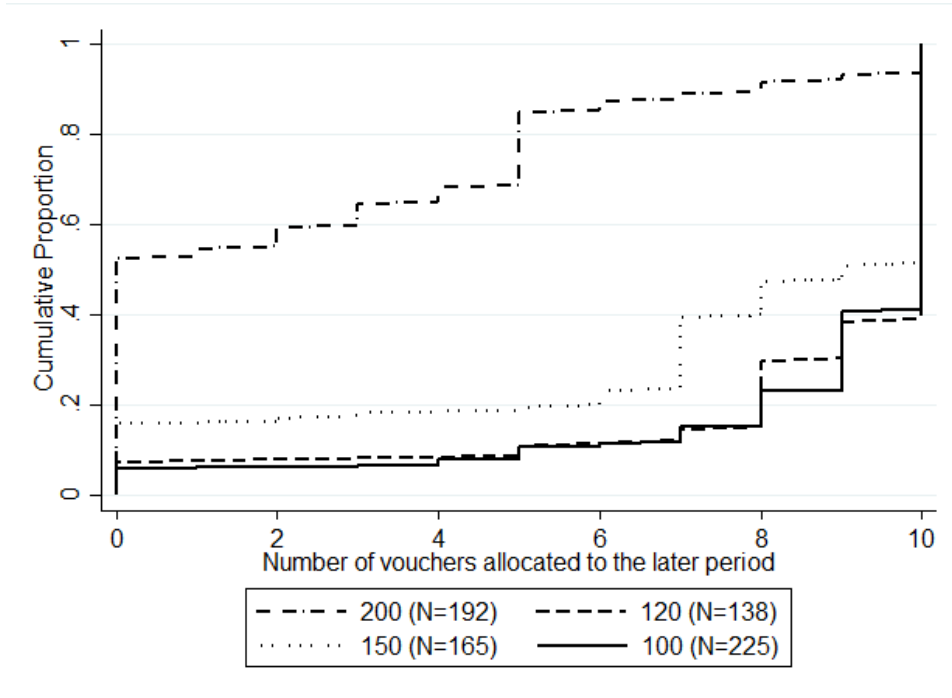
Figure 2: Timeline of the Study



Circles represent two different decision moments, $t = \tau_1$ for a first round at $t=0$ and $t = \tau = 2$ for a second round sixty days later. During these decision moments, people allocate vouchers to a sooner and a later payment date. Squares represent the payment dates at which consumers can choose to receive the future gift. The sooner date is labeled 'S', and the later date is labeled 'L'. These payment dates are either in the period following the first round (for the first choice, $x_{1,1}$) or in the period following the second round (for the second and third choice, $x_{1,2}$ and $x_{2,2}$). The first and third choice concern payout dates in the near future. For the second choice, made in the first round regarding the payment dates in the second round, payout dates are in the distant future.

Figure 3: Distribution of vouchers allocated to later date

(a) By value of vouchers allocated to the sooner date



(b) By choice type (incl. vouchers of 200 NGN)

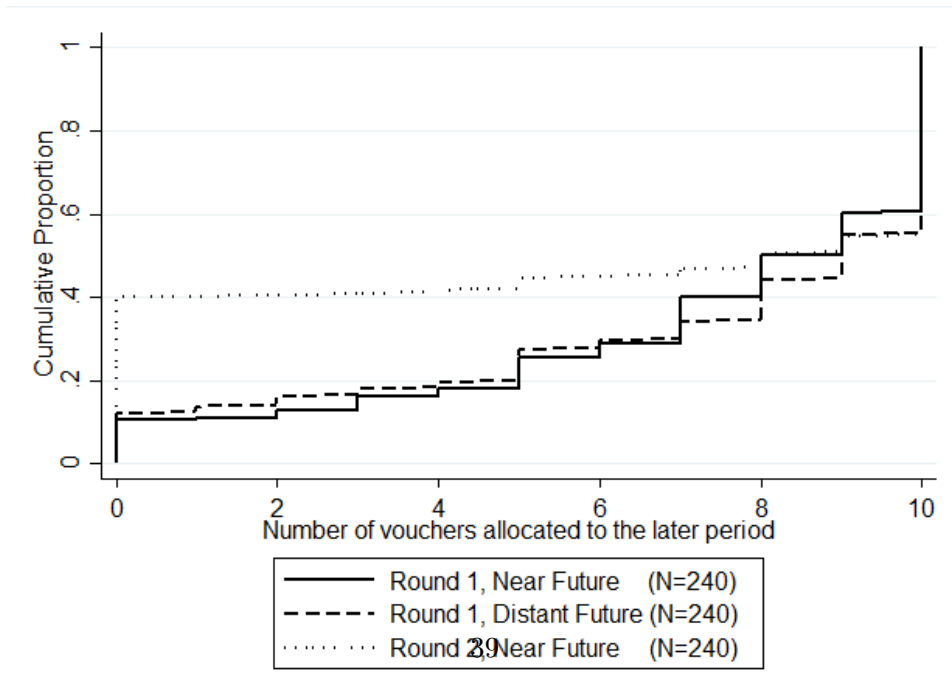
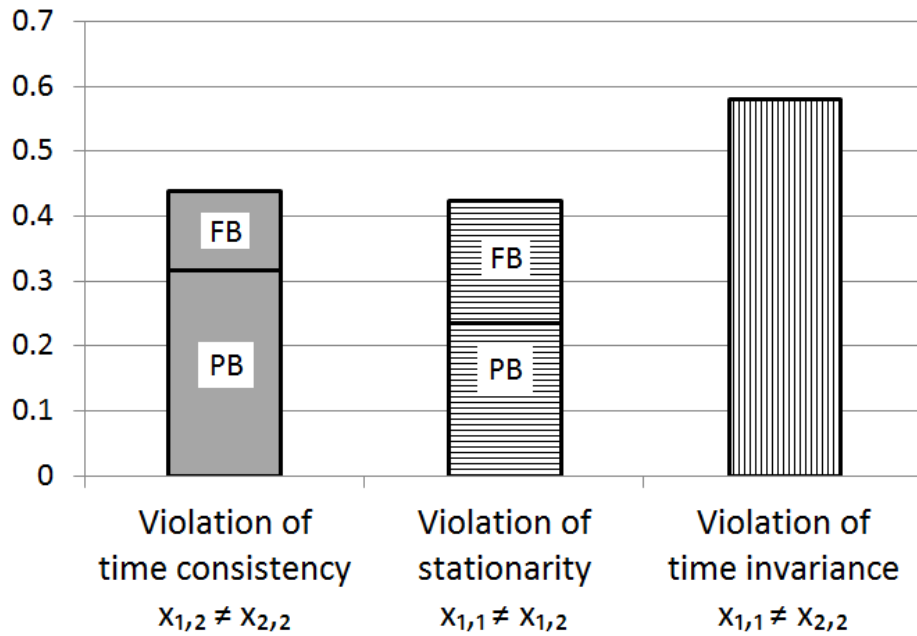
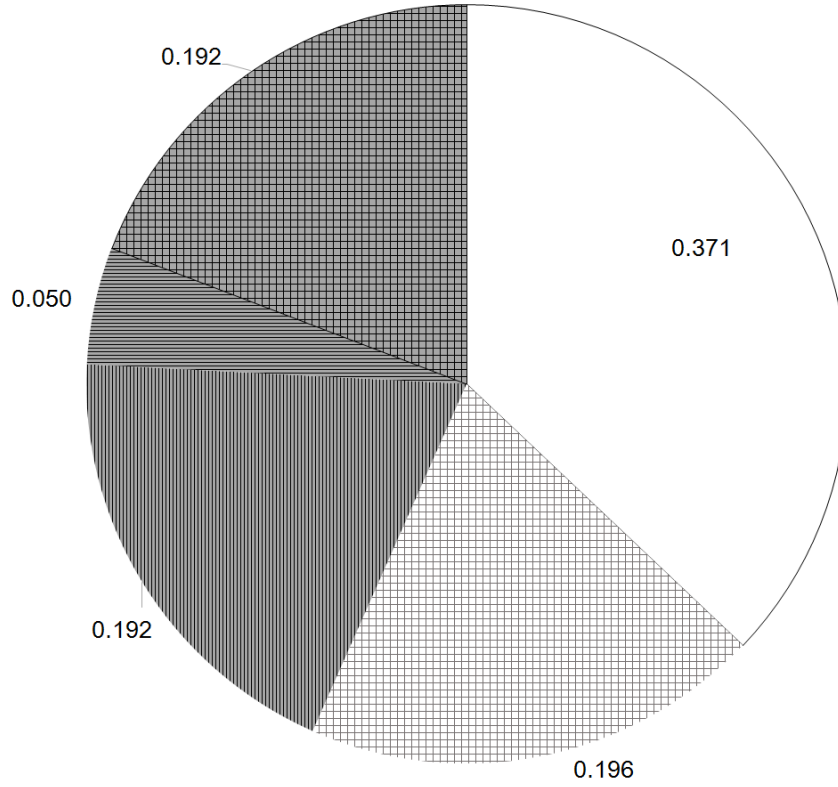


Figure 4: Proportions of participants violating the three concepts



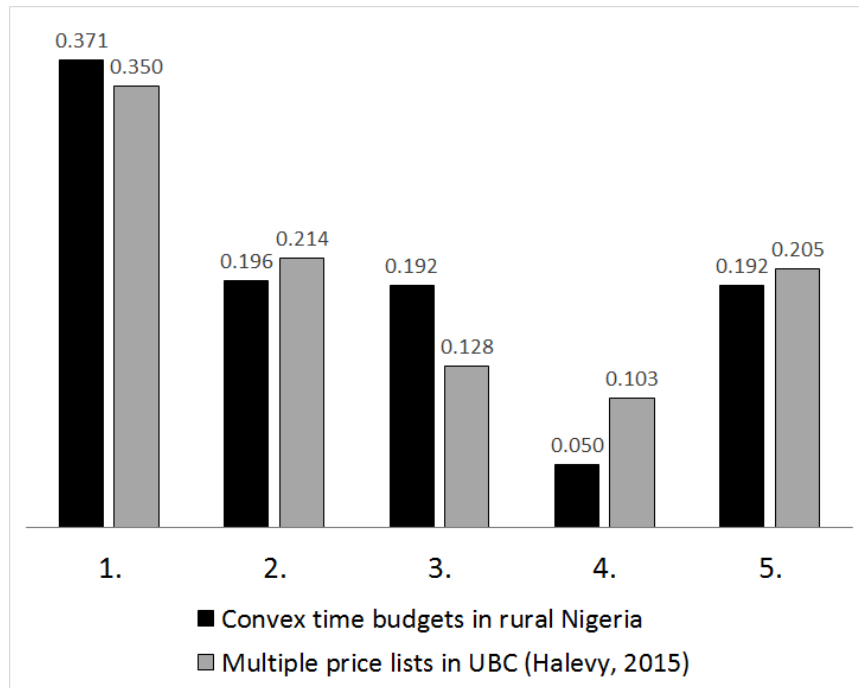
Violations of time consistency (stationarity) are divided into present-biased violations, $x_{1,2} > x_{2,2}$ ($x_{1,2} > x_{1,1}$), noted by PB, and future-biased violations, $x_{1,2} < x_{2,2}$ ($x_{1,2} < x_{1,1}$), noted by FB. Violations of time invariance cannot be classified as either present-biased or future-biased and are hence not divided into these two categories.

Figure 5: Distribution of participants over the five groups



		Time consistency	Stationarity	Time invariance	
		$x_{1,2} = x_{2,2}$	$x_{1,1} = x_{1,2}$	$x_{1,1} = x_{2,2}$	
□	1.	✓	✓	✓	$x_{1,1} = x_{1,2} = x_{2,2}$
≡	2.	✓	X	X	$x_{1,1} \neq x_{1,2} = x_{2,2}$
▨	3.	X	✓	X	$x_{1,1} = x_{1,2} \neq x_{2,2}$
≡	4.	X	X	✓	$x_{1,1} = x_{2,2} \neq x_{1,2}$
▨	5.	X	X	X	$x_{1,1} \neq x_{1,2} \neq x_{2,2}$

Figure 6: Comparing distribution of participants to distribution in Halevy (2015)



Group 1 consists of individuals satisfying time consistency, stationarity and time invariance ($x_{1,1} = x_{1,2} = x_{2,2}$); Group 2 consists of individuals satisfying time consistency, but violating stationarity and time invariance ($x_{1,1} \neq x_{1,2} = x_{2,2}$); Group 3 consists of individuals satisfying stationarity, but violating time consistency and time invariance ($x_{1,1} = x_{1,2} \neq x_{2,2}$); Group 4 consists of individuals satisfying time invariance, but violating time consistency and stationarity ($x_{1,1} = x_{2,2} \neq x_{1,2}$); and finally Group 5 consists of individuals violating time consistency, stationarity and time invariance ($x_{1,1} \neq x_{1,2} \neq x_{2,2}$).

The percentages listed here from Halevy (2015) are based on Column 1 from Table II on page 345 of Halevy, Yoram, 2015. "Time Consistency: Stationarity and Time Invariance." *Econometrica*, 83(1): 335 - 352.

Table 1: Defining Three Types of Violations

Violation of stationarity	$x_{1,1}$	\neq	$x_{1,2}$
Violation of time invariance	$x_{1,1}$	\neq	$x_{2,2}$
Violation of time consistency	$x_{1,2}$	\neq	$x_{2,2}$

$x_{i,j}$ represents the number of vouchers (out of a maximum of ten) that a participant allocates to the later payment date (rather than the sooner) at decision moment i for payment dates j .

Table 2: Description of the participant sample

	(A)		(B)		
	All participants		Revisited participants		Diff. in means
	N	Mean	N	Mean	
	(1)	(2)	(3)	(4)	(5)
Demographic characteristics					
Age	293	40.31	240	40.17	-0.143
Male	293	0.396	240	0.379	-0.017
Muslim	293	0.908	240	0.925	0.017
Married	292	0.908	240	0.908	0.001
Polygamous household	293	0.580	240	0.588	0.007
Lives in village (not in town)	293	0.761	240	0.775	0.014
Number of children	293	5.007	240	5.304	0.297***
<i>Level of education</i>					
- No Education	292	0.589	240	0.596	0.007
- Some primary	292	0.158	240	0.167	0.009
- More than primary	292	0.253	240	0.237	-0.016
Socio-economic characteristics					
<i>Main source of income</i>					
- Farming	293	0.369	240	0.367	-0.002
- Business	293	0.396	240	0.417	0.021
- Other	293	0.106	240	0.096	-0.01
- Nothing	293	0.130	240	0.121	-0.009
Financial balance in round 1	293	61,262	240	71,153	9,891***
Financial balance in round 2	277	50,841	240	50,020	-821
Proportion of participants planning to harvest					
- May	293	0.051	240	0.054	0.003
- June	293	0.038	240	0.037	-0.000
- July	293	0.167	240	0.158	-0.009
- August	293	0.266	240	0.271	0.005
Level of understanding					
Satisfies monotonicity	293	0.904	240	0.912	0.008

Reported p -values are based on t -tests with standard errors (shown in parentheses) clustered by household. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 3: Distribution of vouchers allocated to later payment date

	Summary statistics				<i>p</i> -value equal means		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A. By sooner voucher value (varied between-subjects)							
	200	150	120	100	200	150	120
					=	=	=
					150	120	100
Mean	2.54	7.35	8.57	8.66			
Std Dev	3.23	3.59	2.74	2.59	0.000	0.001	0.746
Observations	192	165	138	225			
Panel B. By type of choice (varied within-subjects)							
	All	$x_{1,1}$	$x_{1,2}$	$x_{2,2}$	$x_{1,1}$	$x_{1,1}$	$x_{1,1}$
					=	=	=
					$x_{1,2}$	$x_{2,1}$	$x_{2,2}$
Mean	6.71	7.27	7.30	5.56			
Std Dev	3.98	3.29	3.53	4.72	0.853	0.000	0.000
Observations	720	240	240	240			
Panel C. Excl. sooner vouchers worth 200 NGN							
	All	$x_{1,1}$	$x_{1,2}$	$x_{2,2}$	$x_{1,1}$	$x_{1,1}$	$x_{1,1}$
					=	=	=
					$x_{1,2}$	$x_{2,1}$	$x_{2,2}$
Mean	8.23	8.58	8.83	7.27			
Std Dev	3.03	2.18	2.11	4.12	0.101	0.000	0.001
Observations	528	176	176	176			

The value of vouchers allocated to the later payment date is fixed at 200 NGN, while the value of vouchers allocated to the sooner payment date varies from 200 NGN to 100 NGN. $x_{i,j}$ represents the number of vouchers (out of a maximum of ten) that a participant allocates to the later payment date (rather than the sooner) at decision moment i for payment dates j . As such, stationarity tests whether the first-round allocation for payment dates in the near future ($x_{1,1}$) is identical to the first-round allocation for payment dates in the more distant future ($x_{1,2}$). Time invariance tests whether allocations for near-future payment dates are identical regardless of whether they were made in the first round ($x_{1,1}$) or in the second round ($x_{2,2}$). Finally, time consistency tests whether the first-round allocation for second-round payment dates ($x_{1,2}$) is identical to the second-round allocation for second-round payment dates ($x_{2,2}$). Reported p -values are based on t -tests with standard errors (shown in parentheses) clustered by household. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 4: Distribution of violations of stationarity and time consistency

	Violation if allocation differs by more than ... vouchers:		Excl participants with ≥ 2 identical corners	Counting 2 identical corners as a violation
	> 0	> 1		
	(1)	(2)	(3)	(4)
Panel A. Counting violations in both PB and FB directions				
No violations of S or TC	0.371	0.492	0.120	0.050
Violation of TC but not of S	0.196	0.258	0.270	0.113
Violation of S, but not of TC	0.192	0.138	0.140	0.058
Violations of both S and TC	0.242	0.113	0.470	0.779
Correlation violations S, TC	0.212	0.095	0.087	0.283
Correlation violations S, TI	0.541	0.424	0.423	0.493
Correlation violations TC, TI	0.548	0.621	0.584	0.627
Panel B. Counting only violations in a PB direction				
No PB violations of S or TC	0.542	0.646	0.330	0.154
PB violation of TC, but not of S	0.213	0.229	0.320	0.196
PB violation of S, but not of TC	0.142	0.058	0.170	0.075
PB violations of both S and TC	0.104	0.067	0.180	0.575
Correlation PB violations S, TC	0.131	0.197	0.021	0.369
Correlation PB violations S, TI	0.517	0.371	0.261	0.518
Correlation PB violations TC, TI	0.738	0.730	0.864	0.689
Panel C. Counting only violations in a FB direction				
No FB violations of S or TC	0.725	0.825	0.540	0.254
FB violation of TC, but not of S	0.088	0.050	0.200	0.154
FB violation of S, but not of TC	0.154	0.100	0.220	0.171
FB violations of both S and TC	0.033	0.025	0.040	0.421
Correlation FB violations S, TC	0.084	0.179	-0.120	0.332
Correlation FB violations S, TI	0.449	0.357	0.353	0.621
Correlation FB violations TC, TI	0.597	0.633	0.819	0.744
Number of observations	240	240	100	240

PB: Present-biased. FB: Future-biased. S: Stationarity. TI: Time invariance. TC: Time consistency. Time invariance cannot be classified as either present- or future-biased. The correlation of present-biased violations of S and TI compares present-biased stationarity violations to time-invariance violations where participants become *more* patient, because when choices satisfy time consistency but violate stationarity in a present-biased direction, choices will have become more patient. The correlation of present-biased violations of TC and TI on the other hand compares present-biased time-consistency violations to time-invariance violations where participants become *less* patient, following a similar line of reasoning. For future-biased correlations, the patterns are exactly reversed: the correlations between future-biased violations of S and TI use time-invariance violations where participants become *less* patient, while the correlations between future-biased violations of TC and TI use time-invariance violations where participants become *more* patient.

Table 5: Outcomes realized in the experiment and in Monte Carlo simulations

Discounting	Linear utility ($\rho = 0$)			CRRA utility ($\rho \neq 0$)					
	Exponential $\rho = 0, \beta = 1$	Hyperbolic $\rho = 0, \hat{\beta} = 0.82$	Hyperbolic $\rho = 0, \hat{\beta} = 0.82$	Exponential $\hat{\rho} = -0.77, \beta = 1$	Exponential $\hat{\rho} = -0.77, \beta = 1$	Hyperbolic $\hat{\rho} = -0.71, \hat{\beta} = 0.72$			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	
μ	Actual	0.09	0.24	0.09	0.24	0.09	0.24	0.09	0.24
<i>Proportion violating time consistency</i>									
Violation: $x_{1,2} \neq x_{2,2}$	0.44	0.85	0.90	0.85	0.90	0.42	0.78	0.35	0.75
Present-biased: $x_{1,2} > x_{2,2}$	0.32	0.43	0.45	0.56	0.52	0.31	0.48	0.17	0.38
<i>Proportion violating stationarity</i>									
Violation: $x_{1,2} \neq x_{1,1}$	0.43	0.85	0.90	0.85	0.90	0.43	0.78	0.35	0.75
Present-biased: $x_{1,2} > x_{1,1}$	0.25	0.43	0.45	0.56	0.52	0.31	0.49	0.17	0.38
<i>Proportion violating time invariance</i>									
Violation: $x_{1,1} \neq x_{2,2}$	0.58	0.85	0.90	0.85	0.90	0.35	0.77	0.35	0.75
Less patient: $x_{1,1} > x_{2,2}$	0.37	0.43	0.45	0.43	0.45	0.17	0.39	0.17	0.38
<i>Correlations between violations of stationarity and time consistency</i>									
Violation	0.21	0.06	0.01	0.06	0.00	0.47	0.14	0.38	0.15
Present-biased	0.13	0.31	0.32	0.31	0.32	0.54	0.33	0.41	0.32

For a detailed description of the simulated model, see Appendix B. Parameters estimated by means of maximum likelihood are marked $\hat{\cdot}$. Symbol ρ is the CRRA coefficient, β a present bias by which instantaneous utility for future payments is discounted, and μ indicates the degree of noise. Choices $x_{1,1}$, $x_{1,2}$ and $x_{2,2}$ represents the number of vouchers allocated to the later payment date in the near-future first-round allocation, distant-future first-round allocation, and near-future second-round allocation, respectively.

Table 6: Logit modeling non-overlapping stationarity and time consistency violations as a function of changes in wealth

	Any violation of TC but not of S	PB violation of TC but not of S	FB violation of TC but not of S	Any violation of S but not of TC	PB violation of S but not of TC	FB violation of S but not of TC
	(1)	(2)	(3)	(4)	(5)	(6)
Large gain in household wealth (> 33,580 NGN)	-0.082 (0.075)	-0.147** (0.071)	0.058 (0.054)	0.151** (0.063)	0.114** (0.055)	0.043 (0.059)
Large loss in household wealth (< - 27,750 A28 NGN)	0.056 (0.072)	0.060 (0.066)	0.046 (0.046)	0.009 (0.066)	-0.036 (0.070)	0.106* (0.064)
Mean Dependent Variable	0.196	0.213	0.088	0.192	0.142	0.154
Pseudo R-squared	0.109	0.149	0.250	0.108	0.115	0.104
Number of Observations	240	240	240	240	240	240
Controls	Yes	Yes	Yes	Yes	Yes	Yes

PB: Present-biased. FB: Future-biased. TC: Time Consistency. S: Stationarity. The reported results are the marginal effects from a logit model with regional dummies and control variables (age, gender, the number of children living in the household, the level of education, a the participant's main source of income, and a dummy to indicate whether a person violates the monotonicity condition). Reported p -values are based on t -tests with standard errors (shown in parentheses) clustered by household. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 7: Effect of diary participation on the ability to plan financially

	(1)	(2)	(3)	(4)	(5)
	Ability to plan finances	Type of planner	Sticks to plans	Only saves leftovers	# times runs out of money
Participates	-0.012 (0.094)	0.124** (0.063)	-0.115** (0.054)	0.009 (0.017)	-0.031 (0.167)
Endline	0.710*** (0.115)	0.182*** (0.052)	-0.168*** (0.046)	0.014 (0.017)	0.535*** (0.146)
Participates X Endline	0.107 (0.156)	-0.110 (0.087)	0.097 (0.076)	-0.014 (0.028)	0.073 (0.222)
Male respondent	-0.048 (0.053)	0.023 (0.041)	-0.033 (0.031)	-0.010 (0.016)	-0.152 (0.097)
Age	0.007*** (0.002)	-0.001 (0.001)	0.001 (0.001)	0.000 (0.001)	-0.000 (0.004)
Household size	-0.004 (0.011)	0.000 (0.008)	-0.001 (0.007)	-0.001 (0.002)	0.004 (0.020)
Has 1 to 6 yrs of education	0.072 (0.084)	-0.055 (0.049)	0.057 (0.041)	0.002 (0.016)	0.154 (0.129)
Has 7 or more yrs of education	0.318*** (0.078)	-0.036 (0.058)	0.054 (0.048)	0.018 (0.019)	0.217 (0.151)
Community effects	Yes	Yes	Yes	Yes	Yes
N	1110	1125	1125	1125	1115
R-squared	0.285	0.031	0.039	0.006	0.072

In Column (1), the dependent variable is the first factor of a principal component analysis for financial planning ability; in Column (2), the dependent variable is a categorical scale of saving behavior, with value 1 for someone who plans well and sticks to these plans, 3 for someone who only saves when money is left over, and 2 for someone in the middle; in Column (3), it is a dummy variable that indicates whether someone plans well and sticks to these plans; in Column (4), the dependent variable is a dummy variable that indicates whether someone only saves when money is left over; and in Column (5), the dependent variable is categorical variable that indicates the number of times a person runs out of money in a month. Reported p -values are based on t -tests with standard errors (shown in parentheses) clustered by household. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Appendices

A Script of the time preference game

A.1 First Round

We appreciate your participation in our study a lot. Today we would like to play a game with you. To compensate you for the time that you will still spend on our study the coming year, you can earn money with the game we play today. First of all I will record your name and some other information about you in the computer.

For the first game I will give you 10 vouchers. The value of a voucher depends on the bowl in which you put it: left or right. Every voucher on the left is worth 200 NAIRA. I will give you the 200 NAIRA in 1 month from now. Is this clear?

For every voucher on the right, I will give you the money tomorrow. How much money you get for every voucher on the right varies. I will tell you in a moment how much money they are worth. Is this clear?

In this game, you can earn real money. I guarantee you that you will receive the money. Me or my colleague will come to pay you personally, here at your compound. It is your money and you can do with it what you want.

SHOW THE VOUCHER TO THE RESPONDENT TO SHOW THAT WE WILL REALLY PAY THEM OUT THE MONEY

For the answer selected, I will give you real Naira. It is possible to put some on the left and some on the right; in that case, I will give you money tomorrow and in 1 month from now. If you choose to have some vouchers on the left and some on the right, I will come twice, that is no problem!!!! It is also possible to put all vouchers on the left; or all on the right. You

will get the money on both sides! Is that clear?

I will ask you 8 different times how many of the 10 vouchers you want to put left, and how many right. After that, the computer will select one of your 8 answers. The choice will be selected by chance. So I cannot influence that. You will only receive the money for the choice in one of the 8 questions, not for each of the 8 questions. Is that clear?

You can also contact my supervisor, Dr. Olawale from UITH or myself in case you do not get paid at the right time. Both our numbers will be given to you on the voucher.

Let's first practice this.

PRACTICE (SCENARIO A)

Practice Question 1

You can choose how many vouchers you want on the left and on the right. For every voucher on the left I will give you 200 NAIRA in 1 month from now. For every voucher on the right, I will give you 200 NAIRA tomorrow. So you have to choose between 200 NAIRA in 1 month from now or 200 NAIRA tomorrow. If you choose to put all vouchers in the left bowl it would mean you get 2000 NAIRA in one month from now. If you choose to put all vouchers in the right bowl it would mean you get 2000 NAIRA tomorrow. Please remember you can make any combination you like, so you can choose to put some in the left and some in the right bowl or all in one of the two.

Please put the vouchers

You have decided to get [NR LEFT] x 200 NAIRA in 1 month from now, and [NR RIGHT] x 200 NAIRA tomorrow. This means that if the computer selects this question, I will give you XX NAIRA in 1 month from now, and

XX NAIRA tomorrow. Do you want to change anything to the number of vouchers on the left or right?

IF VOUCHERS ARE MOVED, REPEAT THE PARAGRAPH ABOVE.

IF NO FURTHER CHANGES: I will write down your answer. If the computer selects this question, I will give you [NAIRA TOTAL LEFT] in 1 month and [NAIRA TOTAL RIGHT] tomorrow. Is there anything unclear?

RECORD THE ANSWER IN THE COMPUTER NOW

Practice Question 2

Now we move on to the next question. The idea is the same. You can choose how many out of 10 vouchers you want on the left, and how many on the right. For every voucher on the left I will give you 200 NAIRA in 1 month from now. For every voucher on the right, I will give you not 200 but 150 NAIRA, tomorrow. So you have to choose between 200 NAIRA in 1 month from now or 150 NAIRA tomorrow. If you choose to put all vouchers in the left bowl it would mean you get 2000 NAIRA in one month from now. If you choose to put all vouchers in the right bowl it would mean you get 1500 NAIRA tomorrow. Please remember you can make any combination you like, so you can choose to put some in the left and some in the right bowl or all in one of the two.

Please put the vouchers

You have decided to get [NR LEFT] x 200 NAIRA in 1 month from now, and [NR RIGHT] x 150 NAIRA tomorrow. This means that if the computer selects this question, I will give you XX NAIRA in 1 month from now, and XX NAIRA tomorrow. Do you want to change anything to the number of vouchers on the left or right?

IF VOUCHERS ARE MOVED, REPEAT THE PARAGRAPH ABOVE.

IF NO FURTHER CHANGES: I will write down your answer. If the computer selects this question, I will give you [NAIRA TOTAL LEFT] in 1 month and [NAIRA TOTAL RIGHT] tomorrow. Is there anything unclear?

RECORD THE ANSWER IN THE COMPUTER NOW

Practice Question 3

Now we move on to the next question. The idea is the same. You can choose how many out of 10 vouchers you want on the left, and how many on the right. For every voucher on the left I will give you 200 NAIRA in 1 month from now. For every voucher on the right, I will give you not 200 but 120 NAIRA, tomorrow. So you have to choose between 200 NAIRA in 1 month from now or 120 NAIRA tomorrow. If you choose to put all vouchers in the left bowl it would mean you get 2000 NAIRA in one month from now. If you choose to put all vouchers in the right bowl it would mean you get 1200 NAIRA tomorrow. Please remember you can make any combination you like, so you can choose to put some in the left and some in the right bowl or all in one of the two.

Please put the vouchers

You have decided to get [NR LEFT] x 200 NAIRA in 1 month from now, and [NR RIGHT] x 120 NAIRA tomorrow. This means that if the computer selects this question, I will give you XX NAIRA in 1 month from now, and XX NAIRA tomorrow. Do you want to change anything to the number of vouchers on the left or right?

IF VOUCHERS ARE MOVED, REPEAT THE PARAGRAPH ABOVE.

IF NO FURTHER CHANGES: I will write down your answer. If the computer selects this question, I will give you [NAIRA TOTAL LEFT] in 1 month and [NAIRA TOTAL RIGHT] tomorrow. Is there anything unclear?

RECORD THE ANSWER IN THE COMPUTER NOW

Question 4 (PRACTICE)

Now we move on to the next question. The idea is the same. You can choose how many out of 10 vouchers you want on the left, and how many on the right. For every voucher on the left I will give you 200 NAIRA in 1 month from now. For every voucher on the right, I will give you not 200 but 100 NAIRA, tomorrow. So you have to choose between 200 NAIRA in 1 month from now or 100 NAIRA tomorrow. If you choose to put all vouchers in the left bowl it would mean you get 2000 NAIRA in one month from now. If you choose to put all vouchers in the right bowl it would mean you get 1000 NAIRA tomorrow. Please remember you can make any combination you like, so you can choose to put some in the left and some in the right bowl or all in one of the two.

Please put the vouchers

You have decided to get [NR LEFT] x 200 NAIRA in 1 month from now, and [NR RIGHT] x 100 NAIRA tomorrow. This means that if the computer selects this question, I will give you XX NAIRA in 1 month from now, and XX NAIRA tomorrow. Do you want to change anything to the number of vouchers on the left or right?

IF VOUCHERS ARE MOVED, REPEAT THE PARAGRAPH ABOVE.

IF NO FURTHER CHANGES: I will write down your answer. If the computer selects this question, I will give you [NAIRA TOTAL LEFT] in 1 month and [NAIRA TOTAL RIGHT] tomorrow. Is there anything unclear?

RECORD THE ANSWER IN THE COMPUTER NOW

Now we will start with the real game, in which you can earn money. I will

now ask you the 8 different questions. I have the ten 200 NAIRA vouchers here.

SCENARIO A

Question 1

You can choose how many vouchers you want on the left and on the right. For every voucher on the left I will give you 200 NAIRA in 1 month from now. For every voucher on the right, I will give you 200 NAIRA tomorrow. So you have to choose between 200 NAIRA in 1 month from now or 200 NAIRA tomorrow.

Please put the vouchers

You have decided to get [NR LEFT] x 200 NAIRA in 1 month from now, and [NR RIGHT] x 200 NAIRA tomorrow. This means that if the computer selects this question, I will give you XX NAIRA in 1 month from now, and XX NAIRA tomorrow. Do you want to change anything to the number of vouchers on the left or right?

IF VOUCHERS ARE MOVED, REPEAT THE PARAGRAPH ABOVE.

IF NO FURTHER CHANGES: I will write down your answer. If the computer selects this question, I will give you [NAIRA TOTAL LEFT] in 1 month and [NAIRA TOTAL RIGHT] tomorrow. Is there anything unclear?

RECORD THE ANSWER IN THE COMPUTER NOW

Question 2

Now we move on to the next question. The idea is the same. You can choose how many out of 10 vouchers you want on the left, and how many on the right. For every voucher on the left I will give you 200 NAIRA in 1 month from now. For every voucher on the right, I will give you not 200 but 150 NAIRA, tomorrow. So you have to choose between 200 NAIRA in 1 month

from now or 150 NAIRA tomorrow

Please put the vouchers

You have decided to get [NR LEFT] x 200 NAIRA in 1 month from now, and [NR RIGHT] x 150 NAIRA tomorrow. This means that if the computer selects this question, I will give you XX NAIRA in 1 month from now, and XX NAIRA tomorrow. Do you want to change anything to the number of vouchers on the left or right?

IF VOUCHERS ARE MOVED, REPEAT THE PARAGRAPH ABOVE.

IF NO FURTHER CHANGES: I will write down your answer. If the computer selects this question, I will give you [NAIRA TOTAL LEFT] in 1 month and [NAIRA TOTAL RIGHT] tomorrow. Is there anything unclear?

RECORD THE ANSWER IN THE COMPUTER NOW

Question 3

Now we move on to the next question. The idea is the same. You can choose how many out of 10 vouchers you want on the left, and how many on the right. For every voucher on the left I will give you 200 NAIRA in 1 month from now. For every voucher on the right, I will give you not 200 but 120 NAIRA, tomorrow. So you have to choose between 200 NAIRA in 1 month from now or 120 NAIRA tomorrow.

Please put the vouchers

You have decided to get [NR LEFT] x 200 NAIRA in 1 month from now, and [NR RIGHT] x 120 NAIRA tomorrow. This means that if the computer selects this question, I will give you XX NAIRA in 1 month from now, and XX NAIRA tomorrow. Do you want to change anything to the number of vouchers on the left or right?

IF VOUCHERS ARE MOVED, REPEAT THE PARAGRAPH ABOVE.

IF NO FURTHER CHANGES: I will write down your answer. If the computer selects this question, I will give you [NAIRA TOTAL LEFT] in 1 month and [NAIRA TOTAL RIGHT] tomorrow. Is there anything unclear?

RECORD THE ANSWER IN THE COMPUTER NOW

Question 4

Now we move on to the next question. The idea is the same. You can choose how many out of 10 vouchers you want on the left, and how many on the right. For every voucher on the left I will give you 200 NAIRA in 1 month from now. For every voucher on the right, I will give you not 200 but 100 NAIRA, tomorrow. So you have to choose between 200 NAIRA in 1 month from now or 100 NAIRA tomorrow.

Please put the vouchers

You have decided to get [NR LEFT] x 200 NAIRA in 1 month from now, and [NR RIGHT] x 100 NAIRA tomorrow. This means that if the computer selects this question, I will give you XX NAIRA in 1 month from now, and XX NAIRA tomorrow. Do you want to change anything to the number of vouchers on the left or right?

IF VOUCHERS ARE MOVED, REPEAT THE PARAGRAPH ABOVE.

IF NO FURTHER CHANGES: I will write down your answer. If the computer selects this question, I will give you [NAIRA TOTAL LEFT] in 1 month and [NAIRA TOTAL RIGHT] tomorrow. Is there anything unclear?

RECORD THE ANSWER IN THE COMPUTER NOW

We are also interested in why you made the choices you made so far. [SUM-

MARIZE THE CHOICES THE RESPONDENT MADE] Can you please explain to me why you made these choices?

WRITE DOWN THE EXPLANATION IN THE FIELD INDICATED IN THE COMPUTER

NOTE: MAKE SURE YOU RECORD THE EXPLANATION OF THE CHOICES MADE IN ALL FOUR QUESTIONS, NOT ONLY THE LAST ONE.

Now we leave this game for a moment. We will come back to it later.

Intentional Break with Other Survey Questions

SCENARIO B

Question 5

Now we come back to the game with the vouchers that we played earlier. I will ask four more questions. In these questions, I change when I give you the money. You can still choose how many vouchers you want on the left and on the right. For every voucher on the left I will now give you 200 NAIRA in 3 months from now. For every voucher on the right, I will now give you 200 NAIRA in 2 months from now. So you have to choose between 200 NAIRA in 3 months from now or 200 NAIRA in 2 months from now.

Please put the vouchers

You have decided to get [NR LEFT] x 200 NAIRA in 3 months from now, and [NR RIGHT] x 200 NAIRA in 2 month from now. This means that if the computer selects this question, I will give you XX NAIRA in 3 months from now, and XX NAIRA in 2 months from now. Do you want to change anything to the number of vouchers on the left or right?

IF VOUCHERS ARE MOVED, REPEAT THE PARAGRAPH ABOVE.

IF NO FURTHER CHANGES: I will write down your answer. If the computer selects this question, I will give you [NAIRA TOTAL LEFT] in 3 months and [NAIRA TOTAL RIGHT] in 2 months. Is there anything unclear?

Question 6

Now we move on to the next question. The idea is the same. You can choose how many out of 10 vouchers you want on the left, and how many on the right. For every voucher on the left I will give you 200 NAIRA in 3 months from now. For every voucher on the right, I will give you not 200 but 150 NAIRA, in 2 months. So you have to choose between 200 NAIRA in 3 months from now or 150 NAIRA in 2 months.

Please put the vouchers

You have decided to get [NR LEFT] x 200 NAIRA in 3 months from now, and [NR RIGHT] x 150 NAIRA in 2 months from now. This means that if the computer selects this question, I will give you XX NAIRA in 3 months from now, and XX NAIRA in 2 months from now. Do you want to change anything to the number of vouchers on the left or right?

IF VOUCHERS ARE MOVED, REPEAT THE PARAGRAPH ABOVE.

IF NO FURTHER CHANGES: I will write down your answer. If the computer selects this question, I will give you [NAIRA TOTAL LEFT] in 3 months and [NAIRA TOTAL RIGHT] in 2 months. Is there anything unclear?

Question 7

Now we move on to the next question. The idea is the same. You can choose how many out of 10 vouchers you want on the left, and how many

on the right. For every voucher on the left I will give you 200 NAIRA in 3 months from now. For every voucher on the right, I will give you not 200 but 120 NAIRA, in 2 months. So you have to choose between 200 NAIRA in 3 months from now or 120 NAIRA in 2 months.

Please put the vouchers

You have decided to get [NR LEFT] x 200 NAIRA in 3 months from now, and [NR RIGHT] x 120 NAIRA in 2 months from now. This means that if the computer selects this question, I will give you XX NAIRA in 3 months from now, and XX NAIRA in 2 months from now. Do you want to change anything to the number of vouchers on the left or right?

IF VOUCHERS ARE MOVED, REPEAT THE PARAGRAPH ABOVE.

IF NO FURTHER CHANGES: I will write down your answer. If the computer selects this question, I will give you [NAIRA TOTAL LEFT] in 3 months and [NAIRA TOTAL RIGHT] in 2 months. Is there anything unclear?

Question 8

Now we move on to the next question. The idea is the same. You can choose how many out of 10 vouchers you want on the left, and how many on the right. For every voucher on the left I will give you 200 NAIRA in 3 months from now. For every voucher on the right, I will give you not 200 but 100 NAIRA, in 2 months. So you have to choose between 200 NAIRA in 3 months from now or 100 NAIRA in 2 months.

Please put the vouchers

You have decided to get [NR LEFT] x 200 NAIRA in 3 months from now, and [NR RIGHT] x 100 NAIRA in 2 months from now. This means that if the computer selects this question, I will give you XX NAIRA in 3 months

from now, and XX NAIRA in 2 months from now. Do you want to change anything to the number of vouchers on the left or right?

IF VOUCHERS ARE MOVED, REPEAT THE PARAGRAPH ABOVE.

IF NO FURTHER CHANGES: I will write down your answer. If the computer selects this question, I will give you [NAIRA TOTAL LEFT] in 3 months and [NAIRA TOTAL RIGHT] in 2 months. Is there anything unclear?

We are also interested in why you made the choices you made in this game where you had to choose between getting money in 2 or 3 months. Can you please explain to me why you made these choices?

WRITE DOWN THE EXPLANATION IN THE FIELD INDICATED IN THE COMPUTER

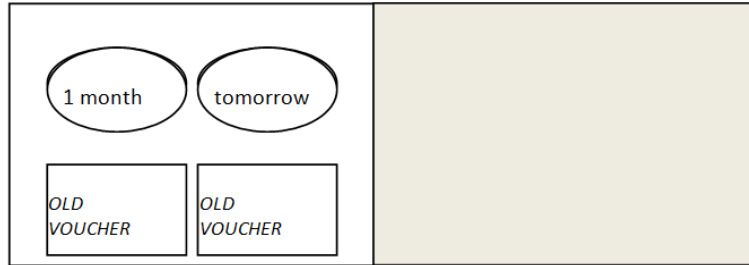
NOTE: MAKE SURE YOU RECORD THE EXPLANATION OF THE CHOICES MADE IN ALL FOUR QUESTIONS, NOT ONLY THE LAST ONE.

The choice that has been picked by the computer is [GIVE THE VOUCHERS TO THE RESPONDENT] Thank you very much for participating in our study.

A.2 Second Round

Two months ago we asked you some questions about how you would divide ten vouchers between 2 and 3 months from that moment. One of those decisions was chosen and will be paid out to you, and we gave you vouchers with the amounts and date of this payout.

Figure 7: Old Allocation



Although our visit today is related to these questions from two months ago, let me stress that your vouchers remain valid and that you will still be paid. Nonetheless, I would like to give you the option to revise your previous decision.

Before we continue, can you bring the vouchers we gave you last time for the two payout periods?

INTERVIEWER CHECKS WHETHER THE AMOUNTS ON THE VOUCHERS IS THE SAME AS THE AMOUNTS IN THE SYSTEM.

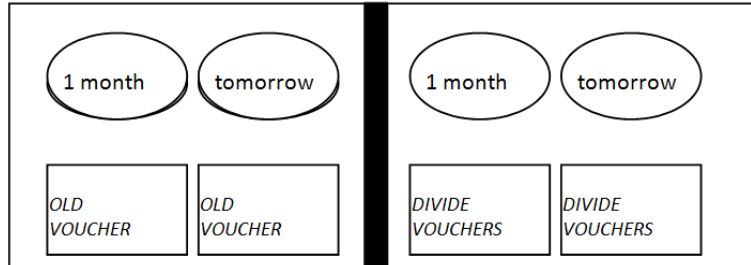
So when we played this game almost 2 months ago, the outcome you selected was:

As you can see the date on the first voucher is in the coming days, while the other is in one month. [TAKE THE OLD VOUCHERS AND SHOW THE DATES]

I hope you still remember the game we played with you: you were asked to divide 10 vouchers between two bowls. Vouchers that you put in the left bowl were worth a different amount of money than vouchers you put in the right bowl.

You now have the possibility to change the timing that you will receive the

Figure 8: Old Allocation & New Allocation



money, so that if you wish, you can divide the money differently between the two time periods. If you don't want to change it, that is fine as well. If you don't change, I will come tomorrow to give you ... NAIRA and in one month to give you ... NAIRA. There is no right or wrong action at this point.

It is possible to put some vouchers on the left and some on the right; in that case, I will give you money tomorrow and in 1 month. If you choose to have some vouchers on the left and some on the right, I will come twice, that is no problem! It is also possible to put all vouchers on the left; or all on the right. You will get the money on both sides! Is that clear?

Whatever you decide to do, the rules stay exactly the same: vouchers put in the left bowl, the '1 month basket,' will be worth 200 NAIRA, while vouchers put in the right bowl, the 'tomorrow basket,' will be worth ... NAIRA.

GIVE NEW SET OF 10 VOUCHERS

Please divide these vouchers over the left and the right bowl.

You have decided to get [NR LEFT] x 200 NAIRA in 1 month from now, and [NR RIGHT] x ... NAIRA tomorrow. Do you want to change anything to the number of vouchers on the left or right?

IF VOUCHERS ARE MOVED, REPEAT THE PARAGRAPH ABOVE.

IF NO FURTHER CHANGES: I will write down your answer. I will give you [NAIRA TOTAL LEFT] in 1 month and [NAIRA TOTAL RIGHT] tomorrow. Is there anything unclear?

RECORD THE ANSWER IN THE COMPUTER NOW

Can you explain your decision a bit further?

IF DECISION WAS REVISED: PREPARE NEW VOUCHERS (YELLOW) AND EXCHANGES THESE FOR THE OLD VOUCHERS.

So once again, thank you for your time. Tomorrow, someone will come again to give you the first payment, and next month the final payment will be paid out.

You can always contact my supervisor, Dr. Olawale from UITH or myself in case you do not get paid at the right time. Both our numbers will be given to you on the voucher.

B Random noise in decisions: details of the model

In Section 4.3, we compare our experimental findings with simulated predictions from a model in which violations of time invariance are driven only by random noise in decision-making. In this section, the details of the model are discussed in more detail.

If $s \in \{1, 2\}$ indicates the decision round, $\sigma \in \{1, 2\}$ the payment round, and $v_S \in \{100, 120, 150, 200\}$ the value of vouchers allocated to the sooner payment date, let the intertemporal utility from allocating x vouchers to the later payment date be $U_{s,\sigma}(x; v_S)$, which is defined in Equations (1) - (3). The probability that a participant allocates x vouchers to the later payment date can be written as the ratio of utility from this allocation to the utility summed over all ten possible allocations, so that choices with higher utility have a higher probability of being selected:

$$P(x_{s,\sigma} = x; v_S) = \frac{U(x_{s,\sigma}; v_S)^{\frac{1}{\mu}}}{\sum_{z=0}^{10} U(z_{s,\sigma}; v_S)^{\frac{1}{\mu}}} \quad (5)$$

where $\mu > 0$ is a parameter specifying the degree of noise (if μ is infinitesimal, then there is no noise, and as μ is going to infinity, decision making becomes an entirely random process). Since in Equations (1) - (3) in Section 2, the optimization problem is equivalent for first- and second-round allocations regarding near-future payment dates, $x_{1,1}$ and $x_{2,2}$, these allocations would be the same in the absence of random noise. In our simulations, time invariance can hence be violated only due to noise.

Following Harrison, Lau and Rutström (2013), we estimate the model using maximum likelihood.¹⁹ We assume that instantaneous utility is of the CRRA type, $u(c) = c^{1-\rho}/(1-\rho)$, where ρ is the coefficient of relative

¹⁹Doing so, we build on STATA routines carefully explained in Harrison (2008). This estimation procedure has the ability to properly analyze corner allocations as well. This is particularly important in our data set, since many participants do not choose an interior allocation, but allocate all vouchers to one of the payment dates. Such corner allocations represent censored decisions, which potentially biases estimates in linear regressions. Andreoni and Sprenger (2012a) propose using Tobit regressions to estimate the model, but the Tobit model makes a number of theoretical assumptions that are inconsistent with the set-up of convex time budget tasks (Harrison, Lau and Rutström, 2013).

risk aversion and consumption c is equal to $c_S = v_S(10 - x)$ on the sooner payment date and $c_L = 200x$ on the later payment date. The estimated (quasi-)hyperbolic discounting parameter β , the noise parameter μ , and the risk aversion parameter ρ , together with a participant's voucher value v_S , the decision round s , and the round in which payments occur σ , yield estimates of the cumulative probability that a participant allocates $x_{s,\sigma}$ vouchers to the later payment date:

$$CDF(a; v_S, s, \sigma) = \sum_{x=0}^a P(x_{s,\sigma} = x) \quad (6)$$

These cumulative distribution functions are in turn used to simulate the allocation every participant chooses in each of the three choices, which allows us to calculate correlations between violations of stationarity, time consistency, and time invariance.²⁰

²⁰The routine follows a procedure described in Meier and Sprenger (2015). First, every participant-choice observation is assigned a random number $z_{ih,s\sigma}$ from a uniform distribution $U \sim [0, 1]$. Second, the random number is compared with the cumulative probabilities. If the random number satisfies $CDF((a-1); V_{ih}, s\sigma) \leq z_{ih,s\sigma} < CDF(a; V_{ih}, s\sigma)$, with $CDF(-1; V_{ih}, s\sigma) = 0$ for a decision moment s , payment dates σ and voucher value V , then the simulated number of vouchers allocated to the later payment date is $\sim X_{ih,s\sigma} = a$. Third, the routine calculates a number of summary statistics: the percentage of participants for whom we observe violations of time invariance, of time consistency, and of stationarity; the direction of these violations; and the correlation between these different violations. This routine is repeated 999 times for each observation to derive 95% confidence intervals for each statistic and p -values for the realized statistics in the experiment.

C Appendix Tables

Table C1: Violations of demand monotonicity by number of interior choices

Number of interior choices in a choice set	Number of choice sets	Violations of demand monotonicity	
		Number of choice sets	Proportion of choice sets
0	187	0	0.0000
1	49	3	0.0612
2	26	3	0.1154
3	75	5	0.0667
4	143	15	0.1049
Total	480	26	0.0542

Table includes all eight allocations that participants made in the first round: four allocations regarding near-future payment dates and four allocations regarding distant-future payment dates. Demand monotonicity implies that the amount allocated to the later payment date is weakly increasing in the return on waiting, and is tested by comparing pairs of allocations within a set of four allocations ('choice set') where only the return on waiting increases. A choice set violates demand monotonicity if any of these pairs violates demand monotonicity.

Table C2: Comparing implemented and non-implemented first-round choices

Timing of payment dates	Choice Value of sooner voucher	Implemented choices			Non-implemented choices			Difference in means
		<i>N</i>	Mean	Std. dev.	<i>N</i>	Mean	Std. dev.	
Near	200	65	3.62	3.18	221	3.46	3.39	0.15
Near	150	55	7.65	2.86	231	8.04	2.16	-0.38
Near	120	46	8.91	2.00	240	8.48	2.10	0.43
Near	100	75	9.05	1.37	211	8.91	2.25	0.13
Far	200	65	3.05	3.22	221	2.86	3.35	0.19
Far	150	55	8.64	2.15	231	8.19	2.32	0.45
Far	120	46	8.98	1.88	240	8.70	2.07	0.28
Far	100	75	8.88	2.22	211	9.20	1.86	-0.32

The value of vouchers allocated to the later payment date is fixed at 200 NGN, while the value of vouchers allocated to the sooner payment date varies from 200 NGN to 100 NGN. Mean represents the average number of vouchers (out of ten) that a participant allocates to the later payment date (rather than the sooner) at decision moment i for payment payment dates j . Reported p -values are based on t -tests with standard errors (shown in parentheses) clustered by household. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table C3: Full results of logit of stationarity and time consistency violations on changes in net household wealth

	Any violation of time consistency $x_{2,2} \neq x_{1,2}$	PB violation of time consistency $x_{2,2} < x_{1,2}$	FB violation of time consistency $x_{2,2} > x_{1,2}$	Any violation of statio- narity $x_{1,1} \neq x_{1,2}$	PB violation of statio- narity $x_{1,1} < x_{1,2}$	FB violation of statio- narity $x_{1,1} > x_{1,2}$
Large gain in household net wealth ($> 33,580$ NGN, highest quartile)	-0.586 (0.538)	-1.042** (0.503)	0.890 (0.771)	1.092** (0.453)	1.040** (0.508)	0.366 (0.504)
Large loss of household net wealth ($< -27,750$ NGN, lowest quartile)	0.397 (0.514)	0.430 (0.466)	0.701 (0.689)	0.065 (0.475)	-0.328 (0.632)	0.898* (0.541)
Age	0.004 (0.014)	0.011 (0.017)	-0.002 (0.021)	-0.031*** (0.012)	-0.042** (0.020)	-0.004 (0.013)
Male respondent	0.652 (0.548)	1.356** (0.539)	-0.268 (0.820)	0.002 (0.561)	0.082 (0.645)	0.814 (0.678)
Number of children in the household	-0.126** (0.058)	-0.112* (0.063)	0.219** (0.097)	-0.108* (0.057)	0.068 (0.071)	-0.044 (0.064)
Level of education: some primary school	-0.200 (0.522)	-0.452 (0.612)	0.252 (0.653)	-0.446 (0.542)	-0.042 (0.655)	-0.727 (0.673)
Level of education: more than primary school	-0.331 (0.577)	-0.562 (0.622)	-0.472 (0.725)	0.260 (0.537)	0.125 (0.662)	-0.287 (0.623)
Source of income: farming	-0.104 (0.401)	-0.186 (0.424)	-1.512* (0.874)	-0.105 (0.568)	-0.478 (0.629)	-0.396 (0.604)
Source of income: nothing	-1.035 (0.725)	-0.984 (0.765)	-0.475 (0.998)	1.114** (0.548)	-0.004 (0.676)	0.979 (0.646)
Poor household (below median; baseline net wealth $< 50,000$ NGN)	-0.435 (0.514)	-0.570 (0.539)	-1.461* (0.845)	-0.046 (0.438)	-0.339 (0.505)	-0.031 (0.503)
Violates monotonicity	-0.487 (0.731)	0.858 (0.662)	1.778** (0.789)	0.015 (0.638)	1.175* (0.640)	1.034 (0.633)
Number of observations	240	240	240	240	240	240
Mean dependent variable	0.196	0.212	0.087	0.192	0.142	0.154
Pseudo R-squared	0.109	0.149	0.250	0.108	0.115	0.104

PB: Present-biased. FB: Future-biased. Estimated using a logit model including dummy variables for regional effects. Standard errors (shown in parentheses) are clustered by household. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.