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Do risk, time and prosocial preferences predict risky sexual behaviour of youths in a low-income, high-risk setting?

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ABSTRACT

Young people in sub-Saharan Africa are particularly at high risk of sexually transmitted infections. Little is known about their preferences and even less about their association with risky sexual behaviour. We conducted incentivized economic experiments to measure risk, time and prosocial preferences in Zimbabwe. Preferences measured at baseline predict biomarker and self-reported measures of risky sexual behaviour gathered 12 months later. We find robust evidence that individuals more altruistic at baseline are more likely to be Herpes Simplex Virus Type-2 (HSV-2) positive 12 months later. Analysis by sex shows this association is driven by our sample of women. Having more sexual partners is associated with greater risk tolerance amongst men and greater impatience amongst women. Results highlight heterogeneity in the association between preferences and risky sexual behaviour.

1. Introduction

Young people in sub-Saharan Africa (SSA) are particularly at high risk of acquiring HIV and other sexually transmitted infections (STIs). In Zimbabwe, the setting for our study, HIV incidence amongst those aged 15–24 years is 2.08 per 1000, and one-third of all new HIV infections in people above the age of 15 were among young people (under the age of 25) (UNAIDS, 2021). Despite widespread awareness of the risks of infection and the availability of preventative methods, risky sexual behaviour remains common in these settings. Sexual behaviour may be influenced by the ways in which individuals perceive and respond to risks of infection (risk preferences), evaluate future benefits and costs of preventative measures in relation to those in the present (time preferences), and carry out social interactions considering (or not) the consequences of their actions on others (social preferences). In this paper we seek to understand the extent to which risky sexual behaviour amongst youth is associated with risk, time and prosocial preferences. A secondary objective is to understand the association between risky sexual behaviour and social proximity with a partner.

Amongst youth in high-income countries, the nature, determinants, and implications of individual preferences have been extensively studied through economic experiments (Bettinger and Slonim, 2007; Sutter et al., 2019). In these settings, preferences of young people have been shown to influence behaviours and outcomes in different domains (O'Donoghue and Rabin, 2001), including education (Castillo et al., 2011; Golsteyn et al., 2014; Cadena and Keys, 2015; Castillo et al., 2018; Castillo et al., 2019; Figlio et al., 2019;

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Hanushek et al., 2022), honesty and deception (Maggian and Villeval, 2016), health behaviours (Sutter et al., 2013; Sutter et al., 2015; Galizzi and Miraldo, 2017) and risky sexual behaviours (Lawyer and Schoepflin, 2013). However, very little is known in general about the preferences of youth in low-income, high-risk settings and even less about their association with risky sexual behaviour.

To fill this gap, we conducted monetarily incentivized economic experiments to measure individual risk, time and prosocial preferences in a general population cohort ($N = 1452$) of 15–24-year-old women and men in Zimbabwe. We analyse associations between risky sexual behaviour and measured preferences, including when accounting for heterogeneity across men and women. Our outcomes are two measures of risky sexual behaviours measured 12 months after the experiments: (i) a laboratory confirmed biomarker of Herpes Simplex Virus Type-2 (HSV-2) status, a well-established clinical measure of risky sexual behaviour (Cowan et al., 1994; Baird et al., 2012); and (ii) a self-reported question on the number of sexual partners in the last 12 months (amongst those reporting having ever had sex).

Often a concern with survey experiments is the possibility of experimenter demand effects - when participants infer the purpose of an experiment and respond so as to help confirm a hypothesis (Zizzo, 2010; de Quidt et al., 2018; Mummolo and Peterson, 2019). Our study design allows us to minimize possible bias from experimenter demand effects in three ways. First, by measuring preferences with real monetary incentives, we elicit respondent choices that are likely to be more aligned with their genuine preferences. Second, rather than relying only on self-reported measures, we use a directly measured biomarker of risky sexual behaviour. Third, along with our use of a biomarker, the 12-month gap between measurement of preferences and outcomes in two ostensibly separate exercises ensures that the connection between the experimental measures of preferences and the health outcomes is not immediately evident to respondents. Despite the 12-month gap, our study has low levels of attrition, with 81.8 % of baseline respondents followed up 12 months later.

In our review of the literature, we found no studies investigating the association between risky sexual behaviour and social preferences. Evidence on the association with time preferences is mixed, with most studies conducted in the United States amongst specific populations. These include clients in sexually transmitted diseases clinics (Chesson et al., 2006), hazardous drinkers selected from emergency departments of hospitals (MacKillop et al., 2015), an online sample of men-who-have sex with men (Jones et al., 2018), and a sample of sexually active undergraduate university students (Lawyer and Schoepflin, 2013). These studies use responses to hypothetical questions about the payoff of a possible prize as measures of time preferences. They find no association with presence of HSV-2 antibodies (Chesson et al., 2006), and mixed results with self-reported measures of sexual risk taking. Only three studies consider risk preferences and risky sexual behaviour. One study amongst Senegalese female sex workers reports no association of HIV status with risk aversion and a negative association with self-reported measures of sexual risk taking with clients (Lépine and Treibich, 2020). Another amongst 213 university students in South Africa found a significant association between HIV status (as well as the perception of being infected with HIV) and risk preferences (Lammers and van Wijnbergen, 2008). The third, a study in Lesotho using hypothetical questions of risk and time preferences found risk-loving people are more likely to be and to become HIV positive, but found no association with time preferences (Björkman Nyqvist et al., 2022).

Our study makes the following contributions. To our knowledge, this is the first study to evaluate amongst the general population of youth in a low-income setting, associations of risky sexual behaviour with experimental measures of preferences. Our paper is also the first to examine the simultaneous association of all three types of preferences – risk, time and prosocial preferences with risky sexual behaviours. In doing so, we contribute to the literature exploring the ability of experimental measures of preferences to predict real-world outcomes (Barsky et al., 1997; Chabris et al., 2008; Tanaka et al., 2010; Meier and Sprenger, 2010; Burks et al., 2012; Sutter et al., 2013; Akerlund et al., 2016; Bradford et al., 2017; Galizzi and Navarro-Martinez, 2018; Kerr et al., 2019; Campos-Mercade et al., 2021; Epper et al., 2022; Farago et al., 2022). Our study also contributes to this literature by documenting that risk, time and prosocial preferences are potentially important sources of heterogeneity in risky sexual behaviours; and that there are some gender differences in such heterogeneity. In addition, by studying the influence of social proximity with a partner, we contribute to the emerging literature in economics studying the influence of interpersonal closeness on economic behaviour and outcomes (Danilov et al., 2013; Harris et al., 2015; Goette and Tripodi, 2021; Hofmann et al., 2021; Robson, 2021; Gächter et al., 2023).

Consistent with previous studies, we do not find robust evidence that a biomarker of risky sexual behaviour (HSV-2 status) is associated with time preferences captured either by a simple nonparametric measure or by the implied discount factor (Chesson et al., 2006; Björkman Nyqvist et al., 2022). We find robust evidence that the likelihood of being HSV-2 positive is positively associated with altruism. We find, a one standard deviation (SD) increase in the amount given away in the dictator game, is associated with an increase from 23.2 % to 26.7 % in the likelihood of being HSV-2 positive 12 months later. In a dictator game, the proportion of a financial endowment that a respondent (dictator) gives away anonymously to a matched stranger is typically interpreted as a measure altruism. Analysis by sex shows that the magnitude of this point estimate is much larger amongst women, with a one SD change being associated with an increase from 25.7 % to 30.1 %. We find no significant association of altruism with reported number of sexual partners. We also find that having more sexual partners is associated with greater risk tolerance, represented by a simple nonparametric measure. This result appears to be driven by our sample of men, who also report considerably more partners than women. In our sample of women, we find having more sexual partners is associated with greater impatience. The identified associations are robust across several alternative specifications and checks including corrections for multiple hypothesis testing.

The rest of the paper is organized as follows. Section 2 provides a conceptual framework to set out the rationale of our hypotheses and the expected associations. Section 3 describes the experimental methods and empirical strategy in detail. Section 4 presents our results and various robustness checks. Section 5 concludes and discusses implications of our findings.

2. Conceptual framework

In this study we use simple measures of risk, time, prosocial preferences and social proximity, and consider their associations with two outcomes of risky sexual behaviour: a biomarker of HSV-2 status and self-reported number of sexual partners in the last 12 months. Our outcomes are distinct in the sources of risk they capture. HSV-2 infection is an accurate composite measure of exposure to risk. It is almost always a result of sexual transmission, not curable (CDC, 2017) and captures direct risk from individual actions as well as risks via a partner's sexual behaviour. On the other hand, number of sexual partners in the last 12 months is a short-term measure of risky behaviour, informative about intensity of risky behaviour. However, like many survey measures on sensitive topics, it is subject to social desirability bias leading to under reporting particularly by women (Gregson et al., 2002). As we show later, there are marked differences between men and women in the prevalence of HSV-2 and in reported number of sexual partners. Thus, we expect differences between our outcomes in the observed associations with preferences, but also differences across women and men.

We expect that greater impatience is positively associated with risky sexual behaviour. Under the standard exponential discounting model, if utility is a function of the costs and benefits of sexual activity, then, in a given time period, an individual would choose a level of sexual activity that maximises their discounted streams of net future utility, given their constant discount rate. Sexual activity in contexts such as our study setting involves trading-off potential costs and benefits. Typically, any hedonic benefits from sexual activity can potentially be offset partially or fully by longer-term consequences of sexual activity, for example, by infection with STIs. More impatient individuals would tend to place higher weight on the short-term benefits of sexual activity than on the longer-term costs associated with risk of STIs. Furthermore, under the non-constant discounting models, and in particular under the quasi-hyperbolic model, individual time preferences can be decomposed into two elements: the baseline long-term level of the discount factor (δ) (as postulated by the standard exponentially discounted utility model) and present bias (β), that is an immediate gratification element (Phelps and Pollak, 1968; Laibson, 1997; Prelec and Loewenstein, 1991). Such preferences imply a sharply declining discount rate in the very short run, after which the discount factor tends to its baseline long-term level (Frederick et al., 2002; Andersen et al., 2008; Cohen et al., 2020; Imai et al., 2021). Quasi-hyperbolic discounting and present bias are the two most invoked theoretical explanations in behavioural economics for impulsive behaviour. Present bias has been related to the widespread observed tendency of some individuals to fall prey of temporally proximal "temptations" and "visceral factors" (Loewenstein, 1996; Loewenstein, 2000). The pioneering article by Loewenstein (1996) lists teenage sexual behaviour as a key example of visceral influence on behaviour. Moreover, due to the related "hot-cold empathy gap" and "projection bias", individuals may make decisions about sexual activity in the "heat of the moment", underestimating the long-term consequences of such decisions and underestimating the influence of such hot states on their decision-making (Loewenstein, 2005a; Loewenstein, 2005b).

Prosocial preferences may influence individual behaviour (Fehr and Schmidt, 1999; Bolton and Ockenfels, 2000; Andreoni and Miller, 2002; Charness and Rabin, 2002; Henrich et al., 2005; Fisman et al., 2015; Bartling et al., 2015). In particular, altruistic individuals sacrifice some benefit to themselves in order to increase benefits to others. Such preferences could affect sexual behaviour. An altruistic person may engage in less risky sex (e.g. extra-marital relationships) in order to protect their long-term partner. On the other hand, altruism would make someone more amenable to requests from others for risky sex (e.g., unprotected sex). In theory, the relationship between our outcomes and prosocial preferences is therefore ambiguous.

Greater risk aversion is generally associated with lower willingness to bear risks. Under Expected Utility Theory (EUT), when faced by a risk of a loss, predictions of the influence of risk aversion on prevention differ depending on whether the preventative action affects the size of the loss (self-insurance) or affects the probability of the loss being incurred (self-protection) (Courbage et al., 2013). In the case of self-insurance, EUT predicts a positive association with risk aversion. On the other hand, under EUT an increase in risk aversion has an ambiguous effect on the propensity to engage in self-protection (Ehrlich and Becker, 1972). In our study, we model outcomes that reflect self-protection against STIs (the loss) – HSV-2 status which is affected by a range of self-protective measures (condom use, abstinence, fewer partners etc.) and number of sexual partners which directly influences the probability of being infected. For these, EUT does not provide an unambiguous prediction about the relationship with willingness to bear risk.

Finally, studies highlight people are more willing to help, cooperate with, and have higher trust in socially close persons (Hoffman et al., 1996; Balliet et al., 2014; Vekaria et al., 2017). Correspondingly, the extent to which young people choose not to use prevention methods with their partners may be driven by their perceived relationship closeness with their partner. Past research shows individuals in trusted relationships characteristically believe that their partner would not have engaged in behaviours that could infect them with STIs (Misovich et al., 1997). On the other hand, not all those with high perceived relationship closeness are likely to be mistaken in their perception of risk. Thus, there is no obvious direction to a potential association with our outcomes.

3. Methods

3.1. Study design and data collection

We conducted economic experiments between July 2018 and December 2019 in 8 communities in Manicaland Province, Eastern Zimbabwe. The communities include two peri-urban small towns, four rural communities (a tea estate, a forestry estate, a subsistence farming village and a roadside settlement) and two high-density urban suburbs. The experiments were conducted as part of a wider study including two pre-registered cluster randomized trials (CRTs) to improve uptake of HIV prevention (Moorhouse et al., 2019; Thomas et al., 2019; Thomas et al., 2020).[1] As part of the CRTs (NCT03565588, NCT03565575), in each community two matched clusters of villages were created at the start of the study. Within each community one cluster was then randomly allocated to the

[1] Analysis of the impact of the interventions in the CRTs, on a different set of pre-registered outcomes is planned as a separate study.

intervention arm of the CRTs while the other was allocated to the control arm. Both intervention and control clusters within a community were included in baseline data collection. As we describe later, the analysis in this paper focuses on those 'not treated' under the CRTs.[2]

The baseline data collection activities included a detailed individual socio-behavioural survey and our experimental tasks to measure risk, time, and prosocial preferences. As part of baseline activities all participants were offered provider-initiated HIV counselling and testing, and dried blood spot (DBS) samples were gathered for laboratory-based HSV-2 testing. 12 months later a follow-up survey and DBS collection were conducted amongst all HIV-negative baseline participants aged 15–24 -years in the control clusters and amongst 15–17-year-old women in the intervention clusters, who were ineligible to participate in the CRT intervention because they were minors. Thus, our study focuses on participants whose behaviour was not plausibly influenced by the intervention in the CRTs. Due to COVID-19 restrictions follow-up data collection had to be suspended from end March to June 2020. During this period in some sites face-to-face follow-up data collection was replaced with telephone interviews for the socio-behavioural survey. DBS collection was implemented face-to-face a few weeks after the telephone interviews, when restrictions were no longer in place.

3.2. Experimental measures of risk, time, prosocial preferences and social proximity

We conducted a set of simple monetarily incentivized experiments to measure risk, time and prosocial preferences in our study population. The experiments were conducted in sessions with 10–20 individuals. Sessions were scheduled throughout the day in a designated room and lasted around 1 hour. All experiments were conducted in the local language Shona. In each session, participants were randomly assigned to seats so that they were not seated next to friends or family. The experiments were administered using digital tablets with one tablet per participant in a session. On arrival at the central location in a community, study participants took part in the experimental sessions either before or after completing their individual surveys. All monetary prizes were made through EcoCash™, a mobile payment system in Zimbabwe that allows participants to receive cash credit on their mobile phones which can be used to purchase goods and services, pay bills etc.

Following a welcome and an introduction by the experimenter, participants were provided an overview of the session and explanations on how they could win incentivized payments. Throughout the experiment the investigators used a script (available from the authors) and subjects received instructions one section at a time. This was followed by a few practice games to allow participants to become familiar with the use of the tablet. In total participants responded to 28 questions. From questions 1–14 which included the risk preference question and the dictator game, one question was randomly selected for payment.[3] The question was selected by asking a participant in the session to select a ball from a bag of numbered balls. Thus, all participants in a session received a reward during the session based on their response to the selected question. From questions 16–27 which were the time preference questions, one question and one participant was randomly selected for payment. Question 15 (which measures interpersonal closeness) and question 28 did not involve incentivized choices.

3.2.1. Time preferences

We measured time preferences with simple Money Earlier or Later (MEL) experiments (Cohen et al., 2020). We used two simple multiple price lists (MPL) in which individuals were asked to make a series of choices between a Smaller Sooner (SS) reward paid at time t or a Larger Later (LL) reward paid in $t + 3$ months (Coller and Williams, 1999; Harrison et al., 2002; Andersen et al., 2008; Tanaka et al., 2010). For each decision, participants were asked if they would prefer \$20 now/one month from now or \$20+X in 3/4 months from now. \$20 is approximately two days of wages in our study setting. Thus, in both timeframes, the delay time horizon is 3 months. The use of a front-end delay (FED) in the design mitigates potential confounding for trust in the elicited discount rates as it equalizes the credibility of future payments in the SS and LL options (Andersen et al., 2014). The amount \$X in the different questions was strictly positive and increased in both MPLs. See Table S1 and Figure S1 in Supplementary Material.

We construct two measures using the MPLs. (i) A non-parametric measure we term '*time preference*', by summing the number of SS options selected across the two MPLs. This simple measure reflects both constant discounting and present-and-future bias and captures the strength of time preferences. (ii) Using the last question in each MPL where the respondents preferred the SS over the LL option, we derive the corresponding implied discount factors (δ) (Phelps and Pollak, 1968; Laibson, 1997). We call these $\delta_{1,4}$ and $\delta_{0,3}$ for the FED MPL and no-FED MPL. As in Meier and Sprenger (2010) in our estimations we use the mean of $\delta_{1,4}$ and $\delta_{0,3}$ and we classify an individual as present-biased *(presentbias = 1)* if they were less patient (i.e. they had lower δ) when the SS payment was received in the present *(*no FED*)* than when it was received with FED, that is, if $\delta_{0,3} < \delta_{1,4}$. Analogously we classify an individual as future-biased *(futurebias=1)* if $\delta_{0,3} > \delta_{1,4}$.

In our experiments we did not force consistency in the responses of participants in the two MPLs, nor excluded participants who showed "inconsistent" choices, i.e. participants who had more than one switching point from SS and LL options. For example, participants in our experiment could choose \$Y in four months rather than \$20 in one month, but then choose \$20 in one month rather

[2] Data collection was completed and analysis beginning when the analysis plan for this study was registered (https://osf.io/3wfxs).

[3] Questions 1-10 measured risk preferences with the Holt and Laury (2002) multiple price list. Low-quality decision-making due to poor comprehension limit the usability of these data (not used in this paper). Question 11 is the ordered lottery sequence measure of risk preference used in this paper, questions 12 and 13 measured subjective belief distributions (not used in this paper and not yet analysed). Questions 14-27 were the dictator game, interpersonal closeness, and time preference tasks, all used in this paper. Question 28 measured time versus money attitudes (not used in this paper and not yet analysed).

than $$Z > Y in four months. Or an individual could make more than one switch within a MPL, for example, choosing the SS option ($20) for the first few choices in the set, then choosing the LL option, and then switching back to the SS option again. The proportion of such "inconsistent" respondents in our sample is similar to the proportions reported by other studies, at 16 % in the $\delta_{1,4}$ MPL and 18 % in $\delta_{0,3}$ (Bettinger and Slonim, 2007; Castillo et al., 2011; Bradford et al., 2019). 76 % of participants made consistent choices across both MPLs. In our empirical analysis we control for whether responses were consistent by including a binary indicator for the participants who were consistent across both $\delta_{1,4}$ and $\delta_{0,3}$(*consistent==1*). In robustness checks we also estimate our models including only the consistent respondents.

3.2.2. Risk preferences

We measured risk preferences using a simple lottery choice experiment also called the "multiple lotteries method" or "ordered lottery sequence". The task involves selecting one option from six pairs of 50/50 gambles. This measure has been widely used in various field settings in both developed and developing countries, and participants rarely report difficulty understanding the task, even in less literate populations (Binswanger, 1981; Dave et al., 2010; Eckel and Grossman, 2002; Castillo et al., 2011). Participant choices and details of the offered gambles are presented in Fig. S2 and Table S2 in Supplementary Material. Participants had to choose from among the six possible gambles (A-F) the one they preferred to play. If this question was chosen for payment, then a toss of a coin was used to determine the payment – "heads" or "tails". Each gamble involved a 50/50 chance of a low or high payoff, and one of the included gambles was a safe alternative involving a sure pay-off of $5.60. Following the sure pay-off gamble, the other gambles increased in both expected return and risk (measured by the standard deviation). More risk averse individuals would choose gambles involving lower risk and lower returns (e.g. very risk averse for lottery A) and only risk-seeking individuals would choose gamble F. We construct two measures of attitudes towards risk based on the data: (i) a non-parametric measure we call '*risk tolerance*', where we use the lottery response as is, taking values from 1 (highly risk averse) to 6 (risk seeking) (ii) we calculate the coefficient of risk aversion 'γ' implied by each gamble, under the assumption of constant relative risk aversion (CRRA). Formally, the utility from a specific gamble under CRRA is defined as $U(Y) = \frac{Y^{1-\gamma}}{1-\gamma}$, where Y is the payoff in the gamble. The range for a specific gamble was calculated by comparing each gamble to the adjacent gamble and solving for the value that generates the same level of utility as the adjacent gamble (see Table S2). In our analysis, we use the midpoint of each range as an individual's implied measure of risk aversion (Eckel and Grossman, 2002).We refer to this as 'γ' going forward. $\gamma > 0$ indicates risk aversion and $\gamma < 0$ indicates risk-loving preferences.

3.2.3. Social preferences

To measure social preferences, participants took part in a one-shot double-blinded dictator game. The dictator game is a simple game where participants (the dictator) are provided a financial endowment to split between themselves and a matched stranger (the recipient) (Forsythe et al., 1994). In our experiment, participants were provided a $10 endowment to split with another randomly selected person in the same session (Fig. S3). As decisions in a one-shot double-blinded dictator game are not confounded by strategic or reputational concerns, a strictly self-interested individual should allocate nothing to the recipient. Therefore, the proportion of money given to the recipient is typically interpreted as a measure of social preferences and, in particular, of altruism or unconditional kindness (Camerer and Thaler, 1995; Charness and Rabin, 2002; Camerer and Fehr, 2004). We use this nonparametric measure as is in our analysis and refer to it as '*altruism*'.

3.2.4. Social proximity with partner

In addition to preferences, to understand the nature and influences of personal bilateral relationships on decision-making, we measured interpersonal closeness amongst our respondents using the 'inclusion of the other in the self' (IOS) scale (Aron et al., 1992). The IOS scale is a pictorial measure encapsulating interpersonal closeness through 7 increasingly overlapping circles. The IOS task asks respondents to assess their relationship with their partner by selecting one out of 7 pairs of increasingly overlapping circles (Fig. S4). The IOS has been widely used in psychology to measure interpersonal closeness in various cultural settings and types of relationships and extensively validated to confirm its predictive ability (Gächter et al., 2015; Branand et al., 2019). It has recently been used in several economic studies (Gächter et al., 2023; Robson, 2021; Goette and Tripodi, 2021; Harris et al., 2015; Danilov et al., 2013) to measure social proximity and cohesion. Statistical evidence shows that the IOS scale successfully tracks key dimensions of relationship closeness, with people selecting more overlapping pairs of circles for a given other, when interactions were more frequent or diverse, and when they perceived strong mutual influence (Aron et al., 1992). Underlying the IOS scale is the self-expansion principle of inclusion of the 'other' in the self. The self-expansion principle signifies that relationship closeness provides an individual opportunity to expand the 'self'. Through this self-expansion, each partner experiences the resources, perspectives, and identities of the other partner to some extent as their own. The extent of inclusion affects how much the other person influences an individual's identity, shapes their views, and affects their perceived costs and benefits of different decisions, resulting in greater cooperation. We refer to the IOS measure as '*closeness*' and use this measure as is in our analysis with 1 representing least closeness and 7 representing maximum closeness. We interpret the magnitude of this result as a percentage point change in the probability of being HSV-2 positive or percentage change in the number of partners from a one SD increase in the *closeness* level.

3.3. Study sample, baseline and follow-up participation

In total, baseline data were collected from a cohort of 3146 individuals aged 15–24 years. 1774 baseline respondents were eligible for follow-up based on study design, of whom 1452 completed follow-up data collection activities. Thus at 81.8 % our study has a high retention rate. This retention rate is similar to, or higher than, other studies in sub-Saharan Africa. For example, the recently concluded PopART HIV Study in Zambia and South Africa had an annual retention rate of 72 % in its population cohort (Hayes et al., 2019). Key to the validity of our study design is that retention in the sample is not associated with our measures of risk, time, and prosocial preferences. To investigate this, we ran a probit regression model using the baseline sample that was eligible for follow-up, with an indicator of study retention (1 = observed at follow-up, 0 = not observed at follow-up) as the outcome and our preference measures and socio-demographic controls as covariates. Importantly, we show that sample retention is orthogonal to preferences and our biomarker outcome (HSV-2 status) (Table S3).

Tables S4 and S5 compare by sex, the full baseline sample ($N = 3146$), the baseline sample eligible for follow-up at 12 months ($N = 1744$) and the sample completing the 12 months follow up (analysis sample) ($N = 1452$). We report normalized differences that provide a measure of the difference between samples that does depend on scale or sample size (Imbens, 2015). Imbens and Rubin (2015) suggest a normalized difference below 0.13 indicates a balance between samples. We find the baseline samples for men and women are very similar in characteristics except for slightly lower mean age (and consequently more 'never married' and 'students') amongst women in the follow-up eligible sample, with normalized differences of 0.30, 0.20 and 0.24 respectively. This is by study design, as those in the intervention arms of the CRT who were not part of the trials because they were minors were eligible for follow-up. For both men and women, a comparison of the 12-month follow-up sample i.e. our analysis sample ($N = 1452$), with the baseline sample eligible for follow-up ($N = 1744$) shows that all normalized differences are below the threshold of 0.13 indicating our 12-month analysis sample is representative of the baseline sample.

3.4. Descriptive statistics

Of the 1452 participants in the follow-up survey 926 (63.77 %) were women with mean age 18.29 years, and 36.22 % were men with mean age 18.48 (Table 1). Over 90 % of men and women have secondary or higher education (Tables S4 and S5). 63.82 % of women and 88.21 % of men have never been married. 51.51 % of women and 54.56 % of men are students and a further 36.93 % of women and 19.58 % of men are unemployed. A similarly high proportion of women and men (~96 %) consider themselves to be at low risk of being HIV positive.

Our two outcome measures from the follow-up survey are HSV-2 status and self-reported number of sexual partners (amongst those reporting having ever had sex). Overall, 22.96 % were HSV-2 positive. We exclude from our biomarker analyses individuals with an equivocal HSV-2 test result (1.18 %). A higher proportion of women (25.43 %) than men (18.61 %) were HSV-2 positive (Table 1). Only 14 % of men and women reported having two or more sexual partners in the last 12 months, amongst those who reported having ever had sex (Table 1). Of these far fewer women (3.26 %) than men (31.50 %) reported having two or more sexual partners in the last 12 months.

Table 1 shows summary statistics of the nonparametric measures. Fig. 1 shows the corresponding distributions. Mean *risk tolerance* is 2.59 (SD = 1.36) (Fig. 1A) and was marginally lower amongst women than men. On average, men and women gave away $2.73 (SD 2.38) in the dictator game (Fig. 1C). Men ($2.93, SD = 2.44) gave away slightly more than women ($2.62, SD = 2.35). We note that the mean amount given away in our dictator game is very close to the standard results in experimental dictator games. In our sample ~27 % of the endowment was given away. Analyses of experimental results show that typically dictators send 20–30 % of their endowment (Camerer and Thaler, 1995; Camerer, 2003; Engel, 2011). We find high levels of impatience in men and women with participants selecting on average 8.35 (SD 3.85) smaller-sooner payments across the 12 MPL options (Fig. 1E). Across both sexes, 44.19 % of respondents consistently display either extreme patience (6.91 %) or extreme impatience (37.28 %). While these responses could reflect extreme negative and positive time preference, they may also arise from low cognitive effort or a lack of understanding.[4] Consequently, we also find low levels of present-biased preferences in our sample, with only 22 % of women and men demonstrating present-biased preferences. Around 19 % of women and men had future-biased preferences. Men and women report similarly high levels of perceived *closeness* in their relationship (5.35, SD = 1.90) (Fig. 1D). Figure S5 displays the non-parametric correlation structure of our measures across women and men along with Spearman's rank correlation coefficients. We find low correlations across measures, suggesting a complementary relationship between measures.

In Table S6 we evaluate the socio-demographic drivers of preferences. We find *risk tolerance* (column 1) is negatively associated with being older, having completed secondary school or higher levels of education and being a student or employed in more formal employment sectors. In the case of *altruism*, consistent with the unconditional differences, men in our sample display greater levels of altruism than women. *Altruism* is positively associated with being in the top quintile of household wealth and negatively with being certain of being HIV positive. The association of altruism with being widowed should be interpreted with caution due to the very small number of individuals in our sample who are widowed. *Time preference* is negatively associated with being older (i.e. older individuals show greater patience) and is positively associated with being married and being in the upper household wealth quintiles.

3.5. Empirical strategy

We begin our analysis by graphically studying nonparametric bivariate associations between our outcomes and each preference

[4] Those selecting the extreme option across both MPLs do not differ significantly from other respondents in either of the outcomes or in the means of most covariates, except that they are more likely to be married, of Methodist denomination, and are less likely to be students. See Table S7 in Supplementary Material.

Table 1
Descriptive statistics.

	Full sample		Women		Men	
	Mean/ N	SD/ %	Mean/ N	SD/ %	Mean/ N	SD/%
Non-parametric preferences						
Risk tolerance (1,2..6)	2.59	1.36	2.52	1.31	2.74	1.43
Altruism ($0-$10)	2.73	2.38	2.62	2.35	2.92	2.44
Time preference (0,1..12)	8.35	3.85	8.37	3.87	8.29	3.84
Parametric preferences						
γ (risk aversion)	4.08	2.08	4.20	2.04	3.88	2.13
δ (discount factor)	0.67	0.19	0.67	0.19	0.67	0.20
presentbias (0,1)	0.22	0.42	0.22	0.42	0.22	0.42
futurebias (0,1)	0.19	0.39	0.19	0.40	0.18	0.39
Social proximity						
Closeness (1,2..7)	5.35	1.90	5.37	1.89	5.33	1.92
Age (years)	18.35	2.84	18.29	2.90	18.48	2.77
N	1452		926		526	
Outcomes						
HSV-2 status at 12 months						
Negative	965	75.86	597	73.70	368	79.65
Positive	292	22.96	206	25.43	86	18.61
Equivocal	15	1.18	7	0.86	8	1.73
N	1272		810		462	
Number of sexual partners in the last 12 months, amongst those reporting having ever had sex						
0	97	13.59	31	7.03	66	24.18
1	517	72.41	396	89.80	121	44.32
2	53	7.42	14	3.26	39	14.29
3 +	47	6.58	0	0	47	17.21
N	714		441		273	

Notes**:** A higher *risk tolerance* value implies greater willingness to bear risk [1 (highly risk averse) – 6 (risk seeking)]. A larger amount of money given away implies greater *altruism* [$0 (least altruistic)-$10 (highly altruistic)]. A higher *time preference* score implies lower patience [0 (extreme patience) – 12 (extreme impatience)]. A higher *closeness* score implies greater social proximity with partner [1 (least closeness) – 7 (maximum closeness)]. A larger γ indicates greater risk aversion and larger δ implies greater patience. *Presentbias* and *futurebias* are binary indicators of present-biased and future-biased preferences respectively.

measure. For each nonparametric preference measure we present the mean of the outcome and 95 % confidence intervals at levels of the preference measure. In the case of preference parameters, we estimate local polynomial regressions with an Epanechnikov kernel function and bandwidth selection by the plugin estimator.

In our primary regression analysis, we estimate the association of risky sexual behaviour with all nonparametric preference measures[5] simultaneously, estimated jointly across women and men. To explore heterogeneity by sex, we also present results separately for women and men.

We model the probability of being HSV-2 positive ($y_{i1}=1$) with a probit model, $y_{i1} = 1(y_{i1}^{*} > 0)$, specified as follows:

$$y_{i1}^{*} = \beta_1 risktolerance_{i0} + \beta_2 altruism_{i0} + \beta_3 timepreference_{i0} + \beta_4 consistent_{i0} + \beta_5 sex_{i0} + \boldsymbol{\lambda}\ \boldsymbol{age}_{i0} + \varepsilon_i \quad (1)$$

Where $i = 1..N$, represents our sample of N individuals; subscripts 0 and 1 represent covariates and outcomes measured at baseline and 12-months later, respectively. For example, y_{i1} is the 12-month follow-up value for an individual i of the outcome HSV-2 status. $risktolerance_{i0}$ is our risk preference measure, $altruism_{i0}$ is our altruism measure and $timepreference_{i0}$ represents our time preference measure, all measured at baseline. $consistent_{i0}$ is an indicator for consistent responses across the two sets of time preference MPLs (i.e. no "switching back" from a LL to a SS option). sex_{i0} is a binary indicator of sex and $\boldsymbol{age}_{i0}$ is a vector of age indicators. ϵ_i is an error term for individual i that possibly exhibits dependence within clusters.

In the case of number of sexual partners in the last 12 months, our outcome variable is a count taking one of the values 0, 1, 2, 3.... Consequently, we estimate a negative binomial regression model with covariates as defined above.

We report results as marginal effects with heteroscedasticity-robust standard errors clustered at the study site level. When we consider the additional (to preferences) association of *closeness* with our outcomes, we simply extend the above models to include our measure of *closeness* as an additional covariate.

In secondary analysis, we estimate our models replacing $risktolerance_{i0}$ with γ_{i0} representing the baseline risk aversion parameter, $timepreference_{i0}$ with δ_{i0}, $presentbias_{i0}$ and $futurebias_{i0}$ representing the baseline discount factor and binary measures of present-and-future bias, respectively.

[5] In these models we do not include separate indicators for present-and-future bias as our nonparametric time preference measure reflects both constant discounting and present-and-future bias.

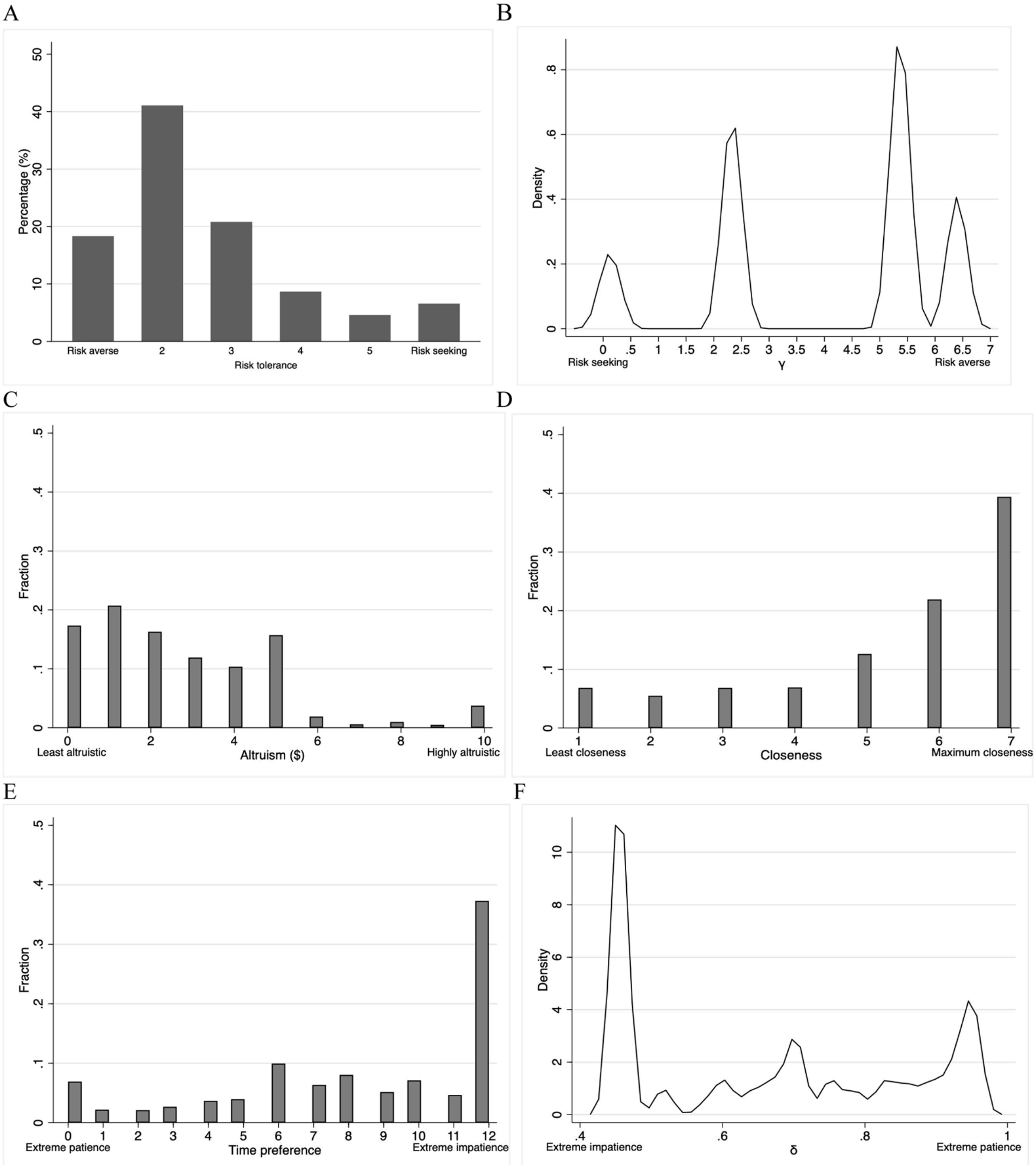

Fig. 1. Distribution of measures
Notes: Graph A: Risk tolerance; Graph B: Risk aversion; Graph C: Altruism; Graph D: Closeness; Graph E: Time preferences and Graph F: Discount factor. Graphs A, C, D and E are non-parametric preference measures. Graphs B and F are kernel density plots of implied preference parameters generated with a Parzen kernel function with bandwidth selection by the plugin estimator.

For both outcomes, we conduct a comprehensive set of robustness checks on our primary analysis which uses the nonparametric measures. We re-estimate the models controlling for a range of additional baseline covariates – level of education, marital status, religious denomination, quintiles of household wealth index, economic sector and perceived likelihood of being HIV positive. We confirm robustness to estimating our models without clustering standard errors, adjusting standard errors for stratification (urban, peri-urban and rural) and clustering, and using ordinary least squares (OLS) with wild cluster bootstrap resampling (Cameron et al., 2008).

Because we estimate our models for 2 outcomes and test for associations with 3 nonparametric preference measures over 3 groups (full sample, women and men), we face a multiple hypothesis testing problem where the probability of a Type 1 error increases as more hypotheses are checked. To control for the family-wise error rate across the 18 hypotheses being tested, we calculate adjusted p-values applying Romano-Wolf step-down corrections with 5000 bootstraps (Romano and Wolf, 2005a; Romano and Wolf, 2005b). Similarly in models where we include *closeness* we adjust *p*-values for 24 hypotheses that are tested.

We verify the robustness of our time preference results by estimating our main specification retaining only those who are consistent

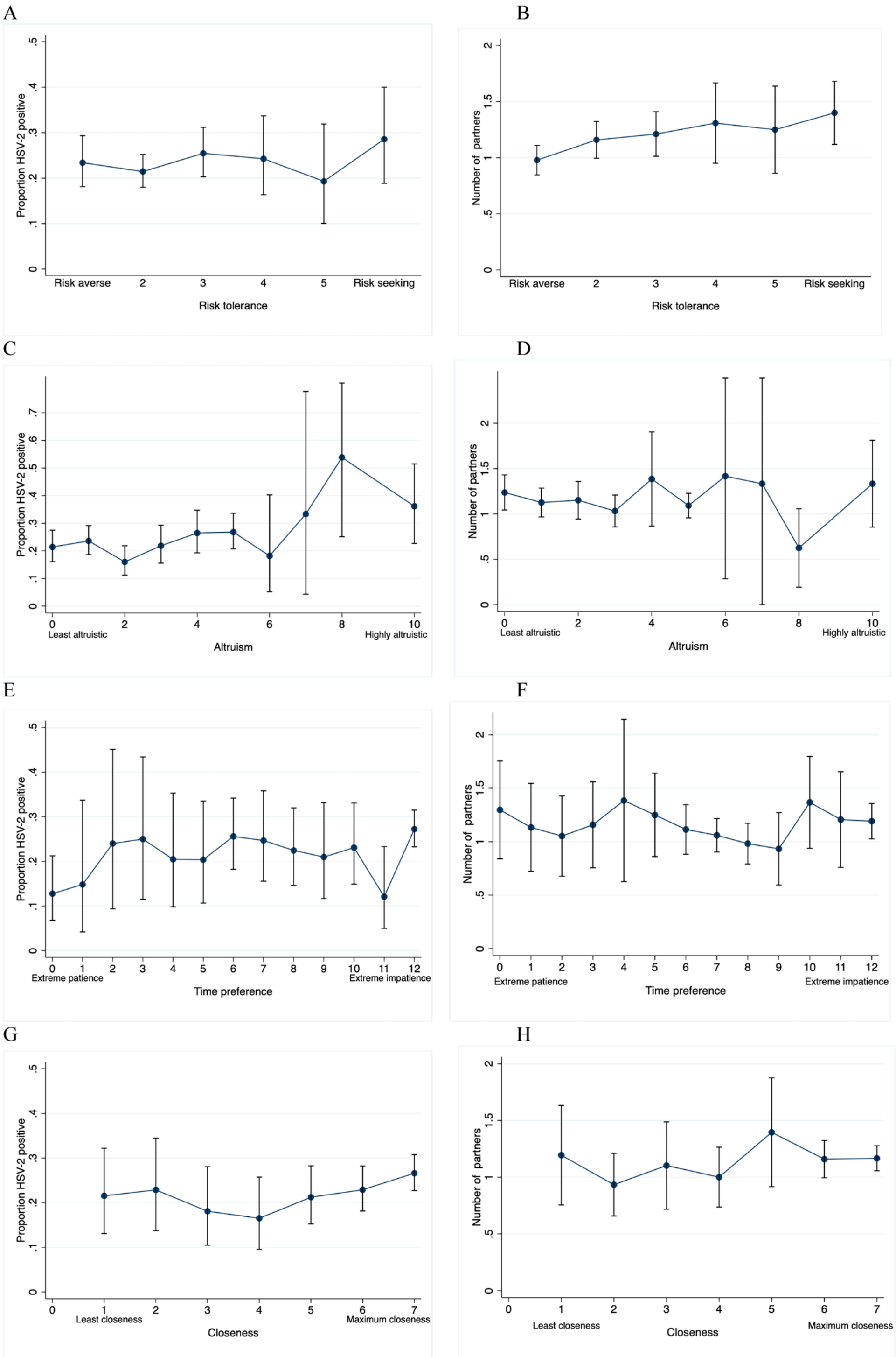

Fig. 2. Outcomes as a function of each nonparametric measure
Notes: Graphs for non-parametric preference measures represent proportion of each outcome at levels of the preference measure. Whiskers represent 95 % confidence intervals. Outcomes are a binary measure of Herpes Simplex Virus Type-2 (HSV-2) positive status and a count of number of sexual partners in the last 12 months, amongst those reporting ‘having ever had sex’.

responders to the time preference questions ($consistent_{i0} = 1$). To confirm that any associations we observe are not driven by selection, or specific to our sample of follow-up participants, we estimate our models replacing the 12-month outcome measures (y_{i1}) with corresponding baseline measures of the outcomes y_{i0}. We show results of baseline associations between risky sexual behaviour and nonparametric preferences for two samples, first a sample restricted to those eligible for the follow-up ($N = 1774$) and second, for an unrestricted baseline sample of all baseline participants ($N = 3146$).

Finally, we verify that any associations of preferences with number of sexual partners in the last 12 months is not due to selection bias. To confirm this is not the case, we estimate models replacing with zero, the number of partners for those who reported having never had sex. Finally, we repeat several of these checks when we include *closeness* in our models. We discuss all these results below.

4. Results

4.1. Links between preferences, social proximity and risky sexual behaviour

Figs. 2 and 3 show the bivariate associations between our outcomes and each preference measure and *closeness*. Figs. 2A and 3A show associations between an indicator of HSV-2 positive status and the nonparametric measure of risk tolerance and the implied risk aversion parameter, respectively. The graphs reveal no obvious relationship between HSV-2 status and risk preference. Fig. 2C shows the association of HSV-2 status with *altruism*. While the point estimates suggest that the proportion who are HSV-2 positive rises with the level of altruism, all the 95 % confidence intervals overlap. We note that the sudden drop in the proportion HSV-2 positive at the upper extreme of the altruism measure is due to poor data support in this region (see Fig. 1C). We also see no clear association between HSV-2 status and either our nonparametric *time preference* measure or implied discount factor δ (Figs. 2E and 3C). The proportion HSV-2 positive is only marginally lower amongst those who are more patient, with overlapping confidence intervals. We note that the sudden drop in the likelihood of being HSV-2 positive in the region of $\delta = 0.55$ is due to poor data support (see Figure 1). Fig. 2G shows no obvious associations of HSV-2 status with *closeness*.

The point estimates in Fig. 2B indicate that the number of sexual partners increases with *risk tolerance*, however the confidence

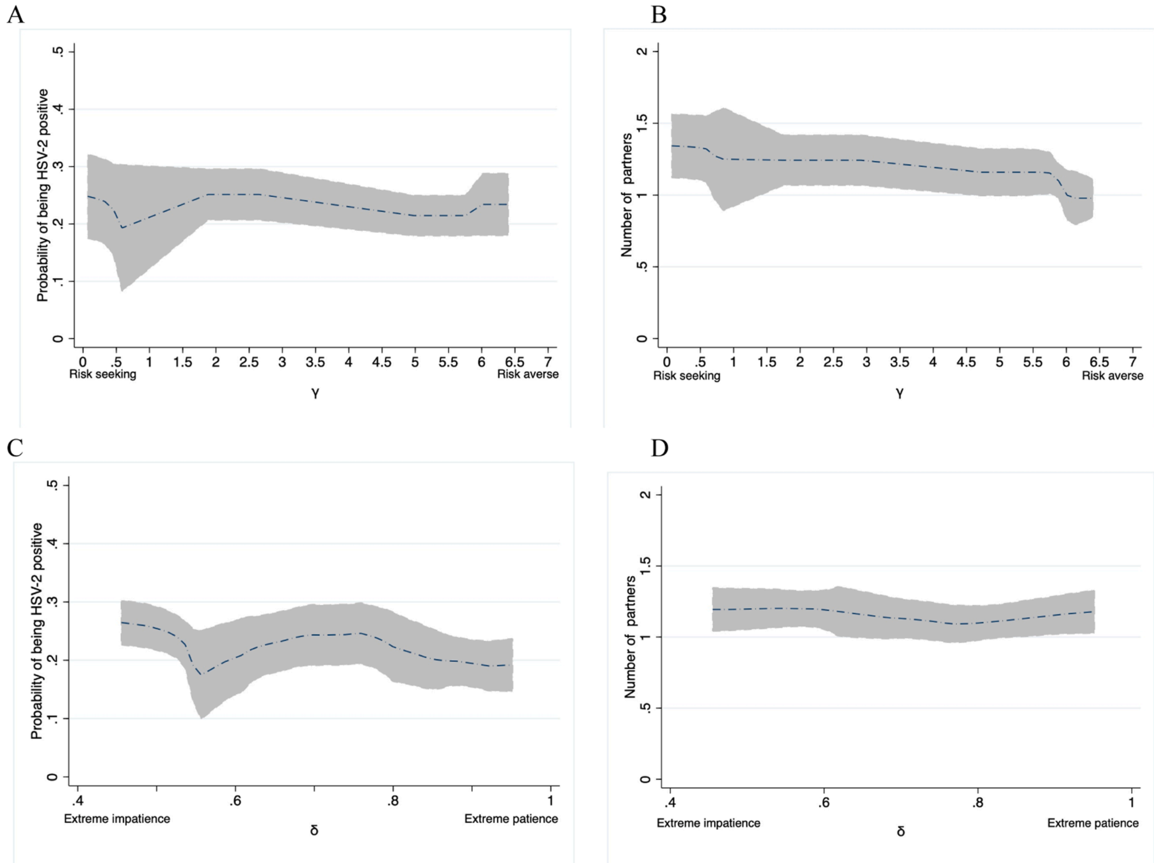

Fig. 3. Outcomes as a function of preference parameters.
Notes: Graphs obtained by bivariate local polynomial regression. The Epanechnikov kernel function is used with bandwidth selection by the plugin estimator. Shaded regions represent 95 % confidence intervals. Outcomes are a binary measure of Herpes Simplex Virus Type-2 (HSV-2) positive status and a count of number of sexual partners in the last 12 months, amongst those reporting 'having ever had sex'.

intervals overlap. The corresponding inverse relationship of number of sexual partners with γ is not obvious in Fig. 3B. We find no clear association of the estimated number of sexual partners in the last 12 months with *altruism, time preference* or δ and *closeness* (Figs. 2D, 2F, 3D or 2H).

Panel A of Table 2 gives estimates of the marginal effects from models that use the nonparametric preference measures adjusting for age and sex. Columns (1)-(3) present results estimating the likelihood of being HSV-2 positive for the pooled sample and by sex. Columns (4)-(6) present corresponding results for number of sexual partners in the last 12 months. We find being HSV-2 positive 12 months later is significantly associated with *altruism* and *time preference,* while having more sexual partners is associated with *risk tolerance* and *time preference*. Table S8 provides expanded results for all covariates.

Specifically, we find a positive and statistically significant association of HSV-2 status with *time preference* (Table 2, Panel A, column 1). A one SD change toward stronger time preferences is associated with an increase from 23.2 % to 26.4 % in the likelihood of being HSV-2 positive 12 months later. The magnitude of the point estimate is similar across women (column 2) and men (column 3). The result for the full sample is robust to the inclusion of a full set of covariates (Table S11) however, it is not robust to adjustments for multiple hypothesis testing (Table 2). We find that the strength and magnitude of the associations we see with time preferences are moderated by inconsistent responses in the MPLs. As discussed earlier, 76 % of respondents made consistent choices across both MPLs. We re-estimate our models on the subsample of consistent respondents (*consistent==1*). The observed associations in the full sample and across sexes are stronger and larger by approximately 20 % (Table S12). Stronger time preference also appears to be associated with more sexual partners (Table 2, column 4) but is significant only in the sample of women (Table 2 column 5). The magnitude of the point estimate implies a one SD change toward stronger time preference is associated with 5 % more reported number of sexual partners in this sample of women. This result is robust to adjustments for multiple hypothesis testing (Table 2), inclusion of a full set of covariates (Table S11) and in the subsample of consistent respondents (Table S12).

Column (1) of Table 2 (panel A) also shows that amongst the preference measures, the point estimate is largest in magnitude for the

Table 2
Marginal effects of preference measures and *closeness* on outcomes.

	HSV-2 status at 12 months			Number of sexual partners in the last 12 months		
	Full sample (1)	Women (2)	Men (3)	Full sample (4)	Women (5)	Men (6)
A. Nonparametric preference measures						
risk tolerance	0.0111	−0.0087	0.0351	0.0637	0.0096	0.1438
Standard error	(0.0105)	(0.0127)	(0.0123)	(0.0175)	(0.0135)	(0.0492)
Unadjusted p-value	0.2904	0.4953	0.0042	0.0003	0.4771	0.0035
RW adjusted p-values	0.7240	0.8820	0.0620	0.0220	0.8820	0.0620
altruism	0.0140	0.0183	0.0080	0.0022	0.0019	−0.0171
Standard error	(0.0049)	(0.0057)	(0.0082)	(0.0179)	(0.0092)	(0.0376)
Unadjusted p-value	0.0041	0.0014	0.3302	0.9020	0.8379	0.6498
RW adjusted p-value	0.0620	0.0380	0.7700	0.9640	0.9640	0.9260
time preference	0.0079	0.0076	0.0079	0.0075	0.0149	−0.0081
Standard error	(0.0036)	(0.0033)	(0.0040)	(0.0122)	(0.0028)	(0.0287)
Unadjusted p-value	0.0277	0.0234	0.0498	0.5382	0.0000	0.7787
RW adjusted p-values	0.1480	0.1460	0.2200	0.8820	0.0000	0.9640
B. Nonparametric preference measures and *closeness*						
risk tolerance	0.0101	−0.0087	0.0307	0.0616	0.0091	0.1398
Standard error	(0.0103)	(0.0128)	(0.0122)	(0.0164)	(0.0134)	(0.0458)
Unadjusted p-value	0.3252	0.4954	0.0116	0.0002	0.4973	0.0023
RW adjusted p-value	0.9000	0.9640	0.1440	0.0240	0.9640	0.0600
altruism	0.0146	0.0183	0.0096	0.0024	0.0022	−0.0180
Standard error	(0.0048)	(0.0059)	(0.0077)	(0.0180)	(0.0094)	(0.0359)
Unadjusted p-value	0.0023	0.0019	0.2169	0.8936	0.8174	0.6159
RW adjusted p-value	0.0600	0.0560	0.7740	0.9900	0.9900	0.9640
time preference	0.0079	0.0076	0.0081	0.0075	0.0146	−0.0072
Standard error	(0.0037)	(0.0033)	(0.0038)	(0.0118)	(0.0032)	(0.0286)
Unadjusted p-value	0.0313	0.0213	0.0322	0.5255	0.0004	0.8011
RW adjusted p-value	0.2300	0.2020	0.2300	0.9640	0.0100	0.9900
closeness	0.0106	0.0010	0.0289	0.0279	0.0091	0.0402
Standard error	(0.0067)	(0.0097)	(0.0060)	(0.0189)	(0.0141)	(0.0406)
Unadjusted p-value	0.1136	0.9203	0.0000	0.1401	0.5179	0.3227
RW adjusted p-value	0.5180	0.9920	0.0080	0.5860	0.9940	0.9000
N	1257	803	454	714	441	273

Notes: Marginal effects averaged over the sample. HSV-2 status at 12 months modelled using probit regressions and number of sexual partners in the last 12 months modelled using negative binomial regressions. Models include age, consistent response in MPLs and sex (full sample model) as covariates with robust standard errors clustered at the site level in parentheses. RW adjusted p-values are Romano-Wolf (Romano and Wolf, 2005a; Romano and Wolf, 2005b) stepdown adjusted p-values from 5000 bootstrap replications. A higher *risk tolerance* score implies greater willingness to bear risk. A larger amount of money given away implies greater *altruism*. A higher *time preference* score implies lower patience. A higher *closeness* score implies greater social proximity with partner.

association with *altruism*. The estimate implies that in this sample, a one SD deviation increase in the amount given away in the dictator game, is associated with an increase from 23.2 % to 26.7 % in the likelihood of being HSV-2 positive 12 months later. The analysis by sex shows this association is significant amongst our sample of women but not amongst men. The magnitude of the point estimate is also larger amongst women (column (2)), with a one SD deviation change being associated with an increase from 25.7 % to 30.1 % in the likelihood of being HSV-2 positive 12 months later. We find no significant association of *altruism* with reported number of sexual partners. The magnitude and significance of these results are robust to adjustments for multiple hypothesis testing (Table 2) and the inclusion of our full set of covariates (Table S11).

We find no significant association of HSV-2 status with *risk tolerance* in our full sample or the subsample of women, but a positive significant association in the sample of men. These results are robust to multiple hypothesis testing (Table 2) and the inclusion of a full set of covariates (Table S11). Interestingly, we find number of sexual partners in the last 12 months is significantly associated with *risk tolerance* and particularly in the sample of men (columns 4 and 6 of Table 2). These associations are robust to adjustments for multiple hypothesis testing and inclusion of other covariates (Table 2 and S11). Amongst men, a one SD greater propensity to tolerate risks is associated with 14.6 % more reported sexual partners (column 6). This effect is about one-third larger than the effect in the full sample (9.3 %) (column 4).

We find the likelihood of being HSV-2 positive 12 months later decreases with the discount factor (Table S9 column 1). As in the case of the nonparametric preference measures, we find that in the subsample of women, greater discounting of future returns is associated with more sexual partners (Table S9 column 5). It would thus seem that the earlier significant associations we saw between the outcomes and nonparametric *time preference* measure (Table 2) are driven by the discount factor. We find no meaningful association between present-or-future bias and risky sexual behaviour (Table S9).

As in the results in Table 2, we find being HSV-2 positive 12 months later is significantly associated with *altruism*, in the full sample and in the subsample of women (Table S9 columns (1) and (2)). The point estimates are of similar magnitude to the nonparametric model (Table 2). Also, consistent with earlier results, number of sexual partners is significantly associated with lower risk aversion (Table S9, columns 4 and 6).

Finally, inclusion of *closeness* does not substantially change the magnitude or significance of observed associations with preferences (Table 2 panel B). In addition to the above associations of preferences, we find that the risk of being HSV-2 positive is positively associated with *closeness* in a relationship and is statistically significant in the subsample of men (column (3)). A one SD increase in the closeness level increases the likelihood of men being HSV-2 positive from 19.0 % to 24.8 %. These associations are robust to corrections for multiple hypothesis testing (Table 2). We do not find evidence of a meaningful association between number of sexual partners and *closeness* (Table 2). Table S10 provides expanded results for all covariates.

We also compare the magnitude of associations from a one SD change in preference measures, *closeness* and key predictors of risky sexual behaviour. Considering HSV-2 status, inclusion of additional covariates and *closeness* does not affect the magnitude of associations seen in the main specification (Table S13). Comparing magnitudes across predictors, the associations with *altruism* and *time preference* are larger than most other key predictors of risky sexual behaviour (e.g. age, household wealth index, education and perceived risk of being HIV positive) (Table S13 column 1). Being male has a similar (in magnitude) association but in the opposite direction, reducing the likelihood of being HSV-2 positive. In the subsamples, the largest positive association is with *altruism* amongst women (Table S13 column 2) and *closeness* amongst men (Table S13 column 3). Inclusion of additional covariates and *closeness* in the models for number of partners, marginally reduces the magnitude of the association with *risk tolerance* in the full sample and in the subsample of men (Table S13, columns 4 and 6). The magnitude of these associations is similar to other key predictors. However, it is one-third the size of the effect of sex i.e., being male is by far the largest driver of reporting more sexual partners (Table S13 column 4).

4.2. Robustness

As discussed above, our main results of an association between HSV-2 and *altruism,* and number of partners with *risk tolerance* and *time preference* (Table 2 panel A) are robust to the inclusion of additional covariates, multiple hypothesis testing and in the subsample of consistent respondents in the time preference MPLs. Here we assess robustness of these estimates further. Results from estimation by ordinary least squares (Table S14) differ little in size from our primary results in Table 2. When we use wild cluster bootstrap p-values (Cameron et al., 2008) estimates remain statistically significant although at higher levels ($p < 0.10$) in some cases, such as associations of outcomes with *time preference*. These findings remain unchanged when standard errors are not adjusted for clustering and when they are adjusted for stratification and clustering (Table S15).

Our main findings show important associations of risky sexual behaviour with measures of preferences, with heterogeneity across men and women. However, it is important to verify that our findings are stable within our sample at a different point in time, and valid in a wider sample of young people. We thus replicate our analysis using two baseline samples. First, using baseline measures of our outcomes and the same baseline nonparametric preference measures, we estimate our main specification on the sample of individuals who were eligible for the 12-month follow-up. Our primary analysis sample (Table 2) is thus a subset of this group, comprising those from this group who participated in the 12-month follow-up data collection exercise. Second, once again using baseline measures of our outcomes and nonparametric preference measures, we estimate our main specification on our full sample of baseline participants i.e., this sample includes the above group and those who were not eligible for follow-up. Qualitatively, the estimates for *altruism* and *risk tolerance* from these two samples are remarkably similar to our main results in Table 2 (Tables S16 and S17). Importantly, like in the other robustness checks discussed earlier, the association of HSV-2 with time preference does not hold amongst men (Tables S16 and S17). In these baseline samples, amongst women the magnitude of the association between number of partners and *time preference* is very small and no longer significant. This may be because women in general report fewer partners (Table 1) and being a year younger when baseline outcomes were measured, more women report having no partners in the previous 12 months (18.16 %) compared to the follow-up survey (7.03 %).

We also verify that our finding of a positive association between HSV-2 status and *altruism* amongst women is robust to excluding those in transactional partnerships. It may be possible that women found here to be pro-social are those in high-risk partnerships such as transactional relationships and our measure of altruism is a proxy for their high-risk status. In the socio-behavioural survey, transactional partnership is measured as the response to the question "Have you given or received money, goods or services in exchange for sex with *this person* in the last month?" where 'this person' refers to their current or last partner. 9.5 % of women report having had transactional sex. We re-estimate our model for HSV-2 status excluding the 9.5 % of women reporting transactional sex with their last or current partner and find our result continues to hold (Table S18).

Our outcome of the reported number of sexual partners in the last 12 months, is conditional on reporting being sexually active i.e., the question was only asked of those who reported 'having ever had sex' in the follow-up survey. It is possible there may be selection bias if those who report being sexually active are different to those reporting having never had sex. To assess if this is the case, we estimate models replacing with zero, the number of partners for those who reported having never had sex. We note though, this version of the outcome is no longer purely an indicator of risky sexual behaviour, as those who have never had sex, especially in our sample of young people, may yet go on to have risky sexual behaviour once sexually active. Thus, we would expect smaller and weaker associations compared to our primary results. We verify the robustness of our results in our primary estimation sample as well as in our full baseline sample. As in our primary results, in both samples we see a clear positive association of number of sexual partners with *risk tolerance* (amongst men) and *time preference* (amongst women) (Table S19). As expected, these estimates are smaller in magnitude but still significant, except in the sample of men in the follow-up survey, where the smaller sample, coupled with the large number of zeros results in less precise estimates.

Finally, we assess the robustness of our result showing a positive association between HSV-2 status and *closeness*, particularly amongst men. Our results for men hold when adjusting for our full set of covariates, when using linear probability models and wild cluster bootstrap resampling and when we use baseline samples (Tables S20 and S21). Similar checks for *closeness* and number of partners confirm the lack of an association (Tables S22 and S23).

5. Discussion and conclusions

We conducted economic experiments to measure risk, time, prosocial preferences and social proximity to partners amongst the general population of youth in a low-income high-risk setting and linked these measures to outcomes of risky sexual behaviour measured 12 months later. We find important differences across outcomes and sexes in their association with preferences. Our biomarker appears to primarily capture the risk to an individual from channels that lead to an underestimation of risk via partners. These channels are altruism for women and interpersonal closeness for men. We do not find robust evidence that our biomarker is associated with time preferences. Consistent with the literature that men are more risk seeking, and more likely to indulge in and report risky activities, we find that our direct measure of sexual risk taking - number of sexual partners in the last 12 months - is positively associated with greater willingness to bear risk. We also find that amongst women, having more sexual partners is associated with greater impatience. These associations are reliably robust across multiple checks, different samples and time periods, and to corrections for multiple hypotheses testing.

Perhaps our most surprising finding is the positive association between positive HSV-2 status and altruism, particularly amongst women. A few potential explanations may be found in the literature examining what dictator games and other social preferences games really capture, and the implications for predicting real-world behaviour (Galizzi and Navarro-Martinez, 2018; Wang and Navarro-Martinez, 2023). Anonymous one-shot dictator games have been widely used to empirically measure altruism (Forsythe et al., 1994; Charness and Rabin, 2002; Camerer, 2003). However, the amount given in one-shot dictator games have been shown to be highly sensitive to the environment and the framing of the choice (Dana et al., 2006; Dana et al., 2007; Bardsley, 2008; Franzen and Pointner, 2012). There is also debate that responses in these games may be influenced by external factors that are beyond the control of the experimenter, including contextual factors, personal beliefs, reputational concerns and internalized cultural and social norms (Levitt and List, 2007; List, 2009). A related strand of literature also argues that sociality is driven not directly by preferences over payoff distributions, but rather by preferences for following social rules i.e. norms may make preferences social (Krupka and Weber, 2013; Kimbrough and Vostroknutov, 2016; Krupka et al., 2017). Furthermore "when a norm is prosocial, people who suffer more from violating social norms will behave more prosocially" (Kimbrough and Vostroknutov, 2016). In our study setting, strong social norms govern the role of women, particularly within partnerships. Women in these settings inherently have low negotiating power and say within partnerships and are expected to acquiesce to requests and needs of their male partners (Eaton et al., 2003; Seidu et al., 2021; Duby et al., 2023). It is thus plausible that in our study setting where women face higher costs from non-compliance with social norms what we measure with the dictator game is acquiescence to requests and expectations, which in turn is associated with an outcome of risky sexual behaviour that captures such risks.

We find no evidence of an association between number of sexual partners and altruism either amongst women or men. This is not surprising for women, given very few women report multiple partners, we only see an association with time preferences. We speculate, that amongst men, it may be that any association between number of partners and social preferences is potentially mediated by attitudes to risk (Fehr and Schmidt, 1999; Brock et al., 2013; Krawczyk and Le Lec, 2016; Müller and Rau, 2016; Freundt and Lange, 2017). In our general population sample, our robust finding that having more sexual partners is associated with greater risk tolerance particularly amongst men, is consistent with the literature highlighting men are in general more likely to engage in risky behaviours (Booth and Nolen, 2012; Eckel and Grossman, 2008) and report these behaviours. In a similar vein, Lépine and Treibich (2020) find that in a sample of female sex workers in Senegal, greater risk aversion is associated with having fewer clients.

We do not find robust evidence of associations between risk tolerance and our biomarker (HSV-2 status). This is consistent with Lépine and Treibich (2020) but different to the findings of two other studies which find a positive association with being HIV positive (Björkman Nyqvist et al., 2022; Lammers and van Wijnbergen, 2008). Mixed predictive power of experimentally elicited risk attitudes is reflected in the wider literature. Multiple factors explain these mixed findings - specific features of the different experimental tasks employed to measure risk preferences (Crosetto and Filippin, 2016; Galizzi et al., 2016; Menkhoff and Sakha, 2017); the growing evidence that risk preferences can be highly domain-specific, so that monetary lotteries may not necessarily translate into taking health risks (Weber et al., 2002; Blais and Weber, 2006; Barseghyan et al., 2011; Riddel, 2012; Galizzi et al., 2016; Ioannou and Sadeh, 2016); and health behaviours may be better explained by other aspects of risk preferences such as probability weighting, loss aversion, or ambiguity aversion (Starmer, 2000; Abdellaoui et al., 2007; Abdellaoui et al., 2008; Trautmann et al., 2011; Vieider et al., 2015; Abdellaoui et al., 2019).

Previous studies have shown mixed evidence on the association between risky sexual behaviour and time preferences. In keeping with these, we do not find robust evidence that our biomarker is associated with time preferences (Chesson et al., 2006; Björkman Nyqvist et al., 2022). Our finding of a robust positive association with number of sexual partners is consistent with the finding of Chesson et al.(2006). Several studies have tried to overcome barriers to use of preventative methods, particularly present-bias (Thirumurthy et al., 2016; Kohler and Thornton, 2012; Chinkhumba et al., 2014; Thirumurthy et al., 2014) or target risky sexual behaviours (Richterman and Thirumurthy, 2022), through financial incentives, with mixed results. Our finding of low levels of present-bias and a lack of association with risky sexual behaviour possibly explains the mixed results from these interventions.

By documenting, for the first time, that risky sexual behaviour is associated with preferences measured in simple economic games involving monetary payoffs, our study contributes to the growing economic literature exploring the ability of experimental measures of preferences to predict real-world outcomes (Barsky et al., 1997; Chabris et al., 2008; Tanaka et al., 2010; Meier and Sprenger, 2010; Burks et al., 2012; Sutter et al., 2013; Akerlund et al., 2016; Bradford et al., 2017; Galizzi and Navarro-Martinez, 2018; Kerr et al., 2019; Campos-Mercade et al., 2021; Epper et al., 2022; Farago et al., 2022). Our findings on the associations with relationship closeness adds to the growing economic literature studying the importance of social proximity on economic decision-making (Gächter et al., 2023; Robson, 2021; Goette and Tripodi, 2021; Harris et al., 2015; Danilov et al., 2013).

Our study is not without limitations. Our tasks for time preferences may be capturing something else, such as liquidity or financial constraints for example (Cubitt and Read, 2007; Cohen et al., 2020; Bartoš et al., 2021; Dean and Sautmann, 2021; Imai et al., 2021). In our dataset, unfortunately, we do not have measures of credit constraints and we only have a measure of household wealth. We use HSV-2, a well-established proxy measure of risky sexual behaviour and analyse prevalence rather than incidence. To have adequate statistical power to study incidence requires a much larger and longer study. COVID-19 restrictions midway through our follow-up survey required a switch to telephone interviews for the socio-behavioural survey and may have affected the reporting of our outcome on the number of sexual partners. However, this does not affect the HSV-2 findings, which are based on biomarkers.

Despite these limitations, our study yields a clear and novel finding: a biomarker of risky sexual behaviour is associated with a simple measure of social preferences, and a self-reported measure of number of sexual partners is associated with greater risk tolerance and time preference.

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Ethical approval

The study has obtained ethical approvals from the Medical Research Council of Zimbabwe (reference number: MRCZ/A/2243), the Biomedical Research and Training Institute, Zimbabwe Institutional Review Board (reference number: AP140/2017) and the Imperial College London Research Ethics Committee (reference number: 17IC4160).

Data and code availability

Data used in this paper can be accessed at http://www.manicalandhivproject.org/data-access.html

CRediT authorship contribution statement

Ranjeeta Thomas: Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing. **Matteo M. Galizzi:** Methodology, Writing – original draft, Writing – review & editing. **Louisa Moorhouse:** Data curation, Project administration. **Constance Nyamukapa:** Project administration, Supervision. **Timothy B. Hallett:** Writing – review & editing, Funding acquisition.

Declaration of Competing Interests

The authors declare that they have no competing interests.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jhealeco.2023.102845.

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