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# Keep up with the winners: Experimental evidence on risk taking, asset integration, and peer effects ☆

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ABSTRACT

The paper reports the result of an experimental game on asset integration and risk taking. We find some evidence that winnings in earlier rounds affect risk taking in subsequent rounds, but no evidence that real life wealth outside the experiment affects risk taking. Controlling for past winnings, participants receiving a low endowment in a round engage in more risk taking. We test a 'keeping-up-with-the-Joneses' hypothesis and find that subjects seek to keep up with winners, though not necessarily with average earnings. Overall, the evidence suggests that risk taking tracks a reference point affected by social comparisons.


## 1. Introduction

In spite of a voluminous literature in psychology and economics, risk taking decisions remain poorly understood. This is unfortunate given how critical risk taking is to important economic decisions. We use an original experiment to revisit a key issue that potentially affects risk taking: asset integration. This refers to the idea that individuals decide about risky prospects by considering the effect of decisions on their final wealth rather than on specific gains and losses (Kahneman and Tversky, 1979). We focus on two kinds of asset integration: (1) integration of winnings between successive tasks within an experiment; and (2) integration of winnings with real life wealth outside the experiment. We also examine whether risk taking is affected by social comparisons, while controlling for other factors that may affect risk taking, such as learning and imitation.

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The study population, partly made of Ethiopian farmers, faces considerable risk in their daily life and is thus well suited to investigate risk taking. Furthermore, because this population is poor, the winnings from the experiment are large relative to their normal income. We thus expect their behavior to be more representative of risk taking by experienced individuals. We also present evidence using university students in the United Kingdom and in Ethiopia.

There is evidence that experimental subjects make risk taking decisions 'as in a bubble', that is, ignoring their non-experimental assets.[2] Perhaps the most convincing evidence of this is that experimental subjects reject profitable lotteries involving payoffs that are small relative to their wealth (Rabin, 2000; Rabin and Thaler, 2001; Johansson-Stenman, 2009). If participants integrated lottery stakes with their total wealth, only extremely risk averse individuals would avoid small profitable lotteries. One way to solve this paradox is to assume that individuals keep total wealth and experimental income mentally separate, which amounts to a lack of asset integration (Cox and Sadiraj, 2006). This was already implied by the risk attitude estimates of Binswanger (1981) and Gertner (1993), and has most recently been claimed by Schechter (2007). While asset integration has been tested using experimental data alone (e.g., Heinemann, 2008), we are aware of only one published study (Andersen et al., 2011) that directly tests asset integration by combining survey and experimental data.[3] They find evidence of only partial asset integration.

We revisit this issue using results from a multiple round experiment and test whether people integrate winnings between successive rounds of the same experiment. Participants are divided into groups of six. At the beginning of each round, three receive a high endowment while the other three receive a low endowment. Initial endowments are common knowledge within the group. From this endowment, participants are asked how much they wish to 'invest' in a lottery that yields, with equal probability, 0 or three times the amount invested. In the context of the experiment, risk taking is represented by the share of the endowment that players invest in the lottery. We take advantage of the fact that players are faced with the same decision three times to investigate dynamic individual and peer effects.

We begin by showing that risk taking within the experiment is uncorrelated with the assets that participants hold outside the experiment, i.e., there is failure of integration with real life assets. For the Ethiopian subject population, we find that winnings from earlier rounds of the experiment increase risk taking. This result does not hold for UK subjects. Taken in combination, these results are consistent with narrow framing: what happens during the experiment is regarded by participants as being in a different frame from their daily lives[4]. But the size of the frame within the experiment may vary across populations.

We also test whether risk taking depends on receiving a low or high endowment in a round. In an expected utility framework, the effect of a high endowment is predicted to be the same as that of past winnings, i.e., positive with an equal coefficient. This is not what we find: participants who receive a high endowment in a round invest a smaller share of it in the lottery than those who receive a low endowment, controlling for past winnings. This suggests that participants who receive a low endowment in a round try to make up for it by taking more risk. This effect can be understood as an application of prospect theory to our experimental setting, and suggests that reference points are affected by the endowment that participants receive at the beginning of each round.

We investigate whether reference points are affected by the winnings of peers.[5] At the end of each experimental round, participants observe the winnings and investment decisions of other players in their group. We examine whether risk taking is affected by how much others invested and won. There are several possible channels by which these may influence risk taking. We test – and reject – several of these channels. The results we emphasize here suggest that subjects' risk taking is affected by social comparisons. We find that experimental subjects act as if they are in an implicit competition with each other: when others win big, they take more risk, presumably to try to keep up with them. We also investigate whether participants behave in a way similar to 'keeping up with the Joneses' in the consumption domain (Duesenbery 1949; Johansson-Stenman et al., 2002).[6]. One simple way of modelling this is by assuming that the reference point or aspiration level is a function of what others earn on average: if participants are falling behind the average of their peers, they then take more risk – up to the point where they are above the average.[7] This idea is reminiscent of Bault et al. (2008) although their experimental setting is different. We test this prediction and find no evidence of such an effect.

Taken together, the results indicate that experimental subjects take experimental earnings into account when deciding how much risk to take: some subject populations (i.e., in Ethiopia but not in the UK) take more risk if they won more in

[2] E.g., much of the evidence in favor of prospect theory or other non-expected utility theories relies on changes of income as opposed to final states. Broadly speaking, this evidence can be interpreted as violating asset integration (see, for example, Battalio et al., 1990 for a similar interpretation).

[3] Heinemann (2008) uses Holt and Laury experimental data to test asset integration but does not have actual wealth data for the studied subjects.

[4] This is an example of 'choice bracketing' as discussed by Read et al. (1999).

[5] Our experimental design also enables us to explore other dynamic effects at the individual and group level. Exploiting the fact that participants make repeated choices after observing their past lottery outcomes, we verify whether we observe either a 'hot hand' effect – by which participants who win lotteries become more risk taking controlling for experimental earnings – or a 'gambler's fallacy' – by which participants instead engage in less risk taking following a win. Croson and Sundali (2005) find some evidence of both in data from a Las Vegas casino. Some of our coefficient point estimates are consistent with the gambler's fallacy, but results are not statistically significant.

[6] There is also a connected literature looking at the relationship between risk-taking and inequality in tournaments, which could have social status as prizes (see Becker et al., 2005; Hopkins and Kornienko, 2010; Hopkins, 2011).

[7] To have this result, we either need to assume standard loss aversion combined with greater risk taking in the domain of 'losses' relative to the reference point such as may be assumed, e.g., in cumulative prospect theory (Tversky and Kahneman, 1992); or we need to assume an aspiration level type of model such as Lopes and Oden (1999) and Genicot and Ray (2010). The two sets of models may be related (Rieger, 2010).

earlier rounds; all seek to compensate for a low endowment in a round by taking more risk; and all take more risk if some players in their group won more than them in earlier rounds. The latter behavior suggests that participants take high earners as reference point when deciding how much risk to take. Risk taking thus appears to have a competitive element, even when participants are quite poor and when the potential earnings from the experiment are large relative to their wealth or income.

## 2. The experiment

We conducted an experiment in Ethiopia in four rural villages, mainly with farmers, and with university students in the capital city, Addis Ababa. As robustness check, the experiment was subsequently replicated in the UK. The details and findings of the UK replication are discussed in the robustness section.

The rural fieldwork in Ethiopia was conducted between February and March 2009. The four villages are located in different agro-ecological regions of the country. Subjects were recruited among household heads and their spouses participating in the Ethiopian Rural Household Survey panel. All participants come from farming households; two-third of them are males. The games with university students took place in February 2010. Addis Ababa university did not have a permanent experimental laboratory at the time so students were recruited through ads posted around campus. Information about participants is given in the Data Section.

The experimental design is based on earlier experiments organized by Zizzo (2003) and Zizzo and Oswald (2001) in a laboratory setting. Participants are asked to repeatedly make the same risky choice. This choice is framed as an investment decision. This enables us to examine whether choices evolve over time as a function of each participant's past winnings and information set. This aspect of the data is the focus of this paper.[8]

The design of the experiment is as follows. Thirty individuals participate in a session and these players are divided into five groups with six players in each, equally divided into high and low income players. Anonymity within each group is strictly maintained even though the thirty participants in a session can see each other. Each player plays three rounds. At the start of each round players are randomly given either a high (Ethiopian Birr 15) or a low (Birr 7) endowment to induce inequality.[9] Each participant then decides how much of this endowment to invest in a more than actuarially fair lottery with a 50% chance of winning thrice the amount invested. Lottery outcomes are independent across participants. After lottery winnings are determined, players are informed of the winnings of the other five members of their group and how much they themselves have won from the lottery.

The game is repeated three times.[10] In each round new groups are formed with different participants. Players are informed about this. At the end of the game, participants leave with all the winnings accumulated over the three rounds plus a participation fee. This was implemented in four rural villages with a total number of 240 participants, and with 60 university students in the city of Addis Ababa. In addition, a slightly different version of the game was played with another 60 students. In this version, participants stay in the same group of six players over the three rounds. We call this treatment the fixed group treatment.[11]

## 3. Testing strategy

We now introduce the econometric testing strategy. After presenting our notation, we explain how we test whether participants integrate their assets or past winnings when deciding how much risk to take. We then introduce social comparisons. At the end of the section we discuss how we address possible confounding effects induced by imitation and learning. Possible confounding effects are discussed in detail in Appendix.

### 3.1. Notation

Let $Z_{it}$ be the initial endowment given to player $i$ in round $t$, with $Z_{it}$ taking one of two values, 7 or 15. Let $X_{it}$ denote how much of this endowment player $i$ invests in the lottery in round $t$. The amount not put at risk is $Z_{it} - X_{it}$. Individuals with a

[8] The experiment also allows participants to destroy, at a cost, other players' payoff. This aspect relates to a literature studying the so-called 'money-burning' experiments and is the focus of a companion paper (Kebede and Zizzo, 2015). In the money burning stage players observe the winnings of other participants in their group of six players, and are allowed to pay something to decrease the earnings of others. In each round the money burning decisions of one of the six group members is selected at random, and only the player whose payoff was 'burned' is told. Given that money burning is rare, few subjects observe it. At the end of the paper we check the robustness of our results to experiencing money burning.

[9] Although more power could in principle have been achieved by varying initial endowments more, maintaining the range of endowments constant keeps the cognitive burden of the game low, a necessity given that a large proportion of rural participants is illiterate. The Birr is the national currency of Ethiopia and at the time of games the exchange rate was around 8 Birr for 1 US$.

[10] Repeating the game a larger number of times could in principle yield valuable information on dynamic effects. This was not feasible given that all experiments were conducted without computers. Adding more rounds would have taken too long, leading to participant fatigue.

[11] The purpose of the fixed group treatment is to test whether money burning affects subsequent investment because subjects react to a change in their expectation of the behavior of people in their group (fixed group), or respond to something less specific – such as a change in the expected behavior of the population or the moral reprobation implicit in money burning (changing group). This aspect of the experiment is used by Kebede and Zizzo (2015), but is not relevant here.

smaller initial endowment $Z_{it}$ can invest less. We define risk taking $x_{it}$ as the proportion of $Z_{it}$ that is invested:

$$x_{it} = \frac{X_{it}}{Z_{it}}$$

Clearly, $0 \le x_{it} \le 1$.[12] Let $Y_{it}$ denote the return on the risky investment. It takes two values with equal probability: 0, and $3X_{it}$.

This game is played for three successive rounds in groups of six players. In one treatment, the six players are the same throughout. In another treatment, the six players change in each round. At the end of each round, players are told how the other members of their group played and how much money they earned. In other words, they are told $Z_{it}, X_{it}$ and $Y_{it}$ for all five other players. Let $W_{it}$ denote the winnings of player $i$ in round $t$. In general $W_{it} = Z_{it} - X_{it} + Y_{it}$.[13]

### 3.2. Risk taking

We first examine decisions when players regard each round of the game in its own narrow frame. With no asset integration with earlier rounds, all three rounds for player $i$ are identical and the decision in each round is of the form

$$\max_{0 \le X_t \le Z_t} \frac{1}{2}U(Z_t - X_t) + \frac{1}{2}U(Z_t + 2X_t) \tag{3.1}$$

This shows that $X_t$ is a function of $Z_t$ only, not of earlier winnings. In linear form we have

$$X_{it} = a + bZ_{it} + u_{it} \tag{3.2}$$

If players have constant relative risk aversion, $x_{it}$ is a constant proportion of $Z_{it}$ and $X_{it} = bZ_{it} + u_{it}$.[14] It is widely believed that relative risk aversion (RRA) is either constant or mildly decreasing – in which case $x_{it}$ increases with $Z_{it}$. In contrast, increasing relative aversion implies that $x_{it}$ falls with $Z_{it}$. Given the small range of variation of $Z_{it}$ relative to participants' wealth, we expect relative risk aversion to be approximately constant with $Z_{it}$ – and hence $x_{it}$ to be constant over the range of $Z_{it}$. Constant relative risk aversion thus requires that $a=0$ and $b>0$ while decreasing relative risk aversion is implied by $a<0$.

A positive $a$ implies increasing relative risk aversion over the narrow range of values taken by $Z_{it}$, something that is a priori unlikely among poor subjects. It is also difficult to reconcile $b=0$ with expected utility. We revisit these issues below when we introduce reference points and loss aversion.[15]

### 3.3. Asset integration

Keeping within the expected utility framework for now, we want to test whether players integrate their winnings from earlier rounds with lottery payoffs when choosing $X_{it}$. If players fully integrate their winnings over the entire experiment, then the utility of each player $i$ in the last round will be a function of the winnings from all rounds. Dropping the $i$ subscript to improve readability, the decision in the last round thus is

$$\max_{0 \le X_3 \le Z_3} \frac{1}{2}U(W_1 + W_2 + Z_3 - X_3) + \frac{1}{2}U(W_1 + W_2 + Z_3 + 2X_3) \tag{3.3}$$

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[12] Given that only integer values of $X_{it}$ are allowed in the experiment, $x_{it}$ can only take a finite – but not negligible – number of values.

[13] When some of $i$'s winnings are destroyed by another player, we subtract this amount from $i$'s winnings from the round and we subtract the corresponding cost from the other player.

[14] To demonstrate, let $U(c) = \frac{c^{1-r}}{1-r}$ where $r$ is the coefficient of relative risk aversion. The optimal choice of risk taking $x$ in our experiment is the solution to

$$\max_x \frac{1}{2}\frac{Z^{1-r}(1-x)^{1-r}}{1-r} + \frac{1}{2}\frac{Z^{1-r}(1+2x)^{1-r}}{1-r}$$

The first order condition is

$$\frac{1}{2}Z^{1-r}\left[-(1-x)^{-r} + 2(1+2x)^{-r}\right] = 0$$

where $Z$ factors out. Simple algebra yields

$$x = \frac{1-2^{-1/r}}{1+2^{1-1/r}}$$

We see that $x$ does not depend on $Z$, tends to 1 when $r$ approaches 0, and falls as $r$ increases.

[15] The reader may wonder why we do not test asset integration using the method proposed by Harrison and Rutstrom (2008) and used by Andersen et al. (2011). The reason is that this method has the advantages and drawbacks of all structural estimation: inference is only as good as the functional assumptions imposed by the researcher. In our particular case, the method requires that the functional form of the utility function be specified, e.g., constant relative risk aversion except for a parametric dependence on wealth. Our method does not impose such structure on the estimation and should therefore be more robust.

where $W_1, W_2$ and $Z_3$ are then predetermined. By analogy with (3.2), we expect risk taking to approximately follow

$$X_{i3} = a_3 + b_3(W_{i1} + W_{i2} + Z_{i3}) + u_{i3} \tag{3.4}$$

with $b_3 > 0$. If participants have constant relative risk aversion, $a_3 = 0$.

Whether or not players integrate past winnings with $Z_{i3}$ can thus be investigated by estimating a model of the form

$$X_{i3} = a_3 + b_3'(W_{i1} + W_{i2}) + b_3 Z_{i3} + u_{i3} \tag{3.5}$$

If players fully integrate their winnings, $b_3' = b_3 > 0$; if they only partially integrate their winnings, we should observe $b_3 > b_3' > 0$. If they do not integrate winnings at all, $b_3' = 0$.

A similar test can be estimated for the second round. The optimization problem in the second round is

$$\max_{0 \le X_2 \le Z_2} \frac{1}{2} EV(W_1 + Z_2 - x_2 Z_2 + Z_3) + \frac{1}{2} EV(W_1 + Z_2 + 2x_2 Z_2 + Z_3) \tag{3.6}$$

where the expectation $E$ is taken over future values of $Z_3$.[16] The same reasoning applies: if players integrate their past winnings when making decisions, then choices should approximately follow a regression model of the form

$$X_{i2} = a_2 + b_2' W_{i1} + b_2 Z_{i2} + u_{i2} \tag{3.7}$$

with $b_2' = b_2 > 0$ while if they do not integrate, then $b_2' = 0$. This can be tested in the same manner as described for (3.5). Eqs. (3.7) and (3.5) form the starting point of our estimation strategy.

By the same reasoning, if players integrate their actual wealth $A_i$ with lottery winnings when deciding $X_{it}$, we expect $X_{it}$ to increase with $A_i$. This can be investigated by estimating a model of the form

$$X_{i1} = a_1 + b_1 Z_{i1} + cA_i + u_{i1} \tag{3.8}$$

$$X_{i2} = a_2 + b_2' W_{i1} + b_2 Z_{i2} + cA_i + u_{i2} \tag{3.9}$$

$$X_{i3} = a_3 + b_3'(W_{i1} + W_{i2}) + b_3 Z_{i3} + cA_i + u_{i3} \tag{3.10}$$

and test whether $c > 0$. If $A_i$ is expressed in the same units as winnings $W_{it}$, we can also test whether $c = b_t' = b_t$ to test whether integration is complete or partial, as in Andersen et al. (2011). With asset integration, the optimal $X_{it}$ may exceed $Z_{it}$, however. Given this, we also estimate the model using tobit with upper limit censoring given by $Z_{it}$.

### 3.4. *Social comparisons and relative utility*

According to prospect theory, risk taking behavior depends on whether the decision maker is below or above his/her reference point (Kahneman and Tversky, 1979). Above the reference point, individuals are predicted to behave in the standard risk averse fashion. Below the reference point, individuals may behave in a risk neutral or risk loving manner. There is also a kink at the reference point, generating strong risk aversion when choosing between prospects just above and below the reference point. The largely unanswered question is what the reference point is (Koszegi and Rabin, 2006, 2007). If the reference point responds to what happens to peers, this opens the door to the possibility that risk taking is affected by social comparisons (e.g., Gill and Prowse, 2012).

#### 3.4.1. *Reference point and asset integration*

We begin by discussing how behavior predictions differ when risk taking decisions are taken relative to a reference point. To illustrate the role of reference points in a simple manner, consider a piecewise linear utility with reference point $M$ and loss aversion coefficient $\eta$ with $0 < \eta < 1$. More complex utility functions have been proposed in the literature, but given the simplicity of our experiment this one suffices.[17] Let the utility function be written as

$$U(C) = C - \eta I(C > M)(C - M)$$

where $C > 0$ denotes payoff, $I(C > M)$ is an indicator function, and parameter $\eta$ captures how strong the kink is at $C = M$. We have $U(C) = C - \eta(C - M)$ for $C > M$ and $U(C) = C$ if $C < M$ otherwise. If $M = 0$, utility is linear in payoff and the optimal $X_{it} = Z_{it}$: participants are risk neutral and are thus predicted to invest their entire endowment. Similarly, if $M$ is large enough, $X_{it} = Z_{it}$ as well. For intermediate values of the reference point $M$, the kink in the utility function induces risk aversion, and $X_{it} \le Z_{it}$.

In our experiment,[18] it can be shown that if $\eta > 0.5$ the relationship between $x_{it}$ and the reference point $M$ is decreasing in $M$ up to a point and increasing above that. For $0 \le M < Z_{it}$ the optimal choice of $X_{it}$ is

$$X_{it} = Z_{it} - M$$

[16] Here $V(\cdot)$ denote the value of the solution to (3.3). Although $V(\cdot)$ is not the same function as the utility function $U(\cdot)$, it inherits much of its curvature from $U(\cdot)$ (Deaton, 1991).

[17] Given that in our experiment probabilities always are 50%, we ignore issues of probability weighting, which tend to affect choices at low and high probabilities only.

[18] The cutoff value of $\eta$ is driven by the fact that, in our experiment, the expected gain from investing is 0.5.

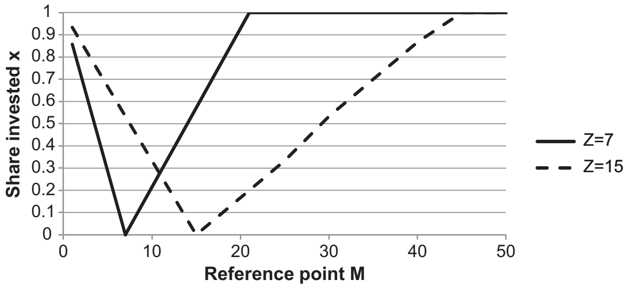


**Fig. 1.** Risk taking and reference point.

At $Z_{it} = M$, $X_{it} = 0$: individuals whose endowment puts them at their reference point invest nothing. This is because, when $\eta > 0.5$, the expected gain from risk taking is more than cancelled by the reduction in utility above $M$. If we keep increasing $M$ above $Z_{it}$, however, we move away from the kink at $M$ and $X_{it}$ starts increasing again as utility approaches risk neutrality.

In Fig. 1 we plot $x_{it}$ against $M$ for endowments $Z_{it} = 7$ and 15, respectively.[19] We see that, when the reference point $M$ is below 10, $x$ when $Z=7$ is less than when $Z=15$, i.e., players who receive a low endowment invest proportionally less. In contrast, for values of $M > 10$, individuals who receive a low endowment invest proportionally *more* in the lottery. The intuition is that players who judge their payoff relative to a high reference point seek to make up for their low endowment by taking more risk. This prediction is difficult to reconcile with standard expected utility theory. Hence, in the context of our experiment, finding that $x_{it}$ is higher for $Z_{it} = 7$ than for $Z_{it} = 15$ is prima facie evidence against the expected utility model – and suggests that participants choose something close to the high endowment as reference point.

Regarding asset integration, the above model makes predictions that are not too dissimilar from expected utility theory. Letting $W$ denote accumulated past winnings, we can rewrite objective function as

$$U(W+C) = W + C - \eta I(W+C > M)(W+C-M)$$

It immediately follows that risk taking increases with $W$ as long as the player is above reference point $M$. The logic is that the higher above the reference point the player is, the less concerned he or she is about falling below it. Below the reference point, risk taking falls with past winnings $W$.

### 3.4.2. Keeping up with the winners

The literature on social comparisons and relative utility does not focus on risk taking but discusses the ways in which others' payoff influence utility directly (e.g., Johansson-Stenman et al., 2002; Gill and Prowse, 2012). It does not predict an effect of social comparisons on risk taking.[20] One form of social comparison relevant for risk taking, however, is the 'keeping up with the Joneses' effect proposed by Duesenbery (1949) in the context of consumption and saving. Applied to risk taking, it predicts that people do not wish to perform less well than their peers. This can be formally represented by letting the performance of peers affect reference point $M$. As illustrated in Fig. 1, $x_{it}$ increases in $M$ over much of its range. Hence, by raising $M$, peer effects may increase risk taking.

This idea is related to the experimental evidence provided by Bault et al. (2008). But our experimental setting is different. Unlike Bault et al. (2008) and Linde and Sonnemans (2012), in our experiment social comparisons between subjects are not made salient by design. Furthermore, our subjects are not asked to choose between positively and negatively correlated outcomes. Rather they receive endowments that are, by design, negative and positively correlated with others in their group. Having received a different endowment, they are then given an opportunity to risk part of it, a dimension that is not present in these other papers.

Within the context of our experiment, a 'keeping up' effect can arise in several possible ways. At the beginning of the game, participants first learn whether they receive a high or low endowment $Z_{it}$. By design, those who receive a low $Z_{it}$ know that others in their group received a high $Z_{it}$. This is because, within each group, three players receive a low $Z_{it}$ and three

[19] $\eta$ is set to 0.9. Other parameters are those of the experiment.

[20] To demonstrate this, it is easy to verify that risk taking is unaffected by any other-regarding preference modelled as a multiplicatively or additively separable term in the utility function. This includes Beckerian altruism and paternalistic preferences.

Letting $\overline{W}_{-it} \equiv \sum_{j \in N_{it}} W_{jt}$, risk taking is also unaffected in an invidious utility function of the form:

$$U\left(\frac{\sum_{s=1}^{t} W_{it}}{\beta \sum_{s=1}^{t} \frac{1}{5}\overline{W}_{-it}}\right)$$

since the $\overline{W}_{-it}$ terms factors out of the coefficient of prudence. This functional form is the one most naturally associated with relative utility preferences studied, e.g., by Clark and Oswald (1998). [Another way of writing invidious preferences is $U(W_{it} - \beta\overline{W}_{-it})$. But with such preferences, risk taking falls with other players' winnings, which is the opposite of the 'keeping up with the Joneses' effect.]

The same observations apply to inequality aversion (e.g., Fehr and Schmidt, 1999) which combines altruistic and invidious preferences into a single utility function.

It remains that the intuition behind the 'keeping up with the Joneses' argument shares some similarity with the spirit of inequality aversion in the sense that the average payoff of others serves as reference point, with a kink in preferences at that reference point.

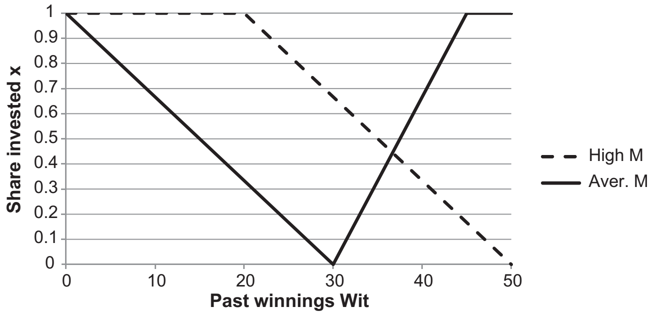


**Fig. 2.** Risk taking and past winnings.

receive a high $Z_{it}$. If participants set the high $Z_{it}$ (the endowment of 15 received by the 'winners') as their reference point, we expect more risk taking for recipients of a low $Z_{it}$. This is illustrated in Fig. 1 which shows that, for $M$ larger than 10, $x_{it}$ is larger for recipients of the low $Z_{it}$.

This possibility can be investigated by comparing risk taking $x_{it}$ between recipients of a low and high endowment $Z_{it}$. As discussed earlier, it is difficult to account for a much higher $x_{it}$ for $Z_{it}=7$ than $Z_{it}=15$ within an expected utility framework. But it is consistent with loss aversion *and* a reference point above 10. Finding such evidence would therefore suggest that participants seek to keep up with the 'winners' of a high $Z$ by taking more risk in that round.

A second possible source of 'keeping up' effect comes from the fact that, at the end of a round, participants observe the winnings of others $G_{-it} \equiv \sum_{j \in N_{it}} 3x_{jt}Z_{jt}r_{jt}$ where $N_{it}$ denotes the set of players that were in $i$'s group in round $t$ and $r_{jt}$ is the $j$'s lottery realization in round $t$.[21] Observing that others have won more may raise $i$'s reference point, thereby inducing $i$ to take more risk to keep up with the winners of earlier rounds. This can be investigated by estimating a model of the form

$$X_{i2} = a_2 + b_2' W_{i1} + b_2 Z_{i2} + \kappa_2 G_{-i1} + u_{i2} \tag{3.11}$$

$$X_{i3} = a_3 + b_3'(W_{i1} + W_{i2}) + b_3 Z_{i3} + \kappa_3 G_{-i2} + u_{i3} \tag{3.12}$$

where we control for learning and imitation to avoid spurious inference (see below). Keeping up with lottery winners in past rounds would manifest itself by positive values of $\kappa_2$ and $\kappa_3$ and by values of $b_2$ and $b_3$ less than 1. We call both effects 'keeping up with the winners' (KW).

Another possibility, arguably more in line with the literature on peer effects, is that people do not wish to perform less well than the *average* of their peers. We call this effect 'keeping up with the average'– or 'keeping up with the Joneses' (KJ) by reference to Duesenbery (1949). Here the behavioral objective is not winning, but rather *not losing*. The difference between KW and KJ is that, by definition, a subject's winning can never be above that of the winners. But they can be above $\overline{W}_{-it}$, the average winnings of the players that $i$ could observe.

How this difference affects model predictions is illustrated in Fig. 2, which shows how risk taking $x_{it+1}$ varies with past winnings $W_{it}$ for an intermediate and high value of the reference point $M$.[22] In KW the reference point $M$ is the highest winnings of all players which, by definition, can never be exceeded by the subject's own winnings $W_{it}$. In this case, $x_{it+1}$ is everywhere non-increasing in $W_{it}$. In contrast, in KJ the subject can be below or above the average $\overline{W}_{-it}$ which is now the reference point $M$. In Fig. 2 this is represented by the broken line at $M=45$. We see that risk taking is non-monotonic: $x_{it+1}$ is decreasing in $W_{it}$ when $W_{it} < \overline{W}_{-it}$ and increasing in $W_{it}$ when $W_{it} > \overline{W}_{-it}$.

It follows that, if KJ is the true model, the relationship between $W_{it}$ and $x_{it}$ should be $U$-shaped around the point where $W_{it} = \overline{W}_{-it}$. In contrast, if KW is the true model the relationship between $W_{it}$ and $x_{it}$ should be monotonically decreasing. To investigate these possibilities, we estimate a version of models (3.11) and (3.12) that uses $x_{it}$ as dependent variable – to keep close to the predictions from Fig. 2 – and that includes or not a quadratic term in $i$'s past winnings relative to the average, i.e., in $R_{it} \equiv W_{it} - \overline{W}_{-it}$. The estimated models are of the form

$$x_{it} = \beta_0 + \beta_1 R_{it} + \beta_2 R_{it}^2 + \beta_1 Z_{it} + v_{it} \tag{KJ}$$

$$x_{it} = \beta_0 + \beta_1 R_{it} + \beta_1 Z_{it} + v_{it} \tag{KW}$$

(KW) implies $\beta_1 < 0$ and $\beta_2 \leq 0$: subjects with high past winnings invest proportionally less. In contrast, KJ implies $\beta_1 < 0$ and $\beta_2 > 0$, with an inflection point at $R_{it} = 0$.

[21] To recall, $r_{it}$ is 0 or 1 with equal probability.

[22] In Fig. 2 $Z_{it}=15$ and the high value $M=65$ and the average value $M=45$.

**Table 1**
Descriptive statistics.

| Variables | Rural sites | | | | | Addis Ababa University | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Mean** | **Median** | **St.dev.** | **Max** | **Min** | **Mean** | **Median** | **St.dev.** | **Max** | **Min** |
| Male dummy | 0.65 | | | | | 0.91 | | | | |
| Age | 46.24 | 45.00 | 13.55 | 85.00 | 18.00 | 21.43 | 21.00 | 2.39 | 44.00 | 18.00 |
| Investment rate $x_{it}$ | 0.29 | 0.29 | 0.23 | 1.00 | 0.00 | 0.56 | 0.47 | 0.29 | 1.00 | 0.00 |
| Lottery winning $W_{it}$ (*) | 5.34 | 3.00 | 7.28 | 45.00 | 0.00 | 7.72 | 0.00 | 10.37 | 45.00 | 0.00 |
| Household assets $A_i$ (*) | 360.06 | 232.25 | 400.68 | 2754.00 | 8.00 | n.a. | – | – | – | – |
| **Education** | | | | | | | | | | |
| No education | 0.50 | | | | | 0.00 | | | | |
| Only literacy | 0.08 | | | | | 0.00 | | | | |
| Primary incomplete | 0.23 | | | | | 0.00 | | | | |
| Primary complete | 0.04 | | | | | 0.00 | | | | |
| Secondary incomplete | 0.04 | | | | | 0.00 | | | | |
| Secondary complete | 0.08 | | | | | 0.00 | | | | |
| Higher education | 0.01 | | | | | 1.00 | | | | |
| Vocational training | 0.02 | | | | | 0.00 | | | | |
| **Religion** | | | | | | | | | | |
| Ethiopian Orthodox | 0.40 | | | | | 0.51 | | | | |
| Muslim | 0.16 | | | | | 0.07 | | | | |
| Protestant | 0.31 | | | | | 0.34 | | | | |
| Catholic | 0.13 | | | | | 0.00 | | | | |
| Other religions | 0.00 | | | | | 0.08 | | | | |

*Source*: Questionnaires filled by experimental subjects in Ethiopia. (*) in Ethiopian Birr, the local currency.

## 4. The data

In Table 1 we present descriptive statistics on participants from the four rural sites and for university students. Most participants are males but the proportion of males rises to 90% in the case of university students. Unsurprisingly, the average age of rural participants is higher than that of students.

On average university participants take more risk: they invest a little over half of their initial endowment in the lottery, which is nearly twice as much as rural players; and the cumulative distribution of investment rates among students is everywhere above that of rural participants. University participants invest their entire endowment in 22% of the games compared to 3% of rural participants. Less than 1% of students invest nothing on lottery compared to 8% of rural participants. Hence, we clearly see higher risk taking among students compared to rural participants. If we assume, as is reasonable in the Ethiopian context, that university students have a higher permanent income, this is consistent with the idea that income affects risk taking. Other factors could also account for this difference – e.g., more risk taking by university students could be explained by higher cognitive abilities (e.g., Dohmen et al., 2010). Since taking risk is profitable in our experiment, it is not surprising to find that the lottery winnings of the students are on average higher than that of rural participants.

Rural participants are covered by earlier household surveys from which we recover the value of their household assets. Household assets include agricultural tools like hoes and ploughs, household furniture and items like beds, tables, chairs and stoves and other valuables like jewelry and watches. Rural households hardly use financial assets. The value of household assets is a very good proxy for household income/wealth (e.g., Filmer and Pritchett, 2001). There is a lot of variation in wealth and expenditure within the participating rural population, as is clear from Table 1. Since there is no corresponding survey of university students, there is no information on their household assets. But even if we did have this information, it is unclear how informative it would be: education is probably a better predictor of students' expected life earnings than whatever assets they may have. For farmers, average winnings from the experiment are equivalent to 1.5% of household assets. Average winnings for students are even larger in absolute terms. This ensures that the experiment provides sufficiently high powered incentives.

There is no variation in the educational level of university participants as all of them are in higher education. Rural participants are more representative of the Ethiopian adult population, with much lower education levels. Half of rural participants have no formal education and more than 80% have at most incomplete primary education.[23] Although vocational skills may increase agricultural productivity, only 2% of rural participants have any form of vocational training.

The heterogeneity of the country in terms of religious beliefs is reflected in the subject population. In both sites, the traditional Ethiopian Orthodox faith is the most common, followed by Protestantism. Muslims are underrepresented compared to the Ethiopian population at large.

[23] These figures are much lower than current school enrolment figures among the young.

## 5. Empirical results

### 5.1. Asset integration

We begin by estimating our baseline regressions:

$$X_{i1} = a_1 + b_1 Z_{i1} + u_{i1}$$
$$X_{i2} = a_2 + b_2' W_{i1} + b_2 Z_{i2} + u_{i2}$$
$$X_{i3} = a_3 + b_3'(W_{i1} + W_{i2}) + b_3 Z_{i3} + u_{i3}$$

Before doing so, we must deal with a potential endogeneity problem with respect to past winnings $W_{i1}$ and $W_{i2}$. By design

$$W_{it} = Z_{it} - X_{it} + 3X_{it} r_{it} = Z_{it} + X_{it}(3r_{it} - 1) \tag{5.1}$$

where $r_{it}$ is $i$'s lottery realization in round $t$. To recall, $r_{it}$ is 0 or 1 with equal probability. It follows that less prudent participants who invest more – i.e., have a higher $X_{it}$ – also have higher winnings $W_{it}$ on average. This could generate a spurious correlation between risk taking $X_{i2}$ and $X_{i3}$ and $W_{i1}$ and $W_{i2}$ that is driven by risk preferences, not by wealth effects within the experiment.

To eliminate this spurious correlation, we construct measures of $W_{i1}$ and $W_{i2}$ that depend on $i$'s initial endowment in the round $Z_{it}$ and $i$'s lottery realization $r_{it}$ but not on $i$'s past investment decisions $X_{i1}$ and $X_{i2}$. These measures, which we denote $\widehat{W}_{i1}$ and $\widehat{W}_{i2}$, are constructed by replacing, in formula (5.1), $i$'s actual investment $X_{it}$ with the average investment of players who, in the same round $t$ and site $v$, received an endowment $Z_{it}$. Let $X(Z_{it}, v, t)$ denote this average. The formula we use through the analysis is thus[24]

$$\widehat{W}_{it} = Z_{it} + X(Z_{it}, v, t)(3r_{it} - 1) \tag{5.2}$$

Results are presented in Table 2. All standard errors are clustered by player groups that constitute independent observations.[25] The first three columns of Table 2 refer to decisions made in the first round of the game. Here the focus is on regressor $Z_{i1}$, the income that participants received at the beginning of round 1. This variable only takes two values, 7 and 15. Columns 4–6 focus on round 2 while columns 7–9 focus on round 3. In addition to $Z_{it}$ the regressions also include accumulated past winnings $\widehat{W}_{i1}$ (in round 2) and $\widehat{W}_{i1} + \widehat{W}_{i2}$ (in round 3).

We report three versions of each regression with different controls. The first version (columns 1, 4 and 7) only includes the above-mentioned regressors plus dummy variables for each of the experimental sites to control for differences in average attributes across sites. The second version (columns 2, 5 and 8) adds controls for whether the composition of the groups was the same across rounds or not, and for whether the experimental session took place in the afternoon – to control for possible mood effects correlated with time of day (e.g., Coates and Herbert, 2008). As further robustness check, the third version (columns 3, 6 and 9) adds individual controls such as age, gender, education and religion which may be correlated with risk taking.

Test results are broadly consistent across the three sets of regressions: $b_1$, $b_2$ and $b_3$ are all small but positive ($b_1$ and $b_2$ significantly so), and $b_2'$ and $b_3'$ are significantly positive in all regressions: investment $X_{it}$ increases with a higher endowment $Z_{it}$ and higher winnings from past rounds $W_{it}$. Further, the point estimate of $b_2'$ is approximately half of $b_2$, a much larger relative effect than that reported by Andersen et al. (2011) for outside wealth. As shown at the bottom of the table, we cannot reject the full integration hypothesis that $b_2 = b_2'$ and $b_3 = b_3'$. However, risk taking itself – i.e., the proportion invested $x_{it}$ – is quite low: in rounds 1, 2 and 3, subjects invest on average 14, 10 and 5 cents for each additional Birr of endowment they receive in the round.

What can we say about relative risk aversion? Since $a_1$, $a_2$ and $a_3$ are all significantly positive, subjects invest a larger proportion $x_{it}$ of their endowment when it is small. For instance, if we consider column (1), we see that students in round 1 invest on average $4.017 + 0.142 \times 7 = 5.011$ when they receive an endowment of 7 ($x_1 = 72\%$) and $4.017 + 0.142 \times 15 = 6.147$ when they receive an endowment of 15 ($x_1 = 41\%$). This indicates negative prudence – and hence risk loving preferences at low levels of $Z_{it}$. To confirm these findings, we report in Fig. 3 the cumulative distribution of $x_{it}$ for the two levels of $Z_{it}$ across the sample. We see that the distribution of $x_{it}$ for $Z_{it} = 7$ stochastically dominates that for $Z_{it} = 15$. We also note that $b$ falls across rounds, suggesting less risk taking at the margin in later rounds of the experiment when subjects have accumulated more earnings. Such findings are difficult to reconcile with an expected utility framework, with or without asset integration.

[24] One complication arises when individual $i$ did not invest anything. In this case $r_{it}$ is not observed. There are 82 such cases in the data. For these, we reconstruct ex post what $r_{it}$ might have been simply by flipping a coin. This procedure introduces some noise in the wealth measure. But it is better than the alternative of replacing, for these individuals, $3r_{it} - 1$ with its expectation $E[3r_{it} - 1] = 0.5$. If we used the latter approach, the resulting wealth measure $\widehat{W}_{it}$ would be affected by $i$ setting $X_{it} = 0$, and thus would still suffer from endogeneity.

[25] In the game version with fixed groups played in the urban area, membership of the groups is not changed between rounds, hence we cluster standard errors by the five groups formed within a session. In the version of the game with variable groups where players are re-matched in each round, we cluster standard errors by session.

**Table 2**
Baseline specification (the dependent variable is $X_{it}$, the amount invested in the lottery).

| Variables | Round 1 | | | Round 2 | | | Round 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** | **(7)** | **(8)** | **(9)** |
| Accumulated winnings ($W_{it}$) | | | | 0.0512* | 0.0523* | 0.0580* | 0.0599* | 0.0553* | 0.0615* |
| | | | | (0.0161) | (0.0157) | (0.0139) | (0.0118) | (0.0103) | (0.0117) |
| Endowment in round ($Z_{it}$) | 0.142* | 0.142* | 0.143* | 0.106** | 0.105** | 0.103* | 0.0537 | 0.0638 | 0.0426 |
| | (0.0444) | (0.0445) | (0.0399) | (0.0379) | (0.0377) | (0.0321) | (0.0462) | (0.0456) | (0.0334) |
| Fixed group dummy | | −1.750* | −1.537* | | −1.280* | −1.021** | | −0.842** | −0.679*** |
| | | (0.276) | (0.381) | | (0.382) | (0.417) | | (0.383) | (0.380) |
| Afternoon session dummy | | 0.411* | 0.497* | | 0.349** | 0.317** | | 0.936* | 0.916* |
| | | (0.139) | (0.171) | | (0.139) | (0.150) | | (0.198) | (0.208) |
| Female dummy | | | −0.473** | | | −0.386 | | | −0.490 |
| | | | (0.196) | | | (0.406) | | | (0.298) |
| (Log) Age | | | −0.367 | | | −1.453* | | | −1.404** |
| | | | (0.530) | | | (0.482) | | | (0.503) |
| At most primary education | | | 0.599* | | | 1.044** | | | 0.734*** |
| | | | (0.207) | | | (0.368) | | | (0.397) |
| Above primary education | | | 0.929** | | | 0.289 | | | 0.789*** |
| | | | (0.379) | | | (0.387) | | | (0.445) |
| Muslim | | | −0.604 | | | −1.196* | | | −0.346 |
| | | | (0.399) | | | (0.331) | | | (0.409) |
| Protestant | | | −0.314 | | | −0.0764 | | | 0.313 |
| | | | (0.521) | | | (0.309) | | | (0.440) |
| Catholic | | | −0.390 | | | −0.0947 | | | −0.0991 |
| | | | (0.323) | | | (0.282) | | | (0.270) |
| Other religion | | | 1.241*** | | | 0.756 | | | 1.554 |
| | | | (0.596) | | | (0.684) | | | (1.109) |
| Yetmen | −2.775* | −3.650* | −2.622* | −2.101* | −2.742* | −1.691* | −2.281* | −2.696* | −0.813 |
| | (0.388) | (0.126) | (0.375) | (0.313) | (0.282) | (0.467) | (0.352) | (0.444) | (0.735) |
| Terufe Kechema | −3.808* | −4.683* | −3.289* | −3.015* | −3.653* | −1.922* | −2.900* | −3.333* | −1.425* |
| | (0.395) | (0.0778) | (0.372) | (0.316) | (0.267) | (0.526) | (0.544) | (0.0768) | (0.425) |
| Imdibir | −3.458* | −4.333* | −2.925* | −3.328* | −3.967* | −2.463* | −3.669* | −4.097* | −2.020* |
| | (0.388) | (0.139) | (0.301) | (0.408) | (0.305) | (0.445) | (0.409) | (0.128) | (0.517) |
| Aze Deboa | −2.742* | −3.617* | −2.230* | −1.697* | −2.336* | −1.051*** | −1.732* | −2.157* | −0.638 |
| | (0.550) | (0.240) | (0.633) | (0.350) | (0.270) | (0.508) | (0.516) | (0.0452) | (0.403) |
| Constant | 4.017* | 4.686* | 4.786** | 3.656* | 4.119* | 8.152* | 3.921* | 3.887* | 7.174* |
| | (0.447) | (0.512) | (1.919) | (0.488) | (0.477) | (1.707) | (0.392) | (0.399) | (1.856) |
| Observations | 360 | 360 | 351 | 360 | 360 | 351 | 360 | 360 | 351 |
| $R^2$ | 0.342 | 0.380 | 0.412 | 0.301 | 0.324 | 0.388 | 0.282 | 0.310 | 0.360 |
| *F*-test for asset integration ($W_{it}=Z_{it}$) | | | | 1.35 | 1.29 | 1.33 | 0.01 | 0.03 | 0.21 |
| (*p*-value) | | | | (0.2600) | (0.2708) | (0.2632) | (0.9100) | (0.8734) | (0.6514) |

Robust standard errors clustered by session (or fixed player group) are given in parentheses.
No education is the omitted education category. Ethiopian orthodox is the omitted religion category. Addis Ababa is the omitted site category.

*** $p<0.01$.
** $p<0.05$.
* $p<0.1$.

The rest of Table 2 checks the robustness of these findings to the inclusion of various controls. The fixed group dummy is negative, indicating less risk taking in groups with a fixed membership across all three rounds. We also find more risk taking in afternoon sessions. Why this is the case is unclear, but it may be due to diurnal variations in the endocrine system where the levels of testosterone and cortisol vary by time of the day (e.g., see Coates and Herbert, 2008). Coefficients on $Z_{it}$ for each round do not change with the addition of these controls while those on $\widehat{W}_{i1}$ and $\widehat{W}_{i1}+\widehat{W}_{i2}$ remain consistent in terms of significance and magnitude across regressions.

In columns 3, 6 and 9, we add controls for the participant's gender, age, education level, and religion. Risk taking varies systematically with some of these individual characteristics. Female participants, for instance, take on average less risk – which is consistent with the bulk of the experimental evidence to date (Croson and Gneezy, 2009). Since individual characteristics are not randomly assigned and are likely to be correlated with socio-economic status, it is unclear how to interpret them. What is clear is that coefficients on $Z_{it}$ and on $\widehat{W}_{i1}$ and $\widehat{W}_{i1}+\widehat{W}_{i2}$ remain virtually unchanged.

To investigate whether our results are an artifact of censoring, we reestimate Table 2 with a tobit estimator that allows for a lower limit of 0 and a variable upper limit $Z_{it}$. Results, not reported here to save space, are very similar to those in Table 2 in terms of coefficient magnitude and significance. This is hardly surprising given that few observations are at the upper limit of $X_{it}$: 4.2% of high endowment observations take value 15 and 14.8% of low endowment observations take value 7.

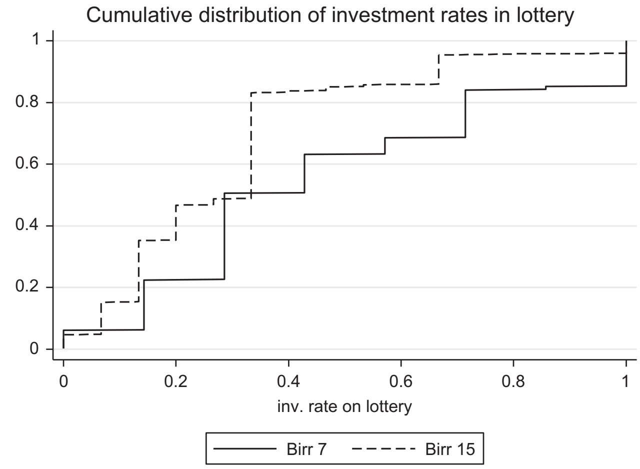


**Fig. 3.** Cumulative distribution of investment rates ($x_{it}$).

**Table 3**
With household assets (the dependent variable is $X_{it}$, the amount invested in the lottery).

| Variables | Round 1 | | | Round 2 | | | Round 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| Accumulated winnings ($W_{it}$) | | | | 0.0765** | 0.0745** | 0.0812 | 0.0919*** | 0.0815*** | 0.0852*** |
| | | | | (0.0295) | (0.0298) | (0.0449) | (0.0128) | (0.0138) | (0.0177) |
| Endowment in round ($Z_{it}$ ) | 0.0598 | 0.0582* | 0.0605* | 0.0775 | 0.0782 | 0.0786 | −0.0585 | −0.0378 | −0.0436 |
| | (0.0343) | (0.0344) | (0.0320) | (0.0666) | (0.0664) | (0.0682) | (0.0368) | (0.0360) | (0.0387) |
| (Log) Assets value ($A_i$) | 0.0181 | 0.0202 | −0.0938 | 0.227 | 0.229 | 0.109 | 0.217 | 0.212 | 0.143 |
| | (0.0837) | (0.0820) | (0.0630) | (0.187) | (0.183) | (0.148) | (0.180) | (0.185) | (0.185) |
| Site dummies | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Afternoon session dummy | No | Yes | Yes | No | Yes | Yes | No | Yes | Yes |
| Individual characteristics | No | No | Yes | No | No | Yes | No | No | Yes |
| Constant | 1.937** | 1.717** | 0.518 | −0.139 | −0.300 | 4.267** | 0.705 | 0.446 | 4.536 |
| | (0.599) | (0.523) | (2.270) | (1.439) | (1.378) | (1.769) | (1.045) | (1.048) | (2.787) |
| Observations | 191 | 191 | 188 | 191 | 191 | 188 | 191 | 191 | 188 |
| $R^2$ | 0.070 | 0.092 | 0.180 | 0.189 | 0.197 | 0.313 | 0.167 | 0.191 | 0.275 |

Robust standard errors clustered by session (or fixed player group) are given in parentheses.
Individual characteristics include female dummy, log(age), dummy=1 if at most primary education, dummy=1 if above primary education, and dummies for Muslim, Protestant, and Catholic.
No education is the omitted education category. Ethiopian orthodox is the omitted religion category.
Addis Ababa sessions are excluded because asset information is missing.
*** $p<0.01$.
** $p<0.05$.
* $p<0.1$.

Next we test integration with household assets as indicated in regression models (3.8) and (3.10). In Table 3 our measure of actual wealth $A_i$ is (the log of) household assets, as measured in a pre-existing household survey. This information is only available for rural subjects. The structure of the regressions is the same as in Table 2. We see that the coefficient of household assets is never statistically significant and remains small in magnitude. To check the robustness of this finding, we reestimate the regressions using for $A_i$ the log of total household expenditures as proxy for permanent income. Results, presented in Table 4, are, if anything, worse: round 1 coefficients now have the wrong sign (but they are not statistically significant). This suggests that, contrary to Andersen et al. (2011) who report a small but significant effect of actual wealth on risk taking, we find no evidence that participants integrate their household assets with winnings from the experiment when choosing how much risk to incur. The coefficient on $Z_{it}$ remains positive, but we lose statistical significance.[26] This is probably due to the smaller size of the sample for which we have external assets.

[26] The $Z_{it}$ coefficients reported in Tables 3 and 4 have $p$-values hovering around 12/13% for round 1, which is just above statistically significant. But they have higher $p$–values in subsequent rounds.

**Table 4**
With household expenditures (the dependent variable is $X_{it}$, endowment invested in the lottery).

| Variables | Round 1 | | | Round 2 | | | Round 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** | **(7)** | **(8)** | **(9)** |
| Accumulated winnings ($W_{it}$) | | | | 0.0836** | 0.0817** | 0.0852* | 0.0886*** | 0.0781*** | 0.0827*** |
| | | | | (0.0265) | (0.0269) | (0.0436) | (0.0116) | (0.0130) | (0.0189) |
| Endowment in round ($Z_{it}$) | 0.0595* | 0.0579* | 0.0593* | 0.0726 | 0.0733 | 0.0759 | −0.0493 | −0.0288 | −0.0376 |
| | (0.0340) | (0.0341) | (0.0316) | (0.0649) | (0.0648) | (0.0664) | (0.0322) | (0.0319) | (0.0410) |
| (Log) Household expenditures | −0.0188 | −0.0212 | −0.0959 | 0.213 | 0.210 | 0.103 | 0.168 | 0.157 | 0.0503 |
| | (0.142) | (0.129) | (0.131) | (0.151) | (0.138) | (0.145) | (0.145) | (0.143) | (0.164) |
| Site dummies | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Afternoon session dummy | No | Yes | Yes | No | Yes | Yes | No | Yes | Yes |
| Individual characteristics | No | No | Yes | No | No | Yes | No | No | Yes |
| Constant | 2.096*** | 1.895*** | 0.322 | 0.599 | 0.459 | 4.513** | 1.537** | 1.282*** | 5.097* |
| | (0.543) | (0.459) | (2.127) | (0.808) | (0.782) | (1.874) | (0.505) | (0.323) | (2.380) |
| Observations | 191 | 191 | 188 | 191 | 191 | 188 | 191 | 191 | 188 |
| $R^2$ | 0.070 | 0.092 | 0.179 | 0.184 | 0.192 | 0.312 | 0.163 | 0.186 | 0.273 |

Robust standard errors clustered by session (or fixed player group) are given in parentheses.
Individual characteristics include female dummy, log(age), dummy = 1 if at most primary education, dummy = 1 if above primary education, and dummies for Muslim, Protestant, and Catholic.
No education is the omitted education category. Ethiopian orthodox is the omitted religion category.
Addis Ababa sessions are excluded because asset information is missing.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

**Table 5**
Social comparisons (the dependent variable is $X_{it}$, the amount invested in the lottery).

| Variables | Round 2 | | | | Round 3 | | | |
|---|---|---|---|---|---|---|---|---|
| | **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** | **(7)** | **(8)** |
| Accumulated winnings ($W_{it}$) | 0.0599*** | 0.0592*** | 0.0630*** | 0.0561 | 0.0585*** | 0.0552*** | 0.0611*** | 0.0700** |
| | (0.0162) | (0.0151) | (0.0149) | (0.0346) | (0.00982) | (0.01000) | (0.0119) | (0.0282) |
| Endowment in round ($Z_{it}$) | 0.101** | 0.101** | 0.103*** | 0.114** | 0.0617 | 0.0650 | 0.0450 | 0.0321 |
| | (0.0383) | (0.0379) | (0.0334) | (0.0532) | (0.0438) | (0.0448) | (0.0329) | (0.0633) |
| Past lottery winnings of others ($G_{-it}$) | 0.158** | 0.130* | 0.125** | 0.254*** | 0.107 | 0.0213 | 0.0264 | −0.0919 |
| | (0.0584) | (0.0635) | (0.0587) | (0.0756) | (0.0672) | (0.0658) | (0.0803) | (0.0946) |
| Own past lottery outcomes ($s_{it}$) | | | | 0.0679 | | | | −0.114 |
| | | | | (0.230) | | | | (0.301) |
| Lottery outcomes of others ($s_{-it}$) | | | | −1.006** | | | | 0.678 |
| | | | | (0.385) | | | | (0.593) |
| Investment of others ($X_{-it}$) | | | | −0.165 | | | | 0.422 |
| | | | | (0.117) | | | | (0.305) |
| Site dummies | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Fixed group and afternoon dummy | No | Yes | Yes | Yes | No | Yes | Yes | Yes |
| Individual characteristics | No | No | Yes | Yes | No | No | Yes | Yes |
| Constant | 2.408*** | 2.971*** | 7.097*** | 6.709*** | 3.060*** | 3.703*** | 7.017*** | 5.387** |
| | (0.607) | (0.735) | (1.547) | (1.436) | (0.758) | (0.660) | (1.989) | (2.234) |
| Observations | 360 | 360 | 351 | 351 | 360 | 360 | 351 | 351 |
| $R^2$ | 0.332 | 0.343 | 0.405 | 0.415 | 0.290 | 0.310 | 0.361 | 0.364 |

Robust standard errors clustered by session (or fixed player group) are given in parentheses.
Individual characteristics include: female dummy, log(age), dummy = 1 if at most primary education, dummy = 1 if above primary education, and dummies for Muslim, Protestant, Catholic, and other religion.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

## 5.2. Social comparisons

Next we turn to social comparisons. We start in Table 5 by estimating Eqs. (3.11) and (3.12):

$$X_{i2} = a_2 + b_2' W_{i1} + b_2 Z_{i2} + \kappa_2 G_{-i1} + u_{i2} \tag{5.3}$$

**Table 6**
Keeping up with the average quadratic form (dependent variable is $x_{it}$, the percentage invested in the lottery).

| Variables | Round 2 | | | Round 3 | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Endowment $Z_{it}$ | $-0.0218^{***}$ | $-0.0228^{***}$ | $-0.0228^{***}$ | $-0.0305^{***}$ | $-0.0308^{***}$ | $-0.0320^{***}$ |
| | (0.00408) | (0.00390) | (0.00439) | (0.00351) | (0.00345) | (0.00371) |
| Past winnings $R_{it}$ | $-0.000675$ | $-0.00128$ | $-0.00178$ | $-0.00199$ | $-0.00239$ | $-0.00287$ |
| | (0.00200) | (0.00193) | (0.00182) | (0.00312) | (0.00321) | (0.00297) |
| Past winnings squared $R_{it}^2$ | 0.000189 | 0.000221 | 0.000182 | 5.43e−05 | 4.53e−05 | 4.36e−05 |
| | (0.000155) | (0.000154) | (0.000151) | (6.61e−05) | (6.88e−05) | (6.68e−05) |
| Site dummies | Yes | Yes | Yes | Yes | Yes | Yes |
| Fixed group and afternoon dummy | No | Yes | Yes | No | Yes | Yes |
| Individual characteristics | No | No | Yes | No | No | Yes |
| Constant | $0.763^{***}$ | $0.814^{***}$ | $1.133^{***}$ | $0.878^{***}$ | $0.884^{***}$ | $1.258^{***}$ |
| | (0.0603) | (0.0578) | (0.171) | (0.0550) | (0.0483) | (0.194) |
| Observations | 360 | 360 | 351 | 360 | 360 | 351 |
| $R^2$ | 0.327 | 0.360 | 0.425 | 0.303 | 0.335 | 0.393 |

Robust standard errors clustered by session (or fixed player group) are given in parentheses.
Individual characteristics include female dummy, log(age), dummy=1 if at most primary education, dummy=1 if above primary education, and dummies for Muslim, Protestant, Catholic, and other religion.
$^{***}p<0.01$, $^{**}p<0.05$, $^{*}p<0.1$.

$$X_{i3}=a_3+b_3'(W_{i1}+W_{i2})+b_3Z_{i3}+\kappa_3G_{-i2}+u_{i3} \tag{5.4}$$

in which $G_{-it}$ represents the past winnings of players who were in $i$'s group in the past:

$$G_{-it}\equiv\sum_{j\in N_{it}}3x_{jt}Z_{jt}r_{jt}$$

If participants seek to keep up with others' winnings, we expect $\kappa_2>0$ and $\kappa_3>0$. As shown in Table 5, coefficient estimates are positive and statistically significant for round 2 but not round 3. Participants increase their own risk taking when others in their round 1 group had large winnings, in line with a simple 'keep-up-with-the-winners' hypothesis where participants take more risk in an effort to catch up with others.

To check that these results are not driven by imitation, gambler's fallacy, or learning from others, we also estimate an extended version of (5.3) and (5.4) that control for the average past investment of peers, and for the proportion of past lottery wins of self and peers. We present in appendix a detailed discussion of these possible confounds and the way we integrate them in our testing strategy. Results, shown in columns 4 and 8 of Table 5, do not change much: coefficient estimates for $\kappa_2$ become larger but remain statistically significant, while those for $\kappa_3$ remain non-significant. The coefficient of the past investment of peers $\overline{X}_{-i,t}$ is non-significant throughout, ruling out imitation. The lottery outcomes of others $s_{-i,t}$ appear with a significant coefficient – but with the wrong sign, something that is difficult to reconcile with learning from others.

Finally we test the 'keeping up with the average' social comparison model (KJ). To this effect, we define relative winnings $R_{it}$ as

$$R_{i1}\equiv\overline{W}_{-i1}-W_{i1}$$

$$R_{i2}\equiv\overline{W}_{-i1}+\overline{W}_{-i2}-W_{i1}-W_{i2}$$

and construct quadratic forms in $R_{it}$ to approximate the V-shaped in Fig. 2. This allows for the possibility that social comparison operates differently depending on whether the participant's past winnings are above or below the average of others. As explained in Section 2, $x_{it}$ is the dependent variable. Keeping up with the average requires a negative linear term and a positive quadratic term.

Estimation of equation (KJ) is presented in Table 6. The coefficient on own endowment $Z_{it}$ is significantly negative throughout, consistent with our earlier results: subjects invest proportionally more in the risky lottery when they receive a low endowment in a round. With respect to social comparisons, joint $F$-tests for $R_{it}$ and $R_{it}^2$ are reported at the bottom of the table together with their significance. Estimated signs are as predicted by KJ – $\beta_1<0$ and $\beta_2>2$ – but coefficients are never individually or jointly significant.

We also estimate model (KW) which is linear in $R_{it}$. If $i$'s reference point is well above the average as in KW, we should only observe the declining portion of Fig. 2. As shown in Table 7, $R_{it}$ has a significantly negative sign in 5 of the 6 regressions

**Table 7**
Keeping up with the average - linear form (dependent variable is $x_{it}$, the percentage invested in the lottery).

| Variables | Round 2 | | | Round 3 | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Endowment ($Z_{it}$) | −0.0220*** | −0.0230*** | −0.0229*** | −0.0312*** | −0.0313*** | −0.0326*** |
| | (0.00406) | (0.00386) | (0.00434) | (0.00328) | (0.00320) | (0.00361) |
| Past winnings ($R_{it}$) | −0.00199 | −0.00281** | −0.00303** | −0.00402*** | −0.00408*** | −0.00450*** |
| | (0.00139) | (0.00121) | (0.00136) | (0.001000) | (0.000961) | (0.00100) |
| Site dummies | Yes | Yes | Yes | Yes | Yes | Yes |
| Fixed group and afternoon dummy | No | Yes | Yes | No | Yes | Yes |
| Individual characteristics | No | No | Yes | No | No | Yes |
| Constant | 0.782*** | 0.835*** | 1.150*** | 0.882*** | 0.888*** | 1.258*** |
| | (0.0686) | (0.0603) | (0.176) | (0.0547) | (0.0477) | (0.193) |
| Observations | 360 | 360 | 351 | 360 | 360 | 351 |
| $R^2$ | 0.324 | 0.356 | 0.422 | 0.302 | 0.335 | 0.392 |

Robust standard errors clustered by session (or fixed player group) are given in parentheses.
Individual characteristics include: female dummy, log(age), dummy = 1 if at most primary education, dummy = 1 if above primary education, and dummies for Muslim, Protestant, Catholic, and other religion.
***p < 0.01, **p < 0.05, *p < 0.1

in linear form, as predicted by KW. Taken together, Tables 6 and 7 thus suggest that subjects want to keep up with *above average* players, that is, with the winners.[27]

### 5.3. Robustness checks

We run a number of robustness checks, detailed in an online Appendix. We show that our results do not change if we include money burning observed in earlier rounds as additional regressor – although this regressor has an independent effect on behavior that is discussed in Kebede and Zizzo (2015). We also reestimate all regressions using a maximum likelihood estimator. OLS regressions reported so far implicitly assume that $X_{it}$ is a continuous variable. In practice, subjects are only allowed a finite set of integer choices. This can be captured by positing a latent continuous variable $X_{it}^*$ and letting $X_{it}$ be a version of $X_{it}^*$ restricted to a finite set of intervals.[28] Results, shown in online appendix Tables A2a–A10a, are very similar to those reported here.

In addition, we investigate whether our results are an artefact of pooling student and rural subjects. To test the validity of pooling, we reestimate all Tables (except 3 and 4, which only apply to rural subjects) with interaction terms between regressors and a student dummy. Results are shown in online appendix Tables A2b–A10b. In the overwhelming majority of cases the interactive terms are not significant: of all the 135 interactive terms in all the regressions, only 12 are significant at the conventional level of 5%. Our conclusions stand even when we control for possible heterogeneity between students and rural subjects.

### 5.4. Replication of the experiment

As a final robustness check, we replicate the experiment with a different subject population, namely with College students at the University of East Anglia (UEA), United Kingdom. We ran 8 sessions of 12 participants each. Subjects are drawn from the pool of student subjects registered with the UEA experimental laboratory. To maximize comparability, the experimental protocol is as close as possible to that used in Ethiopia, and is virtually identical to that of Addis Ababa students. In particular, we use the same pen-and-paper design. The details of the experimental design are the same as those for the Ethiopia sessions.

We took advantage of the replication experiment to take up on a suggestion made by one of the referees and echoed by the editor. In the original experiments, half of the subjects in a group receive an endowment of 7 and the other half received 15. Results show that subjects who receive 7 invest proportionally more than those who receive 15. This finding is hard to explain from expected utility, but can easily be accounted for using prospect theory if subjects have a reference point

[27] Readers familiar with Harrison and Rutstrom (2008) and Andersen et al. (2011) may regret that our approach does not yield an estimate of the coefficient of relative risk aversion $\rho$. It is, however, easy to derive such an estimate from our results. To illustrate, consider the first column of Table 7 and imagine that the coefficients of past winnings $R_{it}$ and current endowment $Z_{it}$ are both zero (which they are not – more about this below). The constant term from the regression 0.782 gives the average investment rate $x$ for student subjects. Using the formula for $x$ at the end of footnote 14, we obtain, e.g., by trial and error, an estimate of $\rho$ equal to 0.281. The problem with this estimate is that the coefficient of $Z_{it}$ is *not* zero, which implies that the coefficient of relative risk aversion is not constant. In other words, the structural assumption behind Harrison and Rutstrom (2008) and Andersen et al. (2011) is rejected in our data, which justifies the use of a more flexible approach.

[28] The same method can also be applied to the model of Harrison and Rustrom (2008), in lieu of the error structure of Luce or Fechner.

**Table 8**
Social comparisons in the UK sample (the dependent variable is $X_{it}$, the amount invested in the lottery).

| Variables | **Round 2** | | **Round 3** | |
|---|---|---|---|---|
| | **(1)** | **(2)** | **(3)** | **(4)** |
| Accumulated winnings ($W_{it}$) | $-0.404^{***}$ | $-0.406^{***}$ | $-0.0212$ | 0.00465 |
| | (0.0816) | (0.0900) | (0.0425) | (0.0429) |
| Past lottery winnings of others ($G_{-it}$) | $0.381^{***}$ | $0.381^{***}$ | $0.114^{**}$ | $0.167^{***}$ |
| | (0.0872) | (0.0876) | (0.0406) | (0.0480) |
| Endowment in round ($Z_{it}$) | $0.506^{***}$ | $0.509^{***}$ | $0.288^{***}$ | $0.219^{***}$ |
| | (0.0892) | (0.0995) | (0.0686) | (0.0756) |
| Own past lottery outcomes ($s_{it}$) | | 0.0207 | | $-0.960^{***}$ |
| | | (0.427) | | (0.274) |
| Session dummies | Yes | Yes | Yes | yes |
| Treatment dummies | Yes | Yes | Yes | yes |
| Constant | 1.104 | 1.107 | 0.487 | 0.305 |
| | (0.923) | (1.01) | (1.178) | (1.236) |
| Observations | 144 | 144 | 144 | 144 |
| $R^2$ | 0.301 | 0.301 | 0.213 | 0.24 |

Robust standard errors clustered at group level are given in parentheses.
$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

situated above 7. What is unclear is whether this high reference point comes from observing other subjects receiving 15 – which could constitute additional evidence of a 'keeping up with the winners' effect.

To test whether the high reference point comes from observing other subjects 'winning' a larger endowment, we introduce two new treatments that only differ in terms of the endowment received at the beginning of each round. In the original experiment 3 subjects receive 7 and 3 others receive 15 (normal treatment). In the two new treatments, all 6 subjects in a group receive the same endowment, i.e., either be 7 (low treatment) or 15 (high treatment). By comparing subjects who receive 7 in a low treatment to those who receive 7 in the normal treatment, we can test whether their investment decisions are the same. If it is, this suggests that the high reference point does not come from observing other subjects receiving 15. For the rest, the experiment is the same as in Ethiopia with one caveat: in 6 of the 8 sessions we omit money burning. The purpose of this omission is to check the robustness of our findings to the absence of money burning. To summarize, treatments are as follows: T1, T2 and T3 are the normal, high, and low treatments, respectively – all without money burning. Treatment T4 is the normal treatment with money burning.

We observe a number of behavioral similarities in the UEA and Ethiopia subject pools. Risk taking $x_{it}$ is higher for subjects who receive 7 than for those who receive 15 across all treatments, and this difference is strongly significant when we compare low and high endowment subjects within treatments T1 and T4: 56% versus 32% with $p$-value$=$0.0000 in T1; and 63% versus 46% with $p$-value of 0.0007 in T4. When we compare low endowment subjects in the normal (T1) and low (T3) treatments, we find virtually identical risk taking $x_{it}$: 56% versus 58% with a $p$-value of 0.64. Similarly, when we compare low endowment subjects in treatments T3 and T4, we find that differences in average risk taking go in the anticipated direction but are not statistically significant: 58% versus 63% with a $p$-value of 0.22. From this we conclude that the endowment received by other players in the group is *not* what drives high reference points.

Some other findings are replicated in the UEA sample. Comparing Table 8 with Table 5, we see that the past lottery winnings of others $G_{-it-1}$ are consistently and positively correlated to the amount invested $X_{it}$ in both rounds. In Table 5, this was not significant for round 3 but now it is highly significant in both rounds. This supports the 'keeping up with the winners' hypothesis. We also find that the coefficient on endowment $Z_{it}$ is positive but less than 1. Results are more disappointing for accumulated winnings $W_{it-1}$: if anything, the effect of past winnings on $X_{it}$ is negative – and statistically significant for round 2. This implies that, among the UEA subjects, we find no evidence of asset integration within the experiment, contrary to what we found in the Ethiopia population.

## 6. Discussion and conclusion

Using data on repeated risk taking in a sequential experiment, we have tested whether participants' behavior follows some commonly hypothesized patterns of behavior. Our key findings can be summarized as follows:

1. *Asset integration with total wealth*: We find *no* evidence of asset integration between the experimental tasks and real world wealth. Participants apply a narrow framing by which they segregate the set of tasks at hand from their outside wealth . This finding provides support to the intuition of much of the literature and, if anything, is particularly strong evidence of narrow framing given that stakes are large relative to participants' normal income and that, unlike Andersen et al. (2011) who find at least some effect, we find no evidence that risk taking responds to wealth.

2. *Asset integration across experimental rounds*: for the Ethiopia sample there is evidence that winnings from earlier rounds raise risk taking in later rounds; for the UK sample the evidence goes in the opposite direction.
3. *High reference point*: Within each round, participants who receive a small endowment risk a higher share of it. This finding is difficult to account for under a reasonable expected utility model. But it can be explained if the aspiration level of low endowment recipients is higher than their endowment. For example, under loss aversion and a high enough reference point (due to this social comparison or otherwise), participants who receive a low endowment may seek to make up for it by risking relatively more than if they had received a high endowment. This finding holds in both the Ethiopia and UK samples.
4. '*Keep up with the winners*': We observe that subjects risk more when other participants they can observe have higher past winnings. We interpret this finding as suggesting that the reference point that subjects use increases in the winnings of others. Hence when others win more, they risk more in an attempt to catch up. This finding holds in both the Ethiopia and UK samples. In Appendix we test and reject the possibility that this may be due to imitation or to gambler's fallacy.
5. '*Keep up with the average*': We only find limited support for it in our experiment. Participants do take more risk when their past winnings are below that of the average of their peers, but not in a way that suggests they regard the *average* winnings of others as reference point. Combined with earlier results, this confirms that participants seek to keep up with winners, but not with the average.

We believe that two of the above results are of particular interest. First, the evidence suggests that participants seek to keep up with the winners. This finding complements existing experimental evidence on social comparisons (e.g., Bault et al., 2008, Linde and Sonnemans, 2012). It highlights the need for further research to ascertain how sensitive social comparisons are to framing and to information about others' earnings.

Second, for the Ethiopia sample – but not the UK sample – we cannot reject full integration of winnings within the experiment. We also find no evidence of asset integration beyond the narrow frame of the experiment. The Ethiopia findings provide some support for Cox and Sadiraj (2006) and Cox et al. (2008) distinction between total wealth and income and confirm the need to separate the two when estimating risk attitude in applied research. They also raise the question of how to interpret models that link risk attitude with overall wealth and income inequality in a population (e.g., Becker et al., 2005; Hopkins and Kornienko, 2010; Hopkins, 2011). One possible interpretation of these models is that economic agents are in a wealth tournament with everyone else in the population. The evidence presented here suggests that this interpretation may be unwarranted, in the sense that agents may not see themselves as part of a tournament involving their overall integrated wealth, but rather of one involving incomes earned in specific micro-decision environments (such as our experiment). More research is needed to ascertain whether our findings generalize outside our experimental setup.

## Appendix A. Possible confounding effects and robustness checks

For the asset integration testing strategy outlined above to be convincing, we need to rule out possible confounding effects. Three possibilities are particularly relevant in our case: learning, imitation, and observed money burning. Fortunately, the structure of the experiment is such that we can test for these effects directly. We also verify that the expectation of money burning does not affect the validity of our asset integration test.

### A.1. Learning

If players revise their priors about winning the lottery based on past experience, winning in early rounds may increase risk taking in subsequent rounds. In the experiment the true winning probability $\alpha$ is 0.5, and this is the probability reported by the experimenter. It is nevertheless possible either that subjects do not believe the experimenter, or that winning makes them feel 'lucky' and lead them to believe that their own 'personal' $\alpha$ is above 0.5 (hot hand effect). In either case, we expect risk taking to increase when the participant won the lottery in earlier rounds, generating a possible confounding effect when testing for asset integration. It is also possible that subjects believe in strong reversion to the mean, in which case having won in the past would lead them to believe the probability of winning again is less than 0.5.

For the above effects, it is the *fact* of winning that is informative about $\alpha$, not how *much* the subject won, which depends on investment $X_{it}$. To capture this idea, let $s_{it}=1$ if $i$ wins in round $t$, $s_{it}=-1$ if $i$ loses in round $t$, and $s_{it}=0$ if $i$ does not risk anything in round $t$, in which case there can be no learning. Identification is achieved because $s_{it}$ is not $i$'s monetary winnings from earlier rounds, but a variable indicating whether $i$ won or lost, irrespective of the risked amount $X_{it}$. If player $i$ increases his/her prior based on winning in earlier rounds, we expect

$$X_{i2}=a_2+b_2'W_{i1}+b_2Z_{i2}+d_2s_{i1}+u_{i2} \tag{6.1}$$

$$X_{i3}=a_3+b_3'(W_{i1}+W_{i2})+b_3Z_{i3}+d_3\left(\frac{s_{i1}+s_{i2}}{2}\right)+u_{i3} \tag{6.2}$$

with $d_2>0$ and $d_3>0$ – and vice versa if participants believe in strong reversion to the mean.

We estimate regressions (A.1) and (A.2) with $s_{i1}$ and $\frac{s_{i1}+s_{i2}}{2}$ included as additional regressors. Results are shown in Table A1. The format is the same as in Table 4 but only rounds 2 and 3 results are shown since it is only in these rounds that learning could have taken place. The coefficients of $s_{i1}$ and $\frac{s_{i1}+s_{i2}}{2}$ are mostly positive and they are statistically significant only in two

**Table A1**
Learning from own past lottery outcomes (the dependent variable is $X_{it}$, the amount invested in the lottery).

| Variables | Round 2 | | | Round 3 | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Accumulated winnings ($W_{it}$) | 0.0535 | 0.0598 | 0.0471 | 0.0689** | 0.0719** | 0.0656** |
| | (0.0384) | (0.0368) | (0.0312) | (0.0281) | (0.0264) | (0.0288) |
| Endowment in round ($Z_{it}$ ) | 0.103* | 0.0962 | 0.116** | 0.0342 | 0.0274 | 0.0335 |
| | (0.0611) | (0.0592) | (0.0490) | (0.0750) | (0.0725) | (0.0650) |
| Own past lottery outcomes ($s_{it}$ ) | −0.0158 | −0.0507 | 0.0744 | −0.127 | −0.237 | −0.0596 |
| | (0.231) | (0.227) | (0.208) | (0.338) | (0.333) | (0.303) |
| Site dummies | Yes | Yes | Yes | Yes | Yes | Yes |
| Fixed group and afternoon dummy | No | Yes | Yes | No | Yes | Yes |
| Individual characteristics | No | No | Yes | No | No | Yes |
| Constant | 3.653*** | 4.109*** | 8.182*** | 3.892*** | 3.829*** | 7.164*** |
| | (0.475) | (0.467) | (1.685) | (0.399) | (0.409) | (1.865) |
| Observations | 360 | 360 | 351 | 360 | 360 | 351 |
| $R^2$ | 0.301 | 0.324 | 0.388 | 0.283 | 0.310 | 0.360 |

Robust standard errors clustered by session (or fixed player group) are given in parentheses.
Individual characteristics include female dummy, log(age), dummy = 1 if at most primary education, dummy = 1 if above primary education, and dummies for Muslim, Protestant, Catholic, and other religion.
No education is the omitted education category. Ethiopian orthodox is the omitted religion category.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

cases. The $b_2'$ coefficient loses its statistical significance, possibly because past lottery outcomes enter the calculation of $\widehat{W}_{i1}$ and $\widehat{W}_{i2}$. To verify this interpretation, we reestimate Table A1 using actual winnings $W_{i1}$ and $W_{i2}$ instead of predicted winnings. With this change, the coefficients of $W_{i1}$ and $W_{i1}+W_{i2}$ become significant again but the coefficients of $s_{i1}$ and $\frac{s_{i1}+s_{i2}}{2}$ remain non-significant. In Table 8, we estimated a similar regression on the UK sample. Here too we find that the coefficients of $s_{i1}$ and $\frac{s_{i1}+s_{i2}}{2}$ are either 0 (in round 2) or significantly negative (in round 3). From these results we conclude that there is no evidence of a hot hand or learning effect.

Players may also revise their priors based on others' lottery outcomes. The logic is the same as above: if players use the fact that others have won to revise their prior about $\alpha$, they will increase risk taking when others win more. To investigate this confounding effect, let $N_{it}$ denote the set of players that were in $i$'s group in round $t$. We estimate

$$X_{i2} = a_2 + b_2' W_{i1} + b_2 Z_{i2} + d_2 s_{i1} + d_2' s_{-i,1} + u_{i2} \tag{6.3}$$

$$X_{i3} = a_3 + b_3'(W_{i1}+W_{i2}) + b_3 Z_{i3} + d_3\left(\frac{s_{i1}+s_{i2}}{2}\right) + d_3' s_{-i,2} + u_{i3} \tag{6.4}$$

where $s_{-i,1} \equiv \frac{\sum_{j \in N_{i1}} s_{j1}}{5}$ and $s_{-i,2} \equiv \frac{\sum_{j \in N_{i2}} s_{j1}+s_{j2}}{10}$. If players revise their prior based on whether others won, we should observe $d_2' > 0$ and $d_3' > 0$, and this can be tested directly since $s_{-i,1}$ and $s_{-i,2}$ are observed by the researcher.[29]

In Table A2 we further test whether participants learn from others using regression models (A.3) and (A.4) which include average past lottery outcomes $s_{-i,t}$ (i.e., proportion of wins) of $i$'s group members in previous rounds. Estimated coefficients are positive in all cases, but never statistically significant. Perhaps this is not too surprising since in Table A5 we found no evidence of learning from one's own past observations.

## A.2. Imitation

Another possible confounding effect arises if players imitate the investment behavior of others. As discussed in the introduction, there are various reasons why players may seek to imitate what others do, such as mimicry, social pressure, or economizing on problem solving.[30] When others invest more, they will, on average, have higher winnings since investment has a positive return. Hence imitating others could generate a correlation between others' winnings and investment that is not due to a keeping-up effect.

[29] If there is learning and players regard others' outcomes as equally informative to their own, we should observe $d_2 = \frac{d_2'}{5}$ and $d_3 = \frac{d_3'}{5}$. This is because $d_2'$ is the coefficient of the average outcome of five other players, and thus should carry five times as much weight as $i$'s own outcome if players regard others' outcomes as informative as their own. In contrast, if player $i$ only cares about own past winnings because they signal good luck, we should observe $d_2' = d_3' = 0$ since, in this case, whether others win contains no information about $i$'s probability of winning.

[30] Indirect learning is unlikely since by design players observe (almost) all the information other players have, and can be controlled for directly through $s_{-i,1}$ and $s_{-i,2}$, as in (A.3) and (A.4). The only exception is in games when players are rematched into different groups in each round. In this case, other players have information from round 1 groups which is revealed in their round 2 behavior – and could influence play in round 3. To allow for this possibility, we estimate round 2 and round 3 imitation effects separately:

**Table A2**
Learning from others (the dependent variable is $X_{it}$, the amount invested in the lottery).

| Variables | Round 2 | | | Round 3 | | |
|---|---|---|---|---|---|---|
| | **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** |
| Accumulated winnings ($W_{it}$) | 0.0605 | 0.0667** | 0.0506 | 0.0680** | 0.0715** | 0.0653** |
| | (0.0365) | (0.0340) | (0.0313) | (0.0270) | (0.0259) | (0.0289) |
| Endowment in round ($Z_{it}$ ) | 0.0942 | 0.0875 | 0.111** | 0.0359 | 0.0283 | 0.0343 |
| | (0.0608) | (0.0584) | (0.0509) | (0.0726) | (0.0713) | (0.0648) |
| Own past lottery outcomes ($s_{it}$) | −0.0589 | −0.0934 | 0.0527 | −0.136 | −0.238 | −0.0603 |
| | (0.219) | (0.213) | (0.212) | (0.335) | (0.330) | (0.299) |
| Lottery outcomes of others ($s_{-it}$) | 0.281 | 0.279 | 0.146 | 0.465 | 0.184 | 0.146 |
| | (0.314) | (0.305) | (0.275) | (0.469) | (0.454) | (0.483) |
| Site dummies | Yes | Yes | Yes | Yes | Yes | Yes |
| Fixed group and afternoon dummy | No | Yes | Yes | No | Yes | Yes |
| Individual characteristics | No | No | Yes | No | No | Yes |
| Constant | 3.665*** | 4.123*** | 8.238*** | 3.923*** | 3.849*** | 7.237*** |
| | (0.483) | (0.473) | (1.684) | (0.402) | (0.429) | (1.798) |
| Observations | 360 | 360 | 351 | 360 | 360 | 351 |
| $R^2$ | 0.303 | 0.326 | 0.388 | 0.285 | 0.311 | 0.361 |

Robust standard errors clustered by session (or fixed player group) are given in parentheses.
Individual characteristics include female dummy, log(age), dummy=1 if at most primary education, dummy=1 if above primary education, and dummies for Muslim, Protestant, Catholic, and other religion.
*** $p<0.01$.
** $p<0.05$.
** $p<0.1$.

To illustrate, let us expand the utility function to include a concern $\mu$ for imitation, e.g.,

$$U_i\left(\sum_{s=1}^{t} W_{is}\right)+\mu|X_{it}-\overline{X}_{-i,t-1}|$$

where $\mu$ is an imitation preference parameter, and $\overline{X}_{-i,t-1}$ denotes the average risk taking behavior of others in the group, as revealed by previous rounds, i.e.

$$\overline{X}_{-i,t} \equiv \sum_{j \in N_{it}} \sum_{s=1}^{t} \frac{1}{5t} X_{js}$$

Players with this utility function adjust their risk taking behavior to imitate that of others, i.e., so that their $X_{it}$ is close to $\overline{X}_{-i,t-1}$. This can be investigated using a regression of the form[31]

$$X_{i2}=a_2+b_2'W_{i1}+b_2Z_{i2}+\mu_2\overline{X}_{-i,1}+u_{i2}$$
$$X_{i3}=a_3+b_3'(W_{i1}+W_{i2})+b_3Z_{i3}+\mu_3\overline{X}_{-i,2}+u_{i3}$$

with $\mu_2>0$ and $\mu_3>0$.

To disentangle imitation from learning, we can control for learning directly as in (6.3) and (6.4) by including $s_{-i,1}$ and $s_{-i,2}$:

$$X_{i2}=a_2+b_2'W_{i1}+b_2Z_{i2}+\mu_2\overline{X}_{-i,1}+\gamma_2 s_{-i,1}+u_{i2} \tag{6.5}$$

$$X_{i3}=a_3+b_3'(W_{i1}+W_{i2})+b_3Z_{i3}+\mu_3\overline{X}_{-i,2}+\gamma_3 s_{-i,2}+u_{i3} \tag{6.6}$$

If there is imitation but no learning, once we control for $\overline{X}_{-i,1}$ or $\overline{X}_{-i,2}$, whether others won or not should not matter: we expect $\mu_2>0$ and $\mu_3>0$ but $\gamma_2=\gamma_3=0$. In contrast, if participants imitate others because of what their behavior reveals about the probability of winning $\alpha$, we expect $\gamma_2>0$ and $\gamma_3>0$ as in (6.3) and (6.4).

In Table A3 we estimate regressions (6.5) and (6.6) to test whether participants imitate the average investment behavior $\overline{X}_{-i,t}$ of other players they have observed, controlling for learning from others through $s_{-i,t}$. We find a positive coefficient on the past investment of other players in $i$'s group, but the coefficient is only statistically significant in round 2. We again find that $s_{-i,t}$ is seldom statistically significant – in one case it is significant at 5% and in another at 10%. From this we conclude that there is some evidence that participants imitate the risk taking behavior of others and that this imitation cannot be understood as driven by learning about the odds of winning the lottery. Other results on $b_2$, $b_2'$, $b_3$ and $b_3'$ are unchanged.

[31] $\overline{X}_{-i,1}=\frac{1}{5}\sum_{j \in N_{i1}} X_{j,1}$ $\overline{X}_{-i,2}=\frac{1}{10}\left(\sum_{j \in N_{i1}} X_{j,1}+\sum_{j \in N_{i2}} X_{j,2}\right)$

**Table A3**
Imitation versus learning from others (the dependent variable is $X_{it}$, the amount invested in the lottery).

| Variables | Round 2 | | | Round 3 | | |
|---|---|---|---|---|---|---|
| | **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** |
| Accumulated winnings ($W_{it}$) | 0.0536*** | 0.0534*** | 0.0581*** | 0.0595*** | 0.0552*** | 0.0617*** |
| | (0.0176) | (0.0160) | (0.0153) | (0.00980) | (0.00946) | (0.0115) |
| Endowment in round ($Z_{it}$ ) | 0.111** | 0.106** | 0.110*** | 0.0651 | 0.0660 | 0.0510 |
| | (0.0410) | (0.0394) | (0.0350) | (0.0454) | (0.0457) | (0.0346) |
| Lottery outcomes of others ($s_{-it}$) | 0.303 | 0.280 | 0.175 | 0.460 | 0.194 | 0.187 |
| | (0.284) | (0.296) | (0.262) | (0.441) | (0.454) | (0.493) |
| Investment of others ($X_{-it}$) | 0.300** | 0.137 | 0.238 | 0.368* | 0.0703 | 0.276 |
| | (0.115) | (0.150) | (0.145) | (0.193) | (0.200) | (0.276) |
| Site dummies | Yes | Yes | Yes | Yes | Yes | Yes |
| Fixed group and afternoon dummy | No | Yes | Yes | No | Yes | Yes |
| Individual characteristics | No | No | Yes | No | No | Yes |
| Constant | 1.909** | 3.243*** | 6.617*** | 1.800 | 3.459** | 5.534** |
| | (0.796) | (1.098) | (1.499) | (1.417) | (1.367) | (2.168) |
| Observations | 360 | 360 | 351 | 360 | 360 | 351 |
| $R^2$ | 0.317 | 0.328 | 0.394 | 0.293 | 0.311 | 0.363 |

Robust standard errors clustered by session (or fixed player group) are given in parentheses.
Individual characteristics include female dummy, log(age), dummy = 1 if at most primary education, dummy = 1 if above primary education, and dummies for Muslim, Protestant, Catholic, and other religion.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

## Appendix B. Additional material for online appendix

### B.1. Money burning

The experiment allows participants to ‘burn’, that is, destroy other subject's winnings at the end of each round. Money burning may be used by participants, among other possible purposes, to discourage deviant risk taking behavior. If so, participants whose winnings have been ‘burned’ in a previous round may be discouraged to invest, generating a negative correlation between risk taking and past exposure to money burning. Because money burning reduces winnings, it also generates the possibility of a spurious correlation between $W_{i1}$ and $W_{i2}$ and risk taking: victims of money burning have lower winnings, and take less risk because they have been chastised.

Although money burning is fairly infrequent (see Kebede and Zizzo, 2015), we deal with this possible confound by re-estimating all regressions with a dummy controlling for whether subject $i$ has experienced money burning in an earlier round. To this effect, we include a dummy that takes value 1 if the subject has experienced money burning in an earlier round. Although this regressor is mostly 0, if it is correlated with other regressors, it may influence our findings. We reestimate all regressions presented in Tables 2–10 with this dummy as additional control. We do find that having personally experienced money burning has a negative effect on risk taking that is statistically significant in some regressions (e.g., Kebede and Zizzo, 2015). But other results do not change. The possibility of money burning in the experiment may however have influenced social comparisons in ways that are difficult to predict. This observation should be kept in mind when assessing the external validity of our findings.

Another concern is whether an *expectation* of money burning may alter inference about asset integration. This point is distinct from having experienced money burning because subjects may expect money burning even if it seldom takes place. To investigate this possibility, let $\gamma$ be the expected after-money-burning return on endowment and investment.[32] In the absence of asset integration, the decision problem becomes

$$\max_{0 \le x_t \le 1} \frac{1}{2} U(\gamma Z_t(1-x_t)) + \frac{1}{2} U(\gamma Z_t(1+2x_t))$$

where $0 \le \gamma \le 1$ by experimental design. It is immediately clear if relative risk aversion is constant, the addition of $\gamma$ does not change anything: $x$ still does not depend on $Z$ or $\gamma$ because they both cancel out of the first order condition.[33] Eq. (3.2)

[32] Although the experimental design allows subjects to apply a different money burning rate on net endowments $Z-X$ and investment return $Y$, (Kebede and Zizzo, 2015) cannot reject the hypothesis that the rate of money burning is the same on $Z-X$ and $Y$.
[33] To demonstrate, assume CRRA as before and let $U(c) = \frac{c^{1-r}}{1-r}$. The first order condition now is: $\frac{1}{2}(\gamma Z)^{1-r}\left[-(1-x)^{-r} + 2(1+2x)^{-r}\right] = 0$ where $\gamma Z$ factors out, as before.

becomes

$$X_{it} = a + b\gamma Z_{it} + u_{it}$$

which implies that, as long as $\gamma > 0$, the coefficient of $Z_{it}$ should be positive.

In the presence of asset integration, (3.3) becomes

$$\max_{0 \le X_3 \le Z_3} \frac{1}{2} U(W_1 + W_2 + \gamma Z_3 - \gamma X_3) + \frac{1}{2} U(W_1 + W_2 + \gamma Z_3 + 2\gamma X_3)$$

where $\gamma$ only applies to the current round since the experiment does not allow subjects to burn winnings from earlier rounds. The corresponding estimating equation for asset integration is

$$\begin{aligned} X_{i3} &= a_3 + b_3(W_{i1} + W_{i2} + \gamma Z_{i3}) + u_{i3} \\ &= a_3 + b_3'(W_{i1} + W_{i2}) + \gamma b_3 Z_{i3} + u_{i3} \end{aligned}$$

Given that $\gamma \le 1$, it follows that, in the presence of full asset integration, the coefficient of $W_{i1} + W_{i2}$ should equal $1/\gamma$ times the coefficient on $Z_{i3}$. In other words, $b_3'$ should be, if anything, larger/more positive than the coefficient of $Z_{i3}$. A similar reasoning applies to (3.7).

In Table 2 we find that $b_2'$ is indeed larger than the coefficient of $Z_{i2}$ although we cannot reject that they are equal. In contrast, $b_3'$ is in general smaller than the coefficient of $Z_{i3}$. In subsequent tables, no clear pattern emerges in the Ethiopia experiment. In the replication experiment, we can compare risk taking in T1 (no money burning) and T4 (money burning). If the expectation of money burning works as a tax on earnings, we expect less risk taking in T4. This is not what we find: if anything, average risk taking is larger in T4 (54%) than in T1 (44%).

## Appendix C. Supplementary data

Supplementary data associated with this paper can be found in the online version at http://dx.doi.org/10.1016/j.euroecorev.2015.07.001.

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