Journal of Economic Behavior & Organization 128 (2016) 134–148

Contents lists available at ScienceDirect

Journal of Economic Behavior & Organization

journal homepage: www.elsevier.com/locate/jebo

Lab and life: Does risky choice behaviour observed in experiments reflect that in the real world?☆

Arjan Verschoor*, Ben D'Exelle, Borja Perez-Viana

School of International Development, University of East Anglia, United Kingdom

ARTICLE INFO

Article history:
Received 30 April 2015
Received in revised form 9 May 2016
Accepted 11 May 2016
Available online 27 May 2016

JEL classification:
C18
C93
D03
D81
O13
Q12

Keywords:
Risk preferences
Experimental methodology
External validity
Choice bracketing
Agricultural investment

ABSTRACT

Risk preferences play a crucial role in a great variety of economic decisions. Measuring risk preferences reliably is therefore an important challenge. In this paper we ask the question whether risk preferences observed in economic experiments reflect real-life risky choice behaviour. We investigate in a sample representative for a rural region of eastern Uganda whether pursuing farming strategies with both a higher expected profit and greater variance of profits is associated with willingness to take risks in an experiment. Controlling for other determinants of risk-taking in agriculture, we find that risky choice behaviour in the experiment is correlated with risky choice behaviour in real life in one domain, i.e. the purchase of fertiliser, but not in other domains, i.e. the growing of cash crops and market-orientation more broadly. Our findings suggest that economic experiments may be good at capturing real-world risky choice behaviour that is narrowly bracketed.

1. Introduction

For adoption of new technologies and thereby economic growth to take place in society, risky investments need to be undertaken. Reward for risk-taking typically comes in the form of a higher return on investment, which is necessary to induce risk-averse investors to put up with larger variation in possible outcomes. One component of research on risky investment decisions is therefore the appropriate measurement of risk aversion, for which economic experiments are often used.[1] The idea is that by stripping away from real-life investment all incidental features, so that only the pure decision task of trading off variation against return remains, risk aversion can be observed in isolation and therefore measured precisely. The assumption is that risk preferences observed in the lab reflect those in real life.

☆ We thank Joshua Balungira and his team at The Field Lab in eastern Uganda for excellent assistance in collecting the data and gratefully acknowledge joint funding from the UK's ESRC and DFID (Grant ES/J008893/1).

* Corresponding author at: School of International Development, University of East Anglia, Norwich NR4 7TJ, United Kingdom. Tel.: +44 01603 592806; fax: +44 01603 451999.

E-mail address: a.verschoor@uea.ac.uk (A. Verschoor).

[1] See Harrison and Rutström (2008) and Charness et al. (2013) for recent surveys.

http://dx.doi.org/10.1016/j.jebo.2016.05.009
0167-2681/

We test this assumption using a lab-in-the-field experiment. For a representative sample from a farming region in eastern Uganda, we examine whether subjects' risk-taking in a Gneezy and Potters (1997) type investment game is associated with their risk-taking in agriculture. Farmers, more than most other groups in society, are used to dealing with uncertainty in their livelihoods decisions due to the numerous factors that cause fluctuations in yields and in the prices of inputs and outputs: the weather, pests, soil fertility, and so forth. Farmers' attitudes to risk have been extensively studied in lab-in-the-field experiments, both in developed and in developing countries.[2] We consider livelihoods decisions that in developed countries would probably not be considered as risk-taking in agriculture: fertiliser purchase and commercialisation more broadly. However, as we show in the paper, in our context, the decisions we consider, which increase participation in inputs and outputs markets, raise both the expected value and the variance of profits compared to the traditional, semi-subsistence agriculture that is still common in the region.[3]

The Achilles' heel of any research that links real-life and experimental behaviour is the potential influence of confounding factors, which gets at the heart of why we do experiments in the first place. If this risk could be eliminated, there would strictly speaking not be any need for experiments, so it needs instead to be minimised as best one can. We have attempted to do so by selecting an area that is homogeneous in terms of culture and agricultural conditions and practices, so that these do not represent confounding factors. Moreover, to minimise the risk of omitted variables bias, we control in the econometric analysis for the other factors that previous literature on risk-taking in agriculture in sub-Saharan Africa identifies as determinants (Heltberg and Tarp, 2002; Knight et al., 2003; Vargas Hill, 2009); we collected data on these variables through a tailor-made questionnaire.

We selected through implementing a multistage cluster sampling design, a representative sample of 1803 farmers: among all of these the questionnaire was administered (including a hypothetical investment question) and a randomly selected 872 participated in the investment game (the second number is lower than the first for reasons of resources). Controlling for other determinants of risk-taking in agriculture, we find that risk-taking in the experiment is associated with the relatively straightforward investment decision of fertiliser purchase. However, for more involved livelihoods strategies that call not only on willingness to take risks but also on other attributes of entrepreneurship, viz. moving away from subsistence farming to growing crops for the market (measured in two alternative ways), we find no evidence of an association with risk-taking in the experiment. By contrast, a hypothetical willingness to take large-scale risks, elicited through a questionnaire, is associated with both fertiliser purchase and growing crops for the market (however measured), suggesting that this is a better proxy for entrepreneurship broadly defined.

We see our main contribution to the literature as follows. We link risk-taking investment in the lab to risk-taking investment in real life: unlike in previous studies, both the expected value and variance of profits are greater in the risky alternatives than in the safe one, in the real-life application and in the experiments. We show that this holds for the agricultural investment measures we consider compared to the traditional agriculture that is still common in the study area. We thus see the main contribution of our paper as comparing real-life and lab behaviour that *a priori* is expected to be similar.

To the best of our knowledge, previous studies do not compare risk-taking behaviour in the lab and in real life in which the expected value and the variance of profits are greater in *both* situations. Strictly speaking, like is therefore not compared with like. Whereas variance of profits and expected profits are always greater in the risky option in the lab, this does not tend to be the case in the real-world behaviour that it is compared with, in previous studies.

Sometimes, the real-world behaviour compared with risky choice in the lab is behaviour that is unsafe but does not unambiguously have a higher expected value than the safe alternative: gambling (Lejuez et al., 2003; Hardeweg et al., 2013), cigarette smoking and heavy drinking (Anderson and Mellor, 2008), or the consumption of food that entails a health risk (Lusk and Coble, 2005). In other studies, risky choice in the lab is linked to real-world technology adoption that reduces the variance of profits: Bt cotton by Chinese farmers (Liu, 2013) or GM corn and GM soy by Midwestern grain farmers in the USA (Barham et al., 2014). In yet other studies, the real-world behaviours studied have ambiguous effects: Chinese farmers' (often excessive) use of pesticides (Liu and Huang, 2013) and self-employment in rural Thailand (Hardeweg et al., 2013) may reduce both the expected value and the variance of outcomes, increase both, or reduce one and increase the other.

Instead, we consider *risk-taking investment* both in the experiment and in real life. We see our main contribution as linking experimental and real-world behaviours that are conceptually comparable: for taking risk, a higher expected return is offered both in the lab and in life. Our advantage on previous studies is thus that we do not compare risk-taking investment in the lab with gambling, unsafe behaviour or risk-reducing investment: the absence of a correlation in such comparisons does not reliably inform us whether the behaviour in the lab conforms to that in real life, since the behaviours are not strictly speaking comparable. For example, there is no good reason why somebody willing to take risk for the sake of a higher return

[2] Examples include farmers in Chile (Henrich and McElreath, 2002), China (Liu, 2013), Ethiopia (Humphrey and Verschoor, 2004b; Yesuf and Bluffstone, 2009; Harrison et al., 2010), France (Reynaud and Couture, 2012), India (Binswanger, 1980, 1981; Humphrey and Verschoor, 2004b; Harrison et al., 2010), Tanzania (Henrich and McElreath, 2002), Thailand (Hardeweg et al., 2013), Uganda (Humphrey and Verschoor, 2004a; Harrison et al., 2010; Tanaka and Munro, 2014), the USA (Herberich and List, 2012) and Vietnam (Tanaka et al., 2010).

[3] Consistent with what we show for Ugandan farmers, Duo et al. (2008, p. 486) show for Kenyan farmers that buying fertiliser is profitable on average but leaves them worse off in some circumstances. Studies of risk-taking in agriculture in developing countries often focus on reliance on the market for inputs or outputs: see e.g. Engle-Warnick et al. (2007), Heltberg and Tarp (2002), Knight et al. (2003) and Vargas Hill (2009).

should *ceteris paribus* also be prone to gambling, or eating unsafe foods. By instead considering comparable behaviours, we test the external validity of the experimental measure.[4]

A second contribution of our paper is that we have a large, representative sample in which there is considerable variation in the real-life behaviour of interest (itself rare in papers of this kind). Importantly, the agricultural investment behaviour we study has the potential to get semi-subsistence farmers out of poverty (Dercon and Christiaensen, 2011), by taking the sort of risk that we also study experimentally. We thus have a comparison of experimental and real-life behaviour that is not only conceptually tight (both are risk-taking investment) but also involves tremendously important behaviour: the type that can help poor farmers escape from poverty.

A third contribution is our conceptual framework, which uses the choice bracketing concept developed by Read et al. (1999) and elaborated in Rabin and Weizsäcker (2009). We show that choice bracketing helps to see when risk-taking investment behaviour could be different in the lab and real life. The term choice bracket refers to the decisions that are considered together by the decision maker. When a real-world behaviour and a lab behaviour are compared, the assumption is that both are narrowly bracketed, i.e. are not considered together with other decisions. If that assumption is violated, then the comparison is no longer valid. For instance, if the risky choice decision in the lab is considered in isolation by the decision maker, but the real-world risky choice decision is not, then we should not necessarily expect similar behaviour in the lab and in real life.

A fourth contribution is the comparison of the performance of hypothetical and experimental measures of risk attitudes in explaining real-world investment behaviour. The hypotetical measure we consider involves larger stakes and captures losses, which experimental measures are limited in capturing.

The remainder of the paper is laid out as follows. Section 2 presents the relevant theoretical considerations and implications for the empirical strategy. In economic theory, the finding of correspondence between risky choice behaviour in real life and an experiment is not self-evident. As we explain in this section, the narrow bracketing of both the real-world and experimental decisions compared in the research (i.e. the decision-maker does not consider their consequences together with the consequences of other decisions) needs to be assumed for a correspondence between the manifestations of risky choice to be expected. Section 3 describes the methods of data collection and the main variables used in the analysis. Section 4 contains descriptive statistics, spearman correlations between real-world, hypothetical and experimental measures of risk preferences, and regression analysis of the real-world measures on the experimental and hypothetical measures, as well as any potentially confounding variables that we have data on. Section 5 discusses the findings of the paper and concludes. As we argue there, when a correspondence is found, as in our case, between experimental and real-life decision-making in some but not in other domains, then dissimilar choice bracketing across domains provides a possible explanation.

2. Theoretical considerations and empirical strategy

Under which conditions would risky choice in an experiment reflect risky choice in real life? First, as discussed in the introduction, like must be compared with like. We focus on real-world risky choice that, like in the experiment we organised, is between options in which a higher expected value of profits always comes at the cost of a higher variance. In order to show that this is the case, we compute expected and variance of profits in accordance with price, yield and costs scenarios based on information provided to us by the agricultural extension officers and other experts that advise the farmers in our sampling area (see Section 3.3).

Second, the choice bracket that the decision-maker applies should be such that the comparison of real-world and experimental behaviour remains valid. For example, if the real-world investment behaviour is part of (unobserved) portfolio management, then the comparison is no longer valid. The term choice bracket refers to the group of choices whose consequences are considered together by the decision-maker (Read et al., 1999). For *prima facie* comparable experimental and real-world choices, if both are *narrowly bracketed*, then the comparison remains valid. To make this point precisely, we adopt the notation and definition of narrow bracketing of Rabin and Weizsäcker (2009, p. 1511). A decision-maker who faces I different choice sets $M_1, \ldots, M_I$ is a narrow bracketer if she considers each choice set in isolation. A choice $m_i \in M_i$ is thus made through evaluating the resulting probability distribution $L_i(x_i|m_i)$ over changes in wealth $x_i \in \mathbb{R}$, but not through evaluating the distribution $F(x^I|\mathbf{m})$ over the sum of wealth changes $x^I = \Sigma_i x_i$ resulting from the vector of choices $\mathbf{m} = (m_1, \ldots, m_I)$.

[4] A number of recent studies have examined the internal validity of experimental methods for eliciting risk preferences, addressing the issue of whether they reliably measure what they ought to measure, through examining inconsistent risk preferences and through considering the stability of risk preferences across experimental set-ups (Dave et al., 2010; Charness and Viceisza, 2012; Reynaud and Couture, 2012). Others have looked at the stability of risk preferences between experimental and questionnaire elicitation methods (Anderson and Mellor, 2009; Lonnqvist et al., 2011), and using questionnaires, between domains of real life (Maccrimmon and Wehrung, 1990; Weber et al., 2002; Hanoch et al., 2006) and between variously framed questions and domains of real life (Dohmen et al., 2011). Our study looks instead at the stability of risk preferences between experiments and real life and is thus a test of the external validity of the experimental method for eliciting risk preferences. Indirect clues of external validity have been implicitly achieved in studies that link experimental risk preferences with subject characteristics that in turn are known to be associated with differential real-world risk-taking: gender (Charness and Gneezy, 2012), higher levels of masculinity (Apicella et al., 2008) and poverty (Tanaka et al., 2010) provide some examples. Direct validation is preferable because it avoids the confounding influence of these mediating characteristics.

Without loss of generality, we can call M_1 the choice set generated by the experiment, $M_2, \ldots, M_I$ the choice sets faced in real life, and M_2 the choice set that forms the basis of the comparison of real-world and experimental risk preferences. If the analyst uses m_1 and m_2 for assessing, respectively, experimental and real-world risk preferences when M_1 and/or M_2 are not narrowly bracketed, then the comparison is no longer necessarily valid. To see this, suppose that M_1 is narrowly bracketed but M_2 is not.[5] In that case, m_1 derives from evaluating $L_1(x_1|m_1)$; and m_2 derives, not from $L_2(x_2|m_2)$, which would be required for a valid comparison, but from the summed distribution that results from including some or all of $m_3, \ldots, m_I$, depending on how broad the choice bracket is. An example relevant in our context would be the growing of a cash crop, more risky than traditional agriculture when considered in isolation, as part of a livelihoods diversification strategy, so for purposes of risk management. In that example, an assessment of risk preferences focused on m_2 alone would underestimate risk aversion and invalidate the comparison with experimentally assessed risk preferences.

For risky choice in experiments to reflect real-life risky choice, narrow bracketing thus needs to hold in both domains. Decision-making pertaining to the latter should proceed in a piecemeal, one-at-a-time fashion, in which changes to wealth, rather than wealth levels, are considered as the carriers of utility. The major theories of choice in economics differ in terms of how they view decision-making in this respect and therefore in their implications for the correspondence between experimental and real-world risky choice. In expected utility theory, risk aversion captured by the concavity of the utility function of wealth would be invisible in the lab, because of the small stakes involved (Rabin, 2000); in prospect theory, which only considers changes to wealth relative to a reference level, correspondence between the two domains is assured provided both are narrowly bracketed (cf. Thaler, 1999); and in the reference-dependent utility theory developed by Köszegi and Rabin (2006, 2007), which marries expected utility theory and prospect theory and in which utility thus derives both from changes to and from levels of wealth, correspondence between the two should be partial and greater the more the former (so-called gain-loss utility) counts for decision-making compared to the latter (consumption utility). In the face of varying theoretical support, a test of the hypothesis that risky choice in experiments reflects that in real life needs to maintain the assumption of narrow bracketing in both choice sets that give rise to the behaviours compared in the analysis.

The third condition that needs to be met for risky choice in experiments to reflect risky choice in real life is that determinants of the latter other than but correlated with risk preferences are controlled for. We selected a representative sample from a culturally, economically, ecologically and agriculturally homogeneous area, and administered a questionnaire among experimental participants designed to measure both risky agricultural investment comprehensively and the factors that previous studies have identified as its major determinants (see Section 3.4). We thus minimise the risk of omitted variables bias through avoiding intra-sample variation in contextual confounds and through controlling in regression analysis for the known co-determinants of our real-world risky choice variables.

If these conditions are met, then we should have a valid test of whether risk preferences are stable across the two domains considered: an experiment and real-life agricultural investment. In short, our empirical strategy is as follows. We select a representative sample from a population consisting of people similar in customs and livelihoods, observe risky choice behaviour in agriculture and its potential determinants among them, and observe their risky choice behaviour in an experiment. We specify a value function over experimental earnings in order to measure risk aversion and, controlling for other factors, regress risk-taking in agriculture variables on this risk aversion measure.

If this test fails to detect stable risk preferences, then dissimilar bracketing in the domains considered is a possible explanation. This could happen if, for instance, the experimental day is a natural bracket, but individual agricultural investment decisions are considered as part of a diversified portfolio.

3. Methods and data

In this section we describe our research site, our main variables of interest and how we collected data on these.

3.1. Study area

We selected a representative sample of 1803 farmers from a rural area in eastern Uganda: Sironko District and Lower Bulambuli District, which together comprise the former Sironko District; for details on sample selection, see Section 3.5. This area has a current estimated population size of about 300,000, most of whom are from the Bagisu ethnic group (and if not, have adopted their customs), and a total land area of 1270 km^2.[6] About 95 percent of people are primarily engaged in own-account crop farming, with the remainder typically growing crops as a secondary activity in addition to salaried employment. Average land holdings are about 1.5 acres, there are very few big farmers in the region, and irrigation use is low. The key distinction between farmers of interest to this paper is that between those who stick to traditional semi-subsistence farming and those who have become more market-oriented, in one form or another. The former mostly grow maize intercropped with

5 A bracket can of course be narrower than the choice set generated by the experiment, i.e. individual experimental decisions may be considered separately even when presented together, for which ample evidence exists (e.g. Tversky and Kahneman, 1981; Camerer, 1989; Battalio et al., 1990; Redelmeier and Tversky, 1992; Rabin and Weizsäcker, 2009).

6 The information presented in this paragraph is taken from the District Local Government Five Year District Development Plans (2010/11–2014/15) for Sironko and Bulambuli.

beans and often, on a very small scale, some coffee and bananas; the food crops are primarily for their own consumption, but a small proportion of the harvest may be sold, as is the coffee. Reliance on bought agricultural inputs is minimal among these semi-subsistence farmers. The more market-oriented farmers rely for their farming more on bought inputs such as improved seeds, pesticides and fertiliser, would hire labour during peak seasons, and grow, in addition to the crops mentioned, more lucrative but input-intensive crops such as cabbages, tomatoes, onions and aubergines. This typology is fairly crude and in reality reliance on markets for inputs and/or outputs takes place along a continuum. As described below, we made use of expert advice to convert the distinction outlined between livelihoods strategies into variables that capture risk-taking in agriculture. In this section, we describe how we collected data on our main variables of interest.

3.2. Elicitation of risk preferences in the experiment

In previous risky choice experiments in developing countries, four main methods have been used for measuring risk aversion. We piloted three of these, each among 20 subjects: the Gneezy and Potters (1997) method, which is an investment game; the Eckel and Grossman (2002) method, an ordered lottery selection design that is itself an adaptation of the classic Binswanger (1980, 1981) design; and the multiple price list method due to Holt and Laury (2002).[7] Unlike previous studies of risk preferences among subjects with little formal education (Dave et al., 2010; Charness and Viceisza, 2012), we found comprehension of the Holt and Laury method to be good, but it required cumbersome implementation. The other two methods were both easy to implement and well understood by pilot subjects. We chose the Gneezy and Potters method because it readily accommodates a larger array of choices, and therefore a narrower range of risk aversion corresponding with each choice, than the Eckel and Grossman method. The other reason we preferred it over the other two is that the decision subjects are asked to take may readily be framed as an investment decision, which allows for a natural comparison with the real-life behaviours we consider.[8]

In our design, subjects are endowed with 20 counters, each representing 400 shillings, so 8000 shillings in total, or about twice average daily earnings in the area. They choose to invest k counters, where $k \in \{0, 1, \ldots, 20\}$ for facing the lottery $(0.5, 8000 - 400k\,; 0.5, 8000 + 800k)$. In other words, their investment is tripled if successful and lost in its entirety if it fails.[9] The fate of their investment is determined by tossing a coin. Experimental instructions are simple and easy to follow (see Appendix A).

We assume a power Constant Relative Risk Aversion (CRRA) utility function over experimental earnings x, which is defined as $U(x) = x^{1-r}/(1-r)$, where r is the coefficient of CRRA. As is conventional, we compute the CRRA coefficient for indifference between investing k and $k-1$, on the one hand, and k and $k+1$ on the other, to find the CRRA coefficient range that corresponds with the observed behaviour of investing k.

The advantage of this measure is that it is incentivised, the disadvantage that it is for small stakes and does not involve real losses, unlike real-life investment. We therefore also asked subjects a hypothetical investment question, adapted from Dohmen et al. (2005, p. 18), about their willingness to invest $y \in \{ 0, 20{,}000, 40{,}000, 60{,}000, 80{,}000, 100{,}000 \}$ in an asset that yields a return of 100 percent if successful and minus 50 percent if a failure, with equal probability. Subjects chose one of six decision cards on which the two outcomes of a possible choice were clearly displayed.

It is possible to compute a CRRA coefficient for the responses to the hypothetical investment question in the same way as for choices made in the experiment, but because we cannot observe loss aversion, we prefer to treat them as an ordinal measure of risk aversion.

3.3. Measuring risk-taking agricultural investment

A measure of risk-taking agricultural investment that suits the aim of this study should capture investment that raises both the expected value and the variability of outcomes, compared to traditional agriculture. Purchasing fertiliser is the iconic example. Although profitable on average, in some circumstances such as critically low output prices or a harvest failure due to

[7] The Binswanger/Eckel and Grossman method has been used by Binswanger (1980, 1981) in India, Barr and Genicot (2008) in Zimbabwe, Yesuf and Bluffstone (2009) in Ethiopia, Attanasio et al. (2012) in Colombia, Cardenas and Carpenter (2013) in six Latin American cities, and by Lahno et al. (2015) and D'Exelle and Verschoor (2015) in Uganda. The Holt and Laury (2002) method has been used by Tanaka and Munro (2014) in Uganda and Hardeweg et al. (2013) in Thailand. In a methodological study in Senegal, the Holt and Laury (2002) method is compared with the Gneezy and Potters (1997) method by Charness and Viceisza (2012); they find comprehension of the former to be poor and propose the latter as an elegant alternative for subjects with low levels of formal education. A fourth method, eliciting the certainty equivalent value of gambles, has given rise to puzzling results in developing country contexts. It is used by Barr and Packard (2002, 2005) who find less risk aversion to be associated with higher contributions to the pension system in Chile but lower in Peru. Henrich and McElreath (2002) in Chile and Tanzania use the method and find that subsistence farmers are risk loving on average (contrary to all other studies). Rather than taking these puzzling findings at face value, it may be wiser to take them as pointing to possible unreliability of the method. It may not be realistic to expect subjects with low levels of education to reveal risk preferences in this way, which requires considerable numerical skills.

[8] A drawback of the Gneezy and Potters method is that it does not allow for the measurement of risk-loving attitudes. Since our purpose is to compare risk aversion in the lab and in real life, this drawback is not relevant for us.

[9] The rate of return on investment was calibrated during the pilot for inducing variation in behaviour, and the probabilities of success and failure were equalised to avoid the confound of probability weighting (Charness and Gneezy, 2010).

Table 1
Main variables used in the analysis.

Variable	Measurement
Fertiliser	Household (HH) purchased fertiliser in past 5 years (dummy)
Cash crops	HH grows cash crops using appropriate inputs (dummy)
Output sold	Proportion of agricultural output sold by the HH
Risk aversion (game)	CRRA coefficient inferred from investment behaviour in experiment
Risk aversion (q'aire)	Hypothetical willingness to invest (1 to most risk averse 6)
Wealth	First principal component in a PCA of the HH's assets
Credit constrained	HH wanted to borrow in the past 2 years but could not (dummy)
Female	Participant is female (dummy)
Age	Participant's age in years
Years of education	Participant's years of education
Own workforce	Number of HH members aged 15–69 working on own farm
Off-farm employment	Any HH member is in paid employment (dummy)
Agricultural extension	Advised by agricultural extension officer in the past 2 years (dummy)
Access to information	HH possesses means for obtaining market information (dummy)
Distance to market	Distance to the nearest daily market in hours

drought, it may leave the farmer worse off than had they not bought it (Duflo et al., 2008, p. 486).[10] In our sample area, about 65 percent of farmers have recently bought fertiliser (see Table 2), so we use in addition the more discriminating measure of whether or not a farmer grows cash crops *and* purchases the appropriate inputs. Based on individual interviews with 29 experts in the study area, we identified cash crops to be tomatoes, onions, cabbages, egg plants (aubergines) and coffee, and the inputs to be improved seeds/seedlings, fertiliser and pesticides. Following expert advice, we say that a farmer is engaged in risk-taking agricultural investment if he or she grows any of these crops using all of these purchased inputs.[11] In previous studies, measures of risk-taking agricultural investment have included whether or not a farmer grows a modern crop (Liu, 2013; Engle-Warnick et al., 2007), or uses any modern agricultural input (Knight et al., 2003), but key informants warned us that such strategies are common in the area among largely traditional farmers who otherwise adopt a safety-first livelihoods strategy while on a small scale trying their luck. By contrast, the combination of cash crops and the appropriate purchased inputs indicates a livelihoods strategy that substantially deviates from traditional agriculture, in their view. Yet, to deal with the possibility that cash crops are grown on a small scale, we also measure degree of crop market participation. Because of heterogeneous risk preferences, as well as transaction costs, rationally choosing farmers, who attempt to attenuate the welfare effects of price shocks, differ in their degree of market participation (Barrett, 2008). We compute the proportion of the harvest that is sold or intended to be sold and use this as our measure of the individual farmer's degree of crop market participation (Heltberg and Tarp, 2002).[12]

We collected data on the extra investment required, compared to traditional farming, for each of the farming strategies that we call risk-taking in agriculture, as well as on price and yield fluctuations in the past 10 years for each of the crops concerned, in order to assess how the expected value and variance of profits of each of these strategies compare to semi-subsistence farming. The figures resulting from these computations are presented in Appendix B and show that each of these strategies leads in terms of profits to worse worst outcomes, better best outcomes, a higher expected value and a larger variance than does semi-subsistence farming, and are thus indeed riskier than traditional farming in the same way that investing in our experimental investment game is riskier than not investing.

3.4. Wealth and other control variables

In order to detect the role of risk preferences in risk-taking agricultural investment, we control in the econometric analysis for the factors that co-determine such investment. Some of these may correlate with risk preferences, and omitting them may bias the estimated effect of risk preferences. The selection of control variables is based on previous literature, to which we refer for a full rationale for their inclusion (Knight et al., 2003; Vargas Hill, 2009; Heltberg and Tarp, 2002). The variables are listed and described in Table 1. Broadly speaking, these can be divided into knowledge of and access to investment opportunities (*Female*, *Age*, *Years of education* and *Agricultural extension*), to markets (*Access to information* and *Distance to market*) and to resources, including self-insurance (*Wealth*, *Credit constrained*, *Own workforce* and *Off-farm employment*). In the context of rural Uganda, the importance of wealth for influencing investment behaviour stems from incomplete insurance and credit markets; assets are necessary for absorbing price and yield shocks, and as collateral for loans (Vargas Hill, 2009,

[10] In addition, the return on fertiliser is often lower than it could be because a sub-optimal amount is being applied (Conley and Udry, 2010). We show in the appendix that even when an optimal amount is applied, purchasing fertiliser is a risky choice decision in the sense defined above: a higher return on average but also greater variance in returns.

[11] With the exception of coffee, for which experts deemed one of (a) buying fertiliser and (b) hiring labour to be on its own sufficient evidence of risk-taking investment, whether or not other inputs are bought. Cf. Vargas Hill (2009) who uses labour allocated to coffee as an indicator of Ugandan farmers' risk-taking behaviour.

[12] When a farmer grows multiple crops, we use for this computation the local price of each crop that prevailed in the period when the bulk of the harvest was sold in order to convert output quantities into monetary values.

Table 2
Summary statistics.

Variable	Abbreviation	Obs	Mean	Std. dev.	Min	Max
Fertiliser	fertiliser	1776	0.65	0.48	0	1
Cash crops	cash_crops	1776	0.31	0.46	0	1
Output sold	outp_sld	1765	0.52	0.31	0	1
Risk aversion (game)	risk_aver_g	872	1.70	2.68	0.13	14.97
Risk aversion (q'aire)	risk_aver_q	1803	2.37	1.52	1	6
Wealth	wealth	1803	−0.03	2.20	−2.69	20.12
Credit constrained	credit_cons	1776	0.55	0.50	0	1
Female	female	1803	0.49	0.50	0	1
Age	age	1803	40.27	13.74	18	73
Years of education	yeduc	1803	5.53	3.43	0	13
Own workforce	work_f_farm	1803	2.31	1.21	0	8
Off-farm employment	off-farm	1803	0.18	0.38	0	1
Agricultural extension	cont_aes	1803	0.39	0.49	0	1
Access to information	info_asset	1803	0.77	0.42	0	1
Distance to market	dist_mkt	1803	0.39	0.61	0	3

Computed using sampling weights.

p. 159). The method we use for computing a wealth index is based on a principal component analysis of the household's assets and due to Filmer and Pritchett (2001). Details of twenty-seven asset types were included in the broad categories household's dwelling, durable consumer goods, vehicles, farm buildings and equipment, land, and livestock.

3.5. *Fieldwork implementation*

Sample selection took place during June–August and data collection during September–December 2012. We randomly selected 10 sub-counties, and within each sub-county 10 villages, so 100 villages in total. In each village, we organised the compilation of a list of all adult (18+) members by household and randomly selected up to 20 adults (some villages had fewer than 20 eligible adults) subject to the constraint of no more than one participant per household. We ensured that both devising the sampling frame and the random selection process were witnessed by a broad representation of village members, to encourage trust in the fairness of the selection process. We assessed availability of the randomly selected individuals and randomly replaced them if necessary (in 5.9 percent of cases). Data collection followed the same basic pattern in each sub-county. In the week before 'game day' we visited all selected participants to administer a household survey questionnaire. The experiment then took place at the end of the week in a central location (usually in a school on a non-school day); for participants from remote villages, we organised transport.

4. Results

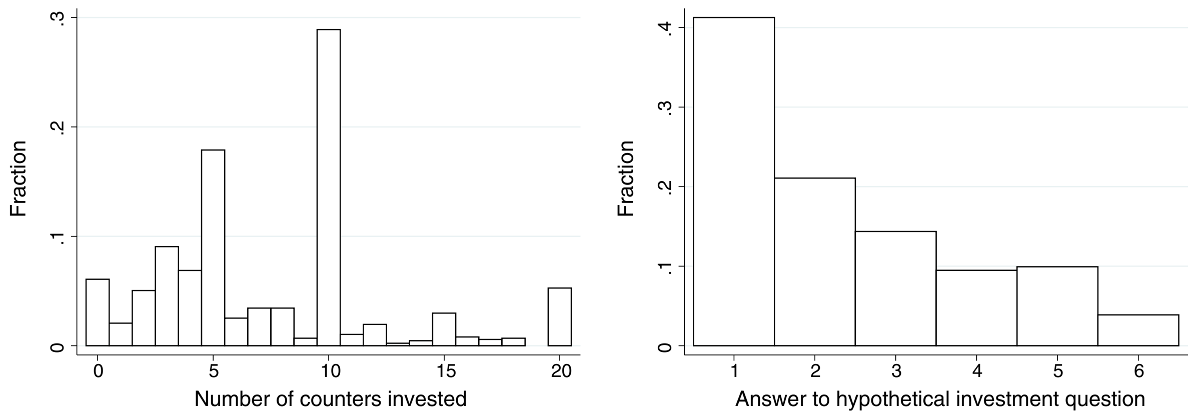
4.1. *Summary statistics and spearman correlations*

Table 2 presents summary statistics of the main variables used in the analysis. The figures presented here have been computed using sampling weights that reflect the multistage cluster sampling described above. They are therefore unbiased estimates of population statistics in the study area.

As mentioned, an estimated 65 percent of the population has purchased fertiliser in the past five years. According to the more restrictive measure, growing cash crops with recommended inputs, 31 percent of the population are risk-takers in their investment behaviour. In terms of constraints on such investment, it is worth noting that 55 percent say they had wanted to borrow in the past two years but could not. Our alternative measure of risk-taking in agriculture, crop market participation, indicates that on average 52 percent of the harvest is sold or intended to be sold.

All of our respondents answered the hypothetical investment question, whereas those in a randomly selected five sub-counties (872 individuals) also participated in the investment game described above. Risk aversion is much higher in the game. The mean CRRA coefficient equals 1.70, whereas it is 1.06 according to the hypothetical question (the table reports the mean of the ordinal measure instead, which we prefer to use in the analysis; see Section 3.2). A paired two-sided *t*-test, restricted to those for whom we have both measures, shows that the mean CRRA coefficient is significantly higher in the game than in the questionnaire ($t = 6.91$; $p = 0.0000$). A comparison of median figures suggests the same. Median investment in the game is 6/20 counters (cf. Fig. 1a). By contrast, median investment in the questionnaire is option 2; 62.3 percent choose option 1 or 2, i.e. invest 80,000 or the maximum 100,000 (see Fig. 1b).

In Table 3, spearman rank correlation coefficients are reported for the variables that are the focus of the analysis. There are four patterns worth drawing attention to. First, the hypothesis that incentivised and hypothetical risk aversion are independent cannot be rejected at the 10 percent level. Second, wealth is not significantly correlated with either of these measures. Third, experimentally incentivised risk aversion is not significantly correlated with risk-taking in agriculture on any measure, whereas hypothetical risk aversion is significantly correlated with all three measures, and so, to a much greater



(a) Counters invested in game (b) Hypothetical willingness to invest

Fig. 1. Investment in the experiment and hypothetically.

Table 3
Spearman rank correlation coefficients.

	Fertiliser	Cash crops	Output sold	Risk aversion game	Risk aversion (q'aire)	Wealth
Fertiliser	1					
Cash crops	0.4101	1				
	(0.0000)					
Output sold	0.2713	0.4441	1			
	(0.0000)	(0.0000)				
Risk aversion (game)	0.0099	0.016	0.0106	1		
	(0.7710)	(0.6390)	(0.7565)			
Risk aversion (q'aire)	−0.0788	−0.0971	−0.104	0.0548	1	
	(0.0208)	(0.0044)	(0.0023)	(0.1082)		
Wealth	0.2867	0.2666	0.3268	−0.0185	−0.0415	1
	(0.0000)	(0.0000)	(0.0000)	(0.5874)	(0.2240)	

p-Values of test of independence.

degree, is wealth. Fourth, all three measures of risk-taking in agriculture are strongly correlated with each other. The overall suggestion is that wealth strongly and risk aversion weakly matters for risk-taking in agriculture; and that experiments are a poor method for capturing the relevant risk aversion. However, potentially important confounds such as credit constraints need to be controlled for before we can draw any firm conclusions.

4.2. Regression analysis

Tables 4–6 report regression analysis of the three measures of risk-taking in agriculture. We restrict the analysis to those who are decision makers about their households' farms. For each measure, six models are presented. The key independent variable in the first two models is risk aversion (the coefficient of CRRA) according to behaviour in the investment game in the experiment; that in the next four models hypothetical risk aversion: an ordinal measure from 1 to 6, with 6 being the most risk averse, representing the six options in our hypothetical investment question. For both risk aversion measures, we first present a model in which wealth is the only household-level control, and next a model that includes the full set of controls. Because the incentivised risk aversion measure was obtained for a sub-sample, columns 5 and 6 present models in which the performance of the hypothetical risk aversion measure is tested in that same restricted sample. All models presented control for village-level fixed effects.

Strikingly, experimentally measured risk aversion is only significant in the fertiliser regressions, whereas hypothetical risk aversion is significant in regressions for all three measures. This result tends to be robust to adding control variables and to restricting the sample. The finding that risk aversion obtained through a questionnaire is a good all-round predictor of real-life caution in various domains echoes that of Dohmen et al. (2011). It is interesting that investment behaviour in the game only significantly predicts real-life behaviour that is 'most like it'. The decision to buy fertiliser is a straightforward investment decision that raises both the expected profit and the spread of possible profits within an existing livelihoods strategy (cf. Section 3.3), which resembles the one-dimensional investment decision subjects are asked to take in the laboratory. Decisions to grow cash crops or to grow for the market more broadly, on the other hand, are complex, multi-dimensional decisions that invoke not only risk preferences but also the nebulous notion of entrepreneurship. Section 5 offers some reflections

Table 4
Probit regression of fertiliser purchase.

	(1)	(2)	(3)	(4)	(5)	(6)
Risk aversion (game)	−0.0485***	−0.0493***				
	(0.0172)	(0.0171)				
Risk aversion (q'aire)			−0.0990***	−0.0623**	−0.115***	−0.0758**
			(0.0237)	(0.0249)	(0.0325)	(0.0345)
Wealth	0.218***	0.147***	0.199***	0.123***	0.212***	0.141***
	(0.0335)	(0.0388)	(0.0234)	(0.0258)	(0.0330)	(0.0382)
Credit constrained		−0.235**		−0.252***		−0.222**
		(0.106)		(0.0776)		(0.105)
Female		−0.0944		−0.104		−0.0768
		(0.112)		(0.0783)		(0.112)
Years of education		0.0123		0.00177		0.0125
		(0.0178)		(0.0126)		(0.0178)
Age		−0.0161***		−0.0127***		−0.0150***
		(0.00403)		(0.00286)		(0.00400)
Own workforce		0.0547		0.0384		0.0503
		(0.0435)		(0.0327)		(0.0440)
Off-farm employment		−0.0876		−0.175*		−0.0761
		(0.144)		(0.102)		(0.144)
Agricultural extension		0.248**		0.261***		0.221**
		(0.110)		(0.0804)		(0.111)
Access to information		0.383***		0.418***		0.418***
		(0.135)		(0.0983)		(0.134)
Distance to market		0.143		0.0232		0.164
		(0.254)		(0.176)		(0.254)
Constant	1.124*	0.485	0.245	0.473	1.410**	0.564
	(0.625)	(0.504)	(0.448)	(0.406)	(0.656)	(0.503)
Observations	830	816	1582	1561	842	828
Wald χ^2	168.30	215.34	354.68	424.72	179.44	220.77
$Prob > \chi^2$	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Pseudo R^2	0.219	0.263	0.224	0.261	0.225	0.263

Dependent variable: fertiliser.
Maximum likelihood probit estimation; marginal probability effects reported.
Standard errors in parentheses, corrected for heteroskedasticity using the sandwich estimator of variance.
Controls included but not reported are dummies for village (all models), and for various recent shocks (models 2, 4, 6).
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

on why hypothetical risk aversion might capture the latter type of decisions better than risk aversion in a lab-in-the-field experiment.

The discrepancy between the simple correlation analysis reported above, which returns an insignificant spearman correlation coefficient between fertiliser purchase and experimental risk aversion, and the multiple regression analysis reported here, in which the relationship is robustly significant, strongly suggests the importance of controlling for potentially confounding factors. Although not the focus of this paper, the performance of the control variables is worth briefly pointing out. Wealth, which as mentioned in Section 3.4 is expected to matter in a context of incomplete credit and insurance markets, is very highly significant in all regressions.[13] Being credit-constrained, as well as having had dealings with an agricultural extension officer, matters for fertiliser purchase, but not robustly so for the other risk-taking-in-agriculture measures, whereas being female matters for these other ones, but not for buying fertiliser. In this context, domestic responsibilities, as well as limited access to networks through which knowledge of and resources for investment opportunities are obtained, are known to impede women's involvement in lucrative agriculture (FOWODE, 2012). The contrast between the significance of the coefficient on the female dummy in the regressions for growing cash crops/any crops for the market on the one hand, and its non-significance in fertiliser regressions on the other, is in line with this contextual information: when access to finance is controlled for, women are not less likely to take the relatively straightforward decision to buy fertiliser, but are less likely to embark on livelihoods strategies that require access to various resources (including labour in peak time), complex information and considerable time. Finally, having the means to obtain market information is significant throughout, the older invest less, formal education never matters, and nor (in this context) do the other controls suggested by the literature.

[13] In theory, wealth could be a determinant of risk aversion. However, because we cannot reject independence of wealth and risk aversion (see Section 4.1), we take wealth to be a straightforward proxy for the means available for financing investment, important in context given incomplete insurance and credit markets (see Section 3.4).

Table 5
Probit regression of growing cash crops with recommended inputs.

	(1)	(2)	(3)	(4)	(5)	(6)
Risk aversion (game)	−0.000839	0.00418				
	(0.0189)	(0.0210)				
Risk aversion (q'aire)			−0.0926***	−0.0526**	−0.109***	−0.0683*
			(0.0244)	(0.0260)	(0.0361)	(0.0391)
Wealth	0.215***	0.199***	0.192***	0.143***	0.206***	0.187***
	(0.0299)	(0.0377)	(0.0217)	(0.0265)	(0.0298)	(0.0371)
Credit constrained		0.121		−0.0489		0.111
		(0.117)		(0.0768)		(0.116)
Female		−0.566***		−0.442***		−0.521***
		(0.120)		(0.0764)		(0.118)
Years of education		0.0121		0.0152		0.0141
		(0.0198)		(0.0132)		(0.0196)
Age		−0.0178***		−0.0134***		−0.0151***
		(0.00451)		(0.00298)		(0.00447)
Own workforce		−0.0108		0.0103		−0.0165
		(0.0519)		(0.0333)		(0.0509)
Off-farm employment		0.0124		−0.0549		0.0112
		(0.152)		(0.101)		(0.149)
Agricultural extension		0.0929		0.164**		0.0825
		(0.119)		(0.0772)		(0.118)
Access to information		0.442***		0.396***		0.468***
		(0.171)		(0.109)		(0.171)
Distance to market		−0.00482		−0.237		−0.00838
		(0.263)		(0.182)		(0.264)
Constant	−0.452	−0.648	−0.352	−0.948*	−0.845	−0.672
	(0.567)	(0.534)	(0.513)	(0.493)	(0.642)	(0.528)
Observations	780	768	1673	1650	791	779
Wald χ^2	128.08	178.23	297.95	376.59	136.02	175.55
$Prob > \chi^2$	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Pseudo R^2	0.178	0.250	0.188	0.236	0.179	0.241

Dependent variable: cash_crops.
Maximum likelihood probit estimation; marginal probability effects reported.
Standard errors in parentheses, corrected for heteroskedasticity using the sandwich estimator of variance.
Controls included but not reported are dummies for village (all models), and for various recent shocks (models 2, 4, 6).
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

4.3. Robustness checks and additional analyses

We performed three additional analyses in order to check the robustness of our main results and to gain insights into the factors responsible for the difference in explanatory power of hypothetical and experimental risk aversion.[14] We summarise these here.[15]

First, we investigated whether the heaped nature of the investment choices in the experiment exerts an influence: observe the relative frequency of 0, 5, 10, 15 and 20 counters in Fig. 1a. Mimicking responses to the hypothetical question, we grouped experimental responses into six categories: 0–3, 4–7, 8–11, 12–14, 15–17 and 18–20 counters invested. We then tested the joint significance of the dummies representing these categories and found exactly the same pattern of significance as across Tables 4–6.

Second, we investigated whether converting responses to the hypothetical investment question into CRRA matters for the performance of hypothetical risk attitudes in the regressions. If so, this could give a clue about the role of loss aversion, since loss aversion is captured by the ordinal variable representing the hypothetical risk attitudes but not by the CRRA. We found that hypothetical CRRA is significant in the fertiliser regression but not in the other two. Looking at Table A1, it can be seen that the probability of losses, as well as their average magnitude, is much smaller for fertiliser than for growing cash crops. This suggests that for explaining the latter, risk attitudes need to include loss aversion.

Third, we investigated the influence of the stringency of our classification of farmers as risk-takers in their investment behaviour, in Table 5. We loosened the classification to include all farmers who grow cash crops, whether or not the recommended inputs are used. We found the same pattern of significance as in Table 5.

[14] We also investigated and dismissed the possibility of multicollinearity by regressing our risk aversion measures on the (other) regressors in our main analyses reported in Tables 4–6.
[15] We are grateful to an anonymous reviewer for suggesting these three analyses.

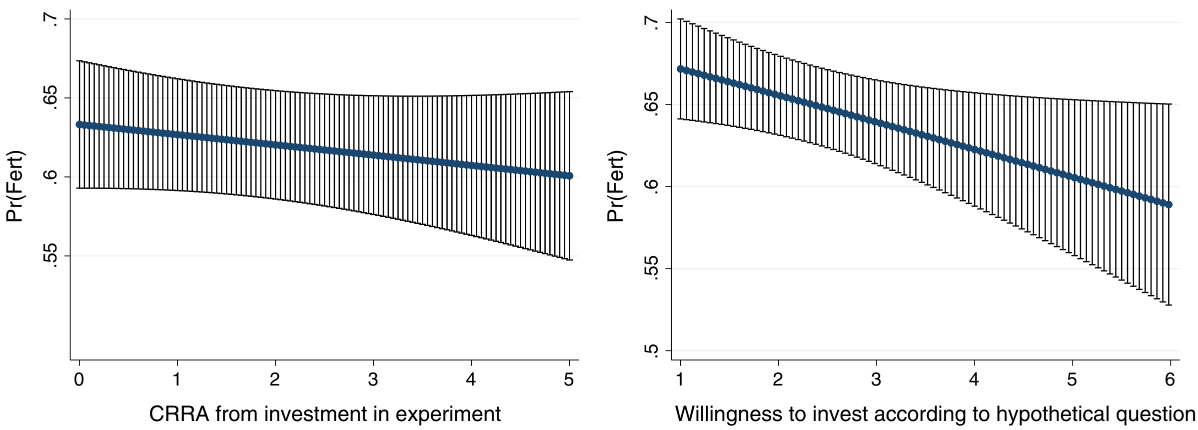
Table 6
Tobit regression of proportion of harvest grown for the market.

	(1)	(2)	(3)	(4)	(5)	(6)
Risk aversion (game)	−0.0000633	0.000528				
	(0.00404)	(0.00378)				
Risk aversion (q'aire)			−0.0177***	−0.00773	−0.0265***	−0.0172**
			(0.00593)	(0.00568)	(0.00804)	(0.00778)
Wealth	0.0434***	0.0346***	0.0402***	0.0275***	0.0426***	0.0341***
	(0.00597)	(0.00673)	(0.00388)	(0.00431)	(0.00577)	(0.00655)
Credit constrained		−0.0192		−0.0413**		−0.0167
		(0.0231)		(0.0173)		(0.0231)
Female		−0.111***		−0.118***		−0.106***
		(0.0234)		(0.0174)		(0.0234)
Years of education		0.00424		0.00368		0.00474
		(0.00404)		(0.00294)		(0.00404)
Age		−0.00198**		−0.00155**		−0.00163*
		(0.000901)		(0.000675)		(0.000915)
Own workforce		−0.00929		−0.0140*		−0.0106
		(0.00958)		(0.00721)		(0.00965)
Off-farm employment		−0.00821		−0.0126		−0.00785
		(0.0314)		(0.0228)		(0.0314)
Agricultural extension		0.0309		0.0388**		0.0261
		(0.0241)		(0.0171)		(0.0240)
Access to information		0.120***		0.124***		0.120***
		(0.0327)		(0.0244)		(0.0327)
Distance to market		−0.0883		−0.445		−0.108
		(0.177)		(0.279)		(0.176)
Constant	0.480***	0.380**	0.693***	0.797***	0.550***	0.422**
	(0.105)	(0.177)	(0.0786)	(0.105)	(0.104)	(0.175)
Observations	848	834	1736	1711	848	834
Pseudo R^2	0.182	0.265	0.162	0.231	0.195	0.271

Dependent variable: outp_sld.
Standard errors in parentheses, corrected for heteroskedasticity using the sandwich estimator of variance.
Controls included but not reported are dummies for village (all models), and for various recent shocks (models 2, 4, 6).
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

4.4. Predicted probability of fertiliser purchase

Risk preferences measured in a field experiment are thus not associated with agricultural livelihoods strategies that through commercialisation seek higher profits while allowing greater variation in net revenues: growing cash crops with the appropriate purchased inputs, and growing for the market more generally. For the one decision for which they matter, we next assess their quantitative importance. Fig. 2a and b plot predicted probabilities of fertiliser purchase along the actual range of incentivised risk aversion (using estimated coefficients of model 1 in Table 4) and hypothetical risk aversion (model 3



(a) By experimental risk aversion (b) By hypothetical risk aversion

Fig. 2. Predicted fertiliser purchase (with 95 CIs).

in Table 4), fixing other covariates at their means.[16] For incentivised risk aversion, when we move along the CRRA coefficient range from one extreme to the other, the predicted probability of fertiliser purchase drops from 63.5 to 60 percent. For hypothetical risk aversion, the least risk averse are 67 percent likely to buy fertiliser, the most risk averse 58.5 percent. Risk aversion, however measured, thus plays a modest but non-trivial role in this particular real-world investment decision.

5. Discussion and conclusions

A challenge for studies of this kind, in which experimental behaviour is compared with that in life, is to identify close-enough real-world analogues. For a region in which self-sufficiency in farming is still common, we took real-world risk-taking to be various modes of engagement with markets for inputs and/or outputs. We ensured that the real-world risk-taking considered offers both a higher expected value and higher variance than safer alternatives and minimised the potential role of confounding factors by selecting a representative sample from a homogeneous area, while controlling in regression analysis for wealth and other co-determinants of investment decisions. Experimentally measured risk aversion, once other relevant factors are controlled for, is significantly associated with fertiliser purchase, but not with more involved risk-taking in agriculture. Whereas fertiliser purchase does not necessitate much engagement with market forces—it can be like dipping a toe in the water—our other measures are about *embracing* market participation. One measure we considered is whether farmers grow lucrative cash crops that require for their success a range of purchased inputs; and the other measures degree of participation in output markets. In contrast to our experimental measure, a hypothetical willingness to take risks is associated with all our measures of real-world risk-taking.

We interpret our findings as follows. First, both experimental risky choice and fertiliser purchase may well be narrowly bracketed decisions, and comparable behaviour to be expected. It is plausible that fertiliser purchase, which can be combined if the farmer so wishes with traditional agriculture, is a separately considered decision, whereas embracing market participation, compared to traditional semi-subsistence agriculture, involves a radical overhaul, so is more likely to be a broadly bracketed decision, considered as part of an overall livelihoods strategy. Fertiliser purchase, like risk-taking in the investment game, is a straightforward investment that can be applied on a modest scale; in both cases, once the 'rules of the game' are understood, it is easy to see that a higher expected return is offered in exchange for larger variance. Throughout their careers, farmers in our study area will take the decision whether or not to apply fertiliser a large number of times. A farmer who is the primary decision maker on his or her farm for, say, 35 years, will take this decision two seasons/year times 35 years equals 70 times. Each time the decision is taken, the likelihood of a financial loss is about 10 percent (implied by the figures in Table A1) which by a farmer operating close to a subsistence threshold may well be considered to be a serious risk. However, the rate of return on investment on fertiliser per season is 117 percent (for comparison: the typical interest rate for an agricultural loan is about 45 percent per season), and the likelihood that summed over 70 seasons a loss results is negligible. A series of identical independent gambles yielding an attractive amalgamated gamble should render each of the individual gambles attractive, unless psychological or other factors are at work that cause the decision-maker to consider the gambles in isolation. Since fertiliser use is far from universal, this suggests narrow bracketing. The near-universal risk aversion in the investment game is suggestive of the same (cf. Section 2).

Second, there is also the possibility that heterogeneous risk preferences help explain why experimentally measured risk aversion is not associated with more involved real-life risk-taking, the growing of crops for the market by farmers whose comparatively safe alternative is subsistence agriculture. Perhaps it helps to think of such risk-taking farmers as entrepreneurs: prepared to orient their 'business strategy' towards exposure to market forces (Barrett, 2008). There is some evidence that the relationship between entrepreneurship and risk preferences is not straightforward. In one study, part-time entrepreneurs were found to be more risk averse (experimentally measured) than non-entrepreneurs, whereas full-time entrepreneurs were less risk averse than either group (Elston et al., 2005), suggesting that unobserved heterogeneity may help explain the absence of a link in our sample between a market orientation in real life and experimental risk-taking.

Third, the discrepancy in correspondence between experimental and various real-life domains of decision-making also suggests domain-specific risk-taking, which is in line with existing evidence. Using the likelihood to engage in various risky behaviours, elicited through questionnaires, Hanoch et al. (2006) show that individuals who engage in recreational risks (e.g. gambling) do not necessarily take more risk than others in other domains. It is thus conceivable that those more prone to recreational gambling or similar thrill-seeking behaviour are *ceteris paribus* less risk averse in the experiment, but not less risk averse in (all) their livelihoods strategies. Likewise, for all we know, entrepreneurs could be relatively risk-seeking in strategic decisions and relatively cautious in operational ones, the latter of which are more closely mimicked in the experiment. The general point is that experimental risk-taking appears to be a poor proxy for entrepreneurship and that there are good reasons why that might be the case.

By contrast, the hypothetical willingness to invest is significantly associated with all three risk-taking-in-agriculture measures.[17] As explained in Section 4.3, this could hint at the role of loss aversion, since the hypothetical investment measure involves not only larger stakes but also losses. At the same time, we cannot reject independence of experimental and

[16] Using any of the other models gives very similar results. For reasons of exposition, Fig. 2a does not show a CRRA coefficient higher than 5; it thereby excludes 6.3 percent of subjects.

[17] Maccrimmon and Wehrung (1990) report similar findings for business executives.

hypothetical willingness to invest.[18] Moreover, in our sample risk aversion is considerably higher in the experiment than in response to the hypothetical question. As in Holt and Laury (2002)'s seminal study, subjects in our sample display considerably less risk aversion in hypothetical, high pay-off risky choice problems than when confronted with the moderate pay-offs of a lab experiment. Since the response to the hypothetical question nonetheless predicts all real-life risk-taking, it is likely to capture a broader predisposition than risk preferences alone, such as entrepreneurship, a readiness to engage with market forces.

The evidence we find for domain-specific risk-taking is of course not at odds with a choice-bracketing explanation: dissimilar bracketing across domains can help explain diverse risky choice behaviour (cf. Thaler, 1999). The general lesson we take from our study is that an experiment may be good at capturing risky choice behaviour in those realms of real life that are 'quite like it': where narrow bracketing is to be expected. The risk preferences revealed in this way are not absent from other domains but invisible because of broader choice brackets.

Appendix A. Experimental instructions (abbreviated)

[Welcome and general introduction and instructions]

There are 20 counters spread out on this table. Each counter is worth 400 Shillings so 20 times 400 equals 8000 shillings. These 20 counters represent the 8000 shillings on the voucher which you have been given a few weeks ago. That money is yours and you can do with it exactly what you like.

For example, you could decide to do nothing with it. That means we give you 8000 actual shillings and you can take those 8000 shillings home.

But we're also giving you the opportunity to invest some or all of that money. Let me show you what happens if you decide to invest.

For example, let's say you decided to invest 4000 shillings. You would then take 10 counters (remember, each counter represents 400 shillings) and you would place them here, right next to the beaker.

Now, we would then toss this coin that has A written on one side and B on the other. We put it in the beaker, put the lid on top, shake it and then we put the beaker upside down, like this; we remove the beaker: and which side of the coin shows?

It's [A/B]. That means the investment [is successful/failed]. So there are 2 possibilities: the investment can succeed or fail. It succeeds when A comes up; it fails when B comes up. Now let me explain what success and failure mean.

If the investment succeeds, we triple what you have invested. So since you had invested 4000, we give you back three times 4000 equals 12,000 [count out cash next to invested counters]. We add that to the money you had not invested (4000) [count out cash next to uninvested counters], so you go home with 4000 + 12,000 = 16,000 [count out total cash].

Now, what happens if the investment fails? Your investment failing means you lose all of it. In this case you go home with the money that you didn't invest. So you will take home 4000 [count out cash next to uninvested counters].

So remember, if your investment succeeds (that is when A comes up) you receive three times the amount you invested PLUS the money you did not invest. And if your investment fails (that is when B comes up), you keep the money you did not invest, but nothing else. I'll give you a few more examples of how that would work out.

[some worked examples]

So, you should feel free to invest any number of counters you choose: you can invest zero counters; you can invest 20 counters, or any number of counters between zero and 20.

[opportunity to ask questions for clarification; we then ask some control questions]

[subject decision and resolution]

Appendix B. Profitability calculations

We obtained costs, price and yields data for the past 10 years for all pertinent crops from agricultural experts in the area (see Section 3.3) and performed profitability calculations for a typical farm household: they grow maize inter-cropped with beans on an acre of land, and buy no agricultural inputs other than maize seeds, for which they pay 50,000 shillings/season. According to the agricultural experts we interviewed, this would sustain a family of 5–8 people so long as richer clan members help provide for their subsistence needs in lean years, which in exchange for various services is common in the region. Barring disasters such as landslides, major illnesses or personal accidents, the worst outcome for such a household is thus an increase in obligations towards relatives, which we normalise as profits per season of zero. We computed for each of the scenarios described in the main text and summarised in Table A1:

Extra costs per season per acre: the fertiliser, pesticides, improved seeds and hiring of labour required compared to traditional agriculture.

Worst and best-case scenarios: based on prices and yields that have prevailed in the area over the past 10 years. In a best(worst)-case scenario all yields are set at their highest (lowest) values, prices for crops sold at their highest (lowest)

[18] Anderson and Mellor (2009) report similar findings of a lack of assocation between risk-taking in incentivised gambles and hypothetical gambles, but it depends on how the latter are framed, as well as on subject type.

Table A1
Profitability calculations.

Scenario	Extra costs	Worst-case profits	Best-case	EV	St. dev.
Traditional	0	0	1.30	0.65	0.38
+ fertiliser	0.18	−0.18	1.89	0.86	0.60
Tomatoes + inputs	0.91	−1.66	3.34	0.84	1.44
Onions + inputs	0.32	−0.92	2.88	0.98	1.10
Cabbages + inputs	0.18	−0.77	2.87	1.05	1.05
Coffee + fertiliser	0.44	−0.19	3.51	1.66	1.07
Average cash crops	0.46	−0.88	3.15	1.13	1.16
.25 land for growing for market	0.12	−0.22	1.76	0.77	0.57
.5 land for growing for market	0.23	−0.44	2.23	0.89	0.77
.75 land for growing for market	0.35	−0.66	2.69	1.01	0.97

Figures are in millions of shillings per acre per agricultural season.

values and prices for crops bought (for subsistence, where appropriate) at their lowest (highest) values. Subsistence needs were set equal to the normal beans and maize yields for the traditional farm household indicated. The last three scenarios indicated in the table are weighted averages of the traditional scenario and the mean of the cash crops scenarios, with the weights determined by the proportion of the land allocated to the growing of cash crops.

The expected value and variance of profits, assuming a continuously uniform distribution in the range from worst to best-case profits.

Appendix C. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.jebo.2016.05.009.

References

Anderson, L.R., Mellor, J.M., 2008. Predicting health behaviors with an experimental measure of risk preference? J. Health Econ. 27 (5), 1260–1274.

Anderson, L.R., Mellor, J.M., 2009. Are risk preferences stable? Comparing an experimental measure with a validated survey-based measure. J. Risk Uncertain. 39 (2), 137–160.

Apicella, C.L., Dreber, A., Campbell, B., Gray, P.B., Hoffman, M., Little, A.C., 2008. Testosterone and financial risk preferences? Evol. Hum. Behav. 29 (6), 384–390.

Attanasio, O., Barr, A., Cardenas, J.C., Genicot, G., Meghir, C., 2012. Risk pooling, risk preferences, and social networks. Am. Econ. J.: Appl. Econ. 4 (2), 134–167.

Barham, B.L., Chavas, J.-P., Fitz, D., Rios Salas, V., Schechter, L., 2014. The roles of risk and ambiguity in technology adoption. J. Econ. Behav. Organ. 97, 204–218.

Barr, A., Genicot, G., 2008. Risk sharing, commitment, and information: an experimental analysis. J. Eur. Econ. Assoc. 6 (6), 1151–1185.

Barr, A., Packard, T., 2002. Revealed preference and self-insurance: can we learn from the self-employed in Chile? World Bank Policy Research Working Paper, pp. 2754.

Barr, A., Packard, T., 2005. Seeking solutions to vulnerability in old age: preferences, constraints, and alternatives for coverage under Peru's pension system, University of Oxford, Centre for the Study of African Economies (CSAE) Working Paper, CSAE WPS 2005-05.

Barrett, C.B., 2008. Smallholder market participation: concepts and evidence from eastern and southern Africa? Food Policy 33 (4), 299–317.

Battalio, R.C., Kagel, J.H., Jiranyakul, K., 1990. Testing between alternative models of choice under uncertainty: some initial results? J. Risk Uncertain. 3 (1), 25–50.

Binswanger, H.P., 1980. Attitudes toward risk: experimental measurement in rural India. Am. J. Agric. Econ. 62 (August), 395–407.

Binswanger, H.P., 1981. Attitudes toward risk: theoretical implications of an experiment in rural India? Econ. J. 91 (364), 867–890.

Camerer, C., 1989. An experimental test of several generalized utility theories? J. Risk Uncertain. 2 (1), 61–104.

Cardenas, J.C., Carpenter, J., 2013. Risk attitudes and economic well-being in Latin America. J. Dev. Econ. 103, 52–61.

Charness, G., Gneezy, U., 2010. Portfolio choice and risk attitudes: an experiment? Econ. Inq. 48 (1), 133–146.

Charness, G., Gneezy, U., 2012. Strong evidence for gender differences in risk taking? J. Econ. Behav. Organ. 83 (1), 50–58.

Charness, G., Gneezy, U., Imas, A., 2013. Experimental methods: eliciting risk preferences. J. Econ. Behav. Organ. 87 (March), 43–51.

Charness, G., Viceisza, A., 2012. Comprehension and risk elicitation in the field: evidence from rural Senegal. IFPRI Discussion Paper.

Conley, T.G., Udry, C.R., 2010. Learning about a new technology: Pineapple in Ghana? Am. Econ. Rev. 100 (1), 35–69.

Dave, C., Eckel, C.C., Johnson, C.A., Rojas, C., 2010. Eliciting risk preferences: when is simple better? J. Risk Uncertain. 41 (3), 219–243.

Dercon, S., Christiaensen, L., 2011. Consumption risk, technology adoption and poverty traps: evidence from Ethiopia. J. Dev. Econ. 96, 159–173.

D'Exelle, B., Verschoor, A., 2015. Investment behaviour, risk sharing and social distance. Econ. J. 125 (585), 777–802.

Dohmen, T., Falk, A., Huffman, D., Sunde, U., Schupp, J., Wagner, G.G., 2005. Individual risk attitudes: new evidence from a large, representative, experimentally-validated survey. IZA Discussion Papers 9(3), pp. 522–550.

Dohmen, T., Falk, A., Huffman, D., Sunde, U., Schupp, J., Wagner, G.G., 2011. Individual risk attitudes: measurement, determinants and behavioral consequences. J. Eur. Econ. Assoc. (1730).

Duflo, E., Kremer, M., Robinson, J., 2008. How high are rates of return to fertilizer? Evidence from field experiments in Kenya. Am. Econ. Rev.: Pap. Proc. 98 (2), 482–488.

Eckel, C.C., Grossman, P.J., 2002. Sex differences and statistical stereotyping in attitudes toward financial risk? Evol. Hum. Behav. 23 (4), 281–295.

Elston, J., Harrison, G.W., Rutström, E., 2005. Characterizing the entrepreneur using field experiments. Max Planck Institute of Economics Working Paper.

Engle-Warnick, J., Escobal, J., Laszlo, S., 2007. Ambiguity aversion as a predictor of technology choice: experimental evidence from Peru. McGill University, Department of Economics, Departmental Working Paper.

Filmer, D., Pritchett, L.H., 2001. Estimating wealth effects without expenditure data – or tears: an application to educational enrolments in states of India? Demography 38 (1), 115–132.

FOWODE, 2012. Gender Policy Brief for Uganda's Agriculture Sector. Forum for Women and Democracy, Mimeo, Uganda, Kampala.

Gneezy, U., Potters, J., 1997. An experiment on risk taking and evaluation periods? Q. J. Econ. 112 (2), 631–645.

Hanoch, Y., Johnson, J.G., Wilke, A., 2006. Domain specificity in experimental measures and participant recruitment? Psychol. Sci. 17 (4), 300–304.

Hardeweg, B., Menkhoff, L., Waibel, H., 2013. Experimentally validated survey evidence on individual risk attitudes in rural Thailand? Econ. Dev. Cult. Change 61 (4), 859–888.

Harrison, G., Rutström, E., 2008. Risk Aversion in Experiments, chapter Risk Aversion in the Laboratory. Emerald, Bingley, UK, Research in Experimental Economics Volume 12.

Harrison, G.W., Humphrey, S.J., Verschoor, A., 2010. Choice under uncertainty: evidence from Ethiopia, India and Uganda. Econ. J. 120 (March), 80–104.

Heltberg, R., Tarp, F., 2002. Agricultural supply response and poverty in Mozambique? Food Policy 27 (1), 103–124.

Henrich, J., McElreath, R., 2002. Are peasants risk-averse decision makers? Curr. Anthropol. 43 (1), 172–181.

Herberich, D.H., List, J.A., 2012. Digging into background risk: experiments with farmers and students? Am. J. Agric. Econ. 94 (2), 457–463.

Holt, C.A., Laury, S.K., 2002. Risk aversion and incentive effects? Am. Econ. Rev. 92 (5), 1644–1655.

Humphrey, S.J., Verschoor, A., 2004a. Decision-making under risk among small farmers in East Uganda? J. Afr. Econ. 13 (1), 44–101.

Humphrey, S.J., Verschoor, A., 2004b. The probability weighting function: experimental evidence from Uganda, India and Ethiopia. Econ. Lett. 84, 419–425.

Knight, J., Weir, S., Woldehanna, T., 2003. The role of education in facilitating risk-taking and innovation in agriculture? J. Dev. Stud. 39 (6), 1–22.

Köszegi, B., Rabin, M., 2006. A model of reference-dependent preferences? Q. J. Econ. 121 (4), 1133–1165.

Köszegi, B., Rabin, M., 2007. Reference-dependent risk attitudes? Am. Econ. Rev. 97 (4), 1047–1073.

Lahno, A.M., Serra-Garcia, M., D'Exelle, B., Verschoor, A., 2015. Conflicting risk attitudes. J. Econ. Behav. Organ. 118, 136–149.

Lejuez, C., Aklin, W.M., Zvolensky, M.J., Pedulla, C.M., 2003. Evaluation of the Balloon Analogue Risk Task (BART) as a predictor of adolescent real-world risk-taking behaviours? J. Adolesc. 26 (4), 475–479.

Liu, E.M., 2013. Time to change what to sow: risk preferences and technology adoption decisions of cotton farmers in China? Rev. Econ. Stat. 95 (4), 1386–1403.

Liu, E.M., Huang, J., 2013. Risk preferences and pesticide use by cotton farmers in China. J. Dev. Econ. 103, 202–215.

Lonnqvist, J.-E., Verkasalo, M., Walkowitz, G., Wichardt, P.C., 2011. Measuring individual risk attitudes in the lab: task or ask? An empirical comparison. Cologne Graduate School (CGS) Working Paper, 2(3).

Lusk, J.L., Coble, K.H., 2005. Risk perceptions, risk preference and acceptance of risky food. Am. J. Agric. Econ. 87 (2), 393–405.

Maccrimmon, K.R., Wehrung, D.A., 1990. Characteristics of risk taking executives? Manage. Sci. 36 (4), 422–435.

Rabin, M., 2000. Risk aversion and expected-utility theory: a calibration theorem? Econometrica 68 (5), 1281–1292.

Rabin, M., Weizsäcker, G., 2009. Narrow bracketing and dominated choices? Am. Econ. Rev. 99 (4), 1508–1543.

Read, D., Loewenstein, G., Rabin, M., 1999. Choice bracketing? J. Risk Uncertain. 19 (1–3), 171–197.

Redelmeier, D.A., Tversky, A., 1992. On the framing of multiple prospects? Psychol. Sci. 3 (3), 191–193.

Reynaud, A., Couture, S., 2012. Stability of risk preference measures: results from a field experiment on French farmers? Theory Decis. 73 (2), 203–221.

Tanaka, T., Camerer, C.F., Nguyen, Q., 2010. Risk and time preferences: linking experimental and household survey data from Vietnam? Am. Econ. Rev. 100 (1), 557–571.

Tanaka, Y., Munro, A., 2014. Regional variation in risk and time preferences: evidence from a large-scale field experiment in rural Uganda? J. Afr. Econ. 23 (1), 151–187.

Thaler, R.H., 1999. Mental accounting matters? J. Behav. Decis. Mak. 12 (3), 183–206.

Tversky, A., Kahneman, D., 1981. The framing of decisions and the psychology of choice? Science 211 (4481), 453–458.

Vargas Hill, R., 2009. Using stated preferences and beliefs to identify the impact of risk on poor households? J. Dev. Stud. 45 (2), 151–171.

Weber, E.U., Blais, A.-R., Betz, N.E., 2002. A domain-specific risk-attitude scale: measuring risk perceptions and risk behaviors? J. Behav. Decis. Mak. 15 (4), 263–290.

Yesuf, M., Bluffstone, R.A., 2009. Poverty, risk aversion, and path dependence in low-income countries: experimental evidence from Ethiopia. Am. J. Agric. Econ. 91 (4), 1022–1037.