Basis risk and Compound-risk Aversion: Evidence from a WTP Experiment in Mali

Ghada Elabed and Michael R. Carter

Preliminary and Incomplete

Abstract

In this paper, we present a novel way to understand the low uptake of index insurance using the interlinked concepts of ambiguity and compound lottery aversion. We begin our analysis by looking at index insurance from the farmer’s perspective, noticing that index insurance is a compound lottery. Specifically, we use the smooth model of ambiguity aversion developed by Klibanoff, Marinacci, and Mukerji (2005) to derive an expression of the willingness to pay to reduce basis risk. Empirically, we implement the WTP measure using framed field experiments with cotton farmers in Southern Mali. In this sample, 57% of the surveyed farmers reveal themselves to be compound-risk averse to various degrees. Using the distributions of compound-risk aversion and risk aversion in this population, we then simulate the impact of basis risk on the demand for an index insurance contract whose structure mimics the structure of an actual index insurance contract distributed in Mali. Compound-risk aversion decreases the demand for index insurance relative to what it would be if individuals had the same degree of risk aversion but were compound-risk neutral. In addition, demand declines more steeply as basis risk increases under compound-risk aversion. Our results highlight the importance of designing contracts with minimal basis risk under compound-risk aversion. This would not only enhance the value and productivity impacts of index insurance, but would also assure that the contracts are popular and have the anticipated impact.

Keywords: Index Insurance, Risk and Uncertainty, Compound Risk, Ambiguity, Field Experiments

1 Introduction

Informal risk mitigation mechanisms in developing countries tend to only insure against idiosyncratic shocks, which affect a single individual, and are therefore costly in terms of forgone income (Alderman and Paxson 1992). Covariate shocks, which affect a group of people, remain widely uninsured in developing countries, making households particularly vulnerable to such risks (Jalan and Ravallion 2001). A growing body of research has produced compelling evidence that uninsured risk impedes economic growth; it leads to a persistence of inefficient traditional agricultural technologies (Morduch 1995) and may thereby contribute
to poverty traps (Dercon and Christiaensen 2011; Carter and Lybbert 2012). Therefore, formal insurance contracts could be a crucial instrument for improving welfare in developing countries.

Index insurance is an example of an innovative financial product designed to insure poor households against shocks. The index is chosen to be some variable that closely correlates with farmers’ yields, and an individual farmer receives his/her indemnity if the index falls below a pre-determined strike point. Index insurance overcomes informational problems and reduces transaction costs, and is therefore cheaper than conventional indemnity insurance. This type of insurance can therefore offer coverage for poor, small-scale farmers who are typically excluded from existing formal insurance markets. However, uptake of the product remains unexpectedly low, despite a decade of efforts to promote index insurance as a tool for poverty reduction in developing countries (Gine and Yang 2007, Cole et al. 2010, Boucher and Mullally 2010, Meherette 2009).

This paper hypothesizes and tests a mechanism that can help explain the low uptake rates of index insurance. We begin our analysis by looking at index insurance from the farmer’s perspective. Compared to conventional indemnity insurance, index insurance is itself a probabilistic investment: payouts are not perfectly correlated with the farmer’s loss. For example, in the case of an area-yield insurance contract, the farmer’s yield can be low when the average yield in the area is high, and vice versa. This imperfect correlation is known as basis risk. Because of basis risk, index insurance is a compound lottery. The first stage lottery determines the individual farmer’s yield, and the second stage lottery determines whether or not the index triggers an indemnity payout. Under the Reduction of Compound Lotteries axiom of expected utility, individuals will reduce this compound lottery to a simple lottery. In this paper, we examine what happens when we relax the assumption that decision makers behave according to the predictions of expected utility theory.

There is a large body of literature on non-expected utility models of decision making under uncertainty, but we focus here on the interrelated concepts of ambiguity and compound risk aversion. Ambiguity aversion was first demonstrated by Ellsberg (1961), who showed that individuals react much more cautiously when choosing among ambiguous risks (with unknown probabilities) than when they choose among risks with known probabilities. While the individual probabilities under index insurance are known, for individuals who cannot computationally reduce a compound lottery to a single lottery, the final probabilities are unknown, as in the Ellsberg experiment. Halvey (2007) corroborates this intuition by experimentally establishing a relationship between ambiguity aversion and compound-risk aversion, showing that those who are ambiguity averse are also compound-risk averse.

Abdellaoui et al. (2011) notes that “(…) behavior towards compound risk is relatively understudied in the literature (…))”, and our paper helps fill this gap by quantifying compound-risk attitudes in a previously unexplored context, and by using a framed field experiment to study the implications of ambiguity and compound-risk aversion on the demand for index insurance. To our knowledge, with the exception of the study by Bryan (2010), we are not aware of any other study that looks at the impact of ambiguity attitudes
Specifically, we use the smooth model of ambiguity aversion developed by Klibanoff, Marinacci, and Mukerji (2005) to derive an expression of the willingness to pay to reduce basis risk (WTP). We define this WTP as the maximum amount of money a farmer is willing to pay and still be indifferent between index insurance and the corresponding conventional indemnity insurance contract. We then show how this measure varies with compound-risk aversion.

Empirically, we implement the willingness to pay measure using framed field experiments with cotton farmers in Southern Mali. In this sample, 57% of the surveyed farmers reveal themselves to be compound-risk averse to various degrees. Using the distributions of compound-risk aversion and risk aversion in this population, we then simulate the impact of basis risk on the demand for an index insurance contract whose structure mimics the structure of an actual index insurance contract distributed in Mali.

Compound-risk aversion decreases the demand for index insurance relative to what it would be if individuals had the same degree of risk aversion but were compound-risk neutral. In addition, demand declines more steeply as basis risk increases under compound-risk aversion. Were basis risk as high as 50%, only 35% of the population would demand index insurance, as opposed to the 60% who would be willing to purchase the product if individuals were simply maximizing expected utility. Previous studies have investigated various other factors for the uptake of index insurance such as lack of financial literacy and exposure to financial markets (Giné et al., 2008); lack of trust (Cole et al. 2010); liquidity constraints and ambiguity aversion. We provide evidence that an unstudied concept, compound-risk, could explain low uptakes of insurance. An implication of this result is the importance of designing contracts with minimal basis risk when farmers are compound-risk averse, to enhance the impacts of index insurance and to assure that farmers actually demand the contracts.

The remainder of the paper is structured as follows. In the next section, we review the relevant literature. We then present the theoretical framework and the derivation of the willingness to pay. In subsequent sections, we describe and present the results of the field experiment in Mali. We conclude with potential policy recommendations.

2 Related Studies

There is ample evidence that people do not behave according to expected utility theory when they face a risky prospect, and most departures from expected utility theory are likely to exacerbate the effects of basis risk. Because of the presence of basis risk, index insurance is a form of probabilistic insurance, a concept introduced by Kahneman and Tversky [1979]. Contrary to the predictions of the expected utility theory, studies of the uptake of probabilistic insurance have found that consumers dislike this type of insurance contract, instead preferring a regular insurance contract that pays with certainty when a loss occurs. Wakker et al. [1997] used survey data to show that the respondents demand about a 30% reduction in the premium to compensate for
a 1% probability of not getting a payment in the case of a loss. Expected utility theory cannot explain these findings. Under reasonable assumptions, an expected utility maximizer would be expected to demand only a 1% decrease in premium to compensate them for the 1% increase in the probability that the insurance contract fails. These observations lead us to wonder about the reasons behind this aversion to probabilistic insurance.

Two main theories explain the attitudes of consumers towards probabilistic insurance: prospect theory, namely the probability weighting function Kahneman and Tversky [1979], Wakker et al. [1997], and rank dependent utility functions Segal [1988]. In this paper, we focus on the inter-related concepts of ambiguity and compound risk aversion. The latter concept was first defined in Abdellaoui et al. [2011], by comparing certainty equivalents between a compound lottery and the equivalent reduced lottery. According to their definition, a decision maker is compound-risk averse (seeking) if the certainty equivalent for the compound lottery is equal (above) the certainty equivalent of the simple lottery. As mentioned in the introduction, even when the individual probabilities under index insurance are given objectively, for individuals who cannot computationally reduce a compound to a single lottery, the final probabilities are unknown.

The relationship between attitudes towards compound lotteries and ambiguity aversion was first established by the recursive non-expected utility model of Segal [1987] who had the novel idea of representing the Ellsberg problem as a compound lottery. In the first stage, the decision maker assigns the probability of getting the various lotteries in the second stage. Halevy [2007] confirmed experimentally the theoretical findings of Segal by demonstrating the existence of a strong link between ambiguity aversion and compound risk attitude. He finds that ambiguity neutral participants are more likely to reduce compound lotteries, behaving according to the expected utility theory. In the contrast, ambiguity averse participants fail to reduce compound objective lotteries.

In our modeling efforts, the smooth model of ambiguity aversion developed by Klibanoff et al. [2005] is most appropriate in our context. Unlike the other existing theories of decision making under ambiguity aversion, this modeling approach relaxes the reduction of compound lottery axiom and allows for a continuous objective function. Therefore, it allows the exploration of the implications of the relationship between ambiguity aversion and compound-risk aversion for the demand for index insurance, and especially the sensitivity of that demand to increases in basis risk.

While the existence of compound-risk aversion or ambiguity aversion is an important finding in and of itself, we further wish to understand the impact of this type of aversion on the demand for index insurance. The literature on this issue is still in its infancy, and tends to focus on the impact of ambiguity on technology adoption. The main assumptions of these recent studies are that new technologies are more uncertain in terms of risk and ambiguity than traditional ones. Therefore, ambiguity averse farmers are expected to be less likely to adopt Engle-Warwick et al. [2007], Ross et al. [2010], Alpizar et al. [2009], Barham et al. [2011]. In the special case of insurance decisions, Bryan [2010] shows that under some theoretical restrictions on the shape of preferences, households that are both ambiguity averse and risk averse will not value insurance
because they perceive it as increasing risk. Based on the results of two experiments in Malawi and Kenya, he finds that ambiguity aversion explains the low uptake of index insurance. The main assumption of his model is that the production function generating the household income is ambiguous (i.e. the relationship between the index and the income). Our work differs from Bryan [2010] in that the ambiguity in our case arises from the payoff structure of the index insurance contract and not the probability distribution of the production function.

3 Conceptual Framework

The goal of this section is to first study the impact of basis risk on the demand for index insurance. We first explore the demand for actuarially unfair index insurance under expected utility maximization. We then note that index insurance appears to the individual as a compound lottery. Compound lottery induces a behavior akin to ambiguity. Then we explore the impact of ambiguity or compound risk aversion on the demand for index insurance, using the model of ambiguity aversion developed by Kilbanof, Marinacci and Mukerji [2005] (referred to as the KMM model). This model captures risk preferences by the curvature of the utility of wealth function, and ambiguity preferences by a second-stage utility functional defined over the expected utility of wealth. Central to this analysis is the concept of generalized uncertainty premium, calculated by Maccheroni, Marinacci and Ruffino (2010), which we also briefly summarize in the following section.

In a second step, we will present a method that characterizes participants according to their compound-risk aversion. The crux of this method is to give the participant a choice between the index insurance and some equivalent conventional indemnity insurance. From this procedure, we will elicit the willingness to pay to reduce basis risk, that is, the maximum amount of money a farmer is willing to pay and still be indifferent between the index insurance and the conventional indemnity insurance contract.

3.1 Index insurance from the farmer’s perspective

According to standard economic theory, an expected utility maximizer faced with an actuarially fair insurance contract will insure the entire amount at risk. If the risk can only be partially insured (as with an index insurance contract), the expected utility maximizing agent will still purchase whatever partial insurance is available if priced at an actuarially fair level. In a more realistic setting, however, insurance companies impose loadings to cover transaction costs. In that case, standard economic theory predicts that a utility maximizer will leave part of the risk uninsured. Index insurance contracts are an example of partial insurance, and typically have a loading of 20%. Therefore, a risk averse agent will purchase index insurance only if basis risk is small enough compared to the fraction of total risk he is exposed to. Moreover, the more risk averse he is, the higher the amount he insures. However, what happens when the individual is not an expected utility maximizer?
In order to understand the behavior of the farmer, let’s first present the payoff structure under an index insurance contract. Consider a farmer who owns one hectare of land and has no sources of income other than what he produces on that land.

Figure 1 below reveals the payoff structure under an example of an index insurance contract. Under this structure, the individual farmer faces, for example, a probability $p$ that yields are good, and with a probability $1 - p$ that he incurs a yield loss $L$. If the individual yields are good, there is a probability $q_1$ strictly less than 1 that the index insurance triggers a payoff, resulting in an income of $(Y_0 - \tau_1 + \Pi)$ equal to the net income under good yields, less the insurance premium plus the value of the insurance indemnity payment. However, there is a probability $1 - q_1$ that the index is not triggered. In that case, no insurance payments are made and the individual receives an income equal to the net income under good yields less the insurance premium $(Y_0 - \tau_1)$.

If the individual experiences poor yields, there is a probability $q_2$ strictly less than 1 that the index insurance will trigger a payoff, resulting in an income of $(Y_0 - L - \tau_1 + \Pi)$ equal to the net income under bad yields, less the insurance premium plus the value of the insurance indemnity payment. However, there is a probability $1 - q_2$ (basis risk) that conditional on poor yields, the insurance contract fails to payoff. In this case, the individual receives a net income of $Y_0 - L - \tau_1$ (equal to the net income under bad yields minus the insurance premium).

Figure 1: Index insurance from the farmer’s point of view.

In the more general case of multiple states of the nature, let’s define two marginal distributions: $f_y$ and $f_X$ are the respective pdfs of the farmer’s yield and the index $X$. Let $y_{IX}$ denote the final wealth of the
farmer after all payments are made under the index insurance contract.

While index insurance is effectively a compound lottery, under the Reduction of Compound Lotteries axiom of expected utility theory (ROCL), the individual will reduce the compound lottery to a simple lottery. Assuming that the individual’s risk preferences are captured by the utility function $u$ defined over final wealth, and assuming that the farmer is risk averse by imposing concavity of $u$ ($u$ is of course also increasing), the objective function of an expected utility maximizer is the following:

$$E_{f_{yX}} [u(y_{1|X})]$$  \hspace{1cm} (1)

where $f_{yX}$ is the joint probability distribution function of the index and the yield.

However, as explained in the prior section, compound lotteries create something akin to ambiguity. While the individual probabilities under the index insurance are known, for poor farmers who cannot computationally reduce a compound lottery to a single lottery, the final probabilities are in fact unknown, as in the Ellsberg experiment.

Under the KMM model of smooth ambiguity aversion, for each realization of the index, the farmer's expected utility is evaluated by an increasing function $v$ that captures compound risk preferences, and the farmer’s objective function is the expected value of $v$ given the probability distribution of the yield. Thus, the farmer’s objective function is given by:

$$E_{f_y} [v(E_{f_{X/y}}u(y_{1|X}))]$$  \hspace{1cm} (2)

where $E_{f_y}$ denotes the expectation with respect to $f_y$. The expectation $E_{f_{X/y}}$ is taken with respect to $f_{y/x}$, the probability distribution function of the index conditional on the realization of the yield. As risk aversion is imposed by the concavity of $u$, under the KMM model, compound-risk aversion is obtained by imposing concavity of $v$: $v' > 0$ and $v'' \leq 0$. In the compound-risk neutral case (i.e., $v$ is linear), this expression reduces to the conventional Von Neumann-Morgenstern expected utility maximization represented by Equation 1.

### 3.2 The demand for index insurance

Having presented the objective functions with and without compound-risk aversion, we look now at the demand for index insurance under these two models of decision making. Central to the analysis in this section is the concept of uncertainty premium derived by Maccheroni, Marinacci and Ruffino [2010] (hereafter MMR), who extended the classic result of Pratt [1964] on the risk premium under uncertainty to the ambiguity framework assuming the KMM model. In the case of index insurance, this uncertainty premium $\rho_X$ is defined such that the farmer is indifferent between receiving the net revenue from the index insurance contract and the certain average revenue $\bar{y}_{1|X}$. This premium solves the following equation:
\[ E_{f_y} \left[ v \left( E_{f_x/y} u(yI_X) \right) \right] = v \left( u \left( \bar{y}_{I_X} - \rho_X \right) \right) \tag{3} \]

**Proposition 1.** Call \( \rho_X^N \) the uncertainty premium of a compound-risk neutral farmer with a utility function \( u \). The solution of Equation 3, if it exists, is lower bounded by \( \rho_X^N \):

\[ \rho_X \geq \rho_X^N \]

The following proof follows Alary et al. [2012]; we provide it for the sake of completeness.

**Proof.** Since \( u \) is concave, using Jensen’s inequality:

\[
v (u(\bar{y}_{I_X} - \rho_X)) = E_f \left[ v \left( E_{X/y} u(yI_X) \right) \right] \]
\[
\leq v \left( E_{f_y} E_{f_x/y} u(yI_X) \right) \]
\[
= v \left( E_{f_x/y} u(yI_X) \right) \]
\[
= v \left( u \left( \bar{y}_{I_X} - \rho_X^N \right) \right)
\]

\( \square \)

Proposition 1 means that compound-risk aversion should decrease the demand for index insurance relative to what it would be if individuals had the same degree of risk aversion but were compound-risk neutral. Intuitively, compound-risk averse agents pay an extra premium to eliminate the ambiguity associated with the secondary lottery.

Now if we consider a compound-risk averse individual, what happens to his demand for index insurance as basis risk increases? The answer to this question is based on the findings of MMR who showed that the uncertainty premium \( \rho_X \) is the sum of an ambiguity premium and the classical risk premium:

\[
\rho_X \simeq -\frac{1}{2} \sigma_{y_{I_X}}^2 \frac{u''(\bar{y}_{I_X})}{u'(\bar{y}_{I_X})} - \frac{1}{2} \sigma_{\bar{y}_{I_X}}^2 \frac{u''(u(\bar{y}_{I_X}))}{v'(u(\bar{y}_{I_X}))} \tag{4}
\]

where \( \sigma_{y_{I_X}}^2 \) is the variance of the final net wealth when purchasing the index insurance contract:

\[
\sigma_{y_{I_X}}^2 = E_{f_y} \left[ E_{f_x/y} [y - \bar{y}_{I_X}]^2 \right]
\]

\( \sigma_{\bar{y}_{I_X}}^2 \) is the variance of the expected revenue under the probability distribution of the index:

\[
\sigma_{\bar{y}_{I_X}}^2 = E_{f_y} \left[ E_{f_x/y} [y - \bar{y}_{I_X}] \right]^2
\]

According to MMR, \( \sigma_{y_{I_X}}^2 \) reflects the “uncertainty on the expectation of the revenue, due to the model
uncertainty that the decision maker perceives. In the particular case of index insurance, this expected value varies because conditional on every yield realization, the distribution of the index yields a different expected wealth.

From Equation 4, it is straightforward to show that:

1. For a compound-risk neutral individual, the uncertainty premium reduces to the classical Pratt premium,

\[ \rho_X^N \approx -\frac{1}{2} \sigma^2 u'(\bar{y}_{IX}) \]

2. For a conventional indemnity insurance, the uncertainty premium also reduces to the classical Pratt premium, whether the farmer is compound-risk averse or not.

3. The results of proposition 1 is verified: a compound-risk averse individual is willing to pay an extra premium to reduce basis risk compared to his compound-risk neutral counterpart, who has the same level of risk aversion. This extra premium is denoted \( \rho^c \), and it is a function of the curvature of \( v \), \( u \) and \( \sigma^2_{y_{IX}} \). Proposition 2 states the impact of basis risk on the demand for index insurance.

**Proposition 2.** As basis risk increases, the demand for the index insurance contract decreases for a compound-risk averse participant. This decrease in demand is higher than under expected utility theory.

The next section describes a methodology to characterize the compound-risk attitudes of the participants.

### 3.3 Deriving a test to separate farmers by compound-risk attitudes

In order to classify the farmers by compound-risk attitudes, let us imagine the situation where a farmer has to choose between the index insurance contract and a conventional indemnity insurance contract. This latter contract yields a net wealth \( y_I \) and pays for sure when the farmer’s yield is low.

From the farmer’s point of view, the conventional indemnity insurance contract is a simple lottery. Therefore, when faced with this contract, his decision criterion reduces to the usual VMN objective function:

\[ E_{f_Y} [u(y_I)] \]  

(5)

Applying the increasing transformation \( v \) does not change the previous program, but has the advantage of making Equations 5 and 2 comparable. Therefore, the utility function of the farmer when facing the indemnity insurance is the following:

\[ v(E_{f_Y} [u(y_I)]) \]  

(6)

Suppose the farmer is facing the decision to purchase either the index insurance contract, or the individual insurance contract. What is the amount of money that makes the farmer indifferent between the two
contracts? By definition, this WTP \( w \) is the maximum amount of money the farmer is willing to give up in order to be indifferent between the index insurance contract, and the individual insurance contract. This WTP solves the following equation:

\[
\mathbb{E}_{f_y} \left[ v \left( \mathbb{E}_{X/y} u \left( y_{1X} \right) \right) \right] = v \left( \mathbb{E}_{f_y} u \left( y_I - w \right) \right)
\]

**Proposition 3.** If the farmer is compound-risk neutral then his WTP \( w^N \) is the difference between the certainty equivalents of the two contracts:

\[
w^N = \bar{y}_I - \bar{y}_{1X} + \rho_X^N - \rho_I
\]

**Proof.** If the farmer is compound-risk neutral, then:

\[
v \left( \mathbb{E}_{f_{X/y}} u \left( y_{1X} \right) \right) = v \left( \mathbb{E}_{f_y} u \left( y_I - w^N \right) \right)
\]

By the definition of the certainty premia \( \rho_X \) and \( \rho_I \), we have:

\[
u \left( \bar{y}_{1X} - \rho_X^N \right) = u \left( \bar{y}_I - \rho_I - w^N \right)
\]

where \( \rho_I \) is the regular Pratt uncertainty premium for the individual insurance contract:

\[
\rho_I \approx -\frac{1}{2} \sigma_{y_I}^2 \frac{u''(\bar{y}_I)}{u'(\bar{y}_I)}
\]

**Proposition 4.** A compound-risk averse individual has a higher WTP compared to his compound-risk neutral counterpart, for the same level of risk aversion:

\[
w \geq w^N
\]

**Proof.** If the farmer is compound-risk averse, then his WTP \( w \) satisfies the following equations, by Jensen inequality

\[
\mathbb{E}_{f_y} \left[ v \left( \mathbb{E}_{X/y} u \left( y_{1X} \right) \right) \right] = v \left( \mathbb{E}_{f_y} u \left( y_I - w \right) \right)
\]

\[
\leq v \left( \mathbb{E}_{f_{X/x}} u \left( y_{1X} \right) \right)
\]

\[
= v \left( \mathbb{E}_{f_y} u \left( y_I - w^N \right) \right)
\]
4 Experimental Design and Data

To test these hypothesis, 331 cotton farmers from 34 cotton cooperatives in Bougouni, Mali participated in a set of framed field experiments. A first game allowed the measurement of their risk aversion coefficients. A second game elicited their WTP as defined above, which allows the elicitation of compound-risk aversion attitudes. This last game closely resembles the theoretical framework described in Section 2 with one difference. If the individual yield is high, the index is no longer triggered. The reason is to mimic the structure of an area yield index insurance product that was designed as part of the ongoing project “Index insurance for Cotton farmers in Mali”, and launched by the Index Insurance Innovation Initiative (I4). More details about this project and the structure of the distributed contract can be found in Elabed et al. 2013.

4.1 Experimental Procedure

The participants are 331 members of 34 cotton cooperatives selected at random from the list of cooperatives participating in the project mentioned above. In addition, a survey gathered detailed information on various socio-economic characteristics of the participating farmers such as demographic characteristics, wealth, assets owned, agricultural production and shocks. Data collection for the survey took place in December 2011 through January 2012, and the experiments took place in January and February 2012.

Three rural area animators translated the experimental protocol from French to Bambara, the local language, and ensured that it is accessible to a typical cotton farmer. Game trials were conducted with graduate students in Davis, CA, and with high school students and cotton farmers who were not part of the final experimental sample in Bougouni, Mali. Local leaders (secretaries of cotton cooperatives and/or village chiefs) assisted us in recruiting the eligible participants from a list of names that we provided.

The sessions took place in a classroom on weekends and in the village chief’s office on weekdays. The sessions took place with members of the same cooperative, and they lasted around two and a half hours, not counting the time necessary to gather or to distribute of gains at the end of each session. We divided the sessions into two parts with a short break between each. Each participant played one pure luck game and four decision and luck games. Each decision and luck game started with a set of six “low stakes” rounds aimed at familiarizing them with the rules, which were followed by a set of six “high stakes” rounds. The only difference between these two types of rounds was the exchange rate used to compute the gains in cash: the gains from a high stake round were 5 times higher than the gains from a low stake round. At the end of the session, we paid the players for only one of the low stake rounds and one of the high stake rounds of every game by having a farmer roll a six-sided die. We used this random incentive device in order to encourage the players to choose carefully. The animator announced the selection procedure to the players at the beginning of every game. In order to incentivize the players to think more carefully about their decisions, we repeated
the following sentence “There is no right or wrong answer. You should do what you think is best for you and your family whether it is choice #1, choice #2, etc.”.

At the end of the session, participants received their game winnings in cash, in addition to a show up fee of 100 CFA. Minimum and maximum earnings, excluding show up fee, were 85 CFA and 2720 CFA and mean earnings was 1905 CFA. The daily wage for a male farm labor in the areas we ran the experiments were between 500 CFA (0.93 USD) and 2000 CFA (3.75 USD) and on average 1040 CFA (1.95 USD). Since literacy rates are very low in the area, we presented the games orally with the help of many visual aids. In addition to the main animator, two rural animators assisted the players with the various materials.

4.2 The Games

The players had to take decisions framed in terms most familiar to them: their decisions were centered on cotton—their main cash crop. Before playing the risk aversion game, the participants learned how to determine their yields and the resulting revenue. Then participants, endowed with one “hectare of land”, had to choose among different insurance contracts.

4.2.1 Determining the yield:

Based on historical yield distributions and pooling all the available data across years and cooperatives, we discretized the density of cotton yields into six sections with the following probabilities (in percent): 5, 5, 5, 10, 25 and 50, respectively. The individual yield values corresponding to the mid-point of those sections are (in kg/ha): 250, 450, 645, 740, 880 and 1530, respectively. Table 1 shows the yield distribution and the corresponding revenue in d, the local currency.

<table>
<thead>
<tr>
<th>Yield range (kg/ha)</th>
<th>Mid point</th>
<th>Probability</th>
<th>Revenue (in d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;300</td>
<td>250</td>
<td>5%</td>
<td>2400</td>
</tr>
<tr>
<td>300-600</td>
<td>450</td>
<td>5%</td>
<td>10400</td>
</tr>
<tr>
<td>600-690</td>
<td>645</td>
<td>5%</td>
<td>18200</td>
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<td>22000</td>
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<tr>
<td>790-780</td>
<td>880</td>
<td>25%</td>
<td>27600</td>
</tr>
<tr>
<td>&gt;880</td>
<td>1530</td>
<td>50%</td>
<td>53600</td>
</tr>
</tbody>
</table>

Table 1: Yield distribution and corresponding revenues

Understanding the notion of probability associated with the yield determination is a challenge that we addressed by using the randomization procedure used by Galarza and Carter [2011] in Peru to simulate the realizations of the individual yields. Every participating farmer drew his yield realizations from a bag containing 20 blocks (1 black, 1 yellow, 1 red, 2 orange, 5 green and 10 blue) which reproduce the probability distribution mentioned earlier, going from the lowest to the highest yield. Figure 2 shows the visual aid provided to farmers to help them understand the game better. Equation 7 computes the individual farmer’s per hectare profits in d without any insurance contract:
\[ \text{profit}_i = p \cdot y_i - \text{Inputs} \quad (7) \]

where the price \( (p) \) of a kg of cotton is set at \( d40 \), the cost of the inputs is set at \( d7600 \) in order to guarantee that the players never incur a real loss in the games with the different contracts.

\[
\begin{array}{ccccccc}
\text{Rendement} & 250 & 450 & 645 & 740 & 880 & 1530 \\
\text{Intrants} & d7600 & d7600 & d7600 & d7600 & d7600 & d7600 \\
\text{Argent de la famille} & d2400 & d10400 & d18200 & d22000 & d27600 & d53600 \\
\end{array}
\]

Figure 2: Visual aid for yield distribution

### 4.2.2 Conventional indemnity insurance contract

After having practiced determining their yields and the corresponding revenue, the player, indexed by \( i \) had to decide whether to purchase an insurance contract. The contract is linear and the payment occurs if the yield falls below the strike point \( T \). In case the farmer is eligible for an insurance payment, the insurance reimburses the difference between the individual yield and the strike point such that the farmer is guaranteed to have an income corresponding to yield \( T \). The premium is set to include a loading cost of 20\%, such that the amount paid is 120\% the amount received on average. Thus, the payment schedule is the following:

\[
payment(y_i) = \begin{cases} 
p \cdot (T - y_i), & y_i \leq T \\
0, & y_i > T \end{cases} \quad (8)
\]

### 4.2.3 The index insurance contract

The index insurance contract is characterized by a strike point \( T \) at the individual level, and by another strike point \( T_z \) at the ZPA (aggregate agricultural area) level. Every participant farmer was explicitly told
that he represents a separate agricultural production area in order to emphasize the fact that the index is independent from the realizations of the other farmers in the group. Thus, compared to the regular indemnity insurance, in order to be eligible for a payment, the farmer has to satisfy an extra condition. The payment schedule is the following:

\[ \text{payment}(y_i) = \begin{cases} p \ast (T - y_i) : & y_i \leq T \text{ and } y_z \leq T_z \\ 0 & \text{otherwise} \end{cases} \]  

Thus, from the player's point of view, once he suffers a loss (i.e. his yield is below the individual strike point), he risks not getting a payment with positive probability. Based on historical data from the area, this probability is set at 20%. Further, the individual-level trigger is set at 70% of the median historical yield, and the contract was priced with a loading cost of 20%. If a farmer decides to purchase an index insurance contract, then he faces a two-stage game. First, he determines his own yield by drawing a block from the yield sack. Then, if the yield is below the individual strike point, he draws another block from a second sack which contains 4 brown blocks (i.e. the index triggered) and one green block (i.e. the index is not triggered).

Note that, contrary to the more general model presented in Section 2, the farmer does not get a payment in case his yield is high. This choice is made in order to mimic the area based yield contract that was distributed in the area to cotton cooperatives.

4.2.4 Game 1: Eliciting risk preferences

The risk aversion game was framed in terms of an insurance decision to elicit risk preferences. While alternative unframed methodologies exist in the literature, this framed design is chosen for pedagogical reasons. Each subject had six different possibilities: don’t purchase an insurance contract, or choose among five different insurance contracts that differ in their strike points, which were 100%, 80%, 70%, 60%, and 50% of the median historical yield (980 kg/ha). In terms of actual yields, this corresponds to 980 kg/ha, 790 kg/ha, 690 kg/ha, 600 kg/ha, and 300 kg/ha, respectively.

The net revenue of farmer \( i \) if he purchases contract \( j \) is given by the following formula:

\[ \text{profit}_{ij} = p \ast y_i + \text{Indemnity}_j - \text{premium}_j \]  

where \( \text{indemnity} \) is an indicator function for the insurance payment, and \( \text{premium} \) is the premium of the insurance contract. Table 2 shows the different revenues associated with each choice and the corresponding risk aversion ranges.

In this game, each player had to determine whether he wanted to purchase an insurance contract, and if so which one. Then, an assistant asked him to draw a block in order to determine his revenue.

Table 2 shows the characteristics of every contract: trigger defined as a percentage of the median yield...
in the region, the premium and the net revenue.

<table>
<thead>
<tr>
<th>Contract #</th>
<th>Trigger (% ybar)</th>
<th>Premium (d)</th>
<th>Net Profit (d)</th>
<th>CRRA range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>250</td>
<td>450</td>
<td>645</td>
</tr>
<tr>
<td>Yield (kg/ha)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proba.</td>
<td></td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>2400</td>
<td>10400</td>
<td>18200</td>
</tr>
<tr>
<td>1</td>
<td>50</td>
<td>600</td>
<td>4280</td>
<td>10280</td>
</tr>
<tr>
<td>2</td>
<td>60</td>
<td>1200</td>
<td>15200</td>
<td>15200</td>
</tr>
<tr>
<td>3</td>
<td>70</td>
<td>1740</td>
<td>18280</td>
<td>18260</td>
</tr>
<tr>
<td>4</td>
<td>80</td>
<td>2700</td>
<td>21300</td>
<td>21300</td>
</tr>
<tr>
<td>5</td>
<td>100</td>
<td>6180</td>
<td>25420</td>
<td>25420</td>
</tr>
</tbody>
</table>

Table 2: Individual insurance contracts and risk aversion coefficient

The last column of Table 2 exhibits the CRRA ranges corresponding to every contract choice, assuming a CRRA utility function. Let’s assume that the player chose the third contract. Assuming monotonic preferences, this implies that he preferred this contract to contracts 2 and contract 4. The upper (lower) bounds of the CRRA range is found by equalizing the expected utility that the farmer derives from contract 2 and 3 (3 and 4). In this case, as Table 2 shows, the CRRA range of the player is (0.27; 0.36). Note that as the level of coverage (measured by the trigger as percentage of the median yield increases, the CRRA increases.

### 4.2.5 Game 2: Eliciting the WTP to reduce basis risk

After having practiced determining his revenue under the index insurance contract, every participant played a game that aimed at eliciting the WTP measure defined above (the amount of money the farmer is willing to pay above the price of the indemnity insurance contract). Specifically, we wanted to see whether the player, whom we call Mr. Toure, preferred the indemnity contract to the index contract as we increase the price of the individual contract from its base price (d1340) to d3540, by increments of 200d.

The elicitation procedure was the following: The animator presented players with the following scenario: Mr. Toure’s friend, Mr. Cisse, is going to Bamako (the capital of Mali, 90 miles away). Mr. Toure asks Mr. Cisse to buy an insurance contract for Mr. Toure. Mr. Toure knows that the price of the individual contract can vary depending on the day, but the price of an index contract is always the same. After highlighting the fact that at the price of d1340, it is always more profitable to buy the individual insurance contract, Mr. Toure was asked to tell Mr. Cisse at which price Mr. Toure should switch to favoring the index insurance contract over the individual insurance contract. Thus, by the end of the game, we have the switching price for every player from which we deduce his willingness to pay to reduce basis risk.

The game reduces to ten choices between 10 paired insurance contracts whose net revenues are listed in table 3. Notice that the price of the index insurance contract does not vary, whereas the price of the individual insurance contract increases by d200 as we move down the table.
<table>
<thead>
<tr>
<th>Index Insurance contract</th>
<th>Indemnity insurance contract</th>
<th>Implied WTP</th>
<th>Implied CRRA under EUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>d1400</td>
<td>d1740</td>
<td>0</td>
<td>(0; 0.49)</td>
</tr>
<tr>
<td>d1400</td>
<td>d1940</td>
<td>d200</td>
<td>(0.49; 0.71)</td>
</tr>
<tr>
<td>d1400</td>
<td>d2140</td>
<td>d400</td>
<td>(0.71; 0.87)</td>
</tr>
<tr>
<td>d1400</td>
<td>d2340</td>
<td>d600</td>
<td>(0.87; 0.99)</td>
</tr>
<tr>
<td>d1400</td>
<td>d2540</td>
<td>d800</td>
<td>(0.99; 1.09)</td>
</tr>
<tr>
<td>d1400</td>
<td>d2740</td>
<td>d1000</td>
<td>(1.09; 1.18)</td>
</tr>
<tr>
<td>d1400</td>
<td>d2940</td>
<td>d1200</td>
<td>(1.18; 1.25)</td>
</tr>
<tr>
<td>d1400</td>
<td>d3140</td>
<td>d1400</td>
<td>(1.25; 1.32)</td>
</tr>
<tr>
<td>d1400</td>
<td>d3340</td>
<td>d1600</td>
<td>(1.32; 1.37)</td>
</tr>
<tr>
<td>d1400</td>
<td>d3540</td>
<td>d1800</td>
<td>(1.37; +∞)</td>
</tr>
</tbody>
</table>

Table 3: Game 2: Eliciting WTP measure.

The last column of Table 3 presents the CRRA ranges implied by the measured WTP if the player behaves according to the predictions of EUT, i.e., if he reduces the index insurance compound-lottery to a simple lottery. However, if a participant is compound-risk averse, then the elicited CRRAs are not true.

In order to deduce the compound-risk aversion of a player, we impose a functional form on the function $v$ we defined earlier. For computational convenience, we impose constant relative compound risk aversion. Thus, the function $v$ defined in Section 2 is given by:

$$v(y) = \begin{cases} \frac{g^1 - y}{1 - g} & \text{if } g \in [0, 1) \\ \log(y) & \text{if } g = 1 \end{cases}$$

(11)

where $g$ is the coefficient of constant relative compound-risk aversion.

Table 4 below lists the predicted coefficients of compound-risk aversion based on the player’s choices in Games 1 and 2. To simplify the calculations, these measures are made after taking the midpoint of every risk aversion range. For example, if the player chose contract 4 in Game 1, then the corresponding CRRA is 0.45. The corresponding $g$ is obtained by equalizing equations 2 and 6.

<table>
<thead>
<tr>
<th>Contract choice in Game 1:</th>
<th>WTP [d]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0.01</td>
</tr>
<tr>
<td>200</td>
<td>0.08</td>
</tr>
<tr>
<td>400</td>
<td>0.14</td>
</tr>
<tr>
<td>600</td>
<td>0.21</td>
</tr>
<tr>
<td>800</td>
<td>0.27</td>
</tr>
<tr>
<td>1000</td>
<td>0.34</td>
</tr>
<tr>
<td>1200</td>
<td>0.40</td>
</tr>
<tr>
<td>1400</td>
<td>0.47</td>
</tr>
<tr>
<td>1600</td>
<td>0.53</td>
</tr>
<tr>
<td>1800</td>
<td>0.59</td>
</tr>
</tbody>
</table>

Table 4: Predictions of the Coefficients of Compound-Risk Aversion.
5 Descriptive analysis of the experimental results

5.1 Participants characteristics

Table 5 provides the descriptive statistics for the experiment participants. All the participants are male, which is not surprising given the division of labor in the area of study: cotton is a male crop. The average participant is approximately 47 years old, has limited formal education (three years of schooling), and belongs to a household with almost 19 members. 71% of the participants are the head of their households, and almost all of them have heard of the cotton insurance contract distributed in the field. The average household head has been a member in the cooperative for almost 8.6 years. The average household economic status is represented by a total livestock value of 1.8 million CFA, a house worth 400,000 CFA and a total land area of 9.62 ha.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>mean</th>
<th>sd/percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>head</td>
<td>1 if the participant is head of household</td>
<td>0.7</td>
<td></td>
</tr>
<tr>
<td>age</td>
<td>Participant’s agent</td>
<td>47.07</td>
<td>13.21</td>
</tr>
<tr>
<td>gender</td>
<td>1 if participant is male</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>education</td>
<td>Participant’s years of schooling</td>
<td>4.55</td>
<td>6.57</td>
</tr>
<tr>
<td>knowledge_ins</td>
<td>1 if participant heard about cotton insurance before</td>
<td>0.92</td>
<td></td>
</tr>
<tr>
<td>age_hh</td>
<td>Head of the household’s age</td>
<td>55.55</td>
<td>15.22</td>
</tr>
<tr>
<td>gender_hh</td>
<td>1 if head of the household is male</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>coop_years</td>
<td>Number of years of household's head membership in the cotton cooperative</td>
<td>8.62</td>
<td>6.28</td>
</tr>
<tr>
<td>hh_size</td>
<td>Size of the household</td>
<td>18.82</td>
<td>11.88</td>
</tr>
<tr>
<td>livestock_2012</td>
<td>Value of livestock in CFA</td>
<td>1,822,602</td>
<td>5,634,664</td>
</tr>
<tr>
<td>ag_value</td>
<td>Value of agricultural equipment in CFA</td>
<td>171,299</td>
<td>247,236</td>
</tr>
<tr>
<td>assets_value</td>
<td>Value of household’s assets in CFA</td>
<td>204,200</td>
<td>164,468</td>
</tr>
<tr>
<td>house_value</td>
<td>Value of the house in CFA</td>
<td>396,952</td>
<td>1,042,061</td>
</tr>
<tr>
<td>land_owned</td>
<td>Total area of land owned in ha</td>
<td>9.62</td>
<td>7.81</td>
</tr>
</tbody>
</table>

Table 5: Descriptive Statistics of the Participants

5.2 Description of the results of Game 1

The last column of Table 6 below shows the distribution of the levels of CRRA of the participants, based on the results of Game 1. The majority of the farmers (78%) chose an insurance contract, and 30% of them chose the highest level of coverage which corresponds to a CRRA level of more than 0.55.

<table>
<thead>
<tr>
<th>Contract #</th>
<th>CRRA range</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>($\infty$; 0.08)</td>
<td>22.56</td>
</tr>
<tr>
<td>1</td>
<td>(0.08; 0.16)</td>
<td>7.32</td>
</tr>
<tr>
<td>2</td>
<td>(0.16; 0.27)</td>
<td>9.76</td>
</tr>
<tr>
<td>3</td>
<td>(0.27; 0.36)</td>
<td>10.67</td>
</tr>
<tr>
<td>4</td>
<td>(0.36; 0.55)</td>
<td>17.99</td>
</tr>
<tr>
<td>5</td>
<td>(0.55; $\infty$)</td>
<td>31.71</td>
</tr>
</tbody>
</table>

Table 6: Distribution of the CRRAs in the sample
6 Empirical Analysis

6.1 Testing the hypothesis of compound-risk neutrality

As we saw in Proposition 3 of Section 3, a compound-risk averse farmer is willing to pay more money to switch from the index insurance contract to the individual insurance contract, than his compound-risk neutral counterpart who has the same level of risk aversion. Therefore, in order to empirically test the hypothesis that farmers are compound-risk neutral (i.e. expected utility maximizers), one should compare the distribution of the CRRA coefficients elicited from Game 1 (last column of Table 2) to those elicited from Game 2 (last column of Table 3). Games 1 and 2 do not elicit the actual CRRA coefficients; rather they provide CRRA classes that are not directly comparable. Therefore, before performing the hypothesis test, we begin by fitting a continuous probability distribution to the CRRAs elicited from both games.

Instead of conducting an exhaustive search of every possible probability distribution, it is more practical to fit a general class distribution to the data. Ideally, this distribution will be flexible enough to reasonably represent the underlying parameters. This section uses the Beta of the first kind (B1), a three-parameter distribution, as the continuous model that represents the data. The Beta distribution of the first kind is one member of a class of distributions called Generalized Beta distributions (GB), a family of five-parameter distributions that encompasses a number of commonly used distributions (Gamma, Pareto, etc.). The GB is a flexible unimodal distribution and is widely used when modeling bounded continuous outcomes, such as income distributions.

Since the B1 distribution is defined for bounded variables, one should make assumptions about the range of the CRRAs. The participants are assumed to be risk-averse since they are poor cotton farmers from a developing country. We allow the upper bound of the elicited CRRA to be 1.7.

Let \( B1(b, p_1, q_1) \) and \( B1(b, p_1, q_1) \) be the probability distribution functions of the CRRAs elicited from Game 1 and Game 2 respectively. The parameter \( b \) is the upper bound of the CRRAs. The Appendix explains the methodology used to estimate these parameters.

Table 7 presents the results of the estimation method:

<table>
<thead>
<tr>
<th></th>
<th>Game 1</th>
<th>Game 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>First parameter</td>
<td>0.68</td>
<td>2.07</td>
</tr>
<tr>
<td>Second parameter</td>
<td>1.99</td>
<td>4.36</td>
</tr>
</tbody>
</table>

Table 7: Estimated parameters of the distribution

We estimate the confidence intervals for the different parameters using the bootstrap method. Table 8 shows the confidence intervals of parameters \( p_1, q_1, p_2 \) and \( q_2 \) at the 5% significance level, obtained after 10000 simulations. The bootstrap parameters appear to be consistent estimates for the actual parameters.
### Table 8: Bootstrap confidence intervals for the parameters.

<table>
<thead>
<tr>
<th></th>
<th>Parameter 1</th>
<th>Parameter 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean</td>
<td>[95% confidence interval]</td>
</tr>
<tr>
<td>Game 1</td>
<td>$p_1$</td>
<td>0.67</td>
</tr>
<tr>
<td></td>
<td>$q_1$</td>
<td>1.98</td>
</tr>
<tr>
<td>Game 2</td>
<td>$p_1$</td>
<td>2.07</td>
</tr>
<tr>
<td></td>
<td>$q_1$</td>
<td>4.37</td>
</tr>
</tbody>
</table>

From Figure 3, it is clear that the estimated parameters follow a normal distribution whose mean is close to the observed values. Therefore, the estimation strategy provides a good fit for the data.

![Histograms of bootstrap for parameter $p_1$ and $q_1$.]

![Histograms of bootstrap for parameter $p_2$ and $q_2$.]

Figure 3: Histogram of bootstrap for parameter $p$ and $q$.

The test of equality of the distributions of the two CRRAs elicited from the games is performed using 10,000 bootstrapped simulations of the data. We reject the hypothesis that the parameters of the two distributions are the same at the 5% level. Therefore, we reject the hypothesis that the sample of farmers compound-risk neutral.

### 6.2 Participants have different compound-risk attitudes

Overall, only 40.18% of the participants were indifferent between the index insurance contract and the equivalent individual insurance contract. This supports the hypothesis that basis risk reduces the demand for index insurance. The remaining 60.82% participants have an average WTP of 395d, which represents 22% of the price of the individual insurance contract.

We presented the coefficient of compound-risk aversion for each demonstrated category of WTP in Table 4. Using the Table 4 coefficients of compound-risk aversion, we derive the number of participants who are
compound-risk averse and disaggregate this number by risk aversion range. As shown in Table 9, 57% of the players are compound-risk averse. Furthermore, most of the compound-risk averse farmers are also the least risk averse (22.39%). While the existence of compound-risk aversion is important in and of itself, we will study its impact on the demand for index insurance in the next section.

<table>
<thead>
<tr>
<th>CRRA Range</th>
<th>0</th>
<th>0.08</th>
<th>0.16</th>
<th>0.27</th>
<th>0.36</th>
<th>0.55</th>
<th>1.7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compound-risk averse participants</td>
<td>73</td>
<td>24</td>
<td>32</td>
<td>35</td>
<td>50</td>
<td>103</td>
<td>186</td>
</tr>
<tr>
<td>% of CRRA range</td>
<td>100</td>
<td>37.5</td>
<td>65.0</td>
<td>74.2</td>
<td>66.1</td>
<td>14.6</td>
<td></td>
</tr>
<tr>
<td>% of total participants</td>
<td>22.39</td>
<td>2.76</td>
<td>7.36</td>
<td>7.98</td>
<td>11.96</td>
<td>4.60</td>
<td>57.07</td>
</tr>
</tbody>
</table>

Table 9: Distribution of Compound-risk Attitudes by CRRA levels.

6.3 Simulating the Impact of Basis Risk

Drawing on the findings of the experiments described above, this section simulates the impact of basis risk on the demand for index insurance under expected utility maximization (equivalently, compound-risk neutrality), and compound-risk aversion. In the following discussion, we assume that the distributions of risk aversion and of compound-risk aversion among the participating farmers reflect the distributions in the overall population.

![Figure 4: Basis Risk and the Demand for Index Insurance.](image)

The dotted curve of Figure 4 illustrates the impact of basis risk on the demand for index insurance assuming that:

1. Individuals are expected utility maximizers,
2. The price of index insurance is 20% above the actuarially fair price, and

3. The distribution of risk aversion in the population of farmers matches the distribution revealed by the experimental games played in Mali.

Here, basis risk is the probability of not getting a payment conditional on the farmer experiencing a loss. As the basis risk increases under this contract structure, the probability of a payout decreases, and the price of the insurance contract in turn declines. However, because the contract is not actuarially fair, a number of agents drop out of the market as basis risk increases. As can be seen in Figure 4, increasing basis risk in an index insurance contract will discourage demand because it fails to sufficiently reduce the risk of collateral loss. For a contract with zero basis risk, i.e. one that pays off for sure in case of a loss, moderately and highly risk-averse farmers (70% of the population in the Mali experiment) ask for index insurance. As basis risk increases, the farmers with the highest risk aversion coefficient are the first to stop demanding the contract. This drop in demand reaches as high as 15% for extremely high levels of basis risk (90%). Despite this decrease in demand, the demand for the partial insurance provided by this index insurance contract remains relatively robust even as basis risk increases (assuming that individuals maximize expected utility).

Basis risk matters even more when people are compound-risk averse. Using the distribution of compound-risk aversion in the population of the farmers, the solid line in Figure 4 shows the impact of basis risk on demand for index insurance. As expected, compound-risk aversion decreases the demand for index insurance relative to what it would be if individuals had the same degree of risk aversion but were compound-risk neutral. In addition, as can be seen in the figure, demand declines more steeply as basis risk increases under compound-risk aversion. Were basis risk as high as 50% (a not unreasonably high number given the kind of rainfall index insurance contracts that have been utilized in a number of pilots), demand would be expected to be only 35% of the population as opposed to the 60% predictions implied by EUT. In short, under compound-risk aversion, designing contracts with minimal basis risk is important, not only to enhance the value and productivity impacts of index insurance, but also to assure that the contracts are demanded.

7 Conclusion

In the absence of traditional insurance markets, poor households in developing countries rely on costly risk-managing mechanisms. Although index insurance provides a good alternative to these households in theory, demand has been surprisingly low. In this paper, we presented a novel way to understand these low uptake rates, using the interlinked concepts of ambiguity and compound lottery aversion.

In a framed field experiments conducted with cotton farmers in Bougouni, Mali we elicited the coefficients of risk-aversion and the WTP measure, and we derived the compound-risk aversion coefficients of the farmers. Individuals generally did not behave in accordance with expected utility theory. Instead we observed 57% of game participants revealed themselves to be compound-risk averse to varying degrees. In fact, the willingness
to pay of those individuals who demand index insurance is on average considerably higher than the predictions of expected utility theory.

Using the distribution of compound risk aversion and risk aversion in this population, we simulated the impact of basis risk on the demand for index insurance. As we expected we found that compound risk aversion decreases the demand for index insurance relative to what it would be if individuals had the same degree of risk aversion but were compound-risk neutral. In addition demand declines more steeply as basis risk increases under compound-risk aversion.

Our results highlight the importance of designing contracts with minimal basis risk under compound-risk aversion. This would not only enhance the value and productivity impacts of index insurance, but would also assure that the contracts are popular and have the anticipated impact.

References


A Appendix: Fitting a B1 distribution to the CRRA

In this section, we estimate the probability density function $f$ of the coefficient of constant relative risk aversion $r$ we elicited from an experiment.

We use Maximum Likelihood estimation assuming that $r$ follows a Generalized Beta distribution of first kind (GB1). The GB1 distribution is defined by the following pdf:

$$f(r; b, p, q) = \frac{(r^{p-1}(1 - \frac{r}{b})^{q-1})}{b^p B(p, q)}$$

for $0 < r < b$ where $b$, $p$ and $q$ are positive. The scaling factor $B(p, q)$ is the Beta function:

$$B(p, q) = \frac{\Gamma(p)\Gamma(q)}{\Gamma(p+q)}$$

where $\Gamma(p) = (p-1)!$.

By construction, our data is partitioned in 6 intervals. Therefore, we do not observe the continuous variable $r$. Following McDonald and Xu [1995], we obtain the parameters of interest ($p$ and $q$) using a Maximum Likelihood estimator based on a multinomial with an underlying density $f(r; b, p, q)$ and cumulative function $F(r; b, p, q)$.

We now derive the log-likelihood function. Let $j$ denote the risk aversion interval $[r_j, \ r_{j+1})$. Player $i$’s true risk aversion coefficient $r$ has a probability $p_i = F(r_{j+1}; a, b, p, q) - F(r_j; a, b, p, q)$ of being in interval $j$. Denoting $m_j$ the number of observations in interval $j$, the likelihood function $L_N$ is the joint probability function:

$$L_N = \prod_{i=1}^{N} p_i$$

Maximizing $L_N$ is equivalent to maximizing the log-likelihood function:
\[ \mathcal{L}_N (b, p, q) = \log \mathcal{L}_N (b, p, q) = \sum_{j=1}^{6} m_j \log (p_j) \]

Where \( m_j \) is the number of observations in the interval \([r_j, r_{j+1}]\). The probability \( p_j \) of being in that interval is

\[ p_j = F (r_{j+1}; a, b, p, q) - F (r_j; a, b, p, q) \]

Since \( r \) is a Beta distribution of the first kind, its cumulative \( F \) is:

\[ F (r; b, p, q) = \int_0^r \frac{t^{p-1} (1 - t)^{q-1}}{B (p, q)} dt = I (\frac{r}{b}; p, q) \]

where \( I (\frac{r}{b}; p, q) \) the regular beta function is the cumulative distribution function of the Beta variable with parameters \( p \) and \( q \) evaluated at \( \frac{r}{b} \).

**Proof.** By definition:

\[ F (r; a, b, pq) = \int_0^r \frac{t^{p-1} (1 - t)^{q-1}}{b^p B (p, q)} dt \]

using the change of variable \( x = \frac{r}{b} \), we obtain the result. \( \square \)