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Risk Sharing and the Demand for Insurance: Theory and Experimental Evidence from Ethiopia

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Abstract

Households, organisations and governments commonly engage in risk sharing. However, residual risk often remains considerable, especially in low-income countries. In response, many policy makers have considered the introduction of insurance. But this raises the question of how demand for insurance depends on the extent of pre-existing risk sharing. We contribute, first, by showing in a simple model that risk sharing is a substitute for indemnity insurance but a complement to index insurance. Second, in an artefactual field experiment with Ethiopian farmers, we are the first to vary the extent of risk sharing exogenously. The predictions from theory are confirmed.

1 Introduction

Households, organisations and governments commonly share risk through transfers and emergency loans. This helps to smooth consumption, but the residual risk tends to be substantial, especially in the face of aggregate shocks which affect the entire risk-sharing group. Notably, weather risk

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and natural disasters remain important sources of vulnerability, particularly in low-income countries. In response, policy makers are increasingly using insurance to manage risk (Clarke and Dercon, 2016). Standard indemnity insurance, which tends to be costly and fraught with asymmetric information problems, has increasingly been supplemented by parametric or indexed insurance products, where payouts are based on objectively verifiable indices such as rainfall measures.[1] These can lower costs and reduce market imperfections, though payouts are imperfectly correlated with actual losses.

In evaluating the relative merits of indemnity and index insurance, it is important to consider their interaction with pre-existing risk-sharing arrangements. Does risk sharing make insurance more attractive, or crowd it out?

We study the effect of risk sharing on demand for indemnity and index insurance, making two key contributions to the literature. The first is to show analytically, in a theoretical framework that is far simpler than those used previously, that risk sharing decreases demand for indemnity insurance but increases demand for index insurance. Intuitively, this is because the greater the extent of risk sharing, the more agents will need to be insured against shocks which are common to the group, which is what index insurance does, rather than shocks specific to the individual, which is what indemnity insurance does. Risk sharing is a complement to index insurance because it pools individual-specific shocks, including the possibility that index insurance does not pay out when an individual suffers a loss (basis risk). Risk sharing is a substitute for indemnity insurance because both serve to pool idiosyncratic rather than aggregate shocks.

The second key contribution is to investigate these relationships empirically. In an artefactual field experiment with farmers in Ethiopia, we study the impact of risk sharing on the demand for both indemnity and index insurance. As far as we are aware, we are the first to vary the extent of

[1]One prominent example is Kilimo Salama, which provides 180,000 low-income Kenyan farmers with parametric insurance against drought and excess rainfall. Another is the Caribbean Catastrophe Risk Insurance Facility (CCRIF), set up by 16 Caribbean governments. It offers country-level parametric insurance to limit the financial impact of devastating hurricanes and earthquakes. In both cases the insurance products are offered to stakeholders who already tend to share risk.

risk sharing experimentally and thereby avoid endogeneity concerns of previous work. We are also the first to test the impact of risk-sharing on *both* indemnity and index insurance in the same experimental setting, thereby allowing a direct comparison of demand for these two types of insurance. Our results confirm the predictions of the theory: risk sharing decreases the number of units of indemnity insurance purchased by 27% and increases the number of units of index insurance by 130%.

Our paper builds on a substantial literature on risk sharing and insurance. Early contributions showed that risk sharing falls short of providing full consumption smoothing (Cochrane, 1991; Mace, 1991; Townsend, 1994). Imperfect risk sharing may arise from limited commitment or information asymmetry (Coate and Ravallion, 1993; Attanasio and Pavoni, 2011), and the role of insurance in this context is the subject of several papers including the seminal work by Arnott and Stiglitz (1991). Boucher and Delpierre (2014) is a more recent contribution. De Janvry, Dequiedt and Sadoulet (2014) and Janssens and Kramer (2016) look at co-ordination problems in the context of introducing insurance to risk-sharing groups. Here, in order to isolate the effect of risk sharing on the demand for insurance, we abstract from these market imperfections and treat the extent of risk sharing as exogenously given in both the theory and the experiment.

We contribute to a recent theoretical literature on the complementarity or substitutability of risk sharing and insurance. Our model is most similar to that of Dercon et al. (2014). We generate predictions similar to theirs, namely that risk sharing is a complement to index insurance but a substitute for indemnity insurance, but in a far simpler theoretical framework. In particular, they make assumptions on the third and fourth derivatives of the instantaneous utility function (prudence and temperance), whereas we only make the standard assumptions of non-satiation and risk aversion. That we do not require these further restrictions on the utility function is particularly important in the light of recent evidence from the experimental literature: Deck and Schlesinger (2014) conclude that, though there is some evidence for prudence, the behaviour of agents appears more consistent with intemperance than temperance. Furthermore, unlike Dercon et al. (2014), we derive simple, closed-form solutions.

Mobarak and Rosenzweig (2012) also model the demand for index insurance in the presence of risk sharing, however, they do not contrast it with indemnity insurance. In a setup with a pair of risk sharing agents, they model aggregate and idiosyncratic risks as independent, additive shocks. They conclude that risk sharing *may* increase demand for insurance when basis risk is high, but they are unable to predict unambiguously the sign of the effect. By contrast, we model risk as a single shock occurring with a probability that depends on the aggregate state (index). This simplifies the analysis, not only permitting analytical solutions, but also allowing for basis risk to arise naturally within the framework rather than representing an additional assumption.

We also build on an empirical literature on the complementarity or substitutability of different forms of risk sharing and insurance.

It is well known that indemnity insurance can crowd out risk sharing in both full and limited-commitment risk-sharing relationships. Attanasio and Ríos-Rull (2000) and Albarran and Attanasio (2003) show that the introduction of government insurance in Mexico reduced the size of transfers in informal risk-sharing arrangements. Cutler and Gruber (1996) show that the introduction of Medicaid in the US crowded out pre-existing private insurance to the extent that between 50 and 70 per cent of the increase in Medicaid coverage between 1987 and 1992 was linked to a decrease in private insurance.

The relationship between index insurance and informal risk sharing is less well tested. Mobarak and Rosenzweig (2012) offer index insurance to different caste networks in India, and find that the demand for index insurance increases with the extent of risk sharing when the latter primarily covers idiosyncratic losses (though these effects are not statistically significant) and decreases with risk sharing when the latter primarily covers village-level shocks. However, since the level and nature of risk sharing in the caste network is endogenous, rather than varied exogenously, it not clear that they are able to fully isolate the effect of risk sharing on demand for index insurance. Dercon et al. (2014) offer index insurance products to risk-sharing groups (*iddir*) in Ethiopia. In their experiment, all participants are subjected to a marketing intervention on the benefits of index insurance, but in some treatment arms, the benefits of risk sharing as a mechanism to manage the basis risk associated with indexed contracts are particularly emphasised. While the authors find that emphasising the benefits of sharing basis risk increased demand for index insurance, their intervention clearly falls short of exogenously varying the extent of risk sharing. Furthermore, neither Mobarak and Rosenzweig (2012) nor Dercon et al. (2014) study indemnity insurance in their experiments.

The rest of the paper is organised as follows. Section 2 presents our theoretical framework and key predictions. Section 3 describes the experimental design. Section 4 lays out the estimation strategy. Section 5 presents the results and Section 6 concludes.

2 Theory

The key predictions of our theoretical framework are that index insurance is a complement to informal risk-sharing agreements, whilst indemnity insurance acts as a substitute. We show this first in a highly stylised setup in order to highlight the intuition, before embedding the result in a standard insurance model with binary loss states.

2.1 Skeletal model

The central intuition can be illustrated using a 'skeletal' model as follows. An infinite number of risk-averse farmers maximise expected utility. Indexed by i, they have stochastic incomes y_i. Expected income, denoted x, is the same for all farmers and itself random, depending, for example, on common weather shocks. An index is able to track x perfectly, and thus underpin an index insurance product against shocks to x.

The farmers implement a costless risk-sharing mechanism, whereby a proportion θ of each farmer's realized income is paid into a common kitty which is then evenly divided among them. Since the number of farmers is infinite, each receives an amount equal to the expected contribution, $E(\theta y_i) = \theta x$, from the kitty. So after risk sharing, farmer i's income is

$$\theta x + (1 - \theta) y_i.$$

Farmers also have access to index and indemnity insurance, which compensate for variation in x and y_i, respectively.

Then if both insurance types are actuarially fairly priced, each risk-averse farmer will fully insure, as follows:

Result 1: In the skeletal model, each farmer purchases θ units of index insurance and $1 - \theta$ units of indemnity insurance.

That is, the proportion of index insurance in the optimal insurance portfolio is equal to the proportion of the farmer's realised income that is paid into the risk-sharing pool. *In other words, the greater the level of risk-sharing in the community, the greater the demand for index insurance and the lower the demand for indemnity insurance.*

Intuitively, indemnity insurance and risk sharing are substitutes because both serve the purpose of smoothing consumption within the group, that is, protecting against idiosyncratic shocks. And index insurance is a complement to risk sharing because the greater the extent of risk sharing, the more the residual risk relates to the aggregate shock, which is what index insurance covers.

Note that this result does not require conditions on the utility function, beyond the standard assumptions of expected utility maximisation, non-satiation and risk aversion. In particular, farmers need not have the same instantaneous utility function. Furthermore, the result does not depend the distributions of x and y_i. In particular, it does not depend on whether farmers' incomes are correlated conditional on x.

2.2 Model with binary loss

The central intuition can be embedded into a more standard insurance framework with a binary loss state. Again, consider an infinite number of risk-averse farmers maximising expected utility. Each farmer has endowment y and faces a possible loss L. With probability q, a drought occurs. The drought shock is common to all farmers. If there is a drought, each farmer incurs the loss with conditional probability P. If the drought does not occur, the conditional probability of incurring the loss is $p < P$. Thus, the expression $P - p$ can be interpreted as a measure of how informative the index is of actual losses.

For simplicity, we assume that farmer losses are independent, conditional on drought outcome. However, unconditional losses are positively correlated, since they all depend on whether or not there is a drought.

This loss and index structure is more in line with Clarke and Kalani (2011), Dercon et al. (2014), and Clarke (2016) than with Mobarak and Rosenzweig (2012) or Boucher and Delpierre (2014). Unlike the latter two papers, in our model there is either a loss or no loss for each participant, and the aggregate state does not affect wealth directly, but modifies the probability of loss.

However, unlike Mobarak and Rosenzweig (2012) and Dercon et al. (2014), but in common with Boucher and Delpierre (2014), we assume that the index tracks expected loss perfectly. This allows us to focus on the trade-off between risk sharing and the demand for insurance. Continuing improvements in index insurance design also makes this assumption increasingly realistic.

As in the skeletal framework above, the farmers engage in costless risk sharing: irrespective of individual outcomes, they all pay a proportion θ of their assets into a common kitty which is then divided equally among them. Hence each farmer pays either θy or $\theta(y-L)$, depending on individual outcome, into the kitty, and receives $\theta(y - PL)$ from the kitty if there is a drought and $\theta(y - pL)$ if there is not.

There are thus four possible outcomes for each farmer, as shown in Table 1.

Table 1: Outcomes after risk sharing, without insurance

Drought	Loss	Probability	Outcome after risk sharing
Yes	Yes	qP	$\theta(y - PL) + (1 - \theta)(y - L)$
Yes	No	$q(1 - P)$	$\theta(y - PL) + (1 - \theta)y$
No	Yes	$(1 - q)p$	$\theta(y - pL) + (1 - \theta)(y - L)$
No	No	$(1 - q)(1 - p)$	$\theta(y - pL) + (1 - \theta)y$

Each farmer has access to two forms of insurance: indemnity insurance and index insurance. Let α be the number of units of indemnity insurance purchased by a farmer. Each unit of indemnity insurance pays out L if and only if the farmer suffers an individual loss, irrespective of whether or not there is a drought. And let β be the number of units of index insurance taken out. Each unit of index insurance pays out L if and only if there is a drought, irrespective of whether the farmer suffers a loss.

Assuming both types of insurance are actuarially fair, premia equal expected losses. Hence the cost per unit of cover is $(qP + (1-q)p)L$ for indemnity insurance and qL for index insurance.

With insurance, the outcome for a farmer in each state of the world is as shown in Table 2. (The probabilities are as in Table 1 and omitted to save space.) The third row in the table, where a loss occurs in spite of there being no drought, represents the basis risk associated with index insurance.

Table 2: Outcomes after risk sharing and insurance

Drought	Loss	Outcome after risk sharing and insurance
Yes	Yes	$\theta(y-PL)+(1-\theta)(y-L)-\alpha(qP+(1-q)p)L-\beta qL+\alpha L+\beta L$
Yes	No	$\theta(y-PL)+(1-\theta)y-\alpha(qP+(1-q)p)L-\beta qL+\beta L$
No	Yes	$\theta(y-pL)+(1-\theta)(y-L)-\alpha(qP+(1-q)p)L-\beta qL+\alpha L$
No	No	$\theta(y-pL)+(1-\theta)y-\alpha(qP+(1-q)p)L-\beta qL$

The farmers' problem is to maximise expected utility over these four outcomes with respect to insurance decisions α and β. At the optimum, the risk-averse farmers choose α and β to ensure full consumption smoothing, such that in each of the four states of the world the farmer gets their autarchic expected income $y - (qP + (1-q)p)L$.

Simple algebraic rearrangement shows that this full consumption smoothing can be achieved by farmers purchasing indemnity and index insurance as follows.

Result 2: In the binary-loss insurance framework, optimal indemnity and index insurance purchases are given by:

$$\alpha = 1 - \theta \qquad \text{and}$$
$$\beta = \theta(P - p)$$

Since full consumption smoothing is achieved costlessly, this is an optimal solution for all utility functions satisfying non-satiation and risk aversion.

The expressions for optimal insurance demand show how indemnity insurance and index insurance are, respectively, a substitute and a complement to group risk sharing. Furthermore, the expression for β nests the familiar result from Clarke (2016) that demand for index insurance is decreasing in basis risk. This is because as $P - p$ decreases, the index is less informative of losses. Indeed, when $P = 1$ and $p = 0$, so that $P - p = 1$, the index is perfectly informative of individual losses, and index insurance becomes equivalent to indemnity insurance. As the expressions for α and β show, in this case one unit of effective indemnity insurance is bought.

Two key assumptions of the model are worth noting. First, both types of insurance are assumed to be actuarially fair. In practice, while governments may subsidise insurance such that the premia are fair, privately provided insurance is generally sold with a mark-up. We retain the assumption of actuarially fair premia for the sake of simplicity and clarity of exposition. In a model with marked-up premia, any positive amount of insurance would reduce expected income. Agents' willingness to make this trade-off (reduced uncertainty in return for lower expected income) would depend on risk aversion and other parameters. But we would not expect the introduction of loaded premia to change the key qualitative predictions, namely that, other things equal, risk sharing is associated with a reduction in the demand for indemnity insurance and an increase in demand for index insurance.

Second, our theoretical model assumes an infinite risk-sharing pool, which clearly does not obtain in practice. However, the assumption of an infinite risk-sharing group can be defended in several ways. In practice, risk-sharing groups are often comprised of relatively large networks of family and friends (Fafchamps and Lund, 2003), so an infinite risk-sharing pool may in some settings be more realistic than, or at least an alternative benchmark to, the two-person risk pools of, for example, Mobarak and Rosenzweig (2012) and Dercon et al. (2014). Furthermore, we would expect the central intuitions of the model to extend to the case of a finite risk-sharing group. Indeed, since these papers, along with that of Boucher and Delpierre (2014), generate similar results without the assumption of an infinite risk-sharing group, it is clear that the assumption is not necessary to obtain similar theoretical results. Rather, the assumption acts as a means of clarifying and simplifying the mechanism behind the results.

2.3 Predictions

In both models, the closed-form solutions for index and indemnity insurance demand generate two clear predictions:

1. Demand for indemnity insurance decreases with the level of risk sharing.
2. Demand for index insurance increases with the level of risk sharing.

3 Experimental design

We conducted an artefactual field experiment in rural Ethiopia. The experiment was conducted over ten sessions, in ten different villages, with 40 invited local farmers in each. Each session lasted a maximum of three hours and was conducted in a classroom with desks, chairs and cardboard dividers. The same eight enumerators were present at all the sessions, each enumerator in charge of training and collecting the responses for five subjects.

The ten sessions were randomly assigned to one of four treatment arms, as shown in Table 3.

Table 3: Number of sessions by treatment arm

	Indemnity insurance	Index insurance
Without risk sharing	3	2
With risk sharing	3	2

Note: Allocation of sessions to the four treatment arms. In all, ten sessions were held, and each participant in a session received the same treatment.

Before taking part in the experiment, subjects were fielded a survey to collect background information. Participants were provided with comprehensive training on the insurance game as a group and through individual instruction and help from the enumerators. There were also un-incentivized practice runs to increase and check understanding. Since many of the subjects were illiterate, the game was explained orally with the help of visual aids, and physical randomization devices (colored tokens and dice) were used.

Subjects were informed that they would be given 200 birr[2] in an envelope at the start of the session, and that during the experiment, they would be exposed to the risk of losing 100 birr. They were also told that they would be able to purchase insurance to mitigate the risk.

The payoffs were substantial for rural Ethiopian farmers, given that the daily wage for unskilled labour was in the range 50–150 birr at the time.

3.1 Aggregate and idiosyncratic shocks

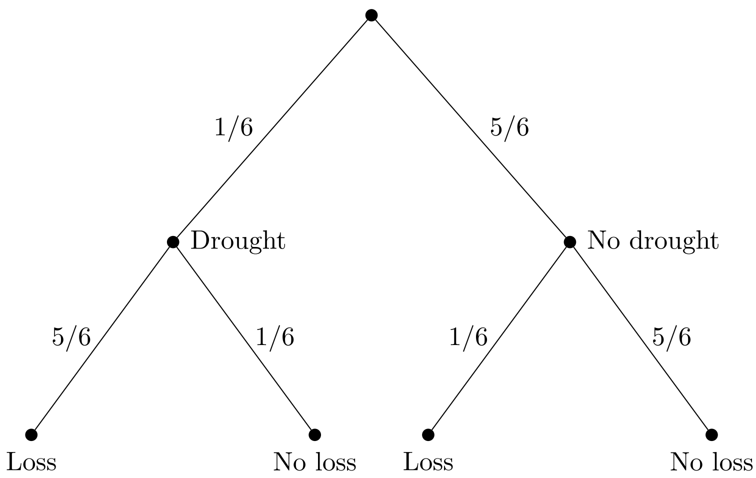
Subjects were introduced to the concepts of aggregate and idiosyncratic shocks. The aggregate shock in the game was framed as a possible region-wide drought, the occurrence of which depended on the color of a token drawn from an envelope. There were 6 tokens in the envelope: 1 yellow and 5 blue. If the yellow token was drawn, the drought occurred, and if a blue token was drawn, it did not. The aggregate shock was drawn at the front of the room so that all participants could see.

Each participant rolled a die to determine whether or not he or she would incur the loss. The dice rolled by the individual participants depended on whether or not the drought occurred: If the drought occurred, each participant would roll a die with 5 yellow sides and 1 blue side. If there was no drought, each participant would roll a die with 1 yellow side and 5 blue sides. If a subject's die showed yellow, he or she suffered a loss of 100 birr, whereas a blue die throw resulted in no loss.

Thus, as in the theory section, the aggregate shock (drought or not) was informative of the probability of suffering individual losses. Each participant's die throw was independent, and there was no group-level loss, but because the choice of die depended on the aggregate shock, farmer losses were unconditionally correlated. The probabilities and states of the game, before considering risk sharing and insurance, are presented in Figure 1. The unconditional expected net payoff in autarchy was $200 - 2 \cdot (5/36) \cdot 100 \approx 172$

[2]The exchange rate at the time of the experiment was 1 USD to 60 birr.

Figure 1: Aggregate shock and idiosyncratic losses



Note: Extensive-form autarchy game. Probabilities are presented next to the branches of the tree. The states are presented at the nodes of the tree representing drought, no drought, loss and no loss. The drought occurs with probability 1/6. The loss occurs with probability 5/6 if there is a drought and with probability 1/6 if not.

birr.

3.2 Risk sharing

The extent of risk sharing was not left to the participants but varied experimentally. In the treatment arms without risk sharing, participants could not share risk with each other during the session.[3]

In the risk-sharing treatment arms, participants were randomly and anonymously paired with another participant in the same session. The identity of their partner was not revealed to the participants. They were informed that, irrespective of the aggregate shock, insurance decisions and payouts, they would be sharing losses with their partner such that if one suffered the 100 birr loss but the other did not, then the latter would transfer 50 birr to the former.

[3]It is still possible that they shared risk after the session, even though subjects did not know with whom they were teamed up. But it is not clear that someone who had done well in the experiments would choose to reveal this. Even if they did, they might have difficulty identifying a deserving recipient, since it would be in everybody's interest to understate their earnings.

The fact that the experiment 'forced' farmers to share risk is important when identifying the effect of risk sharing on insurance demand, because it mitigates concerns that, if risk sharing were optional, farmers might not actually share risk with one another.

As in the the model, losses were shared but insurance premia and payouts were not. This means that the participants did not have an incentive to free-ride on their partner's insurance, which might otherwise depress demand for insurance and confound the mechanism studied here (De Janvry, Dequiedt and Sadoulet, 2014; Janssens and Kramer, 2016). We think this may be realistic in an agricultural context where yield outcomes are observable to all, but insurance contracts possibly not.

3.3 Insurance

Subjects were introduced to either indemnity insurance or index insurance, depending on the session. In the indemnity insurance sessions, subjects were told that they could purchase insurance that would pay out if they incurred the loss, irrespective of whether or not the drought occurred. In the index insurance treatments, subjects were told that they could purchase insurance which would pay out in the case of drought, irrespective of whether or not they suffered a loss.

In either case, participants could purchase 0, 1 or 2 units of insurance. Each unit of insurance was associated with a payout of 50 birr, that is, half the potential loss. Hence, 2 units would provide full insurance. The premium per unit of cover was 20 birr for indemnity insurance and 10 birr for index insurance. Table 4 presents unconditional probabilities, expected payouts and premia for the two insurance types. Note that neither insurance product was priced at the actuarially fair rate. In line with the literature and commercial insurance pricing, indemnity insurance was priced with a higher loading (mark-up above the actuarially fair rate) than index insurance.[4] Lower verification costs and reduced potential for moral hazard are two main reasons why index insurance can be expected to be

[4]Clarke and Kalani (2011) use loadings of 60% for indemnity insurance and 20% for index insurance. Reported commercial loadings range from 70% to 430% for rainfall index insurance (Cole et al., 2013, Table 1) and from 140% to 470% for indemnity insurance (Hazell, 1992, Table 1).

sustainable at a lower mark-up than indemnity insurance.

Table 4: Characteristics of Insurance Products Offered

	Indemnity insurance	Index insurance
Payout per unit of cover	50	50
Unconditional probability of payout	5/18	1/6
Expected payout (=actuarially fair premium)	$125/9 \approx 13.9$	$25/3 \approx 8.3$
Premium charged per unit of cover	20	10
Implied loading / mark-up above fair premium	44%	20%

Note: Each participant was offered either indemnity or index insurance, but not both, and could choose between 0, 1 or 2 units of cover. The premia were set so as to make the loadings roughly in line with the literature.

Table 5 shows net payoffs for an individual participant for each state of the world and each possible insurance decision, in the absence of risk sharing. Net payoffs are given by the endowment (200), minus any insurance premia, minus the loss (100) if incurred, plus any insurance payout. From the table it is clear that participants in the index insurance treatments were exposed to downside basis risk with a probability of 5/36.

Table 6 summarises the structure and timing of the game.

4 Estimation strategy

We use three econometric specifications to estimate the effect of risk sharing on insurance demand. Because the outcome variable is discrete with three possible outcomes (each participant buys 0, 1 or 2 units of insurance), we begin with an ordered probit. Next we run probit regressions where the outcome variable is a binary indicator for buying any (1 or 2 units) insurance versus none (0 units). Finally, we estimate a double probit hurdle model, where a first probit is used to model the decision regarding whether to buy insurance or not (the hurdle), and a second probit models the decision regarding whether to buy 1 or 2 units of insurance, conditional on buying at least one.

The key difference between the hurdle model and the ordered probit is that the hurdle model allows the outcome variable to be thought of as the result of two distinct choices by the participant, whereas in the ordered

Table 5: States and payoffs

			Payoff with indemnity insurance		Payoff with index insurance	
Prob	State	Units	Calculation	Net	Calculation	Net
5/36	Drought,	0	$200 - 100$	100	$200 - 100$	100
	loss	1	$200 - 20 - 100 + 50$	130	$200 - 10 - 100 + 50$	140
		2	$200 - 2 \cdot 20 - 100 + 2 \cdot 50$	160	$200 - 2 \cdot 10 - 100 + 2 \cdot 50$	180
1/36	Drought,	0	200	200	200	200
	no loss	1	$200 - 20$	180	$200 - 10 + 50$	240
		2	$200 - 2 \cdot 20$	160	$200 - 2 \cdot 10 + 2 \cdot 50$	280
5/36	No drought,	0	$200 - 100$	100	$200 - 100$	100
	loss	1	$200 - 20 - 100 + 50$	130	$200 - 10 - 100$	90
		2	$200 - 2 \cdot 20 - 100 + 2 \cdot 50$	160	$200 - 2 \cdot 10 - 100$	80
25/36	No drought,	0	200	200	200	200
	no loss	1	$200 - 20$	180	$200 - 10$	190
		2	$200 - 2 \cdot 20$	160	$200 - 2 \cdot 10$	180

Note: Payoffs in birr for each combination of drought, loss, type of insurance and number units of insurance purchased. The (no drought, loss) state is where index insurance leads to downside basis risk. Risk-sharing transfers (for participants in risk-sharing sessions only) come in addition.

Table 6: Insurance game timing

1. Each subject is given a 200 birr endowment.
2. Each subject buys insurance (0, 1 or 2 units) and pays the premium.
3. The aggregate shock is drawn at the group (session) level.
4. Each subject rolls a die to determine whether (s)he incurs a loss.
5. Subjects incurring a loss pay 100 birr to enumerator.
6. *Subjects are informed of their partner's loss outcome.*
7. *Any loss is shared with partner: receive 50, send 50 or no adjustment.*
8. Insurance pays out.

Note: Italicised items only apply to treatment arms with risk sharing.

probit the decision is best thought of as a single choice. We use both models because it is uncertain how the decision processes of the subjects are best represented. However, all three specifications yield qualitatively similar results.

It is helpful to define a latent variable Y_i^* that is linear in the independent variables:

$$Y_i^* = X_i\beta + \epsilon_i, \quad i = 1, \dots, N$$

The vector of independent variables X_i includes the main treatment variable (a binary indicator for risk-sharing), a constant term and, depending on the specification, fixed effects and control variables. The error terms ϵ_i are standard normally distributed.

In the probit regressions, the binary dependent variable Y_i is 0 if the subject buys 0 units of insurance and 1 if the subject buys 1 or 2 units of insurance. The observed binary outcome Y_i is modelled as follows:

$$Y_i = \begin{cases} 0 & \text{if } Y_i^* \leq 0 \\ 1 & \text{if } Y_i^* > 0 \end{cases}, \quad i = 1, \dots, N$$

For the ordered probit regressions, the latent variable Y_i^* is defined as above. But now the observed outcome variable (the number of units of insurance purchased) Y_i takes on values 0 through 2 according to the scheme

$$Y_i = \begin{cases} 0 & \text{if } Y_i^* \leq \mu_1 \\ 1 & \text{if } \mu_1 < Y_i^* \leq \mu_2 \\ 2 & \text{if } Y_i^* > \mu_2 \end{cases},$$

where μ_1 and μ_2 are threshold parameters to be estimated along with the coefficients β. Thus the probability of each outcome is:

$$\begin{aligned} \Pr(Y_i = 0) &= \Phi(\mu_1 - X_i\beta) \\ \Pr(Y_i = 1) &= \Phi(\mu_2 - X_i\beta) - \Phi(\mu_1 - X_i\beta) \\ \Pr(Y_i = 2) &= 1 - \Phi(\mu_2 - X_i\beta) \end{aligned}$$

Here, Φ is the cumulative distribution function for the standard normal.

The likelihood for the ordered probit can be written

$$L = \prod_{i=1}^{N} \sum_{n=0}^{2} \mathbb{1}\{Y_i = n\} \Pr(Y_i = n),$$

where $\mathbb{1}\{\}$ is the indicator function.

To allow for the possibility that the data have been generated through a process whereby subjects separately decide to purchase zero or a positive amount of insurance, and then decide the number of units to purchase (Mullahy, 1986; Cameron and Trivedi, 1998; Botelho et al., 2009), we estimate the parameters of a double probit hurdle model (Cribari-Neto and Zeileis, 2009). The first probit, with outcome Y_i', determines whether the individual buys at least 1 unit of insurance. This is the 'hurdle'. The second probit, with outcome Y_i'', determines whether the individual buys 1 or 2 units of insurance, conditional on buying at least 1.

Thus, in the hurdle model, the number of units of insurance purchased is given by

$$Y_i = Y_i'(1 + Y_i'').$$

Denoting by β' and β'' the parameter vectors for the first and second probit, respectively, the likelihood function for the hurdle model is

$$\begin{aligned} L = \prod_{i \in \Omega_0} \Phi(-\beta' X_i) \ \cdot \prod_{i \in \Omega_1 \cup \Omega_2} \Phi(\beta' X_i) \\ \cdot \prod_{i \in \Omega_1} \Phi(-\beta'' X_i) \ \cdot \prod_{i \in \Omega_2} \Phi(\beta'' X_i), \end{aligned}$$

where $\Omega_0 = \{i | Y_i = 0\}$ is the set of non-purchasers and $\Omega_1 = \{i | Y_i = 1\}$, $\Omega_2 = \{i | Y_i = 2\}$ are the subjects who choose 1 and 2 units of insurance, respectively.

5 Results

Of the 400 subjects, three started but were unable to complete the experiment due to unanticipated family or work engagements. These three were excused and received their participation fee.

Table 7 presents summary statistics for each of the four treatment arms:

indemnity insurance without (column 1) and with (column 2) risk sharing, and index insurance without (column 4) and with (column 5) risk sharing. As these arms technically form two separate experiments, one for each type of insurance, we test for balance separately. Column 3 presents t-tests for equality of means across the indemnity insurance treatments, and column 6 does the same for index insurance.

Out of 16 balance tests, equality is only rejected at the 5% level for one (marital status for index insurance). This rejection rate is close to what would be expected statistically (5%), but we still present regressions that control for all these observable characteristics.

The last row of Table 7 presents the main outcome variable, the number of units of insurance purchased. The mean comparisons foreshadow our main results: risk sharing decreases the mean number of units of indemnity insurance purchased by 27% (from 1.73 to 1.26) and increases the mean number of units of index insurance by 130% (from 0.60 to 1.38), and the differences are highly statistically significant.

Table 8 shows proportion of individuals purchasing 0, 1 or 2 units of insurance by treatment. The proportion of individuals purchasing at least one unit of indemnity insurance *decreases* from 0.99 to 0.86 when risk sharing is introduced, while the proportion of individuals purchasing at least one unit of index insurance *increases* from 0.46 to 0.93. The mean number of units purchased is repeated for convenience.

Table 9 shows ordered probit regression results for the number of units of insurance purchased (0, 1 or 2). Columns 2, 3, 5, and 6 include enumerator fixed effects. Column 3 and 6 also control for sex, age, age squared, marital status, household headship, literacy, household size, livestock owned in Tropical Livestock Units and land owned in hectares.

The risk-sharing coefficient is everywhere significant at the 1% level. For indemnity insurance, the overall effect is negative, as predicted by the theory. The effect is driven by an increase in the probability that subjects purchase 0 or 1 unit of insurance, and a decrease in the probability that subjects purchase 2 units of insurance.

For index insurance, the overall effect is positive, implying that risk sharing increases demand for index insurance, as predicted. The effect is driven by a reduction in the probability that individuals purchase 0 units

Table 7: Summary statistics and balance checks

	(1) Indemnity insurance, without risk sharing	(2) Indemnity insurance, with risk sharing	(3) Difference t-test (2)-(1)	(4) Index insurance, without risk sharing	(5) Index insurance, with risk sharing	(6) Difference t-test (5)-(4)
Female	0.37	0.39	0.025	0.47	0.42	-0.045
	(0.48)	(0.49)	(0.063)	(0.50)	(0.50)	(0.080)
Age	48.0	44.7	-3.28	42.3	38.6	-3.68
	(13.6)	(13.5)	(1.75)	(13.9)	(10.1)	(1.96)
Married	0.84	0.82	-0.016	0.80	0.62	-0.18
	(0.37)	(0.39)	(0.050)	(0.40)	(0.49)	(0.074)
Household head	0.88	0.88	0.00100	0.91	0.97	0.062
	(0.32)	(0.32)	(0.042)	(0.28)	(0.16)	(0.037)
Literate	0.55	0.59	0.037	0.40	0.50	0.10
	(0.50)	(0.49)	(0.065)	(0.49)	(0.50)	(0.080)
Household size	5.41	5.57	0.16	5.35	4.97	-0.39
	(1.82)	(1.71)	(0.25)	(2.22)	(1.90)	(0.37)
Tropical livestock units	1.86	1.80	-0.061	1.46	1.86	0.40
	(2.42)	(1.81)	(0.28)	(1.60)	(1.66)	(0.26)
Land owned, in hectares	0.72	0.66	-0.063	0.64	0.64	0.0047
	(0.39)	(0.38)	(0.050)	(0.31)	(0.39)	(0.056)
Units of insurance purchased	1.73	1.26	-0.47	0.60	1.38	0.78
	(0.47)	(0.69)	(0.076)	(0.72)	(0.62)	(0.11)
Observations	120	120	.	80	80	.

Note: Summary statistics and balance checks. Columns 1, 2, 4 and 5 present means of variables by treatment arm, with standard deviations in parentheses. Columns 3 and 6 present difference t-tests, with standard errors in parentheses.

Table 8: Insurance demand by treatment

	Indemnity insurance without risk sharing	Indemnity insurance with risk sharing	Index insurance without risk sharing	Index insurance with risk sharing
Proportion who purchase...				
no insurance (0 units)	0.01	0.14	0.54	0.08
partial insurance (1 unit)	0.26	0.46	0.32	0.48
full insurance (2 units)	0.73	0.40	0.14	0.45
some insurance (1 or 2 units)	0.99	0.86	0.46	0.93
Mean units purchased	1.73	1.26	0.60	1.38

of insurance and an increase in the probability that subjects purchase 2 units of insurance.

Table 9: Ordered probit regressions of units of insurance purchased

	Units of indemnity insurance purchased			Units of index insurance purchased		
	(1)	(2)	(3)	(4)	(5)	(6)
Risk sharing	-0.93	-0.92	-1.10	1.23	1.28	1.03
	(0.16)	(0.16)	(0.18)	(0.19)	(0.19)	(0.23)
Marginal change in probability of buying...						
zero units	0.12	0.11	0.13	-0.36	-0.35	-0.24
one unit	0.21	0.21	0.23	0.0084	0.010	0.0065
two units	-0.33	-0.32	-0.36	0.35	0.34	0.24
Enumerator fixed effects	No	Yes	Yes	No	Yes	Yes
Controls	No	No	Yes	No	No	Yes

Note: Ordered probit regressions. The dependent variable is the number of units of insurance purchased. Columns 3 and 6 include control variables for sex, age, age squared, marital status, household headship, literacy, household size, livestock owned in Tropical Livestock Units and land owned in hectares. Robust standard errors are in parentheses.

Table 10 presents probit regressions where the dependent variable is an indicator for whether the participant bought a positive amount (1 or 2 units) of insurance. In line with the predictions, risk sharing decreases the probability of buying indemnity insurance (by about 20%), while it increases the probability of buying index insurance (by about 35%). The risk-sharing coefficient is everywhere significant at the 1% level.

Table 10: Probit regressions

	Indemnity insurance purchased			Index insurance purchased		
	(1)	(2)	(3)	(4)	(5)	(6)
Risk sharing	-1.32	-1.35	-1.77	1.53	1.62	1.81
	(0.39)	(0.39)	(0.51)	(0.25)	(0.25)	(0.38)
Marginal change in probability of buying any insurance						
	-0.16	-0.17	-0.23	0.41	0.42	0.32
Enumerator fixed effects	No	Yes	Yes	No	Yes	Yes
Controls	No	No	Yes	No	No	Yes

Note: Probit regressions. The dependent variable is a binary indicator for whether the participants purchased any insurance (1 or 2 units) or not. Columns 3 and 6 include control variables for sex, age, age squared, marital status, household headship, literacy, household size, livestock owned in Tropical Livestock Units and land owned in hectares. Robust standard errors are in parentheses.

Table 11 shows maximum-likelihood estimates for the hurdle model. In column 1, it is shown that the probability of buying any indemnity insurance, and also the probability of buying two units of insurance conditional on buying at least one, both decrease significantly with risk sharing. This is robust to the inclusion of enumerator fixed effects and control variables in columns 2 and 3. Furthermore, and with reference to the lower half of the table, risk sharing increases the predicted probability of buying 0 or 1 unit of indemnity insurance, but decreases the probability of buying 2 units. For indemnity insurance, the coefficients on risk sharing are everywhere significant at the 1% level.

For index insurance (columns 4–6), risk sharing is associated with a positive and significant (at the 1% level) increase in the propensity to buy at least one unit of insurance. The effect on the propensity to buy two units of insurance, conditional on buying at least one, is also positive but not significant at the 5% level. Risk sharing decreases predicted probability of buying no insurance, and increases the predicted probabilities of buying both 1 and 2 units.

Thus the hurdle model confirms the ordered probit results, but suggests that, for index insurance, the main effect of risk sharing is to increase the probability of buying some insurance rather than to increase the number of units purchased from 1 to 2. For indemnity insurance, it appears that risk sharing increases both the propensity to buy some insurance rather than no insurance, and also the propensity to buy 2 units conditional on buying at least 1.

Table 11: Double probit hurdle model

	Units of indemnity insurance purchased			Units of index insurance purchased		
	(1)	(2)	(3)	(4)	(5)	(6)
$\Pr(Y \in \{1,2\})$:						
Risk sharing	-1.32	-1.35	-1.77	1.53	1.62	1.81
	(0.39)	(0.39)	(0.51)	(0.25)	(0.25)	(0.38)
$\Pr(Y = 2 \mid Y \in \{1,2\})$:						
Risk sharing	-0.73	-0.74	-0.92	0.50	0.49	0.16
	(0.18)	(0.18)	(0.21)	(0.26)	(0.28)	(0.36)
Marginal change in probability of buying...						
zero units	0.13	0.13	0.16	-0.46	-0.46	-0.43
one unit	0.20	0.20	0.21	0.15	0.18	0.24
two units	-0.33	-0.33	-0.37	0.31	0.28	0.18
Enumerator fixed effects	No	Yes	Yes	No	Yes	Yes
Controls	No	No	Yes	No	No	Yes

Note: Double probit hurdle model estimates. The dependent variable is the number of units of insurance purchased. Columns 3 and 6 include control variables for sex, age, age squared, marital status, household headship, literacy, household size, livestock owned in Tropical Livestock Units and land owned in hectares. Robust standard errors are in parentheses.

Appendix Table A.1 presents a robustness check where the ten sessions are left out of the regressions one by one. All specifications are ordered probit regressions and include enumerator fixed effects and control variables.

In the upper panel, it is shown that the negative and significant effect of risk sharing on the demand for indemnity insurance is robust to dropping any of the six indemnity-insurance sessions from the analysis. The risk-sharing coefficient is everywhere significant at the 1% level.

In the lower panel, it is shown that the positive and significant effect of risk sharing on the demand for index insurance is robust to dropping three out of four sessions (significant at the 1% level). When dropping session 8, one of the control sessions for index insurance, the coefficient on risk sharing remains positive but is no longer statistically significant.

Given that there are only six indemnity insurance and four index insurance sessions, and the consequent loss of power associated with dropping one of them, we believe that the robustness check confirms that our main results are not driven by any one outlying session.

6 Conclusion

We present a simple and parsimonious theoretical framework, showing that risk sharing is a substitute for indemnity insurance but a complement to index insurance. In order to test these predictions, we present the first experimental evidence on demand for indemnity and index insurance where the extent of risk sharing is varied exogenously. In an artefactual field experiment with low-income farmers in Ethiopia, the theoretical predictions are confirmed. Our results highlight the importance of considering existing risk-sharing arrangements when considering the introduction of formal insurance contracts.

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A Robustness check

Table A.1: Robustness check: Leaving out sessions one by one

	Units of indemnity insurance purchased						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Risk sharing	-1.10	-0.74	-0.84	-1.34	-1.30	-1.23	-1.62
	(0.18)	(0.20)	(0.21)	(0.22)	(0.23)	(0.20)	(0.25)
Enumerator fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Session dropped	None	#1	#2	#5	#6	#9	#10
	Units of index insurance purchased						
	(1)	(2)	(3)	(4)	(5)		
Risk sharing	1.03	10.8	1.31	0.84	0.24		
	(0.23)	(1.38)	(0.27)	(0.31)	(0.28)		
Enumerator fixed effects	Yes	Yes	Yes	Yes	Yes		
Controls	Yes	Yes	Yes	Yes	Yes		
Session dropped	None	#3	#4	#7	#8		

Note: Ordered probit regressions, leaving out one session at a time. The dependent variable is the number of units of insurance purchased. All regressions include enumerator fixed effects and control variables for sex, age, age squared, marital status, household headship, literacy, household size, livestock owned in Tropical Livestock Units and land owned in hectares. Robust standard errors are in parentheses.