How Does Informal Risk-Sharing Influence Insurance Decisions? Theory with Field Evidence

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Abstract

Weather is a major source of income risk, especially in low-income environments. This paper combines economic theory and randomized field experiments involving Indian farmers to evaluate how the take-up *viz* commercial success of an innovative rainfall insurance product is affected by pre-existing informal risk-sharing arrangements. We document that informal risk-sharing makes individuals (i) less sensitive to basis risk, but (ii) more sensitive to price, with an overall ambiguous effect on insurance demand. The results likely operate through changes in risk attitudes. Our results suggest that the promise of financial innovation can be achieved *if* carefully designed to complement pre-existing schemes.

Keywords: household finance, informal risk-sharing, insurance, *effective* risk aversion

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1 Introduction

> "*...and when basis risk is large, having an informal network can help by providing insurance against basis risk. Thus the presence of informal risk sharing actually increases demand for index-based insurance in the presence of basis risk...*" **World Development Report – Risk and Opportunity (2014)**

Small businesses in emerging markets, which are primarily agrarian, are exposed to a wide range of income risks due to unpredictable weather and climate events. Recently, innovative index-based weather insurance has emerged as a way to help society insure against weather related events.[1] A standard index-based contract pays out when some constructed-index falls below or above a given non-manipulable threshold.[2]

The justification for index insurance is that it overcomes several market frictions, such as moral hazard, that plague traditional indemnity-based insurance and financial instruments. Index-based insurance differs in the sense that the contractual terms (premiums and payouts) are based on a publicly observable and non-manipulable index (local weather). However, this innovation comes with a cost: "basis risk". There is a potential mismatch between the payouts triggered by the local weather and the actual losses associated with weather realizations of the insurance policy holder. This mismatch or "basis risk" arises because weather realized on an individual farm unit will typically be imperfectly correlated with the local weather index, whose construction is typically based on observations recorded at weather stations that surround the policy holder.[3]

Empirical studies of weather index-based insurance are growing (e.g., Cai et al. 2009; Giné and Yang 2009; Cole et al. 2013; Karlan et al. 2014), and have noted two fundamental

[1] The design and coverage for index-based weather insurance can be wide ranging. Hazell et al. (2010) cites at least 36 pilot index insurance projects that were underway in 21 developing countries. Examples include: India–rainfall insurance (Mobarak and Rosenzweig 2012; Cole et al. 2013); Ethiopia–rainfall (Hazell et al. 2010; McIntosh et al. 2013; Duru 2016); China–drought and extreme temperature (Hazzel et al. 2010); Mexico–drought and excess moisture (Hazell et al. 2010); Ghana–rainfall (Karlan et al. 2014); Kenya and Ethiopia–"livestock" weather-insurance (Jensen et al. 2014). According to World Bank (2018), index insurance currently spans many more countries covering approximately 23 million people.

[2] See Carter et al. (2017) for a recent survey of index insurance in developing countries.

[3] Satellite measurements are used in some cases (e.g., Carter et al. 2017; IRI 2013). Even so, the individual weather realizations are not perfectly correlated with the satellite index in practice.

puzzles. The first is that demand for index products has been lower than expected. The second is that the demand seems to be especially low from the most risk averse consumers. Despite its promise, scaling up index insurance will require our understanding of the various constraints to its take-up. Several candidate reasons for the low demand have been offered, including financial illiteracy, lack of trust, poor marketing, credit constraints, present bias, complexity of index contracts, "basis risk" and higher prices compared to expected payouts.

Another suggested explanation for the thin index insurance market in poor populations is an interaction with pre-existing informal risk-sharing arrangements. Indeed, the extent to which informal risk-sharing networks affect the demand for index-based insurance remains an open question, both empirically and theoretically. We consider microfounded reasons underlying the relation between informal risk schemes and formal index insurance. Specifically, we ask: *How does an informal risk sharing scheme impede or support the take-up of formal index insurance?* We analyze this question in an environment where an individual endogenously chooses to join an informal group and make purchase decisions about index insurance. Our analysis shows that the risk aversion of an individual, when part of an informal risk sharing group, becomes lower compared to if he is acting alone — a phenomenon we term "Effective Risk Aversion". The paper documents that "Effective Risk Aversion" is a paramount statistic that underlies individual's purchase decisions about index-based insurance.

We show that informal schemes may either reduce or increase the take-up of index insurance. The main intuition follows from the simple observation that in the presence of a risk-sharing arrangement, an individual becomes more tolerant of risk.[4] This has two implications for the take-up of index insurance. First, the individual becoming more risk-tolerant makes him less willing to buy insurance. Second, the individual becoming more tolerant to the basis risk increases his demand for index insurance. These two forces have opposite effects on the decision to purchase index insurance. To illustrate these two forces, consider

[4] This intuition is comparable to Itoh (1993), who studies optimal incentive contracts in a group. He shows that side contracts can serve as mutual insurance for members in a group and can induce effort at a cheaper cost when members of the group can monitor each other's effort by coordinating their choice of effort. While Itoh (1993) looks at effort decisions, we analyze insurance decisions.

the case of a highly risk averse individual who will not buy index insurance in the absence of risk sharing group because of his sensitivity to basis risk. Being in an informal risk sharing group makes him more tolerant towards basis risk and thus more likely to purchase index insurance. Now consider the case of an individual with intermediate risk aversion who would buy index insurance in the absence of risk sharing group. The presence of informal insurance may crowd out his take-up for index insurance due to his lower willingness to pay. The overall impact of informal risk-sharing schemes on the demand for index contracts may be ambiguous: it depends on whether or not the basis risk effect dominates the price effect. Our analysis thus has implications for informal schemes acting as a substitute or complement to index insurance.

Several testable hypotheses emerge from our theoretical analysis, which are useful for the design of index insurance contracts and understanding the development or commercial success of such innovative financial products. We develop a tractable empirical framework to investigate these hypotheses using data from a panel of field experimental trials in rural India. One advantage of this data is that, we can credibly measure basis risk. Our identification strategy exploits exogenous variation created by the random assignment of households to various risk-sharing treatments. We verify the validity of our design by showing that baseline characteristics are balanced across households that received and did not receive the informal risk-sharing treatments. In our analysis, we compare households that received the risk-sharing treatments with those that did not receive the treatments, including their interactions with basis risk and exogenous variation in the price for index insurance.

Our results imply that informal risk-sharing affects the demand for index insurance, and this effect occurs via two aspects of the index contract: sensitivity to basis risk, and sensitivity to insurance premium. We find economically and statistically significant effects on both. There is evidence that informal risk-sharing makes individuals less sensitive to basis risk; thus increasing demand, but makes individuals more sensitive to premium, and thus decreasing demand for index insurance. The effect of risk-sharing on the sensitivity to basis risk is 88%

lower for households that experience downside basis risk than those that do not experience it, while the effect on the sensitivity to premium is over 100% higher for discounted households than for those without premium discounts. Finally and motivated by our theoretical analysis, we explore changes in risk attitudes as a potential channel underlying these effects, and find suggestive evidence in favor of this. However, we are not able to conclude that changes in risk attitudes entirely drive our results in risk-sharing because there are other alternative explanations.

Related Literature

Financial and insurance innovation are crucial in addressing emerging risks that confront society. Yet, little is known about how the introduction and commercial development of new insurance products are affected by existing informal risk-sharing schemes. Our paper is among a thin and burgeoning literature that evaluates the influence of informal risk-sharing on innovative insurance products in poor environments. The paper intersects the broader literatures on (i) risk-sharing (e.g., Itoh 1993; Townsend 1994; Munshi 2011; Munshi and Rosenzweig 2009 and many subsequent others), (ii) the economics of weather-index insurance and household finance (e.g., Giné, Townsend and Vickery 2008; Mobarak and Rosenzweig 2012; Cole et al. 2013; Cole, Stein and Tobacman 2014; Karlan et al. 2014; Clarke 2016; Cole, Giné and Vickery 2017; Casaburi and Willis 2018), and (iii) the linkages between informal institutions and formal markets (see e.g., Arnott and Stiglitz 1991; Kranton 1996; Duru 2016).

Our paper complements these and other strands of literature in several ways. First, our analysis identify two novel contractual channels through which informal risk-sharing affects the demand for index insurance, both of which operate through changes in risk aversion. Second, our empirical design randomizes informal risk-sharing, thereby allowing us to examine its causal impact on demand decisions about weather insurance. Third, we add to the theoretical literature on index insurance. We present a microfounded model of demand for index-insurance contracts that illuminates several features and testable hypothesis, which we are able to directly investigate empirically. Clarke (2016) studies the relation between individual risk aversion and the take-up of index insurance. He finds that demand is hump-shaped in theory, with demand for the index being higher in the intermediate risk averse region. Unlike Clarke (2016), we incorporate pre-existing risk-sharing arrangements to study their effect on the take-up.

Our model is based on microfoundations, allowing for heterogeneity among individuals and endogenous decisions to join risk-sharing groups. Results are based on the notion of "Effective Risk Aversion"—a consequence of efficient risk sharing. This allows us to identify new channels underlying the effect of informal schemes on the demand for formal index-insurance, and provides novel explanations for the two empirical puzzles based on their interactions. One of our channels relates to the increase in tolerance to basis risk, implying an *increase* in take-up of index insurance. This confirms results found in Mobarak and Rosenzweig (2012), Berg, Blake and Morsink (2017) and others suggesting that informal risk sharing schemes support take-up of formal index insurance. The additional channel we document is connected to the increase in tolerance to aggregate gambles, implying a *decrease* in demand for index insurance.

We add to the financial economics literature related to aggregate risk and individual risk aversion. The notion that a group is, or should be, less risk averse than its members is a familiar one in economics (Samuelson 1964, Vickrey 1964, Arrow and Lind 1970, Chambers and Echenique 2012). Indeed, the idea that aggregate risk aversion is lower than individual risk aversion underlies the economic rationale for equity, insurance and futures markets. The typical mechanism suggested is securitization of risk, that is taking a risk, breaking it into smaller pieces and sharing it leads to lower risk aversion on part of individuals since the size of the gamble is smaller. In contrast, our result regarding aggregate risk aversion being lower than individual risk aversion relies on the central result of Wilson (1968), that the risk tolerance of the group preference is the sum of risk tolerances of each individual at the optimal group consumption.

Finally, our paper is related to the burgeoning literature on climate finance. Studies have looked at financial approaches such as hedging to managing climate-related risks (Engel et al. 2019), the impact of weather-index insurance on production decisions in developing countries (Cole, Giné and Vickery 2017), and how to finance climate and environmental projects (Baker et al. 2018). Other studies have emphasized the broader use of financial instruments by organizations or individuals as part of a risk management strategy to reduce the risks of unexpected weather conditions. Examples of such financial instruments in the context of developed countries include catastrophic bonds, reinsurance sidecars, flood insurance, crop insurance and weather derivatives (See Cummins and Weiss 2009, Froot 2001, Golden et al. 2007, Kunreuther and Michel-Kerjan 2011). Traditional indemnity-based insurance products have not worked well in developing countries, arguably due to adverse selection and moral hazard, thereby highlighting the need for index insurance that overcomes such market frictions. Results from our paper suggest the potential channels through which the take-up of innovative index-insurance may be affected by existing institutions.

Section 2 presents the theoretical model and testable hypotheses. Section 3 discusses the data and summary statistics for a specific index contract providing rainfall insurance. Our empirical strategy is presented in Section 4. Results are contained in Section 5, while the mechanisms and caveats are discussed in section 6. Section 7 concludes. All formal proofs, tables and figures are relegated to the Appendix.

2 Theory

We develop a simple model that captures relevant features of the environment to generate testable predictions for our empirical analysis. To investigate the coexistence and interactions between pre-existing (informal) institutional risk sharing and (formal) index-based insurance, one must specify preferences, shocks and informal arrangements in the economy.

2.1 Setup

We consider an individual i with absolute risk aversion parameter $\gamma_i > 0$, receiving utility $u_i(z) = -e^{-\gamma_i z}$ from consuming income z.[5] The individual faces uncertain income realizations according to

$$z_i = w_i + h_i$$

where w_i and h_i respectively denote the deterministic and the stochastic component of the individual's income. The stochastic component consists of two parts, $h_i = \varepsilon_i + v$: where ε_i is the individual's idiosyncratic risk (e.g., health shocks or illness) and v is the aggregate shock (e.g., drought, rainfall). As we describe below, ε_i corresponds to the part of the stochastic component which can be insured via informal risk-sharing while v corresponds to the portion that can be insured via formal index insurance. We assume the following

$$\varepsilon_i \sim N(0, \sigma_i^2)$$
$$v = \begin{cases} 0 & \text{with probability } 1-p \\ -L & \text{with probability } p. \end{cases}$$

Informal Risk-Sharing There exists a group g that individual i has the option to share risk with. We think of the group as a representative agent with a CARA utility function and absolute risk aversion denoted by γ_g. We denote the income realization of that group as:

$$z_g(\epsilon) = w_g + h_g$$

where w_g and $h_g \sim N(0, \sigma_g^2)$ denotes the deterministic and the stochastic component of the group's income respectively. In this case the stochastic component can only be insured through risk-sharing arrangements. Following Udry (1990), we assume perfect information:

[5] This formulation will imply no wealth effects. In the empirical section, however, we illustrate that our main results are robust to potential wealth effects.

group-idiosyncratic variances are public information and the realizations of shocks are also perfectly observed by all individuals when they occur in the society. This provides enforcement for the informal relationships. If the individual shares risk with the group, he can enter into a binding agreement prior to the realization of their incomes, specifying how their pooled income is going to be shared.

Index Insurance There are no financial markets allowing any individual to insure himself against his idiosyncratic risks. However, with the introduction of index-weather based insurance it is possible to insure against v. Aggregate shocks can be insured by *formal* index-based insurance which is subject to basis risk (E.g., Cole et al. 2013). We model basis risk as in Clarke (2016):

Table 1: **Joint probability structure**

	Index=0	Index=1	
$v=0$	$1-q-r$	$q+r-p$	$1-p$
$v=-L$	r	$p-r$	p
	$1-q$	q	

In Table 1, individual i suffers aggregate risk which can take the value 0 with probability $1-p$ or $-L$ with probability p. There is also an index which can take the value 1 (i.e., payout) with probability q or 0 (i.e., no payout) with probability $1-q$. The index may not be perfectly correlated with the aggregate risk and thus there are four possible joint realizations of the aggregate risk and index. In this case r denotes the probability that a negative aggregate shock is realized but the index suggests no payouts. This corresponds to the downside basis risk faced by the consumer if he purchases index insurance. Similarly, $q+r-p$ corresponds to an upside basis risk where an insured agent does not suffer an aggregate shock and yet payouts are triggered. Note that both downside and upside basis risks are increasing in r. We also assume that the index is informative about the aggregate loss (i.e., moderate basis risk), which is to say that $Prob(v = 0, I = 0) \times Prob(v = 1, I = 1) > Prob(v = 0, I = 1) \times Prob(v = 1, I = 0)$, which in turn implies that $r < p(1 - q)$.

If the individual buys insurance he pays a fixed premium π and receives a stochastic payout η which depends on the level of coverage and on the value of the index. If the individual buys index insurance and the Index=1, the insurance company pays the individual βL. For Index=0, there is no transfer from the insurance company to the individual. Thus the actuarially fair premium is $q\beta L$. Due to loading, administrative costs and lack of competition, the premium is typically not actuarially fair. This is captured as $\pi = mq\beta L$ for $m > 1$.

If the individual buys insurance, his income process is now given by:

$$z_i^1(\epsilon) = w' + \varepsilon_i + v'$$

where $w' \equiv w_i - \pi$ and $v' \equiv v + \eta$. Thus v' and ε_i are independent and the distribution of v' is given by

$$v' = \begin{cases} 0 & \text{with probability } 1 - q - r \\ -L & \text{with probability } r \\ \beta L & \text{with probability } q + r - p \\ -L + \beta L & \text{with probability } p - r. \end{cases}$$

To proceed, we first evaluate the insurance decision of an individual in isolation. We then extend this analysis to allow for the presence of an informal risk-sharing group.

2.2 Demand for Index Insurance: no informal access

Suppose that individual i is faced with the choice of either buying index insurance, denoted by **1**, or not, denoted by **0**. We first consider the case where the individual does not have access to an informal risk-sharing arrangement. In order to determine demand for index insurance, we compare the certainty equivalents for buying versus not buying the index.

Proposition 1. *Consider an individual with CARA utility function and risk aversion parameter $\gamma_i > 0$. The individual buys index insurance if*

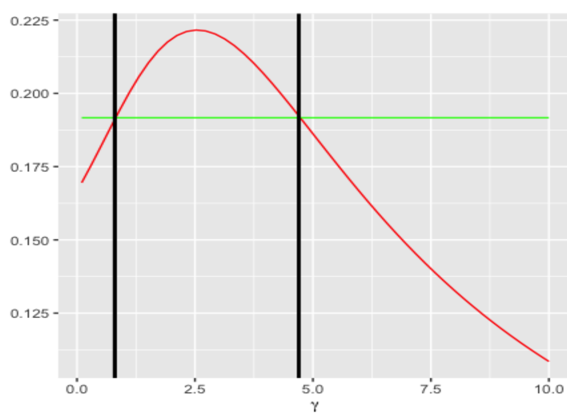
$$CE_i(v') - CE_i(v) \quad \geq \quad mq\beta L$$

where $CE_i(v') \equiv -\frac{1}{\gamma_i}\log([1-q-r]+re^{\gamma_i L}+[q+r-p]e^{-\gamma_i \beta L}+[p-r]e^{-\gamma_i(-L+\beta L)})$ *is the certainty equivalence for the individual faced with* v' *gamble, and* $CE_i(v) \equiv -\frac{1}{\gamma_i}\log([1-p]+pe^{\gamma_i L})$ *is the certainty equivalence for the individual faced with* v *gamble.*

Proof. See Appendix 1.

We illustrate this inequality condition numerically in Figure 1.

Figure 1: **TAKE-UP OF INDEX CONTRACT**



Notes: Assumptions underlying Figure 1 are as follows: $p = q = \frac{1}{3}$, $L = 1$, $r = \frac{1}{9}$, $\beta = 0.5$, $m = 1.15$. The horizontal green line reflects the certainty equivalent from not buying index insurance. The x-axis captures different parameter values for risk aversion. The two vertical black lines correspond to $\gamma = 0.8$ and $\gamma = 4.7$. These two black lines characterize the thresholds where an (risk averse) individual will choose to buy index insurance or not. In this illustration, an individual with a risk aversion parameter value less than 0.8 or more than 4.7 will not purchase index insurance.

In Figure 1, the red curve represents the left side of the inequality, the difference in the CE, while the green line represents the right side of the inequality, $mq\beta L$. The x-axis represents different values for risk aversion, indicating that individuals with risk-aversion levels in between the two vertical black lines purchase index insurance. The decision to buy index insurance is bounded between two thresholds for γ. Within this interval, the above inequality is satisfied and individuals purchase the index cover. Individuals with sufficiently high or low risk-aversion will choose not to buy index insurance. The simple intuition is that high risk-averse individuals do not buy because of the basis risk while low risk-averse individuals choose not to buy because of the positive loading of the premium ($m > 1$).

2.3 Demand for Index Insurance: informal group access

This subsection discusses the informal risk sharing arrangements before the introduction of index insurance. We work with certainty equivalents (CE). Since CE is transferable[6], we have the following Proposition:

Proposition 2. *Suppose individual i decides to join the group g and risk is shared efficiently between them. Then [under transferable CE] we can think of the pair (i, g) as a representative agent with risk aversion parameter γ_{i^*} where $\frac{1}{\gamma_{i^*}} = \frac{1}{\gamma_i} + \frac{1}{\gamma_g}$. This implies that $\gamma_{i^*} < \min(\gamma_i, \gamma_g)$.*

Proof. See Appendix 1.

Proposition 2 allows us to conveniently analyze the decision of individual i to take index insurance in the presence of risk sharing arrangements. It also shows that the risk aversion of the individual i will be effectively lower if he is in a group, as compared to if he was acting as an individual. The latter is summarized in the definition below.

Definition: γ_{i^*} as “Effective Risk Aversion”: This refers to the risk aversion parameter for a representative agent i^* representing group consisting of (i, g) that shares risk efficiently.

The results from propositions 1 and 2 suggests that informal risk-sharing has ambiguous

[6] In Appendix 1, we show that our setup has a transferable utility representation under CE.

effect on the take-up of index insurance. For instance, an individual might initially be too risk averse to buy index insurance on his own, but in the presence of informal arrangements his effective risk aversion might be such that he ends up purchasing the index cover. To illustrate, consider Figure 1. An individual with risk aversion parameter 6 would not have purchased the index insurance if he was acting individually. However, if he pairs with a group that brings his effective risk aversion to the range (0.8, 4.7), then he chooses to purchase the index cover. We also illustrate that it is possible that informal risk-sharing acts as a barrier to take-up of index insurance. For example, consider an individual with risk aversion parameter 3. Acting individually, he will buy the index insurance, but if the presence of a risk-sharing arrangement reduces his effective risk aversion to below 0.8, then he will choose not to buy the index insurance. This analysis provides explanations and predictions for several empirical findings which are discussed in the next subsection.

2.4 Discussions and Implications of the Theory

Our theoretical evaluation of the influence of informal risk-sharing schemes on the demand for index insurance provides several testable hypotheses with implications for the design of index insurance contracts.[7]

First, why might more risk averse individuals not take up index insurance? Our framework suggests a plausible answer. *Absent* risk-sharing arrangements, low take-up among high risk averse individuals may be due to aversion to basis risk (Clarke 2016). However, another plausible reason may be due to the *presence* of informal risk sharing groups. The presence of risk sharing groups leads to effective reduction in an individual's risk aversion, making him more tolerant towards aggregate risk and more responsive to the price of index insurance. For this reason, more risk averse people may end up not buying index insurance, as compared

[7] We note that our model is by no means exhaustive; yet it captures relevant features of our empirical setting. It may be extended to allow for other sources of heterogeneity and frictions such as limited commitment (Ligon et al., 2002), endogeneity (Genicot and Ray 2003) and costly group formation. While the model is simple, it delivers rich testable predictions and motivates our empirical analysis.

to an individual with the same risk aversion parameter who might take it up if the individual was not part of the informal risk sharing group.

Second, why is the take-up for index insurance unexpectedly low (e.g., the overwhelming majority of farmers indicate that too much or too little rainfall is their major source of income risk, yet only a few of them will purchase a rainfall-index contract when offered, even at fair prices)? Possible answers lie in the role of existing informal arrangements. When does informal risk-sharing arrangement *support* the index take-up? Our analysis suggests that high risk averse individuals in risk-sharing arrangements containing intermediate risk averse members are more likely to purchase index insurance. Acting alone, basis risk will act as a disincentive to the take-up of index insurance; however, the presence of the group makes the individual more tolerant to basis risk. When does informal pairing not-*support* index take-up? From our analysis, low to intermediate risk averse individuals that enter any risk sharing group are less likely to purchase index insurance. Their effective risk aversion is lower, and thus they have lower willingness to pay for index insurance. The above discussion leads to the following sets of predictions, which form the basis of our empirical analysis the following sections.

Prediction 1. *Informal risk-sharing arrangements make decision makers less sensitive to basis risk but more sensitive to premium. Thus the overall impact of informal risk-sharing schemes on the demand for index contracts may be ambiguous: it depends on whether or not the basis risk effect dominates the price effect.*

Prediction 2. *Changes in risk attitudes or preferences are likely channels that informal risk-sharing act to affect the take-up of index insurance contracts.*

3 Data and Summary Statistics

3.1 Data and Sources

Ideally, we require data about the demand for index insurance contracts, informal risk sharing, a measure of basis risk, insurance premiums, and risk aversion. For this purpose, we draw on publicly available data sets from a panel of experimental trials that were conducted across randomly selected rural farming households and villages in Gujarat, India.[8] We combine and optimize the use of existing field experimental data sets relevant to our purposes as much as we can. Data on risk aversion come from Cole et al. (2013), which is based on field experiments across 100 villages in 2006/2007. The measure of risk aversion follows Binswanger (1980), whereby respondents are asked to choose among cash lotteries varying in risk and expected return. The lotteries were played for real money, with payouts between zero and Rs. 110. The lottery choices are then mapped into an index between 0 and 1, where high values indicate greater risk aversion.[9]

From Cole, Stein and Tobacman (2014), we obtain data about the take-up of index insurance, premiums, and premium discounts available between 2006-2013 for 60 villages cumulatively. Most of these villages and households overlap with the 100 villages in Cole et al. (2013). This allows us to match households and villages between the two data sets. Our final data are merged from these two sources: the field sites and households overlap in both Cole et al. (2013) and Cole, Stein and Tobacman (2014). We summarize the timeline of the rainfall-index insurance experiments and the available data in Figure 2. Our measure of risk aversion was elicited in 2006, the year right before the risk-sharing treatments were given (2007).

[8] All villages are located within 30km of a rainfall station. Design of rainfall insurance contracts uses information from these rainfall stations.

[9] A value 1 is assigned to individuals that choose the safe lottery. For those who choose riskier lotteries, the $[0, 1)$ mapping indicates the maximum rate at which they are revealed to accept additional risk (standard deviation) in return for higher expected return ($\frac{\Delta E}{\Delta risk}$). Additional details are available in Cole et al. (2013).

3.1.1 Rainfall-Index Contracts and Experimental Setting

The specific index insurance contract that we examine is "rainfall insurance" whose payouts are based on a publicly observable rainfall index. This contract provides coverage against adverse rainfall events (i.e., covering drought and flood) for the summer ("Kharif") monsoon growing season. Design of this contract is based on daily rainfall readings at local rainfall stations, specifying payouts as a function of cumulative rainfall during fixed time periods over the entire June 1-August 31 Kharif season. Typically, the maximum possible payout for a unit-policy is about Rs. 1500. Households have the option to purchase any number of policies to achieve their desired level of insurance coverage. The contracts are offered and paid-out year-to-year, whereby a marketing team visits households in the selected sample each year in April-May to offer the insurance policies. Households are required to opt-in to re-purchase each year to sustain their coverage.

3.1.2 Measuring Basis Risk

Each season, households were asked if they had experienced crop loss in the previous year due to weather in the household panel experiments. We combine this with unique market information about whether the household i located in village v in a contract year t received an insurance payout to define a measure of basis risk

$$briskDOWNSIDE_{ivt} = \mathbf{1}(\mathbf{1}[loss_{ivt-1} = Yes] > \mathbf{1}[payout_{ivt-1} = Yes])$$

$$briskUPSIDE_{ivt} = \mathbf{1}(\mathbf{1}[loss_{ivt-1} = Yes] < \mathbf{1}[payout_{ivt-1} = Yes])$$

which are indicators that capture the potential mismatch or discrepancy between insurance payouts and the actual crop loss (or revenue loss) suffered by the policy holder prior to the insurance purchase decision in contract year t. For instance, this may be due to the fact that the measured rainfall index is imperfectly correlated with rainfall at any individual farm plot. As illustrated, our measure of basis risk allows for the distinction between upside and downside risks, and follows directly from previous discussions in Section 2.

These definitions call for four clarifying remarks. First, both *loss* and *payout* are binary 0-1 variables, indicating the occurrence of the event, hence the amount of coverage purchased plays no role here. Second, since we use the loss from previous year, a negative correlation between basis risk (based on losses at $t-1$) and insurance take-up at t may also be driven by potential liquidity constraints at t (driven by losses at $t-1$). In the empirical analysis, we include household fixed effects which accounts for a lot of such liquidity constraints. Third, since crop losses (but not payouts – from administrative data) are self-reported, there is a potential tendency for households to misreport – thereby impacting our measure of basis risk up or down. In later sections, we document that the loss reports are *uncorrelated* with over seventeen household characteristics including per capita monthly expenditure and risk aversion – an evidence inconsistent with misreporting, and suggesting that the reported crop losses are due to weather shocks. Finally, for households that did not purchase insurance and thus had no option of receiving a payout at t, upside basis risk basis is zero. In a robustness check, we also set downside basis risk to zero for households that did not buy the index at $t-1$ but purchased it at t.

Alternative Measure for Basis Risk

Here we explore the "conditional" correlation between the amount of payout received and the amount of crop loss conditional on coverage (i.e., the number of insurance policies bought), and then use that to construct a new measure of basis risk. Note that conditioning on coverage is crucial since the payout amount is a direct function of the coverage purchased. Let $payA_{ivt-1}$, $lossA_{ivt-1}$ and C_{ivt-1} denote the payout, crop loss and coverage amounts in the previous year. Our approach involves estimating two separate regressions: one for payout amount and one for crop loss amount, and then correlating the residuals from these two regressions. Specifically, we estimate

$$payA_{ivt-1} = \alpha + \beta C_{ivt-1} + \epsilon_{ivt-1}$$

and

$$lossA_{ivt-1} = \alpha + \gamma C_{ivt-1} + \eta_{ivt-1}.$$

Then we compute the correlation between the implied residuals $\hat{\epsilon}_{ivt-1}$ and $\hat{\eta}_{ivt-1}$ by village and market year.[10] This construction provides us an alternative measure of basis risk with variation across village v and time t, $corr_{vt}$ – whereby "smaller" values of $corr_{vt}$ imply the presence of "more" basis risk and vice versa.

Figure A2.2 shows the distribution of $corr_{vt}$. The estimated correlations are shown for the (a) overall sample – varying across village and market year, and (b) three marketing districts: Ahmedabad, Anand and Patan. There is considerable variation/ dispersion in the correlations and suggest the presence of basis risk with correlation values that are less than 1. The annual variation in basis risk is higher in Ahmedabad and Anand than in Patan which is quite stable over the period 2007-2013. In later sections, we replicate our baseline results using this alternative definition of basis risk as a robustness check.

3.1.3 Informal Risk-Sharing

The marketing teams for rainfall insurance used multiple strategies to sell the policies. Their strategies include the use of flyers, videos, and discount coupons, and involved randomization of these three marketing methods at the household level. More importantly, flyers were randomized along two dimensions with the aim of testing how formal insurance interacts with informal risk-sharing arrangements (cf: Cole et al. 2013). The flyers emphasized and

[10]Formally, for each v and t, $corr_{vt} = \frac{\sum \hat{\epsilon}_i \hat{\eta}_i}{\sqrt{\sum \hat{\epsilon}_i^2}\sqrt{\hat{\eta}_i^2}}$ where $\hat{\epsilon}_i$ and $\hat{\eta}_i$ are zero mean errors estimated from the two regressions. The "overall" correlation between $\hat{\epsilon}_{ivt-1}$ and $\hat{\eta}_{ivt-1}$ is 0.035 with a p-value=0.021. The results are robust to the inclusion of either individual, village or market year fixed effects and other household characteristics.

provided cues on "group identity", which has been found to be key for informal risk-sharing (Karlan et al. 2009). The treatments for group identity included:

> **Religion** (Hindu, Muslim, or Neutral): *A photograph on the flyer depicted a farmer in front of a Hindu temple (Hindu Treatment), a Mosque (Muslim Treatment), or a neutral building. The farmer has a matching first name, which is characteristically Hindu, characteristically Muslim, or neutral.*
>
> **Individual or Group** (Individual or Group): *In the Individual treatment, the flyer emphasized the potential benefits of the insurance product for the individual buying the policy. The Group flyer emphasized the value of the policy for the purchaser's family.*

Note that the use of cues on group identity as a measure for risk-sharing has been used in previous literature (e.g., Cole et al. 2013), which we follow here. While such approach may have the downside of not capturing actual risk-sharing since people generally choose who to group and share risk with (possibly, over and beyond religious and family lines), it has an empirical appeal: it allows for randomization of risk-sharing which is extremely useful for identification purposes, at least, as compared to cases where groups form endogenously and share risk. With data on household consumption or transfers, one can confirm differences in risk-sharing ('a la Townsend 1994: the correlation between individual consumption and average consumption at the village level). This will entail a comparison of villages that received more risk-sharing flyers with those that received a few flyers.

3.1.4 Summary Statistics

The summary statistics of all relevant variables in our sample are reported in Table 2. The first two moments and order statistics of each variable are displayed. As shown, the data is made up of information about the demand for rainfall-index insurance, premium and randomized discounts, crop and revenue loss experience of households, treatments for risk-sharing as proxied by cues on "group identity", and basis risks, respectively. The overall data spans 2006-2013, covering 645 households across a pool of 60 villages. Considerable variations exist among the variables which we shall exploit for identifying variation. Our main outcome of interest is binary, denoted "Bought". Bought is defined based on whether households purchased index insurance in given market year. In our sample, about 39% of households bought rainfall-index insurance over the entire panel period.

The average risk aversion is 0.53 with a standard deviation of about 0.32. The overall share of households that received cues on Group, Hindu and Muslim treatments are about 4.0%, 2.8% and 2.9%, respectively. Notice that the sample that received the risk-sharing treatments is small here because the treatments were given in only 2007, while we have a panel data spanning 2006-2013. For the 2007 marketing year, the share of households that received cues on Group, Hindu and Muslim treatments are about 29.7%, 20.8% and 21.5%, respectively (see Table A2.9). Our measure of basis risk that relies on the mismatch between pre-insurance crop losses and index payouts suggest higher relative frequency for downside basis risk (25.5%), as compared to upside basis risk (8.2%). Notice that downside basis risk is much higher than upside basis risk due to the contract's design: cumulative rainfall during fixed time periods which will essentially capture only catastrophic events. Such contracts will not cover mild losses, but the once in many years adverse event. In this case, losses could be larger than payouts for several years simply by design choice. As a result, the chance of downside basis risk would be higher than that of upside basis risk. For our basis risk measure that relies on the mismatch between pre-insurance revenue losses[11] and index payouts, the relative frequency of downside and upside basis risks are quite close. A visual illustration for both downside and upside basis risks are shown in Figure 3. Empirical tests for the various predictions combine these variables with exogenous variations induced by the

[11]Revenue is measured for market years in which households reported a crop loss, and captures the "amount" of crop loss: calculated as the difference between that market year's agricultural output and the mean value of output in all previous years where crop loss was not reported.

random assignment of price discounts and risk-sharing marketing treatments.

A Comparison of Merged Data with Previous Studies

Since the data and treatments were used in other papers, we replicate the distributional statistics of variables from these papers that were used in our empirical analysis. Table A2.8 compares the moments (mean and standard deviation) of variables from our merged baseline data with estimates from the raw/ published data and those directly reported in Table 2 (summary statistics) of Cole et al. (2013). The last three rows of the table report the results from t-tests of equality in means of our merged sample with the published data. Overall, our sample moments are very close and comparable to Cole et al. (2013) – at the 5% level of significance, we fail to reject that null hypothesis that the variables in our merged data are individually not different from the published data.

Similarly, Table A2.9 compares the distribution of variables from our merged baseline data with estimates from the raw/ published data and those directly reported in Table A1 (summary statistics) of Cole, Stein and Tobacman (2014). Our sample variables are very comparable to Cole, Stein and Tobacman (2014).

4 Empirical Strategy

4.1 Intuition

The intuition for our identification strategy is straightforward. We exploit exogenous variation created by the random assignment of the risk-sharing treatments. The decision makers for index insurance who live in households that received the risk-sharing treatments likely become more risk tolerant, as compared to those who did not receive the risk-sharing treatments. In turn, this will have differential impacts on how decision makers respond to either changes in basis risk or insurance premium.

4.2 Balance and Validity of Design

We base our analysis on a comparison of households that received the risk-sharing treatments with those that did not receive the treatments. Identification requires that receiving the risk-sharing treatments (i.e., the assignment of Group, Hindu and Muslim cues) are independent of any relevant household-level characteristics. To test that these households are comparable, we run the following regression on the 2006-2007 baseline data:

$$y_{iv} = \alpha + \mathbf{X}'_{iv}\xi + \epsilon_{iv}$$

where $\mathbf{X}_{iv}$ denotes a vector of seventeen (17) observable household characteristics and village-level dummies. We consider the various cues individually and together (denoted $\boldsymbol{RShare}_{iv}$ below) as outcomes, and show that households show no observable differences across the two groups. Table A2.5 reports the results. The results provide strong evidence in favor of balance, showing no difference across households who received the risk-sharing cues and those that did not receive the cues (except for about two variables which are barely significant at 10% level).

4.3 Model Specification

We begin with a simple panel regression model linking changes in the take-up for index insurance $D_{ivt} = \mathbf{1}(bought = Yes)_{ivt}$ to basis risk $brisk_{ivt}$ and exogenous variation in the price for insurance $Discount_{ivt}$,

$$D_{ivt} = \alpha brisk_{ivt} + \beta Discount_{ivt} + \mu_i + \delta_t + \epsilon_{ivt} \quad (1)$$

where i, v and t index the household, village and market year respectively. This specification includes a set of unrestricted household dummies, denoted by μ_i, which capture unobserved differences that are fixed across households such as access to other forms of insurance. The market-year fixed effects, δ_t control for aggregate changes that are common across households, e.g. aggregate prices, and national policies. α measures the basis risk effect, while β captures the price effect on index demand. Errors are clustered at the village level to allow for arbitrary correlations.

Next, to assess the potential role of informal risk-sharing, we modify the baseline model to include the vector of risk-sharing treatments $\boldsymbol{RShare}_{ivt}$ and their unrestricted interaction with basis risk and insurance price

$$
\begin{aligned}
D_{ivt} = \gamma_1 \boldsymbol{RShare}_{ivt} \times brisk_{ivt} + \gamma_2 \boldsymbol{RShare}_{ivt} \times Discount_{ivt} \quad (2) \\
... + \alpha brisk_{ivt} + \beta Discount_{ivt} + \mu_i + \delta_t + \epsilon_{ivt}
\end{aligned}
$$

Our key parameter of interest γ is identified by household-level exogenous variation in the various treatments for risk-sharing and their interactions with the two forces: basis risk *versus* insurance premium. This provides an estimate of how informal risk-sharing impacts the effects of basis risk and insurance prices on the uptake of index contracts. In practice, $\boldsymbol{RShare}_{ivt}$ is defined in two ways. First, we define it as simple indicator of households that received or not the group flyer: $\boldsymbol{RShare}_{ivt} = 1(\text{Group cues} = Yes)_{ivt}$. The second definition is an indicator for whether or not the household received any of the three risk-sharing cues: $\boldsymbol{RShare}_{ivt} = \mathbf{1}(\text{Group cues} = Yes \text{ or Hindu cues} = Yes \text{ or Muslim cues} = Yes)_{ivt}$. While our main analyses focus on the first definition, we also report estimates for the second definition.

5 Main Results

Tables 3-5 report estimates from multiple specifications of Equations (1) and (2). Column (1) of Table 3 shows the baseline effects of basis risk and price on the take-up of index insurance contracts. Basis risk is negative and statistically significant at 1% level. Discount which is measured as whether or not a household received a premium discount is positive and statistically significant at 1%. The results re-affirm previous evidence of significant relationship between basis risk ('a la Mobarak and Rosenwieg 2012, Clarke 2016) and price ('a la Cole et al. 2013). For example, household's experience of downside basis risk would imply about 13% points decrease in the likelihood of taking-up index insurance, while households that receive premium discounts are about 55% points more likely to take-up index insurance compared to their counterparts who receive no discounts.

Next, Column (3) of Table 3 shows the results of specifications that include the various interaction terms [Equation (2)]. Take-up of rainfall-index insurance is regressed on the risk-sharing treatment proxied by cues on "group identity" and its interaction with basis risk and discount assignments. The direct terms for basis risk and discount are significantly negative and positively, respectively. Their interaction terms with risk-sharing are *both* positive and significant at conventional levels. The latter implies that when combined with risk-sharing, individuals become less sensitive to basis risk (of about $\frac{0.118}{-0.133} \times 100$ =-88% lower) for households that experience downside basis risk than those that do not experience it. Risk-sharing however induces much sensitivity to discount (of over +100% higher). Table 4 replicates the results in Table 3 whereby discount is replaced with the actual amount of premium discount. Similarly, Table 5 shows the results for our alternative definition of risk-sharing.[12] In both cases, the results are qualitatively close to the main estimates reported in Table 3.

Our results suggest that the presence of informal risk-sharing makes decision makers less sensitive to the impact of basis risk and thus incentivize the take-up of index insurance. On the other hand, informal risk-sharing makes individuals more sensitive to the impact of price and thus disincentivize the take-up of index contracts. Both results are congruent with our

[12] The estimated price discount effect is about 0.003. This implies that a 10 percent decline in the price of index insurance increases the probability of purchase by 0.030% points, or 0.10 percent of the conditional mean take-up rate (~0.30). The implied elasticity is 0.01.

theory. Conditional on household and time fixed effects that soak up potential confounding variation, our interpretation is that: while informal risk-sharing acts as a support to the take-up of index insurance (via a reduction in the effect of basis risk's impacts), it could also act a barrier to the take-up of index contracts (via an increase the effect of price impacts).

6 Mechanisms, Caveats and Extensions

6.1 Possible Mechanisms

We discuss various channels that informal risk-sharing may act to impact the take-up of index contracts, basis risk and price effects. Changes in risk attitudes or preferences is a natural candidate.

Risk Preferences

Risk preferences as a channel emerges directly from our theory: being in an informal risk sharing arrangement is a positive shock to the decision maker's risk tolerance. To evaluate this possibility, we use the 2016 data on risk aversion, and modify the baseline specifications to investigate how risk aversion (effective) interacts with the two forces: effects of either basis risk or insurance premium

$$\begin{aligned} D_{ivt} = {} & \gamma_1 \boldsymbol{rAversion}_{ivt} \times brisk_{ivt} + \gamma_2 \boldsymbol{rAversion}_{ivt} \times Discount_{ivt} \\ & ... + \alpha brisk_{ivt} + \beta Discount_{ivt} + \mu_i + \delta_t + \epsilon_{ivt} \end{aligned} \tag{3}$$

All the terms in this model are defined similarly as in previous sections, and errors are clustered at the village level. This evaluation is an alternate to a heterogeneity analysis that compares the basis risk and price effects for risk averse to risk tolerant decision makers. First, note that the direct coefficient on risk aversion is not estimable (but its interaction with the other variables are) since we included household-level dummies which soaks-up any fixed household-level terms. Second, this interaction allows us to ask whether an increase in risk aversion alter the demand-response to basis risk or to insurance premium. The results are reported in Table 6. These are our preferred estimates. Columns (1) and (3) omit the interaction terms, while columns (2) and (4) include the interactions. In all cases, basis risk is significantly negative and premium discount is significantly positive at conventional levels.

The interaction between basis risk and risk aversion is negative and large (but not significant). This implies that increasing risk aversion increases the negative impact of basis risk. The interaction between discount and risk aversion is also negative (but not significant), suggesting that increasing risk aversion decreases the positive impact of price discounts. These results agree with the baseline impacts of informal risk-sharing on basis risk and price effects [Equation (2); E.g., Table 3]. In Table 7, we show the estimates from a very restricted version of Equation (3): it only models the interaction terms. The interaction with basis risk is negative, which is consistent with results from our preferred baseline estimates. However, the interaction of risk aversion with discount in positive. This is inconsistent with our baseline estimates, perhaps because of the imposed restriction. Overall, the results suggest that changes in risk aversion may underlie the estimated impacts of risk-sharing on the take-up of index insurance.[13]

Alternative Interpretations

Do changes in risk preferences explain all the estimated impact of risk-sharing? What of the potential role of changes in beliefs and trust about index insurance contracts? Individuals beliefs and trust about index contracts may change if a risk-sharing neighbor is already

[13] In Appendix 2, we consider the idea that demand for index insurance is hump-shaped in risk aversion under moderate basis risk (Clarke 2016 and Figure 1). To capture this, we replicate Tables A2.1 and A2.2 by including linear and squared interaction terms for risk aversion. There is (insignificant) evidence of hump-(i.e., inverted U) shaped impact of risk aversion on basis risk's effect on index insurance demand, but U-shaped impact of risk aversion on discount's effect on demand. For the interaction with basis risk: the slope of the quadratic term is larger (negative), thus implying an overall negative effect effect of risk aversion on basis risk's effect. For the interaction with discount: the slope of the linear term is larger (negative), thus suggesting an overall negative effect of risk aversion on price discount's effect on index demand. These results are consistent with the hypothesis that changes in risk attitudes may explain how risk-sharing impacts the demand for index insurance. Finally, we verify that under moderate basis risk (i.e., $0.10 \leq r \leq 0.12$), take-up is nonmonotonic in risk aversion (although nonsignificant), where the linear term is positive and the quadratic term is negative (results are available upon request).

buying index insurance or not. This may be in the form of good, bad, or no reviews about the index product. Indeed, there is much literature showing that trust and identity are important aspects of groups or organizations (E.g., Akerlof and Kranton 2000) and risk-sharing networks (E.g., Attanasio et al. 2009). For the specific case of index insurance, previous empirical work (E.g., Cole et al. 2013) has shown that trust is an important non-price determinant.

In Cole et al. (2013), it was shown that the religion of the farmer combined with whether the flyer has Hindu or Muslim elements matter for take-up of insurance – finding that Hindu farmers shown the group flyer with Muslim symbols decrease take-up and the same with Muslim farmers shown flyers with Hindu symbols. Cole et al. (2013) described this effect as "identity". Here we use this as a proxy for trust in the index product and explore it as an alternative channel for our risk-sharing results. Specifically, we replicate our baseline results for a subsample of individuals that had a match in their religion with the religious symbol of the group flyer, as well as for individuals that had a mismatch.

The results are shown in Table A2.14 of the Appendix. The impact of risk-sharing on the effect of basis risk and discount is much higher (and mostly significant) for the subsample with a match in religion and the religious symbol of the group treatment, less so for the mismatched subsample. This provides suggestive evidence that identity or trust effects could be relevant. However, in the absence of actual data on trust (or beliefs), it is difficult to directly test the role of changes in beliefs and trust, or preferably benchmark its importance to that of changes in risk preferences.[14] Finally, while our theory gives a direct prediction for risk preferences and corroborated by the empirical exercise, we note that both channels are possible and likely drive our main results. We are unable to conclude that changes in risk preferences entirely drive our results on risk-sharing because there are other alternative

[14] Next, by priming individuals about being part of a group, they may feel that the payout will have to be shared with other members in the group. Such need to share the payout could alternatively lower take-up of the index. But the fact that people are able to form and share risk informally would suggest that they are not averse to sharing; implying that such sharing effects may be minimal. Indeed, the sharing effect could even be lower if individuals have other-regarding preferences such as reciprocity or if they share their payouts for altruistic reasons.

explanations. Nonetheless, it is interesting that the empirical pattern of effects from risk aversion are consistent with the theoretical results.

6.2 Effects of Wealth

Our theoretical analysis and predictions are both based on CARA, which has the simplifying property of no wealth effects. Here we evaluate whether or not the main results are sensitive or robust to potential wealth effects. To do this, we re-estimate our baseline model with an additional control for households wealth. We used factor analysis to estimate the wealth of households based on eight asset holdings or ownership: $\mathbf{1}$(Electricity=Yes), $\mathbf{1}$(Mobile Phone=Yes), $\mathbf{1}$(Sew Machine=Yes), $\mathbf{1}$(Tractor=Yes), $\mathbf{1}$(Thresher=Yes), $\mathbf{1}$(Bull cart=Yes), $\mathbf{1}$(Bicycle=Yes), and $\mathbf{1}$(Motorcycle=Yes), where $\mathbf{1}(.)$ is a logical indicator that equals 1 whenever the argument in the bracket is true, and 0 otherwise. Figure A2.1 shows the estimated distribution of wealth.

Tables A2.3 and A2.4 report results from the model that controls for wealth. The estimate on wealth is positive but not significant. However, the estimates for our key parameter of interest γ are similar to the main results (i.e., very close and well within the confidence intervals of the main estimates). The robustness of our empirical results to potential wealth effects is reassuring and agrees with classical models of consumer choice and aggregation of risk (E.g., Arrow and Lind 1970; Chambers and Echenique 2012).

6.3 Reporting of Losses

Since crop losses (but not payouts) are self-reported, there is a potential tendency for households to misreport, e.g., overstate losses, and thus might impact our measurement of basis risk up or down. The crop loss reports could depend on the quality or features of individual farm plots, which may correlate with household characteristics. It could also be that the more risk averse (or less risk averse) farmers misreport their loss experiences, either because their threshold of loss is different, or because they are more likely to have irrigation, or some other factor. To assess potential misreporting, we regress households reported-crop loss experience on a vector of seventeen (17) household characteristics: spanning socio-demographics, educational level, asset holdings, access to formal insurance, per capita monthly expenditure, risk aversion, and indicators for whether a respondent has a muslim name and irrigates the farm. We also include village-level fixed effects to control for unobserved differences across villages such as plot quality at the community-level.

Results are shown in Table A2.6. None of these 17 variables is statistically significant at conventional levels, an evidence inconsistent with misreporting. Such evidence is more consistent with a reporting behavior whereby crop losses occur due to weather shocks and then households report them as such. This finding hold across the wide range of model specifications, which differ based on the included controls.

6.4 Setting Downside Basis Risk to Zero

Here we set basis risk (downside) to zero for all households that did not buy index insurance at marketing year $t-1$ and so had no option of receiving a payout at t. We then replicate our baseline results under this restriction. The results are reported in Table A2.14. For easy comparison, columns (1) and (3) replicate the baseline results, while columns (2) and (4) report the new estimates after setting basis risk to zero for all households that had no option of receiving a payout because they did not purchase insurance in the previous market year. The results are very similar across all specifications, suggesting that our main results are not sensitive to this restriction.

6.5 Revenue-Based Definition of Basis Risk

In section 3, we derive basis risk on the basis of the *mismatch* between index insurance payouts and either the loss experience of crops or revenues. Our baseline analysis are based on crop loss experiences. Results pertaining to revenue loss are reported here to evaluate the sensitivity of our baseline estimates to the definition of basis risk. These are shown in Table A2.7. Columns (1)-(2) repeat the baseline estimates that are based on crop loss experiences, while columns (2)-(3) are based on revenue losses. Qualitatively, the results are similar: the revenue-based definition of basis risk is negative, and its interaction with risk sharing is positive. Discounts have positive effect on the demand for index contracts, and their interactions with risk sharing are also positive. In addition, the size of the coefficients are very similar for the discount terms.

6.6 Restricting Analysis to Treatment Years: 2007-2008

The risk-sharing treatments were given in only 2007, while the randomized discounts on insurance premium were given in 2007 and 2008 marketing years. However, in our baseline analysis, the data spans 2006-2013 – which allows us to take advantage of (previous) year-to-year variation in basis risk and to capture possible dynamic impacts of the treatments (see e.g., Cole, Stein and Tobacman 2014). In addition, the data for multiple years reflect time and individual effects which may reduce the impact of any misreporting for crop loss experiences. For example, a farmer may misreport in 2007 because he/she was going through financial rough patch but will be less likely to do so again in a subsequent year which may be a good year. Here we replicate the baseline analysis for only 2007-2008 to examine whether or not our baseline results hold.

Tables A2.10 and A2.11 display the implied results, illustrating that if we limit the sample to 2007-2008, the results are similar qualitatively in terms of signs and for most variables in terms of statistical significance.

6.7 Correlation-Based Definition of Basis Risk

In section 3, we constructed an alternative measure for basis risk, exploring the "conditional" correlation between the amount of payout received and the amount of crop loss conditional on coverage and other observables. Our baseline analysis defines basis risk as the simple *mismatch* between the binary 0-1 variables, $\mathbf{1}$(Index payout=Yes) and $\mathbf{1}$(Crop loss experience=Yes). Here we replicate our empirical exercise using the correlation-based definition of basis risk. The results are shown in Tables A2.12 and A2.13. As expected, a higher positive correlation between the amount of payout and crop loss (i.e., less basis risk) in the previous market year increases index insurance take-up. The interaction between this correlation and risk-sharing is negative. For discounts, the sign is positive and the interactions with risk-sharing is also positive, as before. These results are consistent and close to those reported in our baseline analysis; thus both provide a useful empirical benchmark for thinking about basis risk.

7 Conclusion

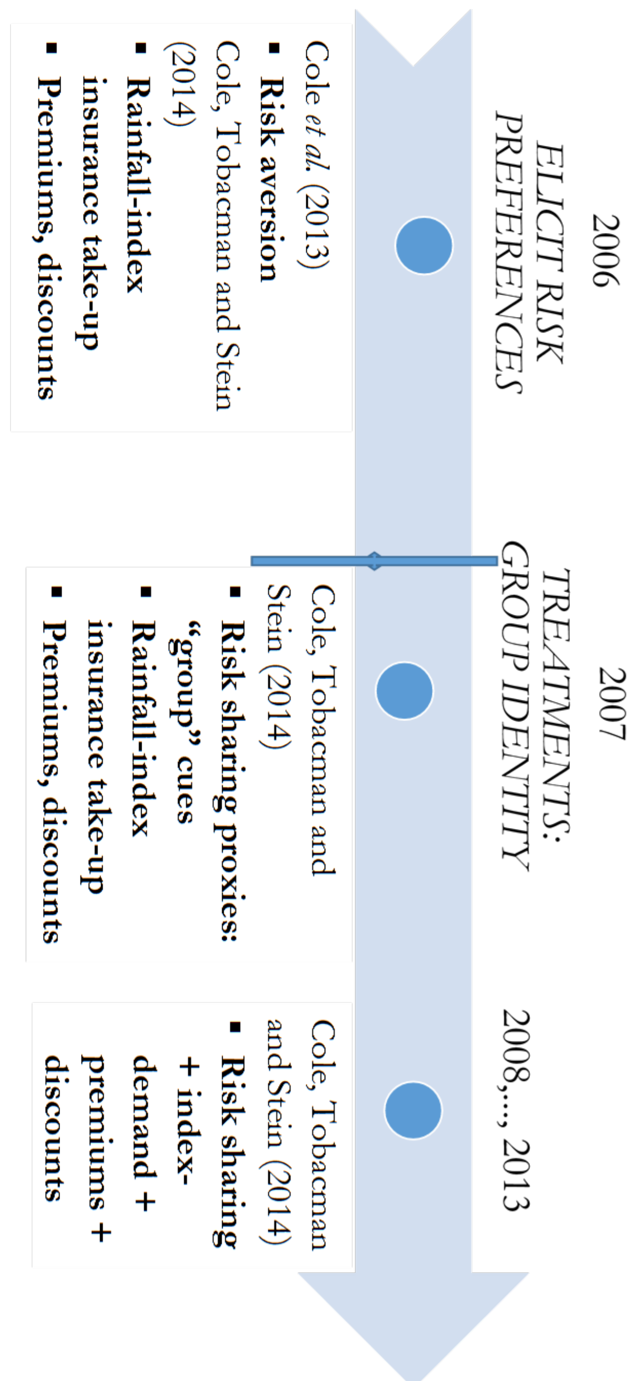
This paper provides new evidence that the effect of informal risk-sharing schemes on the demand for index insurance occurs *via* two aspects of the index contract (i) sensitivity to basis risk, and (ii) sensitivity to insurance premium, which *likely* operate through changes in risk aversion. In our model, we consider the case of an individual who endogenously chooses to join a group and makes decisions about index insurance. The risk aversion of an individual, when part of an informal risk sharing group, becomes lower compared to if he is acting alone — a phenomenon we term "Effective Risk Aversion". We appeal to this phenomenon of "Effective Risk Aversion" to establish that it can lead to either reduced or increased take-up of index insurance, and emphasize how these results provide alternative explanations for two empirical puzzles (i) unexpectedly low take-up for index insurance, and

(ii) demand being particularly low for the most risk averse.

Our model provide testable hypotheses with implications for the design of index insurance contracts. We draw on data from a panel of field experimental trials in India to provide evidence for the predictions that emerge from our theoretical analyses. We find that informal risk-sharing makes individuals less sensitive to basis risk; thus increasing demand, but makes individuals more sensitive to premium, and thus decreasing demand for index insurance. The effect of risk-sharing on the sensitivity to basis risk is 88% lower for households that experience downside basis risk than those that do not experience it. Analogously, the effect on the sensitivity to premium is over 100% higher for discounted households than for those without premium discounts. There is suggestive evidence that changes in risk preferences is a likely channel that informal risk-sharing may act to impact the take-up of index insurance.

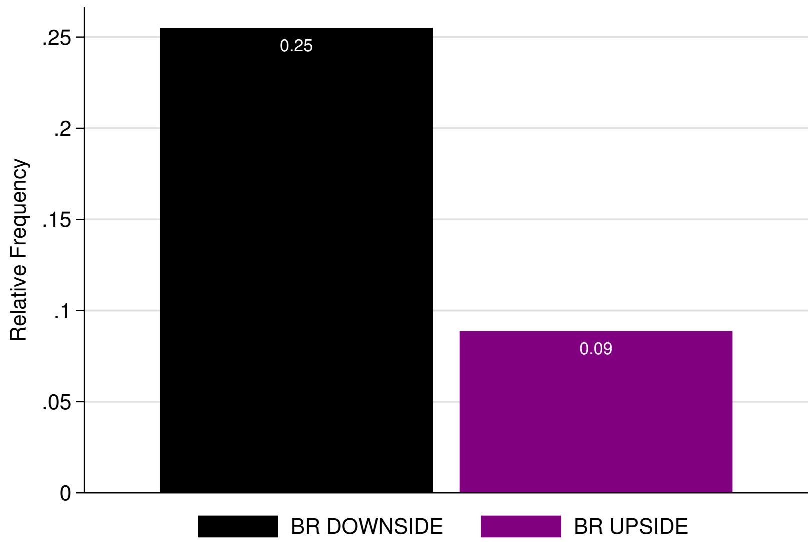
Our study is an initial step towards the broader understanding of the linkages between informal risk-sharing and the market for formal index insurance. In ongoing research, we vary and test several aspects of predictions from the model in the laboratory. This line of work has broader implications for the design and introduction of innovative insurance and financial contracts aimed at mitigating environmental sources of income risks in low-income and emerging societies.

Figure 2: **TIMELINE OF THE DATA AND EXPERIMENTAL/ MARKETING TRIALS**

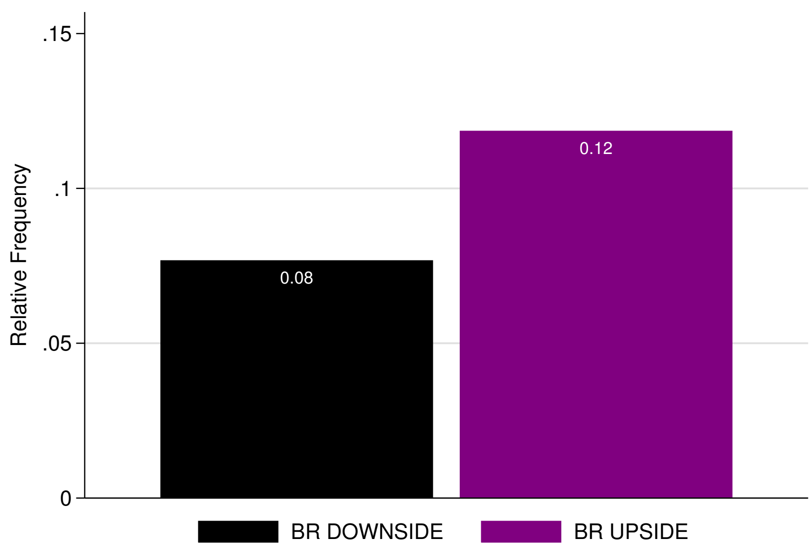


Notes: Figure shows the timeline of the data sets and experimental treatments that we combined for our empirical analysis. The two primary sources of our data are Cole et (2013) and Cole, Tobacman and Stein (2014). Major parts of our data come from the latter source.

Figure 3: **Distribution of basis risk**



(a) **DOWNSIDE VERSUS UPSIDE BASIS RISK: CROP LOSS**



(b) **DOWNSIDE VERSUS UPSIDE BASIS RISK: REVENUE LOSS**

Notes: Figures display the distribution of basis risk measured as the mismatch between households experience of pre-insurance loss in crops or revenue and receiving an index payout, respectively. This is shown for both downside and upside basis risks. As expected, downside basis risk is much higher than upside basis risk due to the contract's design: cumulative rainfall during fixed time periods which will essentially capture only catastrophic events. Revenue is measured for market years in which a crop loss is reported, and captures the "amount" of crop loss: calculated as the difference between that market year's agricultural output and the mean value of output in all previous years where crop loss was not reported. Downside basis risk is unexpectedly lower than upside basis risk, perhaps due to the historical aggregation of yields–in some years, one may be too far or close to the index payout trigger. We only used this revenue-based measure of basis risk in the robustness analysis.

Table 2: **Data summaries–pooled 2006-2013**

Variables	Obs.	Mean	Std. dev.	Min	Max
Index-Demand					
1(bought=Yes)	4,948	0.390	0.488	0	1
Risk Aversion	4,919	0.528	0.316	0	1
Price and Discounts					
Premium	4,948	159.4	56.08	44	257
Discount	4,871	5.352	17.51	0	90
1(Got Payout=Yes)	4,948	0.119	0.324	0	1
Payout Per Policy	1,929	63.75	56.50	0	257
Payout Amount	4,949	0.056	0.265	0	3,208
Pre-Insurance Losses					
1(Crop Loss=Yes)	4,948	0.292	0.455	0	1
1(Revenue Loss=Yes)	4,948	0.094	0.292	0	1
Risk-Share Treatments					
1(Group cues=Yes)	4,871	0.039	0.195	0	1
1(Hindu cues=Yes)	4,871	0.027	0.164	0	1
1(Muslim cues=Yes)	4,871	0.028	0.167	0	1
Basis Risk [BR]					
BR DOWNSIDE: Crop Loss	4,948	0.255	0.426	0	1
BR UPSIDE: Crop Loss	4,948	0.082	0.274	0	1
BR DOWNSIDE: Rev. Loss	4,948	0.082	0.274	0	1
BR UPSIDE: Revenue Loss	4,948	0.107	0.309	0	1
Number of Years				2006	2013
Number of Households				649	649
Number of Villages				52	52
Number of Districts				3	3

Notes: Table reports the summary statistics of the panel data used for our empirical analysis. This include information about take-up of rainfall-index insurance, premium and randomized discounts, crop and revenue loss experience of households, multiple treatments for risk-sharing, proxied by cues on "group identity", and basis risks respectively. **1**(.) is a logical indicator that takes the value 1 whenever the argument in the bracket is true, and zero otherwise. The *merged* data spans 2006-2013, covering 649 households across a pool of 52 villages. These are located in three districts in the state of Gujarat, namely: Ahmedabad, Anand and Patan.

Table 3: **INFORMAL RISK-SHARING IMPACTS, AND THE TAKE-UP OF INDEX CONTRACT**

DV: **1**(bought=Yes)	(1)	(2)	(3)
bRisk	-0.131***		-0.133***
	(0.0227)		(0.0227)
bRisk $\times$ *riskShareT1*			0.118**
			(0.0496)
1(discount=Yes)	0.558***		0.458***
	(0.0775)		(0.0891)
1(discount=Yes) $\times$ *riskShareT1*			0.488***
			(0.0958)
riskShareT1		-0.074	-0.243***
		(0.0554)	(0.0468)
Constant	0.178**	0.184***	0.199***
	(0.0514)	(0.0357)	(0.0477)
Observations	4948	4948	4948
R-squared	0.197	0.123	0.205
Number of Households	649	649	649
Household FEs	Yes	Yes	Yes
Mkt Year FEs	Yes	Yes	Yes

Notes: Table reports the results from regressions of take-up for rainfall-index insurance on a vector of treatments for risk-sharing proxied by cues on "group identity" and their interactions with basis risk and discount assignments–exogenous variation in insurance premium at the household level. **1**(.) is a logical indicator that takes the value 1 whenever the argument in the bracket is true, and zero otherwise. Columns (1)-(3) differ based on the included risk-sharing treatments and interactions with basis risk (*downside*), and controls for premium discount. Columns (1) and (2) omit the various interaction terms, while column (3) includes the interactions. Errors are clustered at the village level. Stars indicate significance: $***$, $**$, and $*$ stand for significance at the 1%, 5%, and 10% level, respectively.

Table 4: **INFORMAL RISK-SHARING IMPACTS, AND THE TAKE-UP OF INDEX CONTRACT**

DV: $\mathbf{1}$(bought=Yes)	(1)	(2)	(3)
bRisk	-0.129***		-0.128***
	(0.0232)		(0.0231)
bRisk × *riskShareT1*			0.114**
			(0.0494)
Discount	0.003***		0.003***
	(0.0005)		(0.0006)
Discount × *riskShareT1*			0.929***
			(0.0387)
riskShareT1		-0.074	-0.413***
		(0.0554)	(0.0393)
Constant	0.333***	0.184***	0.330***
	(0.0396)	(0.0357)	(0.0397)
Observations	4871	4948	4871
R-squared	0.134	0.123	0.171
Number of Households	649	649	649
Household FEs	Yes	Yes	Yes
Mkt Year FEs	Yes	Yes	Yes

Notes: Table reports the results from regressions of take-up for rainfall-index insurance on a vector of treatments for risk-sharing proxied by cues on "group identity" and their interactions with basis risk and (*amount of*) discount assignments–exogenous variation in insurance premium at the household level. $\mathbf{1}(.)$ is a logical indicator that takes the value 1 whenever the argument in the bracket is true, and zero otherwise. Columns (1)-(3) differ based on the included risk-sharing treatments and interactions with basis risk (*downside*), and controls for premium discount. Columns (1) and (2) omit the various interaction terms, while column (3) includes the interactions. Errors are clustered at the village level. Stars indicate significance: $***$, $**$, and $*$ stand for significance at the 1%, 5%, and 10% level, respectively.

Table 5: **INFORMAL RISK-SHARING IMPACTS, AND THE TAKE-UP OF INDEX CONTRACT**

DV: **1**(bought=Yes)	(1)	(2)	(3)
bRisk		-0.136***	-0.1312***
		(0.0236)	(0.0241)
bRisk × *riskShareT2*		0.113**	0.105**
		(0.0392)	(0.0411)
1(discount=Yes)		0.350**	
		(0.1086)	
1(discount=Yes) × *riskShareT2*		0.560***	
		(0.1112)	
Discount			0.003***
			(0.0006)
Discount × *riskShareT2*			0.179***
			(0.0072)
riskShareT2	-0.071	-0.287***	-0.418***
	(0.0596)	(0.0606)	(0.0467)
Constant	0.182***	0.220***	0.332***
	(0.0355)	(0.0456)	(0.0397)
Observations	4948	4948	4871
R-squared	0.123	0.212	0.195
Number of Households	649	649	649
Household FEs	Yes	Yes	Yes
Mkt Year FEs	Yes	Yes	Yes

Notes: Table reports the results from regressions of take-up for rainfall-index insurance on a vector of treatments for risk-sharing proxied by cues on "group identity" and their interactions with basis risk and discount assignments–exogenous variation in insurance premium at the household level. **1**(.) is a logical indicator that takes the value 1 whenever the argument in the bracket is true, and zero otherwise. Columns (1)-(3) differ based on the included risk-sharing treatments and interactions with basis risk (*downside*), and controls for premium discount. Column (1) omits the various interaction terms, while columns (2)-(3) include the interactions. Errors are clustered at the village level. Stars indicate significance: ∗∗∗, ∗∗, and ∗ stand for significance at the 1%, 5%, and 10% level, respectively.

Table 6: **CHANGES IN RISK PREFERENCES AS A CHANNEL FOR RISK-SHARING IMPACTS**

DV: **1**(bought=Yes)	(1)	(2)	(3)	(4)
bRisk	-0.131***	-0.130***	-0.130***	-0.112***
	(0.0227)	(0.0305)	(0.0232)	(0.0292)
bRisk × *riskAversion*		-0.00376		-0.0371
		(0.0454)		(0.0430)
1(discount=Yes)	0.558***	0.543***		
	(0.0775)	(0.0852)		
1(discount=Yes) × *riskAversion*		0.0244		
		(0.0591)		
Discount			0.00352***	0.00395***
			(0.000596)	(0.00111)
Discount × *riskAversion*				-0.000855
				(0.00137)
Constant	0.179***	0.178***	0.333***	0.332***
	(0.0515)	(0.0505)	(0.0397)	(0.0385)
Observations	4948	4919	4871	4842
R-squared	0.197	0.197	0.135	0.135
Number of Households	649	645	649	645
Household FEs	Yes	Yes	Yes	Yes
Mkt Year FEs	Yes	Yes	Yes	Yes

Notes: Table reports the results from regressions of take-up for rainfall-index insurance on risk aversion and its interactions with basis risk and discount assignments–exogenous variation in insurance premium at the household level. **1**(.) is a logical indicator that takes the value 1 whenever the argument in the bracket is true, and zero otherwise. Columns (1)-(4) differ based on the interactions with basis risk (*downside*), and controls for premium discount. Columns (1) and (3) omit the various interaction terms, while columns (2) and (4) include the interactions. Errors are clustered at the village level. Stars indicate significance: $***$, $**$, and $*$ stand for significance at the 1%, 5%, and 10% level, respectively.

Table 7: **CHANGES IN RISK PREFERENCES AS A CHANNEL FOR RISK-SHARING IMPACTS**

DV: **1**(bought=Yes)	(1)	(2)	(3)	(4)
bRisk	-0.131***		-0.130***	
	(0.0227)		(0.0232)	
bRisk × *riskAversion*		-0.179***		-0.184***
		(0.0339)		(0.0356)
1(discount=Yes)	0.558***			
	(0.0775)			
1(discount=Yes) × *riskAversion*		0.444***		
		(0.0524)		
Discount			0.00352***	
			(0.000596)	
Discount × *riskVersion*				0.00348***
				(0.000641)
Constant	0.179***	0.215***	0.333***	0.309***
	(0.0515)	(0.0419)	(0.0397)	(0.0358)
Observations	4948	4948	4871	4842
R-squared	0.197	0.158	0.135	0.128
Number of Households	649	645	649	645
Household FEs	Yes	Yes	Yes	Yes
Mkt Year FEs	Yes	Yes	Yes	Yes

Notes: Table reports the results from regressions of take-up for rainfall-index insurance on risk aversion and its interactions with basis risk and discount assignments–exogenous variation in insurance premium at the household level. **1**(.) is a logical indicator that takes the value 1 whenever the argument in the bracket is true, and zero otherwise. Columns (1)-(4) differ based on the interactions with basis risk (*downside*), and controls for premium discount. Columns (1) and (3) omit the various interaction terms, while columns (2) and (4) include the interactions. Errors are clustered at the village level. Stars indicate significance: $***$, $**$, and $*$ stand for significance at the 1%, 5%, and 10% level, respectively.

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Appendix 1

Proof of Proposition 1

Suppose that individual i is faced with the choice of either buying index insurance, denoted by **1** or not, denoted by **0**. We first consider the case where the individual does not have access to an informal risk-sharing arrangement. In order to determine demand for index insurance, we compare the certainty equivalents for buying versus not buying the index. Formally, consider individual i whose income process is given by

$$z_i^0(\epsilon) = w_i + \varepsilon_i + v$$

where the independent shocks are

$$\begin{aligned} \varepsilon_i &\sim N(0, \sigma_i^2) \\ v &= \begin{cases} 0 & \text{with probability } 1-p \\ -L & \text{with probability } p \end{cases} \end{aligned}$$

If individual does not buy the index: the expected utility of individual i is

$$\begin{aligned} E(-e^{-\gamma_i z_i^0}) &= E(-e^{-\gamma_i(w_i+\varepsilon_i+v)}) \\ &= -E(e^{-\gamma_i w_i})E(e^{-\gamma_i \varepsilon_i})E(e^{-\gamma_i v}) \\ &= -e^{-\gamma_i w_i} e^{\frac{\gamma_i^2 \sigma_i^2}{2}}([1-p] + pe^{\gamma_i L}) \end{aligned}$$

For individual i with CARA utility function with income z_i, we derive the certainty equivalent (CE_i) according to:

$$-e^{-\gamma_i CE_i} = E(-e^{-\gamma_i z_i})$$

Thus, the certainty equivalent for individual with no index insurance is given by

$$\begin{aligned} CE_i^0 &= -\frac{1}{\gamma_i}\log E(e^{-\gamma_i z_i^0}) \\ &= -\frac{1}{\gamma_i}(-\gamma_i w_i + \frac{\gamma_i^2 \sigma_i^2}{2} + \log([1-p] + pe^{\gamma_i L}) \\ &= w_i - \frac{\gamma_i \sigma_i^2}{2} - \frac{1}{\gamma_i}\log([1-p] + pe^{\gamma_i L}) \end{aligned}$$

If the individual buys insurance, his income process is now given by:

$$z_i^1(\epsilon) = w' + \varepsilon_i + v'$$

where $w' \equiv w_i - \pi$ and $v' \equiv v + \eta$. Thus v' and ε_i are independent and the distribution of v' is given by

$$v' = \begin{cases} 0 & \text{with probability } 1-q-r \\ -L & \text{with probability } r \\ \beta L & \text{with probability } q+r-p \\ -L+\beta L & \text{with probability } p-r \end{cases}$$

If the individual buys the index: the expected utility is

$$\begin{aligned} E(-e^{-\gamma_i z_i^1}) &= E(-e^{-\gamma_i(w'+\varepsilon_i+v')}) \\ &= -E(e^{-\gamma_i w'})E(e^{-\gamma_i \varepsilon_i})E(e^{-\gamma_i v'}) \\ &= -e^{-\gamma_i w'} e^{\frac{\gamma_i^2\sigma_i^2}{2}}([1-q-r] + re^{\gamma_i L} + [q+r-p]e^{-\gamma_i \beta L} + [p-r]e^{-\gamma_i(-L+\beta L)}) \end{aligned}$$

Thus, the certainty equivalent for individual with index insurance is given by

$$\begin{aligned} CE_i^1 &= -\frac{1}{\gamma_i}\log E(e^{-\gamma_i z_i^1}) \\ &= -\frac{1}{\gamma_i}(-\gamma_i w' + \frac{\gamma_i^2\sigma_i^2}{2} + \log([1-q-r] + re^{\gamma_i L} + [q+r-p]e^{-\gamma_i\beta L} + [p-r]e^{-\gamma_i(-L+\beta L)}) \\ &= w' - \frac{\gamma_i\sigma_i^2}{2} - \frac{1}{\gamma_i}\log([1-q-r] + re^{\gamma_i L} + [q+r-p]e^{-\gamma_i\beta L} + [p-r]e^{-\gamma_i(-L+\beta L)}) \end{aligned}$$

Thus, the individual buys insurance if $CE_i^1 \geq CE_i^0$.
Using the expressions for CEs from above this condition can be rewritten as

$$w' - \frac{\gamma_i\sigma_i^2}{2} - \frac{1}{\gamma_i}\log([1-q-r] + re^{\gamma_i L} + [q+r-p]e^{-\gamma_i\beta L} + [p-r]e^{-\gamma_i(-L+\beta L)}) \geq w_i - \frac{\gamma_i\sigma_i^2}{2} - \frac{1}{\gamma_i}\log([1-p] + pe^{\gamma_i L})$$
$$-mq\beta L - \frac{1}{\gamma_i}\log([1-q-r] + re^{\gamma_i L} + [q+r-p]e^{-\gamma_i\beta L} + [p-r]e^{-\gamma_i(-L+\beta L)}) \geq -\frac{1}{\gamma_i}\log([1-p] + pe^{\gamma_i L})$$
$$-\frac{1}{\gamma_i}\log([1-q-r] + re^{\gamma_i L} + [q+r-p]e^{-\gamma_i\beta L} + [p-r]e^{-\gamma_i(-L+\beta L)}) + \frac{1}{\gamma_i}\log([1-p] + pe^{\gamma_i L}) \geq mq\beta L$$

where the second inequality uses $w' \equiv w_i - \pi$. Observe that $-\frac{1}{\gamma_i}\log([1-q-r] + re^{\gamma_i L} + [q+r-p]e^{-\gamma_i\beta L} + [p-r]e^{-\gamma_i(-L+\beta L)}) = CE_i(v')$ i.e., the CE for individual faced with v' gamble. Equivalently:$-\frac{1}{\gamma_i}\log([1-p] + pe^{\gamma_i L}) = CE_i(v)$.

Thus the individual buys index insurance if

$$CE_i(v') - CE_i(v) \quad \geq \quad mq\beta L$$

Tranferable Utility (TU) Representation under Certainty Equivalent (CE)

Since our set up has a non-transferable utility (NTU) representation, we first show that the model has a transferable utility (TU) representation under certainty equivalents (CE). The set-up is NTU because of the heterogeneity in risk-aversion where one unit of income yields utility $u_i(1) = -exp(-\gamma_i)$ for an individual i with risk aversion γ_i, but utility $u_g(1) = -exp(-\gamma_g) \neq u_i(1)$ for a representative agent acting for the group g with risk aversion γ_g. We work with CE units, which allows for TU representations. This is stated in the following Lemma.

Lemma 1. *The NTU model has a TU representation where CEs are transferable across individuals* (i, g).

Proof of Lemma 1

The proof for Lemma 1 is similar to arguments in Wang (2014).

Let z_i and z_g denote the income of individual i and representative individual g. Suppose i and g form a pair. We denote the combined income of the pair, $z_{i^*} \equiv z_i + z_g$. If i wishes to promise utility ξ to his partner g, then the corresponding efficient sharing rule $(z_{i'} - s(z_{i^*}, \xi),\, s(z_{i^*}, \xi))$ must satisfy

$$s^*(z_{i^*}, \xi) \equiv \arg\max_s Eu_i(z_{i^*} - s) \quad s.t. \quad Eu_g(s) \geq \xi \tag{1}$$

Varying ξ, the solutions s^* describe the set of efficient sharing rules.

Let $f(z_{i^*})$ denote the joint density function for combined income. Plugging in the utility functions of the individuals allows us to restate the above optimization program as

$$\max \int -e^{-\gamma_i (z_{i^*} - s(z_{i^*}))} f(z_{i^*}) dz$$
$$s.t. \int -e^{-\gamma_g s(z_{i^*})} f(z_{i^*}) dz \geq -e^{-\xi}$$

The inequality in the constraint will hold with equality since transferring income to individual g comes at the cost of reducing i's income.

Solving the constrained optimization problem gives us

$$s^*(z_{i^*}) = \frac{\gamma_i}{\gamma_i+\gamma_g} z_{i^*} + \frac{1}{\gamma_g}\log(\int -e^{-\frac{\gamma_i\gamma_g}{\gamma_i+\gamma_g} z_{i^*}} f(z_{i^*})dz) + \frac{1}{\gamma_g}\xi$$

This allows us to rewrite individual i's expected utility as

$$Eu_i(\xi) = -e^{\frac{\gamma_i}{\gamma_g}\xi}(\int -e^{-\frac{\gamma_i\gamma_g}{\gamma_i+\gamma_g} z_{i^*}} f(z_{i^*})dz)^{\frac{\gamma_i+\gamma_g}{\gamma_g}}$$

where as individual g's expected utility can be written as

$$Eu_g(\xi) = -e^{-\xi}$$

For individual i with CARA utility function with income z_i, there is a simple relation between the certainty equivalent (CE_i) and the expected utility:

$$-e^{-\gamma_i CE_i} = E(-e^{-\gamma_i z_i})$$

which gives us

$$CE_i = -\frac{1}{\gamma_i}\log E(e^{-\gamma_i z_i})$$

We apply this to the efficient risk sharing problem to get

$$CE_g = \frac{\xi}{\gamma_g}$$

and

$$CE_i = -(\frac{1}{\gamma_i} + \frac{1}{\gamma_g})\log(\int -e^{-\frac{\gamma_i\gamma_g}{\gamma_i+\gamma_g} z_{i^*}} f(z_{i^*})dz) - \frac{1}{\gamma_g}\xi$$

Thus we observe that increasing certainty individual of individual g by one unit leads to a reduction in certainty equivalent of individual i by one unit. Hence certainty equivalents are transferable across individuals and since expected utility is a monotonic transformation of certainty equivalent, we get that the expected utility is transferable as well. This concludes the proof of Lemma 1.

Proof of Proposition 2

From the proof of Lemma 1, we found that if risk is shared efficiently then we get

$$\begin{aligned} CE_i + CE_g &= -(\frac{1}{\gamma_i} + \frac{1}{\gamma_g})\log(\int -e^{-\frac{\gamma_i\gamma_g}{\gamma_i+\gamma_g}z_{i^*}} f(z_{i^*})dz) \\ &= -\frac{1}{\gamma_{i^*}}\log(\int -e^{-\gamma_{i^*}z_{i^*}} f(z_{i^*})dz) \\ &= -\frac{1}{\gamma_{i^*}}\log E(e^{-\gamma_{i^*}z_{i^*}}) \end{aligned}$$

With TU, the sum of the CEs correspond to the joint maximization of the group (i, g)'s welfare. From the last equality, this is identical to the maximization problem of a representative individual with risk aversion parameter $\gamma_{i^*}$and income process z_{i^*}.

Further, since $\frac{1}{\gamma_{i^*}} = \frac{1}{\gamma_i} + \frac{1}{\gamma_g}$ we have that $\gamma_{i^*} = \frac{\gamma_i\gamma_g}{\gamma_i+\gamma_g} < \min(\gamma_i, \gamma_g)$.

Additional Remarks

We can also examine whether it is optimal for individual i to join the group g. To do this, we compare the CE of the group if they were sharing risk efficiently to the sum of CEs for the individual i and group g if they were acting separately. Indeed, joining the group provide welfare gains to the individual (and the group), as noted by Wilson (1968). The proof is by contradiction. Suppose that i and g are un-matched, then i and g can form a pair where each consumes his income. In this case, each is at least as well-off in the pair, as compared to remaining unmatched. However, by the mutuality principle (Wilson 1968), both can be better-off when in the group. This requires their income shares to rise and fall together with the independent random part of their incomes. The following Lemma formally shows that it is efficient for i and g to form a pair.

Lemma 2. *Suppose risk is shared efficiently within a group. Then it is efficient for individual i to join group g.*

Proof of Lemma 2

Let CE_g^0, $CE_{i^*}^0$ denote the certainty equivalent for the group g without individual i and the certainty equivalent for group g with individual i joining respectively. We want to show that $CE_{i^*}^0 > CE_g^0 + CE_i^0$. Notice that:

$$CE_{i*}^0 = w_i + w_g - \frac{\gamma_{i^*}(\sigma_i^2 + \sigma_g^2)}{2} - \frac{1}{\gamma_{i^*}}\log([1-p] + pe^{\gamma_{i^*}L})$$

and

$$CE_g^0 \quad = \quad w_g - \frac{\gamma_g \sigma_g^2}{2}$$

Hence it is sufficient to show that

$$w_i + w_g - \frac{\gamma_{i^*}(\sigma_i^2 + \sigma_g^2)}{2} - \frac{1}{\gamma_{i^*}} \log([1-p] + pe^{\gamma_{i^*} L}) \quad > \quad w_g - \frac{\gamma_g \sigma_g^2}{2} + w_i - \frac{\gamma_i \sigma_i^2}{2} - \frac{1}{\gamma_i} \log([1-p] + pe^{\gamma_i L})$$

$$-\frac{\gamma_{i^*}(\sigma_i^2 + \sigma_g^2)}{2} - \frac{1}{\gamma_{i^*}} \log([1-p] + pe^{\gamma_{i^*} L}) \quad > \quad -\frac{\gamma_g \sigma_g^2}{2} - \frac{\gamma_i \sigma_i^2}{2} - \frac{1}{\gamma_i} \log([1-p] + pe^{\gamma_i L})$$

The last inequality follows from the following two claims:
CLAIM 1: $\frac{\gamma_g \sigma_g^2}{2} + \frac{\gamma_i \sigma_i^2}{2} > -\frac{\gamma_{i^*}(\sigma_i^2 + \sigma_g^2)}{2}$

Proof: This follows from observing that $\gamma_{i^*} < \min(\gamma_g, \gamma_i)$ by lemma 2.

CLAIM 2: $-\frac{1}{\gamma_{i^*}} \log([1-p] + pe^{\gamma_{i^*} L}) > -\frac{1}{\gamma_i} \log([1-p] + pe^{\gamma_i L})$

Proof: This follows from observing that the LHS is the CE for a representative agent with risk aversion γ_{i^*} for a gamble v while the RHS is the CE for an individual with risk aversion $\gamma_i > \gamma_{i^*}$ for the same gamble v. Since CE is decreasing in risk aversion, the claim follows.

Appendix 2

Table A2.1: **CHANGES IN RISK PREFERENCES AS A CHANNEL FOR RISK-SHARING IMPACTS**

DV: **1**(bought=Yes)	(1)	(2)	(3)	(4)
bRisk	-0.131***	-0.135***	-0.130***	-0.136***
	(0.0227)	(0.0329)	(0.0232)	(0.0304)
bRisk × *riskAversion*		0.0382		0.120
		(0.131)		(0.134)
bRisk × *riskAversion*^{2}		-0.0412		-0.154
		(0.126)		(0.131)
1(discount=Yes)	0.558***	0.587***		
	(0.0775)	(0.0924)		
1(discount=Yes) × *riskAversion*		-0.263		
		(0.162)		
1(discount=Yes) × *riskAversion*^{2}		0.283**		
		(0.134)		
Discount			0.00352***	0.00466***
			(0.000596)	(0.00127)
Discount × *riskAversion*				-0.00525
				(00335)
Discount × *riskAversion*^{2}				0.00435
				(0.00291)
Constant	0.179***	0.178***	0.333***	0.332***
	(0.0515)	(0.0504)	(0.0397)	(0.0384)
Observations	4948	4919	4871	4842
R-squared	0.197	0.166	0.135	0.136
Number of Households	649	645	649	645
Household FEs	Yes	Yes	Yes	Yes
Mkt Year FEs	Yes	Yes	Yes	Yes

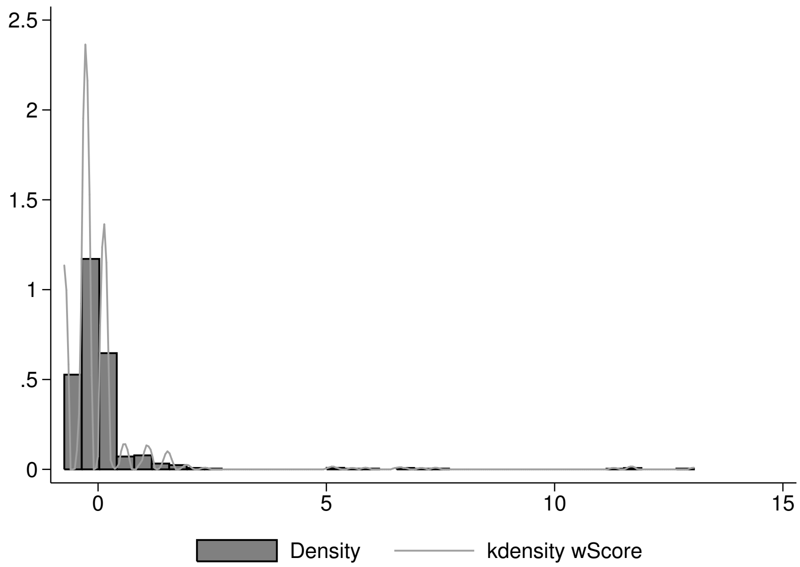
Notes: Table reports the results from regressions of take-up for rainfall-index insurance on risk aversion (linear and quadratic terms) and its interactions with basis risk and discount assignments–exogenous variation in insurance premium at the household level. **1**(.) is a logical indicator that takes the value 1 whenever the argument in the bracket is true, and zero otherwise. Columns (1)-(4) differ based on the interactions with basis risk (*downside*), and controls for premium discount. Columns (1) and (3) omit the various interaction terms, while columns (2) and (4) include the interactions. Errors are clustered at the village level. Stars indicate significance: $***$, $**$, and $*$ stand for significance at the 1%, 5%, and 10% level, respectively.

Table A2.2: **CHANGES IN RISK PREFERENCES AS A CHANNEL FOR RISK-SHARING IMPACTS**

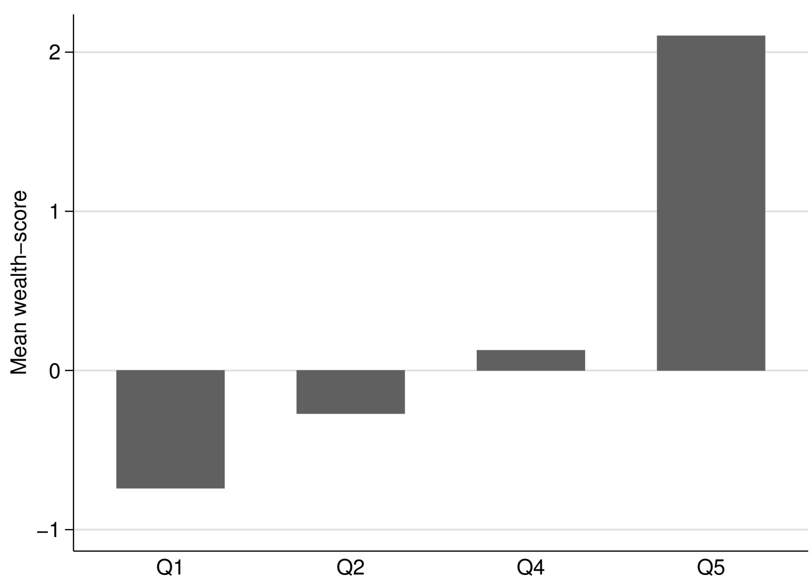
DV: **1**(bought=Yes)	(1)	(2)	(3)	(4)
bRisk	-0.131***		-0.130***	
	(0.0227)		(0.0232)	
bRisk × *riskAversion*		-0.432***		-0.357***
		(0.110)		(0.117)
bRisk × *riskAversion*^{2}		0.307**		0.212*
		(0.118)		(0.125)
1(discount=Yes)	0.558***			
	(0.0775)			
1(discount=Yes) × *riskAversion*		1.204***		
		(0.160)		
1(discount=Yes) × *riskAversion*^{2}		-0.846***		
		(0.134)		
Discount			0.00352***	
			(0.000596)	
Discount × *riskAversion*				0.00905***
				(0.00256)
Discount × *riskAversion*^{2}				-0.00672**
				(0.00299)
Constant	0.179***	0.209***	0.333***	0.316***
	(0.0515)	(0.0451)	(0.0397)	(0.0367)
Observations	4948	4919	4871	4842
R-squared	0.197	0.166	0.135	0.130
Number of Households	649	645	649	645
Household FEs	Yes	Yes	Yes	Yes
Mkt Year FEs	Yes	Yes	Yes	Yes

Notes: Table reports the results from regressions of take-up for rainfall-index insurance on risk aversion (linear and quadratic terms) and its interactions with basis risk and discount assignments–exogenous variation in insurance premium at the household level. **1**(.) is a logical indicator that takes the value 1 whenever the argument in the bracket is true, and zero otherwise. Columns (1)-(4) differ based on the interactions with basis risk (*downside*), and controls for premium discount. Columns (1) and (3) omit the various interaction terms, while columns (2) and (4) include the interactions. Errors are clustered at the village level. Stars indicate significance: $***$, $**$, and $*$ stand for significance at the 1%, 5%, and 10% level, respectively.

Figure A2.1: **Distribution of household wealth**



(a) **ASSET-BASED WEALTH INDEX**



(b) **ASSET-BASED WEALTH INDEX**

Notes: Figures display the distribution of household wealth. Wealth is estimated using Factor analysis and based on eight (8) household asset holdings: **1**(Electricity=Yes), **1**(Mobile Phone=Yes), **1**(Sew Machine=Yes), **1**(Tractor=Yes), **1**(Thresher=Yes), **1**(Bull cart=Yes), **1**(Bicycle=Yes), and **1**(Motorcycle=Yes). **1**(.) is a logical indicator that equals 1 whenever the argument in the bracket is true, and 0 otherwise. Q3 is missing, as there are few to no households in this bracket.

Table A2.3: **WEALTH EFFECTS: INFORMAL RISK-SHARING IMPACTS AND CONTRACT UPTAKE**

DV: **1**(bought=Yes)	(1)	(2)	(3)
Wealth score	–	0.00202	0.00558
		(0.00720)	(0.00805)
bRisk	-0.101***	-0.100***	-0.0975***
	(0.0202)	(0.0200)	(0.0208)
bRisk × *riskShareT1*	0.101***	0.100***	0.0968***
	(0.0202)	(0.0201)	(0.0210)
1(discount=Yes)	0.558***	0.559***	
	(0.0926)	(0.0928)	
1(discount=Yes) × *riskShareT1*	0.442***	0.441***	
	(0.0926)	(0.0928)	
Discount			0.00333***
			(0.000562)
Discount × *riskShareT1*			0.197***
			(0.000602)
riskShareT1	-0.203***	-0.203***	-0.417***
	(0.0403)	(0.0405)	(0.0396)
Constant	0.156***	0.157***	0.303***
	(0.0570)	(0.0572)	(0.0459)
Observations	4948	4942	4848
R-squared	0.187	0.187	0.142
Number of Households	649	649	649
Mkt Year FEs	Yes	Yes	Yes

Notes: Table reports the results from regressions of take-up for rainfall-index insurance on a vector of treatments for risk-sharing proxied by cues on "group identity" and their interactions with basis risk and discount assignments–exogenous variation in insurance premium at the household level. **1**(.) is a logical indicator that takes the value 1 whenever the argument in the bracket is true, and zero otherwise. Columns (1)-(3) differ based on the included risk-sharing treatments and interactions with basis risk (*downside*), and controls for premium discount. Column (1) omits the various interaction terms, while columns (2)-(3) include the interactions. Errors are clustered at the village level. Stars indicate significance: $***$, $**$, and $*$ stand for significance at the 1%, 5%, and 10% level, respectively.

Table A2.4: **WEALTH EFFECTS: INFORMAL RISK-SHARING IMPACTS AND CONTRACT UPTAKE**

DV: **1**(bought=Yes)	(1)	(2)	(3)
Wealth score	–	0.00230	0.00518
		(0.00722)	(0.00772)
bRisk	-0.105***	-0.104***	-0.103***
	(0.0211)	(0.0209)	(0.0216)
bRisk × *riskShareT2*	0.105***	0.103***	0.100***
	(0.0211)	(0.0213)	(0.0221)
1(discount=Yes)	0.445***	0.446***	
	(0.114)	(0.114)	
1(discount=Yes) × *riskShareT2*	0.555***	0.554***	
	(0.114)	(0.114)	
Discount			0.00309***
			(0.000570)
Discount × *riskShareT2*			0.197***
			(0.000602)
riskShareT2	-0.203***	-0.203***	0.197***
	(0.0403)	(0.0405)	(0.000582)
Constant	0.181***	0.182***	0.307***
	(0.0535)	(0.0537)	(0.0468)
Observations	4948	4942	4848
R-squared	0.195	0.194	0.172
Number of Households	649	649	649
Mkt Year FEs	Yes	Yes	Yes

Notes: Table reports the results from regressions of take-up for rainfall-index insurance on a vector of treatments for risk-sharing proxied by cues on "group identity" and their interactions with basis risk and discount assignments–exogenous variation in insurance premium at the household level. **1**(.) is a logical indicator that takes the value 1 whenever the argument in the bracket is true, and zero otherwise. Columns (1)-(3) differ based on the included risk-sharing treatments and interactions with basis risk (*downside*), and controls for premium discount. Column (1) omits the various interaction terms, while columns (2)-(3) include the interactions. Errors are clustered at the village level. Stars indicate significance: $***$, $**$, and $*$ stand for significance at the 1%, 5%, and 10% level, respectively.

Table A2.5: **TREATMENT BALANCE ON HOUSEHOLD CHARACTERISTICS**

	1[GROUP] (1)	**1**[HINDU] (2)	**1**[MUSLIM] (3)	**RShareA** (4)	**RShareB** (5)
1(Head=Male)	-0.00843	-0.000152	-0.0101*	-0.00837	-0.0118
	(0.00721)	(0.00600)	(0.00606)	(0.00714)	(0.00881)
Log(Age)	-0.0132	0.0256*	0.0148	0.0131	0.0303
	(0.0162)	(0.0146)	(0.0121)	-(0.0155)	(0.0235)
Log(Household Size)	-0.00869	0.00502	0.00452	-0.00850	0.00688
	(0.00752)	(0.00608)	0.00592)	(0.00744)	(0.00914)
1(≥Secondary Educ)	0.000384	0.00568	(0.00150	0.000313	0.00281
	(0.0102)	(0.00904)	(0.00929)	(0.0101)	(0.0129)
1(Electricity=Yes)	-0.00623	-0.000607	0.00226	-0.00616 -	-0.000712
	(0.00689)	(0.00635)	(0.00626)	(0.00683)	(0.00910)
1(Mobile Phone=Yes)	0.0131	-0.00106	0.00169	0.0127	0.00592
	(0.0153)	(0.0121)	(0.0135)	(0.0150)	(0.0187)
1(Sew Machine=Yes)	0.00840	-0.00340	0.0113	0.00837	0.00463
	(0.0147)	(0.0105)	(0.0124)	(0.0146)	(0.0169)
1(Tractor=Yes)	-0.0185	0.0109	-0.00676	-0.0178	-0.00214
	(0.0138)	(0.0360)	(0.0237)	(0.0133)	(0.0397)
1(Thresher=Yes)	-0.0148	0.0246	-0.00794	0.0152	0.00762
	(0.0146)	(0.0378)	(0.0146)	(0.0141)	(0.0390)
1(Bull cart=Yes)	0.00699	0.00867	-0.00938	0.00677	0.00179
	(0.0144)	(0.0154)	(0.0115)	(0.0143)	(0.0193)
1(Bicycle=Yes)	0.00428	0.000697	-0.00222	0.00417	-0.00302
	(0.00660)	(0.00587)	(0.00550)	(0.00651)	(0.00821)
1(Motorcycle=Yes)	-0.0205	0.00147	0.00223	-0.0198	-0.00385
	(0.0126)	(0.0133)	(0.0140)	(0.0123)	(0.0188)
1(Any Insurance=Yes)	0.00460	0.00116	-0.00424	0.00444	0.00120
	(0.00606)	(0.00502)	(0.00525)	(0.00600)	(0.00759)
Log(1+Per Capita m.Exp)	-0.00225	-0.000768	0.00332	-0.00219	0.00223
	(0.00437)	(0.00391)	(0.00363)	(0.00433)	(0.00567)
Risk Aversion	-0.0117	0.000163	-0.00247	-0.0115	-0.00225
	(0.00980)	(0.00814)	(0.00811)	(0.00970)	(0.0121)
1(Muslim name=Yes)	-0.01000	-0.0145	0.00787	-0.00991	-0.0113
	(0.0116)	(0.00900)	(0.0101)	(0.0115)	(0.0145)
1(Irrigate=Yes)	-0.0164	-0.0226**	-0.00356	-0.0163	-0.0299*
	(0.0130)	(0.00994)	(0.0116)	(0.0129)	(0.0171)
Constant	44.34***	30.66***	31.75***	41.02***	71.42***
	(3.027)	(2.564)	(2.609)	(2.826)	(3.576)
Observations	4,768	4,768	4,768	4,841	4,841
R-squared	0.090	0.065	0.071	0.083	0.138
Linear Time Trend	Yes	Yes	Yes	Yes	Yes
Village FEs	Yes	Yes	Yes	Yes	Yes

Notes: Table reports the results from regressions of risk-sharing treatment groups on a vector of household characteristics. **1**(.) is a logical indicator that equals 1 whenever the argument in the bracket is true, and 0 otherwise. Columns include the set of all seventeen (17) demographic characteristics. Errors are robust to heteroskedasticity. Stars indicate significance: $***$, $**$, and $*$ stand for significance at the 1%, 5%, and 10% level, respectively.

Table A2.6: **REGRESSION OF REPORTED CROP LOSS ON HOUSEHOLD CHARACTERISTICS**

DV: [CROP LOSS=Yes]	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
1(Head=Male)	-9.14e-05	0.00113	0.000787	0.00250	0.00228
	(0.0135)	(0.0138)	(0.0138)	(0.0139)	(0.0140)
Log(Age)	0.0142	0.0121	-0.00156	-0.00393	-0.00441
	(0.0545)	(0.0548)	(0.0560)	(0.0559)	(0.0563)
Log(Household Size)	0.0165	0.0163	0.0186	0.0202	0.0241
	(0.0138)	(0.0138)	(0.0144)	(0.0145)	(0.0156)
1(≥Secondary Educ)		-0.00958	-0.00651	-0.00594	-0.00727
		(0.0183)	(0.0183)	(0.0183)	(0.0184)
1(Electricity=Yes)			0.00967	0.0106	0.0130
			(0.0145)	(0.0146)	(0.0148)
1(Mobile Phone=Yes)			0.0272	0.0260	0.0218
			(0.0322)	(0.0323)	(0.0323)
1(Sew Machine=Yes)			0.0237	0.0263	0.0278
			(0.0287)	(0.0287)	(0.0288)
1(Tractor=Yes)			0.0498	0.0460	0.0545
			(0.0653)	(0.0658)	(0.0675)
1(Thresher=Yes)			0.105	0.108	0.105
			(0.0741)	(0.0743)	(0.0780)
1(Bull cart=Yes)			-0.0147	-0.0157	-0.0187
			(0.0353)	(0.0356)	(0.0358)
1(Bicycle=Yes)			0.000902	0.00236	0.00163
			(0.0126)	(0.0127)	(0.0128)
1(Motorcycle=Yes)			-0.0317	-0.0315	-0.0337
			(0.0285)	(0.0285)	(0.0292)
1(Any Insurance=Yes)				-0.0115	-0.0112
				(0.0126)	(0.0127)
Log(1+Per Capita m.Exp)					0.00795
					(0.00948)
Risk Aversion					-0.00452
					(0.0199)
1(Muslim name=Yes)					-0.0298
					(0.0254)
1(Irrigate=Yes)					0.0534
					(0.0374)
Constant	86.43***	86.44***	85.77***	85.78***	85.13***
	(6.7331)	(6.732)	(6.756)	(6.775)	(6.799)
Observations	4,941	4,941	4,941	4,941	4,941
R-squared	0.279	0.279	0.279	0.280	0.282
Linear Time Trend	Yes	Yes	Yes	Yes	Yes
Village FEs	Yes	Yes	Yes	Yes	Yes

Notes: Table reports the results from regressions of reported-crop loss experience on a vector of household characteristics. **1**(.) is a logical indicator that equals 1 whenever the argument in the bracket is true, and 0 otherwise. Columns (1)-(5) differ based on the included controls. Column (1) includes only demographic characteristics, column (2) adds a control for educational level, column (3) adds controls for household assets, column (4) adds an indicator for whether the household has any formal insurance, while column (5) adds controls for per capita monthly expenditure, risk aversion, and indicators for whether respondent has a muslim name and irrigates farm. Errors are robust to heteroskedasticity. Stars indicate significance: $***$, $**$, and $*$ stand for significance at the 1%, 5%, and 10% level, respectively.

Table A2.7: **REVENUE DEFINITION: INFORMAL RISK-SHARING IMPACTS AND CONTRACT UP-TAKE**

DV: **1**(bought=Yes)	(1)	(2)	(3)	(4)
bRisk	-0.134***	-0.128***		
	(0.0227)	(0.0231)		
bRisk × *riskShareT1*	0.119**	0.114**		
	(0.0496)	(0.0494)		
bRisk [Revenue]			-0.0962***	-0.107***
			(0.0283)	(0.0286)
bRisk [Revenue] × *riskShareT1*			0.0108	0.0370
			(0.0703)	(0.0707)
1(discount=Yes)	0.458***		0.454***	
	(0.0892)		(0.0917)	
1(discount=Yes) × *riskShareT1*	0.488***		0.495***	
	(0.0958)		(0.0976)	
Discount		0.003***		0.00322***
		(0.0006)		(0.000614)
Discount × *riskShareT1*		0.929***		0.186***
		(0.0387)		(0.00785)
riskShareT1	-0.244***	-0.413***	-0.219***	-0.388***
	(0.0469)	(0.0393)	(0.0449)	(0.0392)
Constant	0.199***	0.330***	0.113**	0.254***
	(0.0478)	(0.0397)	(0.0471)	(0.0377)
Observations	4948	4971	4948	4871
R-squared	0.205	0.171	0.198	0.165
Number of Households	649	649	649	649
Household FEs	Yes	Yes	Yes	Yes
Mkt Year FEs	Yes	Yes	Yes	Yes

Notes: Table reports the results from regressions of take-up for rainfall-index insurance on a vector of treatments for risk-sharing proxied by cues on “group identity” and their interactions with basis risk and discount assignments–exogenous variation in insurance premium at the household level. **1**(.) is a logical indicator that takes the value 1 whenever the argument in the bracket is true, and zero otherwise. Columns (1)-(3) differ based on the definition of basis risk. Columns (1)-(2) ar based on crop loss experiences, while columns (2)-(3) are based on revenue losses. Errors are clustered at the village level. Stars indicate significance: $***$, $**$, and $*$ stand for significance at the 1%, 5%, and 10% level, respectively.

Table A2.8: **COMPARISON OF SAMPLE VARIABLES WITH COLE ET AL. (2013)**

Variable	**Merged sample (pooled: 2006-2013)**		**Cole et al. (2013) NOTE: Market Year==2006**			
	Mean	Std. Dev.	Mean		Std. Dev.	
			Raw data	In Table 2: Winsorized at 1%	Raw data	In Table 2: Winsorized at 1%
Risk aversion	0.527	0.315	0.517	0.540	0.314	0.250
Household size	5.890	2.421	5.941	5.850	2.494	2.390
Muslim (yes=1)	7.762%	26.75%	9.165%	8.730%	28.86%	28.20%
T-test (of equality in means)	*p*-value					
Risk aversion	0.247					
Household size	0.486					
Muslim (yes=1)	0.060					

Notes: Table compares the moments (mean and standard deviation) of variables from our merged baseline data with estimates from the raw/ published data and those directly reported in Table 2 (summary statistics) of Cole et al. (2013). The last three rows of the table report the results from t-tests of equality in means of our merged sample with the raw/ published data. We simply restrict attention to variables from Cole et al. (2013) that were used in our empirical analysis. Overall, our sample moments are very close and comparable to Cole et al. (2013) – at the 5% level of significance, we fail to reject that null hypothesis that the variables in our merged data are individually not different from the published data.

Table A2.9: **COMPARISON OF SAMPLE VARIABLES WITH COLE, STEIN AND TOBACMAN (2014)**

Variable	**Merged sample (pooled: 2006-2013)**	**Cole, Tobacman and Stein (2014) -- (pooled:2006-2013)**	
		Raw data	In Table A1
Purchase rate / bought(Yes=1)	0.390	0.390	0.40
Average market price per policy (Rs.)	159.42	160.542	161
Average price paid per policy (Rs.) (if purchased)	63.75	59.351	59
Experienced crop loss (yes/no) (number)	1,445	1,965	1,965
Payout (yes/no), (number)	589	860	860
Average discount (Rs.)	5.352	4.016	-
Share of households receiving "group" risk-sharing treatment	0.0396	0.0297	-
Share of households receiving "hindu" risk-sharing treatment	0.0277	0.0208	-
Share of households receiving "muslim" risk-sharing treatment	0.0287	0.0215	-
Share of households receiving "group" risk-sharing treatment (if market year=2007)	0.2970	0.2970	-
Share of households receiving "hindu" risk-sharing treatment (if market year=2007)	0.2080	0.2080	-
Share of households receiving "muslim" risk-sharing treatment (if market year=2007)	0.2150	0.2150	-

Notes: Table compares the distribution of variables from our merged baseline data with estimates from the raw/ published data and those directly reported in Table A1 (summary statistics) of Cole, Stein and Tobacman (2014). We simply restrict attention to variables from Cole, Stein and Tobacman (2014) that were used in our empirical analysis. Overall, the distribution of our sample variables is very comparable to Cole, Stein and Tobacman (2014).

Table A2.10: **2007-2008 DATA: INFORMAL RISK-SHARING IMPACTS, AND THE TAKE-UP OF INDEX CONTRACT**

DV: **1**(bought=Yes)	(1)	(2)	(3)
bRisk	-0.052		-0.052
	(0.0318)		(0.0357)
bRisk × *riskShareT1*			0.0176
			(0.0850)
1(discount=Yes)	0.752***		0.726***
	(0.0411)		(0.0432)
1(discount=Yes) × *riskShareT1*			0.096
			(0.0866)
riskShareT1		-0.027	-0.019
		(0.0542)	(0.0457)
Constant	0.107***	0.394***	0.112***
	(0.0448)	(0.0225)	(0.0160)
Observations	1298	1298	1298
R-squared	0.539	0.108	0.540
Number of Households	649	649	649
Household FEs	Yes	Yes	Yes
Mkt Year FEs	Yes	Yes	Yes

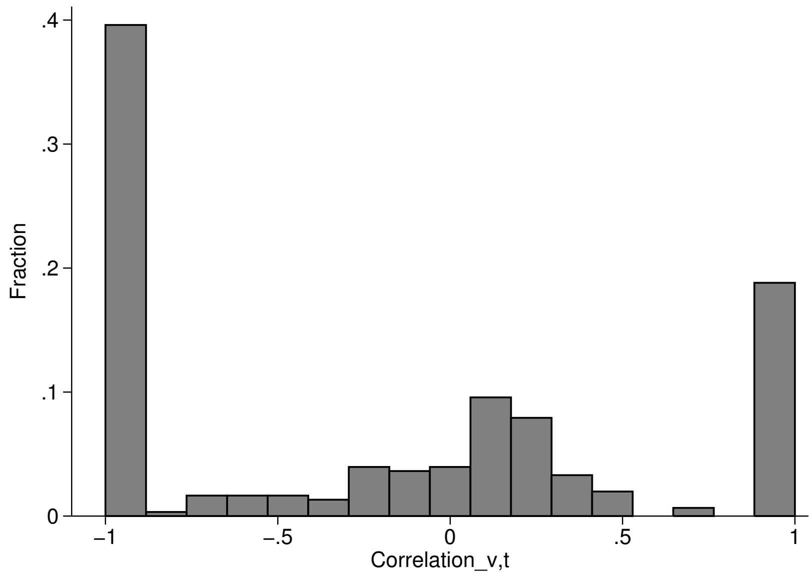
Notes: Table reports the results from regressions of take-up for rainfall-index insurance on a vector of treatments for risk-sharing proxied by cues on "group identity" and their interactions with basis risk and discount assignments–exogenous variation in insurance premium at the household level. The sample is restricted to marketing years in which the exogenous treatments were given: 2007-2008. **1**(.) is a logical indicator that takes the value 1 whenever the argument in the bracket is true, and zero otherwise. Columns (1)-(3) differ based on the included risk-sharing treatments and interactions with basis risk (*downside*), and controls for premium discount. Columns (1) and (2) omit the various interaction terms, while column (3) includes the interactions. Errors are clustered at the village level. Stars indicate significance: $***$, $**$, and $*$ stand for significance at the 1%, 5%, and 10% level, respectively.

Table A2.11: **2007:2008 DATA: INFORMAL RISK-SHARING IMPACTS, AND THE TAKE-UP OF INDEX CONTRACT**

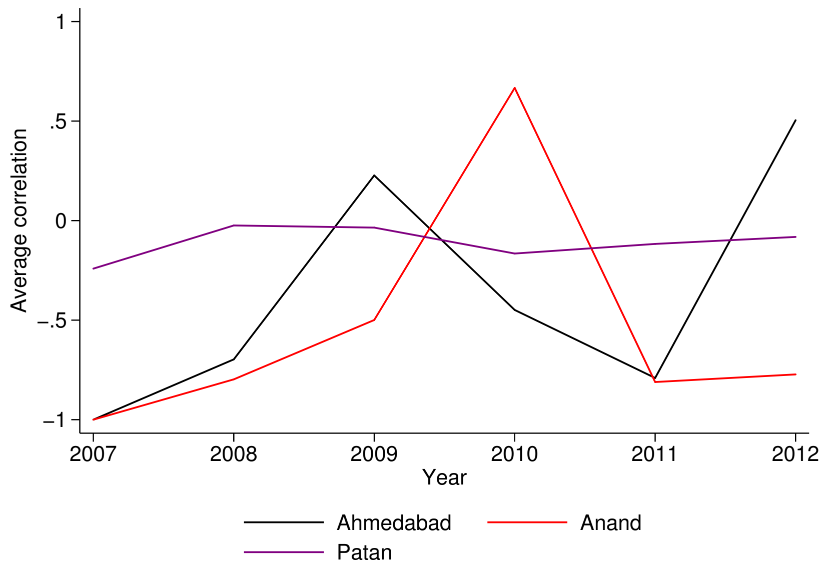
DV: **1**(bought=Yes)	(1)	(2)	(3)
bRisk	-0.097**		-0.080**
	(0.0387)		(0.0398)
bRisk × *riskShareT1*			0.046
			(0.0926)
Discount	0.004***		0.003***
	(0.0006)		(0.0006)
Discount × *riskShareT1*			0.159***
			(0.0160)
riskShareT1		-0.027	-0.313***
		(0.0542)	(0.0559)
Constant	0.396***	0.394**	0.403***
	(0.0189)	(0.0225)	(0.0228)
Observations	1298	1298	1298
R-squared	0.164	0.108	0.297
Number of Households	649	649	649
Household FEs	Yes	Yes	Yes
Mkt Year FEs	Yes	Yes	Yes

Notes: Table reports the results from regressions of take-up for rainfall-index insurance on a vector of treatments for risk-sharing proxied by cues on "group identity" and their interactions with basis risk and (*amount of*) discount assignments–exogenous variation in insurance premium at the household level. The sample is restricted to marketing years in which the exogenous treatments were given: 2007-2008. **1**(.) is a logical indicator that takes the value 1 whenever the argument in the bracket is true, and zero otherwise. Columns (1)-(3) differ based on the included risk-sharing treatments and interactions with basis risk (*downside*), and controls for premium discount. Columns (1) and (2) omit the various interaction terms, while column (3) includes the interactions. Errors are clustered at the village level. Stars indicate significance: $***$, $**$, and $*$ stand for significance at the 1%, 5%, and 10% level, respectively.

Figure A2.2: **Distribution of basis risk: *CORR* (payout, loss amount | coverage, x)**



(a) **OVERALL DISTRIBUTION OF BASIS RISK**



(b) **DISTRIBUTION OF BASIS RISK ACROSS MARKETING DISTRICTS**

Notes: Figures display the distribution of basis risk measured as the "conditional" correlation between the amount of payout and the amount crop loss suffered conditional on the coverage amount (the number of insurance policies bought). The estimated correlations are shown for the (a) overall sample – varying across village and marketing year, and (b) three marketing districts: Ahmedabad, Anand and Patan. In both cases, theres is consideration variation in the correlations and suggest the presence of basis risk with correlation values that are less than 1. The annual variation in basis risk is higher in Ahmedabad and Anand than in Patan which is quite stable over the period 2007-2013. The overall correlation between $\hat{\epsilon}_{ivt-1}$ and $\hat{\eta}_{ivt-1}$ is 0.035 with a p-value=0.021.

Table A2.12: **CORRELATION-BASED DEFINITION: INFORMAL RISK-SHARING IMPACTS, AND THE TAKE-UP OF INDEX CONTRACT**

DV: **1**(bought=Yes)	(1)	(2)	(3)
corr	0.027		0.028
	(0.0169)		(0.0171)
corr × *riskShareT1*			-0.024
			(0.0375)
1(discount=Yes)	0.995***		0.971***
	(0.0263)		(0.0301)
1(discount=Yes) × *riskShareT1*			0.051*
			(0.0258)
riskShareT1		-0.060	-0.039
		(0.0517)	(0.0331)
Constant	0.014***	0.184***	0.026***
	(0.0315)	(0.0357)	(0.0355)
Observations	3773	4948	3773
R-squared	0.156	0.102	0.156
Number of Villages	52	52	52
Village FEs	Yes	Yes	Yes
Mkt Year FEs	Yes	Yes	Yes

Notes: Table reports the results from regressions of take-up for rainfall-index insurance on a vector of treatments for risk-sharing proxied by cues on "group identity" and their interactions with basis risk (i.e., *corr*: defined as the "conditional" correlation between the amount of payout received and the amount of crop loss conditional on coverage) and discount assignments–exogenous variation in insurance premium at the household level. **1**(.) is a logical indicator that takes the value 1 whenever the argument in the bracket is true, and zero otherwise. Columns (1)-(3) differ based on the included risk-sharing treatments and interactions with basis risk, and controls for premium discount. Columns (1) and (2) omit the various interaction terms, while column (3) includes the interactions. Errors are clustered at the village level. Stars indicate significance: $***$, $**$, and $*$ stand for significance at the 1%, 5%, and 10% level, respectively.

Table A2.13: **CORRELATION-BASED DEFINITION: INFORMAL RISK-SHARING IMPACTS, AND THE TAKE-UP OF INDEX CONTRACT**

DV: $\mathbf{1}$(bought=Yes)	(1)	(2)	(3)
corr	0.029*		0.029
	(0.0173)		(0.0174)
corr × *riskShareT1*			-0.035
			(0.0379)
Discount	0.002***		0.002***
	(0.0005)		(0.0005)
Discount × *riskShareT1*			0.199***
			(0.0049)
riskShareT1		-0.060	-0.397***
		(0.0517)	(0.0651)
Constant	0.385***	0.184**	0.382***
	(0.0540)	(0.0357)	(0.0638)
Observations	3773	4948	3773
R-squared	0.097	0.102	0.130
Number of Villages	52	52	52
Village FEs	Yes	Yes	Yes
Mkt Year FEs	Yes	Yes	Yes

Notes: Table reports the results from regressions of take-up for rainfall-index insurance on a vector of treatments for risk-sharing proxied by cues on "group identity" and their interactions with basis risk (i.e., *corr*: defined as the "conditional" correlation between the amount of payout received and the amount of crop loss conditional on coverage) and (*amount of*) discount assignments–exogenous variation in insurance premium at the household level. $\mathbf{1}(.)$ is a logical indicator that takes the value 1 whenever the argument in the bracket is true, and zero otherwise. Columns (1)-(3) differ based on the included risk-sharing treatments and interactions with basis risk, and controls for premium discount. Columns (1) and (2) omit the various interaction terms, while column (3) includes the interactions. Errors are clustered at the village level. Stars indicate significance: $***$, $**$, and $*$ stand for significance at the 1%, 5%, and 10% level, respectively.

Table A2.14: **ZERO *bRisk*: INFORMAL RISK-SHARING IMPACTS, AND THE TAKE-UP OF INDEX CONTRACT**

	1(discount=Yes)		**1(Discount)**	
DV: **1**(bought=Yes)	(1)	(2)	(3)	(4)
bRisk	-0.133***	-0.043**	-0.128***	-0.045**
	(0.0227)	(0.0175)	(0.0231)	(0.0174)
bRisk× *riskShareT1*	0.118**	0.169***	0.114**	0.152
	(0.0496)	(0.043)	(0.0494)	(0.044)
1(discount=Yes)	0.458***	0.456***		
	(0.0891)	(0.0911)		
1(discount=Yes) × *riskShareT1*	0.488***	0.509***		
	(0.0958)	(0.0972)		
Discount			0.003***	0.003
			(0.0006)	(0.0006)
Discount × *riskShareT1*			0.929***	0.189***
			(0.0387)	(0.0079)
riskShareT1	-0.243***	-0.317	-0.413***	-0.475***
	(0.0468)	(0.0511)	(0.0393)	(0.0434)
Constant	0.199***	0.094***	0.330***	0.353***
	(0.0477)	(0.0466)	(0.0397)	(0.0115)
Observations	4948	4948	4871	4871
R-squared	0.205	0.197	0.171	0.163
Number of Villages	649	649	649	649
Village FEs	Yes	Yes	Yes	Yes
Mkt Year FEs	Yes	Yes	Yes	Yes

Notes: Table reports the results from regressions of take-up for rainfall-index insurance on a vector of treatments for risk-sharing proxied by cues on "group identity" and their interactions with basis risk and discount assignments–exogenous variation in insurance premium at the household level. Basis risk is set to zero for all households that did not buy insurance at $t-1$ and so had no way of receiving a payout at t. $\mathbf{1}(.)$ is a logical indicator that takes the value 1 whenever the argument in the bracket is true, and zero otherwise. Columns (1) and (3) replicate the baseline results, while columns (2) and (4) report the new estimates after setting basis risk to zero for all households that had no option of receiving a payout because they did not purchase insurance in the previous year. Errors are clustered at the village level. Stars indicate significance: $***$, $**$, and $*$ stand for significance at the 1%, 5%, and 10% level, respectively.