Selling Formal Insurance to the Informally Insured

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Abstract

Unpredictable rainfall is an important risk for agricultural activity, and farmers in developing countries often receive incomplete insurance from informal risk-sharing networks. We study the demand for, and effects of, offering formal index-based rainfall insurance through a randomized experiment in an environment where the informal risk sharing network can be readily identified and richly characterized: sub-castes in rural India. A model allowing for both idiosyncratic and aggregate risk shows that informal networks lower the demand for formal insurance *only if* the network indemnifies against aggregate risk, but not if its primary role is to insure against farmer-specific losses. When formal insurance carries basis risk (mismatches between payouts and actual losses due to the remote location of the rainfall gauge), informal risk sharing that covers idiosyncratic losses enhance the benefits of index insurance. Formal index insurance enables households to take more risk even in the presence of informal insurance. We find substantial empirical support of these nuanced predictions of the model by conducting the experiment (randomizing both index insurance offers, and the locations of rainfall gauges) across castes for whom we have a rich history of group responsiveness to household and aggregate rainfall shocks.

JEL Codes: O17, O13, O16.

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I. Introduction

Nearly three-fourths of the 1.3 billion people worldwide living on less than US$1 per day depend on agriculture for their livelihoods (World Bank, 2005). Agricultural activity is inherently risky, and unpredictable rainfall is one of the dominant sources of weather-related production risks in agrarian regions. Indeed, Parchure (2002) estimates that in India about 90% of variation in crop production levels is caused by variation in rainfall levels and patterns.[1] Yet 90 percent of the Indian population and 88 percent of the Indian workforce is not covered by any formal insurance (Mukherjee, 2010).

The absence of formal insurance among poor rural populations does not mean that the poor are uninsured. There is a large literature documenting the mechanisms and assessing the effectiveness of informal risk-sharing schemes among rural populations in poor countries, and especially in India (Mazzocco and Saini, forthcoming; Townsend, 1994; Ravallion and Dearden, 1988; Rosenzweig, 1988; Rosenzweig and Stark, 1989). However, these studies generally find that risk-sharing is incomplete, which in turn leads exposed farmers to choose low risk and lower-yield production methods, asset portfolios, and crops, instead of riskier but more profitable alternatives (Rosenzweig and Binswanger, 1993; Carter and Barrett, 2006).

Various frictions such as information asymmetries, contract enforcement costs and fraud limit the ability of formal credit and insurance markets to mitigate risk (Rothschild and Stiglitz, 1976; Finkelstein and McGarry, 2006). In recent years, weather index-based insurance has sparked much interest among development researchers and practitioners as a prominent alternative that addresses

[1] In a household survey conducted in Andhra Pradesh, 89% of surveyed rural landowners cite drought as the most important single risk they face (Giné et al. 2007).

some of these concerns (IFAD 2010; World Bank 2010). The innovative feature of index-based insurance is that the payment schemes are based on an *exogenous* publically observable index, such as local rainfall. This design mitigates the moral hazard and some types of adverse selection problems common to insurance schemes that indemnify individual losses. It also eliminates the need for in-field assessments, thereby lowering the cost of providing insurance. In theory, an optimally designed weather index-based insurance product can address many market failures, mitigate underinvestment in more profitable agricultural technology, and increase productivity even among risk-averse individuals (Barnett *et al.*, 2008). However, the existing evidence indicates that take-up rates for index insurance products are extremely low even when actuarially-fair rainfall insurance contracts are offered (Cole *et al.*, 2009).

One long-standing hypothesis explaining thin formal insurance markets in poor populations is that pre-existing informal risk-sharing arrangements in place either reduce the demand for formal insurance or prevent formal markets from being established. Arnott and Stiglitz (1991) develop a model with moral hazard showing that if formal insurance providers and informal risk-sharing communities are both incapable of monitoring risk-taking, then informal risk-sharing schemes will drive out any formal contracts. On the other hand, if informal communities are better able to monitor risk behavior than formal insurers, then both formal and informal insurance contracts can coexist and increase welfare. Moral hazard under imperfect monitoring plays an important role in this analysis. Index-based weather insurance contracts are not subject to moral hazard concerns, so the extent to which informal risk-sharing affects the demand for *index* insurance remains an open question, both theoretically and empirically.

One major disadvantage of index insurance is the presence of basis risk, or the potential mismatch between index-based payouts and the actual losses incurred by the policy holder, as farm-level crop yields (or even rainfall realized on the farm) may not perfectly correlate with the rainfall index. The number of existing rainfall stations used to calculate payments and payouts is limited. Only a small proportion of the potential client population is proximate to a rainfall station, and the potential for basis risk is thus high. Clarke (2011) shows in a model incorporating basis risk that even when actuarially-fair index insurance contracts are offered to farmers who are not liquidity constrained, those farmers will not purchase full insurance. In Clarke's model, however, there is no informal risk-sharing.

In this paper we examine theoretically and empirically the impact of informal risk-sharing and basis risk on the demand for index insurance, and the effects of informal and index insurance on risk-taking. We first set out a modified version of the Arnott-Stiglitz cooperative risk-sharing framework in which members of a community simultaneously and cooperatively choose the amount of risk to take and the rules governing indemnification. We show that if the community cannot achieve the first best (but still incomplete) constrained optimum, the ability to provide greater group-level indemnification can lower risk taking. We then combine this model of informal risk-sharing with Clarke's model of index insurance with basis risk. We show that in the absence of basis risk, farmers choose full-coverage, actuarially-fair index insurance, independent of the community's ability to informally insure against idiosyncratic losses. Introducing basis risk, however, creates a complementarity between informal risk sharing and the gains from index insurance: communities that are better able to insure individual losses may have a greater demand for index insurance. In other words, the negative effects of basis risk on the demand for index insurance are attenuated among those more informally insured.

A challenge in empirically assessing the relationship between informal group risk-sharing and the demand for formal insurance products is the identification of the boundaries of the appropriate risk-sharing groups. In India, the sub-caste or *jati* is a centuries-old institution whose salience is maintained over generations through strict rules on marital endogamy. The *jati* institution exists in almost all major states of India. The *jati* has been shown to play an important role in business investments, in employment, and in risk sharing (Munshi, 2011; Munshi and Rosenzweig, 2006; Mazzocco and Shaini, forthcoming).[2]

To test the model and quantify the relationships between informal risk sharing and the demand for indexed rainfall insurance, we use national survey data that contains information on *jati* membership, transfers, informal loans, individual losses from production shocks and rainfall histories for a large sample of rural Indian households. We develop a method for estimating how the characteristics of *jatis* affect the extent to which household losses are indemnified and how, in turn, different rates of indemnification affect risk-mitigation. Because the survey data provide information on household-level losses from distress events as well as village-level inter-temporal rainfall variation, we are able to identify the extent to which each caste indemnifies individual losses

[2] Mazzocco and Shaini directly show that the jati and not the village in India is the relevant risk-sharing group, consistent with recent theoretical work showing that even incomplete cross-community risk-sharing schemes enhance welfare relative to schemes confined to village populations (Bramoullé and Kranton, 2007). This is also consistent with empirical evidence that the majority of transfers and informal loans to households in India originate outside the village (Rosenzweig and Stark, 1989), as we also show below in our data. Our findings are thus particularly policy-relevant for India, but risk-sharing groups exist in many populations. For example, there is evidence of risk-sharing along ethnic lines in West Africa (Grimard 1997, La Ferrara 2003).

and losses from adverse weather events. That is, we are able to test whether and by how much *jatis* provide a form of informal index insurance themselves.

Next we conduct a randomized experiment to examine how these estimates of *jati*-specific indemnification rates against idiosyncratic and aggregate shocks affect households' responsiveness to offers of a formal index insurance contract. For these experiments we draw on the same population from which the survey data were obtained, in order to ensure that the experiment sample belonged to the same set of *jatis* for which we estimated *jati*-level indemnification rates.

In addition to randomizing the offer of and price of the index product, we also randomly placed automatic rainfall stations in a subset of the sampled villages. Contract payouts occur on the basis of rainfall measured at these stations, so a household's distance from a rainfall station is a major determinant of basis risk. Our approach thus combines estimated natural population variation in informal risk sharing estimated from survey data, quasi-randomized basis-risk variation, and designed (randomized) variation in the offer of and the price of a formal insurance contract, to assess how basis risk and informal risk sharing interact in conditioning the demand for formal index insurance. The randomized design component of the project ensures that demand factors are identified in explaining low take-up rates, and also allows us to identify the effect of index insurance on subsequent risk-taking by farmers.

Previous marketing experiments have explored other constraints limiting the widespread adoption of insurance products in developing countries, including liquidity constraints, contract complexity, trust, and limited liability credit (Giné *et al.*, 2008; Cole *et al.*, 2010; Giné and Yang, 2009; Cai *et al.*, 2009). In spite of the large prior literature on the importance of informal risk-sharing in developing countries, ours is the first study (according to the best of our knowledge) to empirically explore how informal risk sharing affects the provision of, the demand for, and the welfare effects of formal insurance. Furthermore, we are also the first to empirically examine the importance of basis risk in limiting demand for index insurance, and how this interacts with informal risk sharing.

We structure our analysis by first setting up a model of a formal index contract subject to basis risk in the presence of informal risk sharing (section II). Section III of the paper describes the survey data and the experimental protocol, including the sampling frame for the experiment, the insurance product, and the randomization design. In section IV we set out the method for identifying caste-specific indemnification rates using household, village, and caste-level information from the survey data. Section V discusses the estimates of the caste-level determinants of indemnification of idiosyncratic and of aggregate losses. We find that *jatis* both compensate for individual losses and pay out on the basis of village-level rainfall shocks. The estimates identify specific caste characteristics that contribute to indemnifying losses, including the caste's average landholdings, diversification into professional occupations, and the number of same-caste households in the village. Castes with greater landholding inequality are less able to insure risk.

Armed with estimates of each caste's ability to informally insure, section VI examines how these affect the demand for a formal insurance product in our randomized experiment. The results confirm the predictions of the model: members of *jatis* that already informally indemnify aggregate rainfall shocks are less likely to purchase the index product, but we do not observe the same type of crowding-out for *jatis* that cover idiosyncratic shocks well. Basis risk is a significant impediment to the take-up of the index insurance product. However, the negative effect of basis risk is attenuated for households in *jatis* that more successfully indemnify individual losses. Furthermore, in villages with a rainfall station (i.e., no basis risk), household demand for index insurance is not affected by the extent to which the informal network is able to indemnify idiosyncratic risk. Thus, informal insurance is both a complement to formal index insurance and a substitute, depending on the level of basis risk and the nature of the informal insurance arrangement, consistent with the model.

In section VII we assess the effects of informal and formal index insurance on risk taking. We find that, again consistent with the model, in *jatis* with higher levels of informal loss indemnification, households are more likely to reduce their risk taking after experiencing an adverse shock. Conversely, households with either informal or formal aggregate or index insurance increased their risk-taking. In particular, rice farmers offered the formal index insurance product in our experiments were significantly more likely to subsequently plant a portfolio of rice varieties that were higher-yield but less drought resistant.[3] Section VIII concludes with implications for policy.

II. Theory

a. Informal Incomplete Insurance Model with Monitoring and Endogenous Risk

We first examine the behavior of a community that is able to monitor the risk-taking of its members and faces strictly independent income shocks. Our goal in this section is to establish the relationship between informal group-based risk sharing and risk taking by group members. As in the Arnott-Stiglitz (1991) non-dysfunctional model we assume the group behaves cooperatively and we represent the behavior of the group as a two-member game with identical partners. Each

[3] Only one other study (Cai *et al.*, 2009) has examined the effect of formal insurance on rural risk taking.

member enjoys income *w,* has a von Neumann-Morgenstern utility function with the properties that U'>0 and U"<0, and faces an independent adverse event with probability *P* drawn from a common distribution. The occurrence of the event reduces income *w* by an amount *d*. *P* can be lowered by investing in a risk-mitigating technology *e*, but *e* also lowers income *w*, so that

(1) $$P'(e)<0,\ P''(e)>0 \text{ and } w'(e)<0,\ w''(e)>0$$

The rules of the game are that if a group member incurs a loss she receives a payment δ from her partner as long as the partner does not also incur a loss. Thus, she also pays out δ if the partner incurs a loss and she does not.

Partners behave cooperatively, choosing *e* and δ to maximize:

(2) $$E(U) = U_0(1- P)^2 + U_1P^2 + (1 - P)P(U_2 + U_3),$$

where $U_0 = U(w)$, $U_1 = U(w - d)$, $U_2 = U(w - \delta)$, $U_3 = U(w - d + \delta)$.

The FOC for both risk-taking *e* and indemnification δ are, respectively:

(3) $$e: \quad P'[-2(1 - P)U_0 + 2PU_1 + (1 - 2P)(U_2 + U_3)]$$
$$= -w'[U_0'(1- P)^2 + U_1'P^2 + (1 - P)P(U_2' + U_3')$$

(4) $$\delta: \quad (-U_2' + U_3')P(1 - P) = 0$$

From (4), optimal δ (denoted δ^*) is $d/2$, which solves $-U_2' + U_3' = 0$ for any positive *P*. Thus the best that the community can do is indemnify half of losses. Insurance is limited and welfare less than full-insurance because payouts are stochastic.

This simple model ignores such issues as commitment limits and liquidity constraints. Suppose that for these and other reasons the group cannot attain first-best constrained insurance δ^*, so that $\delta < \delta^*$. We now establish the following proposition:

Proposition 1: *An increase in the ability to informally indemnify individual losses, if communities are below the first-best constrained optimum, may decrease risk-taking.*

The effect of exogenous variation in δ, below δ^*, on risk mitigation e is:

$$(5) \qquad de/d\delta = -[(1 - 2P)(U_2' + U_3')P' + (1 - P)P(-U_2'' + U_3'')w'']/\Phi,$$

$$\text{Where } \Phi = (w')^2[U_0''(1 - P)^2 + U_1''P^2 + (1 - P)P(U_2'' + U_3'')]$$
$$+ [U_0'(1 - P)^2 + U_1'P^2 + (1 - P)P(U_2' + U_3')][w'' - P''W'/P']$$
$$+ 2(P')^2[U_0 + U_1 - U_2 - U_3] < 0$$
$$\text{and} \quad -U_2' + U_3 > 0, \; -U_2'' + U_3''<0 \; for \; \delta < \delta^*.$$

For $P \geq ½$, increased coverage δ unambiguously increases risk-mitigation, but below ½, the effect may be positive as well. Thus, increased informal *individual* insurance provision may reduce risk-taking.

b. Informal Risk-sharing and Formal Index Insurance with Basis Risk

We now distinguish between aggregate risk and idiosyncratic risk and introduce formal index insurance. Let q be the exogenous probability that an adverse weather event causes a loss L for both partners. Aggregate risk q, which is uninsurable by the group, is assumed to be independent of P, which is idiosyncratic risk. The index insurance contract pays out to both group members a portion of the loss a when an index passes some threshold value.[4] We assume this payout occurs with exogenous probability r. r and q may not coincide. Following Clarke (2011), we define a basis risk parameter ϱ as the joint probability that there is no payout from index insurance but each community member experiences the loss L. A nice feature of this characterization of risk is that one can interpret an increase in ϱ as an increase in basis risk, without any change in the marginal probabilities r or q characterizing the index and weather events.

[4] Because both partners are identical they will either take up the insurance or not together.

We assume that the providers of index insurance charge a premium $qmaL$. If $m = 1$, the premium is actuarially fair; $m<1$ would indicate a subsidy and $m>1$ added administrative costs. In this formulation, there are four states depending on the index outcome and the occurrence of the aggregate event, overlaid on the states associated with the independent risks.[5] The expected utility of the informally-insured group facing idiosyncratic, aggregate and basis risk from taking on the index contract is then:

$$
\begin{aligned}
(6) \qquad E(U) &= (r - \varrho)[U_0(1 - P)^2 + U_1P^2 + (1 - P)P(U_2 + U_3)] \\
&+ \varrho[u_0(1 - P)^2 + u_1P^2 + (1 - P)P(u_2 + u_3)] \\
&+ (q + \varrho - r)[U_4(1 - P)^2 + U_5P^2 + (1 - P)P(U_6 + U_7)] \\
&+ (1 - q - \varrho)[u_4(1 - P)^2 + u_5P^2 + (1 - P)P(u_6 + u_7)],
\end{aligned}
$$

where $U_0 = U(w - L + (1 - qm)aL)$, $U_1 = U(w - d - L + (1 - qm)aL)$, $U_2 = U(w - \delta - L + (1 - qm)aL)$, $U_3 = U(w - d - L + \delta + (1 - qm)aL)$, $U_4 = U(w + (1 - qm)aL)$, $U_5 = U(w - d + (1 - qm)aL)$, $U_6 = U(w - \delta + (1 - qm)aL)$, $U_7 = U(w - d + \delta + (1 - qm)aL)$, and $u_0 = u(w - L(1 - qma))$, $u_1 = U(w - d - L(1 - qma))$, $u_2 = u(w - \delta - L(1 - qma))$, $u_3 = u(w - d + \delta - L(1 - qma))$, $u_4 = u(w - qmaL)$, $u_5 = U(w - d - qmaL)$, $u_6 = u(w - \delta - qmaL)$, and $u_7 = u(w - d + \delta - qmaL)$.

The group chooses the amount of coverage a, conditional on its ability to defray losses from idiosyncratic events δ, by maximizing (6). The FOC for a in this model is

$$
\begin{aligned}
(7) \qquad & (1 - qm)\{(r - \varrho)[U_0'(1 - P)^2 + U_1'P^2 + (1 - P)P(U_2' + U_3')] \\
& \qquad + (q + \varrho - r)[U_4'(1 - P)^2 + U_5'P^2 + (1 - P)P(U_6' + U_7')]\} \\
= \quad & qm\{\varrho[u_0'(1 - P)^2 + u_1'P^2 + (1 - P)P(u_2' + u_3')] \\
& \qquad + (1 - q - \varrho)[u_4'(1 - P)^2 + u_5'P^2 + (1 - P)P(u_6' + u_7')]\}
\end{aligned}
$$

[5] For each of the states to have a positive probability, the restrictions $0 < \varrho < q(1 - r)$ and $q - r \leq \varrho$ must hold.

Clarke (2011) shows that in this model of index insurance without community risk-sharing of idiosyncratic risk, increases in basis risk and in administrative costs lower the optimal amount of coverage a^* purchased. It is easy to show that these results carry through if there is community risk-sharing of idiosyncratic risk, as here, and δ is constrained. From (7) we can also establish the following propositions:

Proposition 2: *If there is no basis risk and index insurance is actuarially fair, the partners will choose full index insurance ($a^* = 1$) and variation in δ will have no effect on the demand for index insurance.*

With m=1 and no basis risk, q = r and $\varrho = 0$ and expression (6) becomes

(8) $$U_0'(1 - P)^2 + U_1'P^2 + (1 - P)P(U_2' + U_3') = u_4'(1 - P)^2 + u_5'P^2 + (1 - P)P(u_6' + u_7'),$$

for which the only solution is $a^* = 1$, no matter what the value of δ is.[6]

Proposition 3: *If index insurance is actuarially fair but there is basis risk, the index is informative, and some index insurance is purchased, then an increase in the ability of the group to indemnify idiosyncratic losses may increase a^*.*[7]

With m=1, $0 < \varrho < r(1 - q)$, so that the index is informative about the aggregate loss,

(9) $$\begin{aligned} da^*/d\delta = \{&(1 - P)P\{(r - \varrho)(1 - q)(U_3'' - U_2'') - \varrho q(u_3'' - u_2'') \\ &+ (q + \varrho - r)(1 - q)(U_7'' - U_6'') - (1 - q - \varrho)q(u_7'' - u_6'')\}/\Theta, \end{aligned}$$

$$\begin{aligned} \text{where} \quad \Theta = &(1 - q)^2\{(r - \varrho)[U_0''(1 - P)^2 + U_1''P^2 + (1 - P)P(U_2''+ U_3'')] \\ &+ (q + \varrho - r)[U_4''(1 - P)^2 + U_5''P^2 + (1 - P)P(U_6'' + U_7'')]\} \\ &+ q^2\{\varrho[u_0''(1 - P)^2 + u_1''P^2 + (1 - P)P(u_2'' + u_3'')] \\ &+ (1 - q - \varrho)[u_4''(1 - P)^2 + u_5''P^2 + (1 - P)P(u_6'' + u_7'')]\}<0. \end{aligned}$$

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[6] This result is consistent with the model of Smith (1968), in which the demand for actuarially-fair index insurance without basis risk is unaffected by the presence or amount of idiosyncratic risk.

[7] As discussed in Clarke (2011), an infinitely risk-averse agent will never purchase actuarially-fair index insurance if there is any basis risk. This is because the contract worsens utility in the worst state (a loss of income L without the contract versus a loss of $L(1 + a)$ with the contract).

Expression (9) can be either positive or negative. One the one hand, a community with a greater ability to insure idiosyncratic risk derives greater value from the formal contract because it lessens the utility loss in the worst state (u_3, when the group incurs both the loss L and the loss d, pays the insurance premium, but receives no compensation from the contract). Given that $\delta<1/2$ (less than optimal), the term in (9) associated with the worst outcome under the contract, $-\varrho q(u_3'' - u_2'')/\Theta$, is positive. On the other hand, greater indemnification of the idiosyncratic loss when the aggregate loss is partially indemnified by the contract lowers the utility gain from the contract: the term $(r - \varrho)(1 - q)(U_3'' - U_2'')/\Theta$ in (9) is negative. It is thus unlikely that the amount of informal insurance will not affect the demand for formal insurance when there is basis risk. However, the positive term is greater and the negative term is smaller the larger the basis risk ϱ., and we get the following lemma:

Lemma 1: *Given the existence of basis risk, the relationship between informal coverage and the take-up of formal index insurance will be more positive the greater the basis risk.*

Finally, the model suggests that subsidizing index insurance in the presence of basis risk increases the coverage a^* for a given δ, which can increase risk-taking. The reduced cost of the insurance contract increases income equally in both the worst states and the best states, but the marginal utility gain in the worst state is higher. Gains in income in the good states lower the marginal utility gain from increasing risk and thus w, but the disutility from increasing risk declines less.

III. Data

We use four data sets to examine the relationships among informal risk sharing, the demand for index insurance, basis risk, and risk-taking. The first is a comprehensive listing of all rural households residing in 202 sampled villages in 15 major Indian states from the 2006 round of the Rural Economic and Development Survey (REDS) carried out by the National Council of Economic Research (NCAER). The second is from the collection of village-level characteristics for the sampled villages obtained during the REDS listing activity. The third is from a sample of households drawn from the listings as part of the REDS survey in 2007-8. The fourth data set is from a sample that we drew in 2010 from the REDS listing in three states (Andhra Pradesh, Uttar Pradesh and Tamil Nadu) to carry out our randomized marketing of an index insurance product.

a. The 2006 REDS Listing and Village Data.

The 2006 REDS listing is part of the sixth round of a survey begun in 1968 in all states of India. The initial survey, the Additional Rural Income Survey, randomly sampled 250 villages within 100 districts, originally selected according to the presence or not of the Intensive Agricultural District Program (IADP) or the Intensive Agricultural Area Program (IAAP), programs that were designed to channel credit and fertilizer to promote new seed varieties during the green revolution. The 2006 listing provides for 202 of those original villages information for every resident household on caste and sub-caste (*jati*), landholdings, and the household head's occupation and age. The 2006 round omitted the states of Assam and Jammu and Kashmir because of political unrest, and in our study we exclude two more states, Kerala and Gujurat, because caste information was not collected. The total number of listed households in the 202 villages in 15 states is 99,760. The village-level survey provides information on markets, village institutions and programs, and monthly rainfall.

We use the REDS listing data for two purposes: (1) to measure the aggregate characteristics of the *jatis* and (2) as a sample frame to draw the new sample of households for the experimental treatment, described below. There are 3,266 unique *jatis* represented in the listing data. We will use the term caste for *jati* in our subsequent discussion.

b. The 2007-8 REDS Survey Data

In 2007 and 2008, the NCAER drew a new sample of 8,659 households from the listing data. This sample included all the households that were sampled in the last round of the REDS in 1999, all split-off segments of those original households, plus a random sample of households that had not previously been included (31% of the total sample). The sampled households were surveyed using a comprehensive instrument eliciting information on all sources of income, demographics, credit, transfers, landholdings, and education. There are 7,342 sampled households in the states with caste codes. We only include sampled households who belonged to castes that had 50 or more representatives in the listing data, so that caste-level characteristics can be reliably measured. This restriction results in a sample of 5,405 eligible households in 202 villages distributed among 359 caste groups.

A unique feature of the REDS survey is that it ascertained from each household a history of adverse ("distress") events that occurred at the village- and household-level from the 1998-99 through the 2005-06 crop years, as well as the value of any household-specific losses that resulted from those events in each year. The distribution of event types by level of aggregation is listed in Table 1. In addition, respondents were asked if they subsequently carried out any risk-mitigating actions such as changing crops or technology in response to a distress event.

The REDS survey also provides information on financial transfers and loans by source and type for the crop year 2005-06.[8] Remittances and "assistance received at the time of difficulty" are distinguished from gifts for festivals and marriage. We exclude the latter from our measure of caste-based indemnification of losses as well as all transfers from formal sources such as charitable or religious institutions. The data indicate that risk-sharing arrangements clearly extend beyond the village: only 9.2% of informal "assistance" transfers originated in the village, and outside-village remittances (excluding those few from outside the country) outnumbered inside-village remittances by 2 to 1. Loans taken are also categorized by source, distinguishing informal loans provided by family and friends from formal sources such as banks and other informal sources such as private moneylenders, landlords and shopkeepers. The majority of informal loans from friends/family (61%) also originated outside the village. We use the sum of informal loans from friends and family members, plus remittances and financial assistance from informal sources (regardless of geographic origin) as our measure of informal indemnification.[9]

The village-level survey also provides monthly rainfall from 1999-2006 for each village, which enables the construction of rainfall deviations by crop year. Data on household-level losses, village level shocks, risk mitigation, and financial transfers and loans allow us to assess the extent to which caste-based risk-sharing indemnifies not only on the basis of individual household losses but also on the basis of weather shocks.

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[8] Eswaran and Kotwal (1989) and Udry (1994) show that loans are important mechanisms used in mutual insurance schemes.

[9] Due to fungibility we do not exclude informal loans by "purpose." Over 51% of the informal loans are in fact categorized as for the purpose of consumption or medical treatment. The next largest category (13.3%) is agricultural loans.

c. The Three-State RCT sample and Experimental Protocol.

In order to study how caste-based informal insurance affects the demand for a formal insurance product and subsequent risk-taking, we conducted a controlled experiment to sell an index insurance product to households drawn randomly from the REDS listing villages. Conducting the experiment in these villages allows us to relate the product purchase decisions (and subsequent risk-taking behavior) to the rich characterization of the caste groups that the REDS listing data permit. Accordingly, we selected households for the experiment from the set of castes that are well represented in the REDS listing data.

c.1. Sample Selection. For the marketing experiment we selected three REDS states that contain a large number of REDS listing households: Uttar Pradesh, Andhra Pradesh and Tamil Nadu. Our first activity was to draw a sample for the experiments using the REDS listing in these three states as the sampling frame. REDS collected data from 63 villages in these three states. We randomly selected 42 of these villages for the marketing experiment, while the 21 other villages were assigned to a control group so as to preserve an unadulterated comparison sample for the analysis of the effects of being offered formal insurance on subsequent risk-taking. In all villages, we identify "cultivators" (households engaged in farming and making decisions on agricultural inputs, outputs, crop choice, etc) and "agricultural laborers" (households supplying labor in the agricultural sector, but not making cultivation decisions), based on each person's primary and secondary occupation codes collected in the REDS listing data. The income in agricultural labor households, like that in cultivator households, is dependent on rainfall outcomes but such households are arguably less exposed to basis risk from index weather insurance. Cultivator households form a useful sample for our study of the effects of index insurance on agricultural investment and input decisions.

Next we counted the number of households in each caste (or *jati* code) in the REDS listing data in order restrict our experiment sampling frame to only households that have at least 49 other households from the same caste represented in the REDS listing. This 50-household lower bound on the caste sample size ensures that we can construct caste-average characteristics for each of the subjects of our marketing experiment with reasonable statistical precision. These restrictions on occupation and caste size left us with roughly 19,685 households in 118 different castes in the three states, with 12,201 of those households in the treatment villages. We randomly selected 5,100 of these households to receive insurance marketing treatments, stratified by type of occupation: ~300 households in occupations entirely unrelated to agriculture, ~2400 cultivator households, and ~2400 agricultural laborer households. We were ultimately able to market the insurance product to 4,667 rural households in Tamil Nadu (TN), Andhra Pradesh (AP) and Uttar Pradesh (UP).

Before any marketing activities began, we conducted baseline surveys in September-October 2010 in TN, October-December 2010 in UP and October 2010 - January 2011 in AP. Our baseline survey asked all respondents about their previous use of a broad range of insurance products and government insurance schemes, but the vast majority (98%) had no prior exposure to formal insurance products. In contrast, many of these households—29.8%—did participate in the Government of India's National Rural Employment Guarantee (MG-NREG) scheme, which carries features of labor or unemployment insurance for rural residents. Table 2 provides these summary statistics for the 4,260 respondents from the baseline survey selected to receive an offer of the index product. The table shows that respondents own 1.42 acres of land on average, but this is an average for a sample in which farmers are over-represented. 25% of the sample belongs to scheduled castes and tribes, and about 95% of the sample is Hindu.

c. 2. Insurance Product. We designed a new insurance product for these sample villages in collaboration with the Agricultural Insurance Company of India Lombard (AICI). AICI local offices and marketing affiliates in each of the three states then marketed the product in the project villages. The rainfall insurance policy we designed is an example of a "Delayed Monsoon Onset" index-based insurance product, which insures against agricultural losses due to delayed rainfall. We first define an expected onset date of the monsoon using historic rainfall data, collected either from government-owned Automatic Weather Stations (AWS) or from private stations operated by local state agricultural universities (e.g. Tamil Nadu Agricultural University). Monsoon onset is defined as a certain level of rainfall accumulation (varied between 30-40mm) as measured by the block-level Automatic Weather Station (AWS). The onset date is considered delayed if the target amount of rainfall is not reached by one of three pre-selected "trigger" or payout dates.

Unit prices for the Delayed Monsoon Onset product varied across blocks depending on the rainfall risk as assessed by AICI. The price for a unit of insurance varied from Rs 80 to Rs 200 (USD 1.6 - 4), with an average price of Rs.145 in our sample villages. The three trigger dates varied across villages: the first (Rs.300) payout came if the monsoon was between 15-20 days late; a larger (Rs.750) payout came if the monsoon was 20-30 days late; and the largest (Rs. 1200) came if the monsoon was between 25 and 40 days late. For example, the insurance product was priced at Rs. 129 per unit in Dindigul in Tamil Nadu. If a farmer purchased 5 units of insurance, paying Rs. 645 in premiums, then he would receive Rs. 1500 if the monsoon associated with the 2010 *Kharif* (defined as an accumulation of 40mm of rainfall) was delayed by at least 20 days, Rs. 3750 if it was delayed by at least 25 days, and Rs. 6000 if it was delayed by at least 30 days. The product pricing and payout attributes were determined by AICI based on their internal actuarial calculations, and accounts for their administrative costs of marketing the product.

The insurance policy was not crop specific, thus providing broad coverage for monsoon onset. In addition, since a large share of the sample is comprised of landless agricultural laborers, a purchasing unit was independent of the land holdings of the buyer. The key element of our insurance product was its simplicity and transparency. This was done to reduce any purchasing bias which could arise from the respondent not being able to easily understand the product.

c.3. Experiment Design and Randomization of Treatments. The first insurance marketing and sales interventions were conducted in Tamil Nadu in October 2010 (prior to the November 2010 monsoon season), followed by interventions in Andhra Pradesh and Uttar Pradesh in January-March 2011 (prior to the onset of monsoon in May). The 4,667 households in the 42 treatment villages who completed the baseline survey were randomly assigned to different sales and marketing treatments, as described below. The marketing visits were conducted by Center for Micro Finance (CMF) field staff who were trained in the local AICI offices in each state. The marketers were entirely separate from and independent of the enumerators from the survey firms that were contracted to conduct the baseline surveys. Marketers and a field monitor visited each household and offered the insurance policy. If the household could not make a purchase decision during the first visit, then the team returned for the second visit a week later. In order to ensure uniform marketing, as well as to secure and confirm proper treatment application, marketers were instructed to memorize marketing scripts during training and to follow them as closely as possible during household visits.

The main experiment involved household-level random assignment of insurance premium discounts. Each household was given the opportunity to make a lottery pick that would provide a 0%, 10%, 50%, or 75% discount on AICI's stated price for the monsoon onset insurance that village. Each household faced a 10% chance of receiving no discount, and a 30% chance of receiving each of the other three levels of discounts. The fraction of sample households that ultimately received each level of discount is detailed in Table 3. Furthermore, in order to encourage households to purchase multiple units of insurance, we offered quantity or "bulk" discounts of 10%, 15% or 20% off the total insurance premium if the households purchased 2, 3-4, or 5+ units of insurance respectively. Unlike the simple pricing discounts, these bulk discounts were not randomly assigned.[10]

Table 4 and Figure 1 present summary statistics on insurance take-up at the different (randomly assigned) price points. Overall, roughly 40% of all households purchased some insurance (see Table 2). Of those, 38% purchased multiple units of insurance, with 17% purchasing 5 units or more. Figure 1 shows that both the take-up rates and the number of units purchased were greater at the higher levels of discounts. The average price paid per unit of insurance in the sample, accounting for the various discounts, is Rs. 80.

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[10] In addition to the randomization of price discounts, we also randomly varied the content of the marketing scripts narrated to the sample households by the insurance marketers. The script was varied along three independent dimensions: (a) a "Framing" variation which marketed the product either as a standard insurance product or as "lottery" or "gamble" about the rainfall onset date for which the household could buy tickets, (b) households received (or not) detailed information about the historical variation in rainfall in that location, on which our insurance product design was based, and (c) households were told that marketers would return the following year to sell them the same product. These three independent dimensions of variation resulted in eight possible combinations of marketing scripts, one of which was narrated to each of the sample households. An appendix provides detailed descriptions of the scripts. We do not discuss in this paper the effects of script variation, which were minimal.

Finally, implementing this project required us to build rainfall measuring gauges for all sample villages in Uttar Pradesh since existing rainfall stations were not available. We randomly selected 12 of the 19 sample villages in UP to receive a rainfall gauge that was placed in the village itself, while in the other seven villages the rainfall gauge was placed in the nearest block (which replicates the situation in the other two states). A private firm called National Collateral Management Services Limited built and maintained these rainfall gauges. All respondents were informed about the location of the nearest weather station as part of insurance marketing. This additional intervention creates some designed variation in each farmer's perceived (and actual) distance to the rainfall gauge, and therefore generates variation in the basis risk faced by each farmer. The farmer's perceived distance to the nearest rainfall station was elicited in the baseline survey prior to the treatment but after the construction of the rain stations in Andhra Pradesh and Uttar Pradesh but not Tamil Nadu. The mean reported distance was 4 kilometers, with a standard deviation of 5.9 kilometers.

c. 4. Follow-up Survey. In June-July 2011, several months after the intervention, and after the planting and harvesting period, we conducted one additional round of follow-up surveys in Tamil Nadu in order to track household behavior following insurance purchase. Our results on risk-taking are based on this Tamil Nadu sample comprised of baseline households that we re-visited, plus an additional "control sample" of 648 households from villages where no insurance product was marketed. The control sample only includes households who belong to (the randomly assigned) castes that did not receive insurance marketing offers in treatment villages. The mismatch in both village location and caste between treatment and control minimizes the possibility of spillovers.

A novel feature of the Tamil Nadu survey is that we asked farmers detailed questions about their crop choices for both the regular (*Kharif*) and the irregular cropping seasons following the insurance marketing offers. In a separate section, all farmers were also asked to characterize the perceived average return and riskiness attributes (e.g. drought resistance, pest resistance) of each of these crops. This allows us to characterize the riskiness of the crop portfolios of treated and non-treated farmers.[11]

IV. Identifying the Strength of Informal, Group-based Idiosyncratic and Index Insurance by Caste

We use the combined REDS listing, village-level and household survey data to first estimate the determinants of informal indemnification δ_j for each caste group *j*, distinguishing between (partly endogenous) individual household losses and exogenous shocks that members of the caste experience jointly. In the sample, caste members are distributed among different villages within a state and experience both household-specific shocks and village-level shocks. While incurring a household-specific loss depends in part on common (group-level) agent actions, as in the model, the likelihood and magnitude of a village-level shock are not subject to control by any members of the group. Indemnification of the village shock thus is similar to index insurance, and village-level shocks are insurable by the group as long as long as such shocks are not perfectly correlated across villages inhabited by caste members, who are spread across a state.

[11] We also collected detailed information on agricultural costs and revenues, which required that we conduct these follow-up surveys only after farmers' harvest and sales activities were completed. We focus here on initial risk choices and do not examine revenue consequences.

We assume that the transfer payment δ_{ijk} made to household i in caste group j in village k in response to a household-specific loss d_{ijk} or an aggregate village production shock ζ_{kj} is given by

$$\delta_{ijk} = \eta_j(d_{ijk} + d_j) + \iota_{ij}\zeta_{kj} + \boldsymbol{X}_j\boldsymbol{\beta} + \boldsymbol{X}_{ij}\boldsymbol{\gamma} + \mu_j + \varepsilon_{ijk}\,, \tag{10}$$

where $\boldsymbol{X}_{ij}$, is a vector of household characteristics, $\boldsymbol{X}_j$ is a vector of caste characteristics, μ_j contains all unmeasured characteristics of the caste including the village- and individual-level losses and shocks experienced by other caste members, and ε_{ijk} is an iid household-level error term. We have decomposed the household shock into that part that is idiosyncratic to the household d_{ijk} and that part reflecting group-specific (endogenous) equilibrium risk-taking d_j.

We also assume that η_j and ι_j, the caste's ability to indemnify household-specific losses and village shocks, respectively, are functions of the vector of caste-level characteristics, so that $\eta_j = \eta(\boldsymbol{X}_j)$ and $\iota_j = \iota(\boldsymbol{X}_j)$. Linearizing the indemnification functions, we obtain

$$\delta_{ijk} = \Sigma\eta^j{}_n X_{jn}(d_{ijk} + d_j) + \Sigma\iota^j{}_n X_{jn}\,\zeta_{kj} + \Sigma\beta^j{}_n X_{jn} + \Sigma\gamma^i{}_m X_{ijm} + \mu_j + \varepsilon_{ijk}, \tag{11}$$

where the $\eta^j{}_n$ and the $\iota^j{}_n$ are parameters of the indemnification functions, X_{ijm} are characteristics of the households and $\gamma^i{}_m$ are the associated parameters reflecting how household characteristics affect the level of group-based household transfers. We thus identify variation in how responsive each caste is to shocks from variation in the group characteristics of the castes, assuming that the relationship between caste characteristics and responsiveness is the same across castes.

A problem in estimating (11) using OLS is that the common component of household loss levels d_j may be correlated with caste level unobservables μ_j determining payments, as the cooperative model indicates that the group's ability to indemnify individual losses affects group-level risk choices. To obtain consistent estimates of the $\eta^j{}_n$ and $\iota^j{}_n$ we thus employ caste-level fixed effects, which remove the caste-level linear variables, the unobservable fixed effect μ_j and the common and endogenous component of the household losses d_j. Losses may vary across individuals due to deviation from caste norms in risk-taking as well as due to shocks.[12] This yields consistent estimates of $\eta^j{}_n$ and $\iota^j{}_n$ if individual shocks to payments ε_{ijk} are uncorrelated with individual losses d_{ijk} net of the caste fixed effect. The financial assistance equation we estimate is:

(12) $$\delta_{ijk} = \Sigma\eta^j{}_n X_{jn} d_{ijk} + \Sigma\iota^j{}_n X_{jn}\zeta_{kj} + \Sigma\gamma^i{}_m X_{ijm} + u_j + \varepsilon_{ijk},$$

where u_j is the caste fixed effect.

In our model, group members are identical, and thus the model is silent as to how differing characteristics of individual group members map into different levels of indemnification within a risk-sharing network. The literature on risk sharing (Coate and Ravallion, 1993; Ligon *et al.*, 2002) provides little guidance regarding how payments/transfers are distributed among members, or how the characteristics of risk-sharing groups permit them to deal more or less successfully with commitment and other problems that limit the ability of the group to self-insure.[13] We assume that the group's ability to indemnify risk and avoid moral hazard depends on the group's level of resources (Munshi and Rosenzweig, 2010), its ability to agree on common actions, its ability to diversify risk, and its ability to monitor. Accordingly we include in the set of X_{jn} covariates the mean level of landholdings of the caste and the proportion of landless households as reflecting caste resource capacity. Based on Foster and Rosenzweig's (2002) analysis of household break-ups, which indicated that inequality leads to disagreement and division, we also include the standard deviation of caste landholdings in the indemnification function. To reflect the diversification of the income

[12] We find below that households adjust their individual risk-taking *ex post* in response to shocks, but these adjustments appear to conform to norms associated with caste-level indemnification rates.

[13] The ability of groups to punish in the event of reneging is shown to facilitate risk-sharing with limited commitment (Ligon *et al.*, 2002). Presumably community groups with more access to resources might be more successful in the enforcement of agreements.

sources of the caste, we include in the $\boldsymbol{X}_j$ vector the proportion of caste household heads in professional and technical occupations.[14] Finally, we assume that the number of households belonging to the same caste in a village is positively associated with monitoring capacity. Accordingly we expect that a caste's ability to indemnify individual losses caused by aggregate shocks, η_j and ι_j, will be positively associated with mean caste landholdings, the occupational variable and the number of same-caste households in the village but negatively associated with the caste-level landlessness and land inequality.

We use as the measure of d_{ijk} an indicator variable for whether or not a sample household reported a loss as a result of either village- or household-level shocks in the 2005/06 crop year. For the village-level shock ζ_k we use the deviation of crop-year rainfall in 05/06 from its 7-year village mean. The financial assistance variable is an indicator for whether the household received any financial assistance or loans from family or caste members inside or outside the village in the same crop year. Less than 25% of households received such payments in any given year. We estimate equation (12) using maximum-likelihood conditional logit to avoid both predicted probabilities below and above the zero and one probability bounds and heteroscedastic errors, conditioning on the caste fixed effect.[15]

The caste-level variables are computed from the REDS village listing data using all households that belonged to one of the 350 castes with 50 or more households represented. Table 5 provides the descriptive statistics for the estimation sample. The data indicate that the risk of a financial loss is non-trivial: over 21% of households reported that they experienced a financial loss in

[14] Occupational diversification may reflect caste-level risk-aversion and thus be correlated with caste-level unobservables. These are, however, impounded in the caste-fixed effect.

[15] The quantitative estimates are not very different, but slightly less precise (given biased *t*-statistics in the linear model), when the linear fixed-effects model is estimated. In all subsequent estimates using the caste-specific measures of indemnification based on the estimates of (12), results are very similar when the indemnification measures are based on the linear and conditional logit coefficients.

the crop year 05/06, and more than half had experienced losses in the past seven years. Almost 24% of households received financial assistance in crop year 05/06. For 85% of households experiencing a loss, however, the amount of assistance was less than half of the loss. Given that the financial assistance variable includes informal loans that may have been acquired for purposes other than consumption-smoothing, this suggests that δ is less than half for almost all households. Informal insurance thus is far from complete, and indemnification rates are below the constrained optimum defined in the model, as was assumed for the comparative statics.

V. Estimates of Caste Responsiveness to Household and Village-level Shocks

The first column in Table 6 reports the ML conditional logit estimates of (12). The set of interactive caste coefficients associated with both the household loss and the rainfall shock are jointly statistically significant at the 0.01 level, indicating that caste characteristics matter for loss indemnification. Caste groups appear to provide a form of index insurance, providing assistance in response to rainfall shocks in addition to personal losses. The signs of the caste coefficients for both types of shocks conform to our expectations about the individual caste variables: households belonging to castes with larger average landholdings, with a higher proportion of households in occupations mostly unaffected by weather variations, and with a larger number of same-caste households in their village are more likely to receive assistance when they experience a loss or a village-level rainfall shock, but are less likely to receive informal aid when their caste is characterized by a higher level of landholding inequality.

Individual household characteristics appear to affect the probability of assistance. Landless households are more likely to receive aid, while households in which the head is in a professional occupation are less likely to get aid. To assess whether household characteristics - in addition to caste characteristics - also affect the responsiveness of informal assistance to shocks, in column (2) we add interactions between the three household characteristics and the two shocks. This set of six interaction coefficients (not reported in the table) are not jointly statistically significant and, as can be seen, the sets of caste-level interaction coefficients are robust to the inclusion of the household interaction variables. Indeed, the precision of the caste coefficients improves for all but one variable - eight of the ten caste-level coefficients are statistically significant in column two at the 8% level and five at the 5% level. Finally, the last column reports the computed marginal effects on the probability of assistance and their associated *t*-statistics derived from the log-odds coefficients.

We can obtain two measures of the ability of each caste to indemnify against household- and village level adverse shocks for all the castes in the sample using the coefficient estimates from column two (the "structural" logit coefficients) and column three (the marginal effects) of Table 6: $\eta_j = \Sigma\eta^j{}_n X_{jn}$ and $\iota_j = \Sigma\iota^j{}_n X_{jn}$. The sample estimate of η_j based on the marginals (log-odds) is 0.152 (2.74) with a standard error of 0.0777 (1.01). The sample estimate of ι_j based on the marginals (log-odds) is 0.142 (0.449) with a standard error of 0.0186 (0.0322). Across the 350 castes there is evidently considerable variation in both of the computed caste-specific indemnification parameters - the range, for example, of the marginals-based values for η_j (ι_j) is from 0.04 to 0.5 (0.07 to 0.1).

VI. Estimates of the Effects of Informal Risk-Sharing on Take-up of Formal Insurance

We use the constructed indemnification indices characterizing each caste's ability to indemnify against household losses to first assess how the strength of informal risk sharing of the two types of risk—individual and weather-based—affects the demand for formal index insurance.

That is, we test Propositions 2 and 3 and Lemma 1 using the experiment sample (drawn from the REDS listing) in three states that were randomly offered the index insurance product. The estimating equation is

$$i_{ij} = \kappa_1\eta_j + \kappa_2\eta_j D_i + \kappa_3 D_i + \kappa_4 \iota_j + \mathbf{x_{ij}}\boldsymbol{\kappa_5} + \varsigma_{ij}, \quad (13)$$

where i_{ij} takes on the value of one if respondent i in caste j purchases the insurance product and is otherwise zero; D_i is the distance to the nearest weather station as reported by the respondent, with the variable taking on the value of zero for weather stations in the village; **x** is vector of respondent and randomly-varied index product characteristics; and ς_{ij} is an error term.

Randomization ensures that none of the right hand side variables reflect the determinants of the supply of insurance. Thus the κ parameters identify demand relationships only. We assume that D_i is positively related to basis risk ϱ_i. Therefore the model suggests that $\kappa_3<0$. Proposition 2 derived from the model suggests that for respondents with weather stations in the village ($D_i=0$ and so that $\varrho_i= 0$) the demand for index insurance will be independent of the ability of the caste group to share idiosyncratic risk, so $\kappa_1=0$. Proposition 3 and Lemma 1 suggest that if informal risk-sharing and index insurance indemnification are complements when there is basis risk, $\kappa_2>0$: as distance to the weather station increases, the caste's ability to indemnify idiosyncratic risk will enhance the demand for index insurance. However, we also expect that, if a caste group is already providing a high level of payments on the basis of weather variation, the demand for the index insurance product will be lower, $\kappa_4<0$.

We also include in the specification the locale-specific actuarial unit price of the insurance contract and the randomized contract subsidy. For the $\mathbf{x}_{ij}$ variables we include the total owned landholdings of the household, capturing in part both its wealth and ability to pay for the product and the returns to *ex post* protection (operational scale). We also include the coefficient of variation of annual rainfall based on the seven-year time-series of rainfall for each village from the REDS data, which reflects aggregate (village-level) risk. Finally, we include an indicator for non-cultivating agricultural labor households.

As noted, distance to weather stations was not recorded in the sample of respondents in Tamil Nadu. The first column of Table 7 reports the estimates of equation (13), without any distance variables, obtained from the full sample of respondents who received the insurance product offer in all three states. The second column reports estimates from the same specification using the sample from two of the states where distance information was obtained. As can be seen, the estimates are quite similar and a Chow test leads to non-rejection of the hypothesis that the sets of coefficients estimated from the Tamil Nadu sample and that from the combined Andhra Pradesh and Uttar Pradesh samples are identical, net of state fixed effects. The similarity of the estimates suggests that where we obtained the distance information does not introduce selection bias.

The estimates in both columns indicate that, on average, in caste groups where indemnification of idiosyncratic risk is higher, the demand for the index insurance product is also higher, but the coefficients for η_j in both samples are not statistically significant. On the other hand, where the caste group is more strongly indemnifying against village-level weather events, the demand for the formal weather insurance product is statistically significantly lower. The point estimates indicate that a one standard deviation increase in the index of informal, caste-based rainfall indemnification decreases the probability of take-up by 3.6 percentage points, or 9%. Informal insurance substitutes for formal index insurance, but only if the informal insurance itself is partly index-based (i.e. indemnifies against aggregate risk), as is evidently the case for many caste groups.

The other coefficients in the specification conform to expectations - the demand for weather-based index insurance increases with village-level weather risk and with subsidies and decreases with base actuarial price (controlling for weather risk). The point estimate for the randomized subsidy indicates that cutting the price in half relative to the actuarial price increases the probability of take-up by 17.6 percentage points, suggesting that the price elasticity for the product is -0.44. Finally, as we expected, demand for the weather insurance product is only slightly lower for landless, non-cultivating laborers than for cultivators: the point estimate suggests that such households are only 3.4 percentage points (8.5%) less likely to purchase the index contract, although their income is 25% less on average.

The specification used to obtain the estimates reported in the first two columns is incomplete in that variation in basis risk and the interaction between basis risk and informal insurance are not taken into account. The third column adds a control for distance to the automatic weather station (AWS), and therefore the sample is limited to the two states where distance information was collected. As expected, the coefficient is negative but is not statistically significant. However, the specification does not take into account the theoretical prediction that the distance (basis risk) effect depends on the extent of informal idiosyncratic insurance.

We add the interaction between distance and η_j in the fourth column of Table 7. The set of coefficients now conforms to the predictions of the model incorporating basis risk and informal indemnification of household losses. First, distance to the weather station, in the absence of any informal insurance coverage (η_j=0), negatively affects take-up. The statistically significant negative coefficient on distance (κ_3) suggests that basis risk is an impediment to demand for index-based weather insurance. For every kilometer increase in the (perceived) distance of the weather station for a farmer without any informal risk protection there is a drop-off in demand for formal index insurance of 6.4%. Second, in the absence of basis risk (weather station is situated in the village, D_i=0), there is no relationship between the amount of informal risk-sharing of idiosyncratic risk η_j and index insurance demand, κ_1=0. Third, a higher level of informal risk-sharing with respect to idiosyncratic risk increases the demand for index insurance the greater the degree of basis risk - the interaction between the distance variable and η_j is positive and statistically significant (κ_2>0).

One potential problem with the estimates is that the measures of informal protection against risk η_j and ι_j may be picking up other aspects of the castes that affect the demand for insurance. Castes which are more risk-averse, for example, may have more informal protection against idiosyncratic risk and may also have a greater interest in formal index insurance.[16] We can, however, estimate equation (13) including a caste fixed effect, which picks up all characteristics of the caste that would directly affect the demand for index insurance. In doing so, we can no longer identify the direct effects of variation in the informal indemnification measures, but we can assess whether the weather station distance-η_j interaction coefficient is robust to the comprehensive control of caste characteristics. Column 5 of Table 7 reports the caste fixed effect estimates, and the interaction coefficient changes little and retains its statistical significance. Informal indemnification of idiosyncratic risk increases the gains from index insurance more the greater the basis risk. One

[16] As shown by Clarke (2011), it is not necessarily true that more risk-averse agents prefer index insurance when there is basis risk, given that in the highest marginal utility state, as noted, agents are made worse off by the index contract.

significant change, however, from controlling for the fixed effects, is that the positive effect of owned landholdings at the household level on the demand for index insurance becomes substantially larger, and the coefficient achieves statistical significance at the 8% level.

As a further check on the possibility that the η_j – distance interaction coefficient picks up other characteristics of the caste whose effects vary by distance to the weather station, we add interaction terms (i) between weather station distance and the informal indemnification of aggregate losses by castes (ι_j) and (ii) between weather station distance and the indicator variable for agricultural laborers in the last specification. We add the additional interaction term for because the negative effect of distance to the nearest weather station on the take-up of index insurance should be attenuated for agricultural laborers, whose income is not as directly tied to any individual plot-level shocks. So the difference between the demand by cultivators and agricultural laborers for index insurance should shrink as weather station distance increases, since distance more strongly increases basis risk for the cultivators.

The positive relationship between informal individual risk protection at the caste level and distance from the weather station retains its statistical significance and magnitude when these interactions terms are added. The added interaction of distance and the weather-based caste protection measure is statistically insignificant.[17] The sign of the coefficient on the AWS distance variable and the agricultural laborer interaction term is positive as expected: the negative effect of weather station distance on index insurance demand is less strong for the landless wage workers.

[17] Unless the caste is able to provide an index product that has no basis risk, or can observe rainfall received by caste members better than the weather stations, there is no theoretical reason why the effect of having more caste-based protection against weather shocks on the demand for formal index insurance should depend on the amount of basis risk.

The point estimate indicates that in a village with a weather station ten kilometers away (high basis risk for cultivators), the demand for the index insurance contract is no different for cultivators and pure wage workers. The coefficient, however, is just barely larger than its standard error.

VII. Informal Insurance, Index Insurance and Risk-Taking

We now examine the relationships between informal risk sharing, index insurance and risk-taking using both the non-experimental and experimental data.

a. Informal Insurance and ex-ante Risk Reduction

We first test proposition 1 of the model, that higher levels of *ex post* protection against idiosyncratic losses in cooperative risk-sharing schemes may be associated with more conservative investments and thus lower average incomes. We also examine the relationship between informal coverage based on rainfall shocks and risk-taking. Because indemnification based solely on weather shocks does not increase the liabilities of the group if group members take more risk so that such insurance may lead to less conservative practices.

The community model assumed that risk-taking and indemnification were co-operative group-based decisions in which individual actions were perfectly monitorable. In reality the relationship between actions (risk decisions) and outcomes (losses) may be imperfectly known, with losses informative about the consequences of *ex ante* risk-taking. The 2007/08 REDS survey respondents who had experienced any adverse shock in each of the seven years between the current and last survey rounds were asked to provide the measures they had taken after experiencing the loss to prevent future losses, if any. Of the 49.3% of the landowners who had experienced at least one loss, over a third (35.7%) took some risk-mitigating action. We will analyze whether the propensity to reduce risk *ex post* is affected by the amount of caste-level indemnification.

Table 8 lists the type and frequency of the actions reported by the subset of landowning households who had ever experienced losses from any of the distress events listed in Table 1 and taken a risk-reducing action in the seven-year period. Since specific actions are related to specific distress events (crop choice versus livestock immunization), we aggregate across event types and study the determinants of *any* *ex ante* risk-reducing action in the first year after experiencing a loss. We focus exclusively on landowners (85% of the sample) because the most common risk-mitigating actions - crop choice and technology change - pertain only to cultivators. The equation we estimate is

(14) $$e_{ijk} = e_{\zeta}\,\zeta_{ijk} + e_{\eta\zeta}\eta_j\,\zeta_{ijk} + e_{\iota\zeta}\,\iota_j\,\zeta_{ijk} + \Sigma e^{i}_{m}X_{ijm} + \Sigma e^{i}_{\zeta m}X_{ijm}\,\zeta_{ijk} + e_j + \xi_{ijk},$$

where e_{ijk}=1 if the landowner *i* in caste *j* in village *k* takes any risk-mitigating action, ζ_{ijk}=1 if the household experienced a shock, e_j is a caste fixed effect, and ξ_{ijk} is an iid error. We expect that $e_{\zeta}>0$, $e_{\iota\zeta}<0$, and possibly that $e_{\eta\zeta}>0$.

There are two shortcomings to this analysis. First, we can only identify the effects of having experienced a loss on subsequent risk behavior for those households who experienced a loss, and incurring losses may reflect *ex ante* risk behavior. We will employ a caste-fixed effect estimator. If losses reflect the unmeasured preferences or area characteristics of castes, this endogenous component of losses will be absorbed by the caste fixed effect. The remaining variation in losses is then due to exogenous shocks and deviations from appropriate risk-taking due to misperceptions about the relationship between risk and loss at the individual level.

Second, whether any action is taken by a household will likely depend on whether the household had already taken the action in a prior year. We use only information on the first retrospective loss to minimize censoring, but because we do not have a full history prior to the seven-year the survey interval, we will incur some censoring bias. Censoring should make our estimates of $e_{\eta\zeta}$ and $e_{\iota\zeta}$ conservative (biased to zero), because we are more likely to observe actions in our sample of years/respondents among those with possibly higher costs of adjustment or learning. If informal indemnification of idiosyncratic losses increases *ex ante* risk-reduction then households with lower adjustment costs have already taken action against risk, and $e_{\eta\zeta}$ will be biased downward.

The first column of Table 9 reports the estimates of (14) with loss interaction terms but without household characteristics. The estimates indicate that among households experiencing a shock, those who are members of castes characterized by a higher degree of idiosyncratic loss indemnification are, as is consistent with the model, significantly more likely to take actions that reduce their exposure to risk. Informal risk-sharing with respect to individual losses thus evidently comes with a cost: more conservative behavior, which presumably results in lower average incomes for the group. On the other hand, those landowning households with informal indemnification based on village rainfall shocks are less likely to enhance their protection *ex ante* against losses. Finally, inclusion of interactions of the shock with characteristics of the household, as seen in column two of the table, does not affect the estimates of the effects of two types of informal insurance on risk-mitigating behavior.

b. The effects of formal index insurance on risk-taking.

The estimates of the relationship between informal risk-sharing based on rainfall events and risk mitigation imply that formal index insurance should increase *ex ante* risk-taking. In this section we use data from our follow-up experimental sample of rice farmers in Tamil Nadu[18] to estimate the effect of offering formal insurance on initial crop variety choice in the *Kharif* season and to assess how the two types of informal insurance coverage mediate the effect of the treatment.

Farmers in Tamil Nadu were asked to rate the yield, drought tolerance, disease resistance, and insect resistance of subsets of the 94 individual rice varieties they had planted in the 2010 *Kharif* season (prior to the experiment) using a three-category ordinal scale. Table 10 reports the rating distributions, and shows that the varieties differ in quality with respect to these attributes, and presumably farmers face trade-offs among them in choosing crops to plant. We use the group ratings for each rice variety with respect to two crop properties - drought tolerance and yield - to construct two indexes characterizing the riskiness and yield potential of the actual portfolio of rice varieties planted by each sample farmer subsequent to the randomized offer of the insurance product. The formulas for the two crop portfolio indexes are given by

(15) $$I_{li} = \Sigma a_{is}\sigma_{ls}/\Sigma a_{is},$$

where l indicates whether the characteristic is drought resistance or yield, σ_{ls}=the fraction of all farmers rating rice variety s "good" with respect to the characteristic l, and a_{is}=acreage of rice variety s planted by farmer i. The median crop portfolio consisted of varieties that were rated 57% good for drought tolerance and 63% good for yield; 10% of farmers planted rice varieties that were rated

[18] 97% of the farmers in the Tamil Nadu sample were exclusively cultivating rice in the Kharif crop season.

good by all farmers for tolerance but only 5% had portfolios in which all varieties were universally considered good for yield.

The estimating equation is

(16) $$I_{li} = g_{\omega l}\omega_i + g_{\omega l\eta}\omega_i\eta_j + g_{\omega l\iota}\omega_i\iota_j + \mathbf{x_{ij}g} + g_j + \varepsilon_{ij},$$

where ω_i=1 if the index insurance product was offered to the farmer, g_j is the caste fixed effect, and ε_{ij} is an iid error. We expect that $g_{\omega l}>0$ for l=drought resistance and $g_{\omega l}<0$ for l=yield. In this intent-to-treat analysis, farmers offered the index insurance will be less conservative than those not offered the insurance. Because we found that respondents with informal insurance were more likely to take up the product if offered, we also expect that the treated group with a higher caste-specific individual indemnification η_j will be more likely to choose riskier portfolios with higher yields, i.e. $g_{\omega l\eta}>0$ for yield and $g_{\omega l\eta}<0$ for drought tolerance. Similarly, for farmers in castes that already provide informal weather-based coverage, the treatment effect will be attenuated for both risk and yield, $g_{\omega l\iota}<0$ for yield and $g_{\omega l\iota}>0$ for drought tolerance.

Table 11 reports the caste fixed effects estimates of equation (16) with and without the interaction terms. The linear estimates in columns one and three indicate that offering the index insurance product reduced the fraction of the planted rice acreage rated 'good' for drought resistance by six percentage points (10%) and increased the acreage rated 'good' for yield by five percentage points (9%). Offering index insurance apparently increases agricultural risk-taking. The interaction coefficients suggest that, as expected given the effects on take-up, among the farmers with more informal insurance against individual losses (controlling for caste fixed effects), the index insurance treatment effects on risk-taking and yield are reinforced, but the effects are only marginally statistically significant. The interactions with the weather-based caste insurance variables suggest that such informal insurance reduces the impact of the treatment, but none of these effects are statistically significant.

VIII. Conclusion

A large literature in economics has emphasized the importance of geographically-spread informal risk-sharing networks in rural populations of low-income countries where the burden of income shocks is large, but has also shown that the insurance provided by these networks is incomplete and that farmers' incomes are lower as a consequence of *ex ante* risk-mitigating behavior. The lack of thriving formal insurance markets in such populations has motivated academic and policy interest in formal index insurance products that have the promise of alleviating the risk burden of farmers without many of the problems associated with other forms of insurance. Despite this promise, the actual take-up of index insurance unless heavily subsidized is low.

In this paper we examined whether the existence of informal insurance crowds out the market for formal index insurance in a context in which the index insurance product is subject to basis risk and examine the effects of both informal risk-sharing and index insurance on risk-taking. We show in a simple model incorporating cooperative informal risk sharing and index insurance subject to basis risk that formal insurance products and informal risk sharing networks interact in the market in ways that depend upon the type of informal indemnification and the extent of basis risk afflicting the index-based insurance product. When individuals in a group face both idiosyncratic and aggregate risk, informal networks lower the demand for formal insurance only if the network indemnifies against aggregate risk. We also show that informal risk-sharing networks may in fact reduce risk-taking if the network primarily indemnifies against idiosyncratic risk. When the formal insurance product is imperfect due to mismatches between the rainfall-index-based payouts and the actual losses incurred by the policy holders (basis risk), however, informal risk sharing, by covering household losses that are the consequence of basis risk, enhance the benefits from formal index insurance contracts that permit increased risk-taking.

Using a combination of non-experimental and experiment-based survey data from rural India in which we randomized both the provision of an index insurance product and distance to rainfall stations, we find that sub-castes both compensate for individual losses and pay out on the basis of village level rainfall shocks. We also find empirically that basis risk, as measured by the perceived distance of the respondent to the nearest rainfall station, is a significant impediment to the take-up of the index insurance product. However, consistent with the model the negative effect of basis risk is attenuated for households in sub-castes that more successfully indemnify individual losses. Households in sub-castes that already informally provide insurance coverage based on aggregate shocks on the other hand are less likely to purchase the index product. Thus, our findings indicate that informal insurance is both a complement to formal index insurance and a substitute, depending on basis risk and the nature of the informal insurance arrangement.

We also assessed the effects of informal and formal index insurance on risk taking. Consistent with the model, indemnification of losses appears to come at a cost: in sub-castes with higher levels of informal loss indemnification, farm households are more likely to reduce risk after experiencing an adverse shock compared with their counterparts in sub-castes with inferior rates of personal indemnification. However, both informal and formal index insurance increased risk-taking. In particular, in our experimental setting rice farmers offered the index insurance product were more likely to subsequently plant a portfolio of rice varieties that was significantly higher-yield but less drought resistant. Index insurance thus appears to not only improve welfare but to increase average incomes, particularly when the product is offered in locations where rainfall stations are in closer proximity or where the informal risk-sharing communities are capable of significantly offsetting idiosyncratic household losses.

In summary, we find that pre-existing informal risk-sharing arrangements, such as membership-by-birth in *jatis* in India, are clearly important institutions that condition the demand for formal insurance. Policy decisions on whether to promote formal insurance at all depend on the specific reasons that informal risk sharing is incomplete (Kinnan, 2011). The next step in this research agenda is to understand why and how specific attributes of communities affect their abilities to provide informal insurance against idiosyncratic losses and aggregate losses. The existing literature on risk sharing does not provide much guidance on this point. Our estimates uncover a number of caste characteristics that enhance and limit the group's ability to indemnify losses (e.g. the share of caste households engaged professional occupations, land inequality, and the number of same-caste households in the village) that may assist the development of a theoretical foundation for analyzing a group's ability to solve commitment and monitoring problems and self-insure.

Finally, in the course of marketing insurance products for the randomized experiment component of this project, we found that agricultural laborers, whose livelihoods are weather-dependent, demonstrate as strong a demand for weather index insurance as cultivating landowners. Strikingly, landless laborers currently do not have access to index insurance markets because regulatory restrictions in India prevent the sale of such contracts to non-cultivators. Laborers are less susceptible to basis risk, and the relative demand for index insurance is particularly strong among this group compared with cultivator households in villages that are farther away from rainfall stations.

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Table 1

Distribution of Distress Event Types, 1999-2006

Distress Type	Percent
Village level	
Crop loss	15.9
Drought	18.2
Floods/hailstorm	12.9
Pest attack	8.9
Livestock epidemic	3.1
Dry wells	3.1
Water-borne diseases	2.1
Epidemic	2.2
Household level	
Price increase	12.4
Crop failure	7.8
Sudden health problem	5.5
Death of immediate family member	5.1
Fire, theft, loss/damage of assets, job loss, theft/robbery, dry well	2.7

Table 2

Descriptive Statistics for Respondents Offered Insurance Product (N=4,260)

Variable	Mean	Standard Deviation
Held formal agricultural insurance before	0.0234	0.144
Participated in MGNREG Scheme	0.298	0.457
Caste's financial loss insurance index (η_j)	0.336	0.149
Caste's village-level insurance index (ι_j)	628	180
Distance (km) to nearest automatic weather station (aws)*	4.08	5.89
Purchased marketed insurance product	0.403	0.491
Actuarial price, Rupees	80.2	45.1
Subsidy fraction	0.449	0.277
Village coefficient of variation of rainfall	9.95	5.19
Non-cultivating agricultural laborer	0.419	0.493
Total owned land, all respondents (acres)	1.42	3.28
Scheduled caste/tribe	0.253	0.435
Non Hindu	0.0533	0.225

*Not available for Tamil Nadu sample

Table 3

Distribution of Marketing Framing and Price Discounts

	TN		AP		UP	
Type of Discount Selected	N	Share	N	Share	N	Share
Discount = 0%	54	6.13	151	7.6	133	7.58
Discount = 10%	288	32.69	516	26.14	346	19.72
Discount = 50%	281	31.9	648	32.83	633	36.07
Discount= 75 %	258	29.28	660	33.43	643	36.64
Total	881	100	1975	100	1755	100

Table 4

Insurance Take-up Rates by State

State	Marketed	Purchased	Take-up Rate
Tamil Nadu	895	347	39%
Andhra Pradesh	1971	759	38.5%
Uttar Pradesh	1762	750	43%

Table 5

Descriptive Statistics for REDS 2007-8 Sample (N=5,268)

Variable	Mean	Standard Deviation
Any loans, non-regular transfers from caste/family in 05/06 crop year	0.239	0.426
Amount of informal financial assistance in 05/06, Rupees	1,340	10,839
Any loss in 05/06 crop year	0.211	0.407
Any loss in past 7 years	0.545	0.498
Amount of loss 05/06, Rupees	1,674	7,159
Village rain shock: deviation from total rainfall mean in 05/06 crop year (mm)	75.5	311.6
Owned land (acres)	2.74	4.9
Landless	0.333	0.471
Number of family members in agriculturally-unrelated occupations	0.114	0.353
Mean owned land of caste	1.49	1.86
Standard deviation of owned land holdings in caste	4.12	15.2
Fraction of caste landless	0.391	0.271
Mean number of family members in ag.-unrelated occupations in caste households	0.0606	0.0487
Number of own caste households in the village	134.2	147.8

Table 6

ML Conditional Logit Estimates of the Determinants of Receiving Financial Assistance (Informal Loans + Non-regular Transfers in Crop Year 2005/6)

Variable/Coefficient type	Log-Odds	Log-Odds	P
Adverse village rain deviation in 05/06	-0.00183	-0.00179	0.00045
	(2.96)	(2.91)	(2.90)
×Caste's mean land holdings	0.000256	0.000274	0.00007
	(1.90)	(1.95)	(1.95)
×Caste's proportion landless	0.00139	0.00165	0.00041
	(1.09)	(1.47)	(1.46)
×Caste's proportion hh's with in non-ag. occupations	0.0206	0.0207	0.0052
	(4.31)	(4.60)	(4.60)
×Caste's standard deviation of land holdings(x10^{-3})	-0.00232	-0.00426	0.0011
	(0.22)	(0.39)	(0.39)
×Number of same-caste households in village(x10^{-3})	0.00109	0.00114	0.00028
	(1.22)	(1.22)	(1.22)
Any individual household loss from distress event in 05/06	-0.833	-0.794	-0.195
	(2.09)	(2.09)	(2.17)
×Caste's mean land holdings	0.144	0.165	0.0412
	(1.69)	(2.01)	(2.01)
×Caste's proportion landless	1.37	1.22	0.305
	(1.89)	(1.91)	(1.92)
×Caste's proportion hh's with in non-ag. occupations	3.05	3.25	0.81
	(1.61)	(1.76)	(1.76)
×Caste's standard deviation of land holdings(x10^{-3})	-16.5	-18.8	-4.69
	(2.09)	(2.43)	(2.43)
×Number of same-caste households in village(x10^{-3})	1.77	1.73	0.00043
	(1.92)	(1.90)	(1.91)
Household own land holdings	0.00211	0.0064	0.00159
	(0.27)	(1.42)	(1.42)
Household landless	0.325	0.3	0.0744
	(3.33)	(3.29)	(3.35)
Number of persons in hh in non-ag. occupations	-0.135	-0.159	-0.0395
	(2.46)	(2.34)	(2.33)

Include interactions with household variables	N	Y	Y
Caste fixed-effects	Y	Y	Y
N	4,660	4,660	4,660

Absolute values of asymptotic *t*-ratios in parenthesis, clustered at the state level

Table 7

Fixed-Effect Estimates: Determinants of Formal Insurance Take-up

	Three States	Two States	Two States			
Variable/Est. Method	FE-State		FE-State		FE-Caste	
η_j × Distance to aws	0.125	0.151	0.142	0.0228	-	-
	[0.77]	[0.82]	[0.15]	[0.15]		
η_j × Distance to aws	-	-	-	0.151	0.139	0.157
				[2.48]	[2.09]	[2.30]
ι_j	-198	-209.6	-213.6	-209.7	-	-
	[1.95]	[1.49]	[1.51]	[1.53]		
ι_j × Distance to aws	-	-	-	-	-	-18.6
						[0.85]
Distance to aws (km)	-	-	-0.00101	-0.0254	-0.0246	-0.019
			[0.48]	[2.56]	[2.66]	[1.96]
Agricultural laborer	-0.0343	-0.0341	-0.0357	-0.028	-0.0238	-0.0379
	[1.70]	[1.52]	[1.65]	[1.23]	[1.10]	[1.39]
Agricultural laborer × Distance to aws	-	-	-	-	-	0.00333
						[1.03]
Actuarial price	-0.00143	-0.00159	-0.00162	-0.00167	-0.00154	-0.00157
	[1.77]	[1.71]	[1.71]	[2.58]	[2.56]	[2.55]
Subsidy	0.389	0.355	0.351	0.35	0.376	0.372
	[2.68]	[2.10]	[2.05]	[2.71]	[3.14]	[3.07]
Owned land holdings	0.000405	0.000445	0.00045	0.000648	0.00353	0.0035
	[0.16]	[0.17]	[0.17]	[0.26]	[1.75]	[1.75]
Village coefficient of variation, rainfall	0.523	0.751	0.781	0.747	0.874	0.908
	[1.56]	[2.02]	[2.04]	[1.91]	[2.53]	[2.43]
N	4,260	3,338	3,338	3,338	3,338	3,338

Absolute values of t-ratios in brackets, clustered at the village level. Specifications also include scheduled tribe or caste indicator and whether non-Hindu

Table 8

Distribution of Post-Shock Risk-Mitigating Measures, 1999-2006

Measure	Percent
Changed crop choice	26.7
Improved technology	17.9
Immunized self	16.7
Modified diet	12.9
Deepened/added wells	7.0
Immunized livestock	6.1
Sought more secure job	4.3
Shored up house to prevent damage	3.3
Took up arms/hired guards	3.3
Installed water purifier	1.8

Table 9

Caste Fixed-Effects Estimates: Effect of an Adverse Event on Subsequent Action to Reduce Risk by Farmers

Variable	(1)	(2)
Experience adverse event (village or household)	0.237	0.229
	[3.22]	[2.95]
$\times \eta_j$	1.21	1.23
	[2.76]	[2.75]
$\times \iota_j$	-238	-249
	[1.78]	[1.82]
×Head's years of schooling	-	0.00306
		[1.09]
×Owned land holdings	-	-0.00133
		[0.56]
Head's years of schooling	0.00178	0.000348
	[1.39]	[0.33]
Owned land holdings	-0.00026	-0.00133
	[0.22]	[0.56]
N	3,600	3,600

Absolute values of t-ratios in brackets, clustered at the village level.

Table 10

Properties of Rice Varieties Planted by Tamil Nadu Rice Farmers

Property	Yield	Drought Resistant	Disease Resistant	Insect Resistant
Good	61.0	58.9	40.3	34.7
Neither good nor poor	30.7	30.9	46.2	50.6
Poor	8.3	10.2	13.5	14.7
Total	100.0	100.0	100.0	100.0
Number of varieties		94		
Number of farmers		364		

Table 11

Intent-to-Treat Fixed-Effects Caste Estimates of Index Insurance on Risk and Yield:

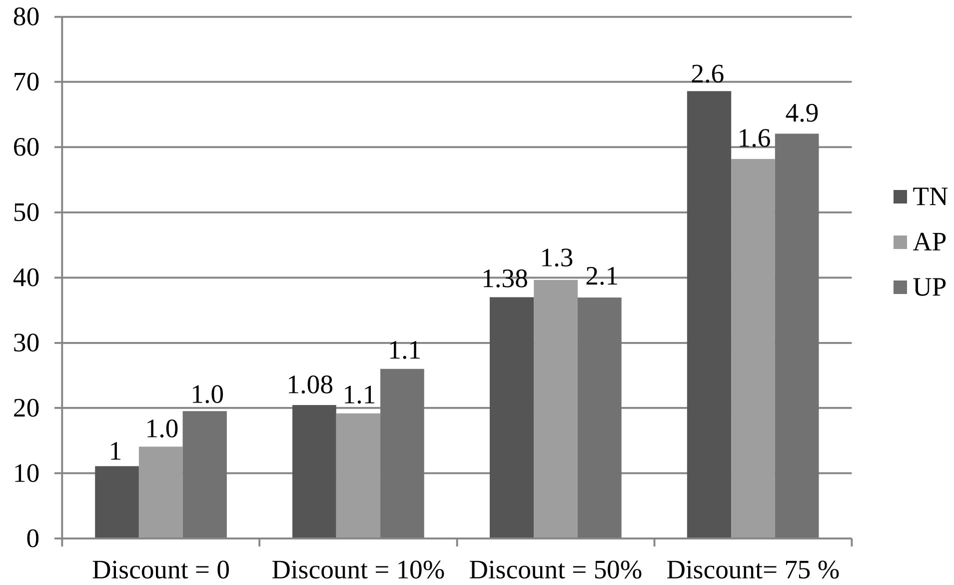
Proportion of Planted Crop Varieties Rated "Good" for Drought Tolerance and Yield, Tamil Nadu *Kharif* Rice Farmers

Crop Characteristic:	Good Drought Tolerance		Good Yield	
Variable	(1)	(2)	(1)	(2)
Offered insurance	-0.0593	0.376	0.0519	-0.517
	[2.67]	[1.74]	[1.93]	[1.54]
$\times\eta_i$	-	-1.64	-	2.13
		[1.32]		[1.47]
$\times\iota_j$	-	181.5	-	-232.9
		[0.63]		[0.75]
Owned land holdings	0.0000934	0.0000468	0.00056	0.00131
	[0.02]	[0.02]	[0.12]	[0.26]
Village coefficient of variation, rainfall	0.351	0.398	-0.516	-0.567
	[0.88]	[1.08]	[0.81]	[0.95]
N	325	325	325	325

Absolute values of t-ratios in brackets, clustered at the caste/village level.

Figure 1

Rainfall Insurance Take-up Rates and Average Number of Policy Units Purchased



Appendix on Insurance Marketing Scripts

Insurance Script: Normal (households were marketed a standard insurance package):
Monsoon Start Date Scheme – Kharif 2010 is a unique rainfall insurance product specially designed for several districts in Tamil Nadu. This product is designed in consultation with Centre for Insurance and Risk Management, Institute for Financial Management and Research (IFMR) and researchers at Yale University, USA. This insurance scheme is expected to provide effective risk management aid during October and November 2010.

For the required premium of Rs. ____, the policy will compensate for a delay in the start of the monsoon rains beyond a specified date. For example, at this location, the expected date of monsoon start has been specified as _____*date*_____. This "expected date of monsoon" for this location (____*date*____) was chosen after studying historical rainfall data for the past 20 years on when the monsoon in this location started. If the monsoon is delayed by 30 days or more, or in other words, if it arrives after ____*date*____, then you will be compensated Rs. 1200 for every unit of insurance purchased. With smaller delays – for example, a delay of 25 days, you will receive a smaller payout. Please see the offer sheet for the details.

Onset of monsoon is defined as an accumulation of 40mm of rain beginning from the preset date of the NE Monsoon (see offer). Rainfall will be measured by district level Automatic Weather Stations (AWS) and monitored by the Indian Meteorological Department as well as Tamil Nadu Agricultural University.
The cost and coverage levels are specified for every unit of insurance purchased. Consumers can purchase multiple units to increase coverage. The scheme is voluntary, and any person who stands to lose financially is the monsoon is delayed can take insurance under the scheme. This includes farmers who cultivate, but also laborers without any land who work in agriculture, and depend on income from farming activities.

Insurance Script: Gamble (households were marketed a "financial product" rather than an insurance package)

Monsoon Start Date Scheme – Kharif 2010 is a unique opportunity specially designed financial product that gives you the opportunity to earn a payout that depends on whether the monsoon is delayed this year. This product is designed in consultation with Centre for Insurance and Risk Management, Institute for Financial Management and Research (IFMR) and researchers at Yale University, USA.

Buyers will be charged an entry fee of Rs. _____ for every unit of the financial product they purchase, and in return, they will receive a cash payout if the monsoon in Tamil Nadu is delayed. For example, at this location, the expected date of monsoon start has been specified as _____*date*_____. This "expected date of monsoon" for this location (____*date*____) was chosen after studying historical rainfall data for the past 20 years on when the monsoon in this location started. If the monsoon is delayed by 30 days or more, or in other words, if it arrives after ____*date*____, then you will be compensated Rs. 1200 for every unit of the product purchased. With smaller delays – for example, a delay of 25 days, you will receive a smaller payout. Please see the offer sheet for the details.

Onset of monsoon is defined as an accumulation of 40mm of rain beginning from the preset date of the NE Monsoon (see offer). Rainfall will be measured by district level Automatic Weather Stations (AWS) and monitored by the Indian Meteorological Department as well as Tamil Nadu Agricultural University. The cost and coverage levels are specified for every unit purchased. Participants can purchase multiple units to increase the amount of the potential payout. Participation in this scheme is voluntary, and anyone with an interest in the arrival date of the 2010 Northeast monsoon can purchase this product.

Addendum for "Return" script:

We will return next year to sell the same product to you before the onset of next year's monsoon.

Addendum for "Historic" script (varied by district)

To better understand the potential delay in the monsoon this year, we looked at historical data from the past 22 years. We know whether the start of the monsoon was delayed in any year during the past 22 years, and by how many days. We used this information to determine the fair price for this product.

The past 22 years of rainfall data for this district can tell you what the payouts of this product would have been in each of those years. For example, the onset of the monsoon was delayed in ____*district*____ by ____*# of days*____ days in ____*year*____. That year, the payout from this product would have been ____*amount of Rs.*____ Rs. In ____*year*____, the onset of the monsoon was delayed by ____*# of days*____ days, and the payout would have been ____*amount of Rs.*____. In some years, when the monsoon arrives on time, there is no payout. Since 1985 in ____*district*____ there would have been payouts in both *1997* and *2001*, but not in any of the other years when there was no delay in the onset of the monsoon.