# Selling Formal Insurance to the Informally Insured

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Abstract

The take-up of insurance contracts by farmers in developing countries is puzzlingly low, but these farmers often participate in informal risk sharing. We examine theoretically and empirically the impact of informal risk-sharing on the demand for index insurance, and the effects of index insurance purchase on subsequent risk-taking. In theory, informal risk sharing can crowd out demand for index insurance if the network indemnifies rainfall risk, but it could also be a complement to index insurance if the contract carries basis risk (i.e. mismatches between payouts and actual losses due to the remote location of the rainfall gauge). Using field experiments that randomize both the location of rainfall gauges and offers of index insurance contracts to Indian farmers for whom we have detailed data on the nature and extent of their prior community risk sharing, we find substantial support for the theoretical predictions. Demand for index insurance is lower with greater basis risk, but indemnification of household-specific losses by the network mitigates this effect. Rainfall insurance enables households to take more risk even in the presence of informal insurance.

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 the dominant risk (Giné et al. 2007). 90% of variation in crop production in India is caused by variation in rainfall (Parchure 2002). Yet 90 percent of the Indian population and 88 percent of the workforce do not have any insurance coverage (Mukherjee, 2010).

The absence of formal insurance among poor rural populations does not mean that the poor are uninsured. A large literature documents informal risk-sharing schemes among rural populations, especially in India (Mazzocco and Saini, forthcoming; Townsend, 1994; Ravallion and Dearden, 1988; Rosenzweig, 1988; Rosenzweig and Stark, 1989). 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).

One long-standing hypothesis explaining thin formal insurance markets in poor populations is that pre-existing informal risk-sharing arrangements either reduce the demand for insurance or prevent formal markets from being established (Arnott and Stiglitz 1991). Moral hazard plays an important role in this analysis: if insurance providers cannot monitor risk-taking, then informal risk-sharing schemes will drive out formal contracts. Such frictions arising from information asymmetries, contract enforcement costs and fraud in general limit the ability of formal credit and insurance markets to mitigate risk (Rothschild and Stiglitz, 1976; Finkelstein and McGarry, 2006).

Weather index-based insurance has emerged as a prominent alternative that addresses some of these concerns (IFAD 2010; World Bank 2010; Caplin et al 2009). Payment in such schemes is based on an *exogenous* publically observable index (such as local rainfall), which mitigates the moral hazard and some types of adverse selection problems that arise when insurance indemnifies individual losses (Barnett *et al.*, 2008). Index insurance also eliminates the need for in-field assessments. However, take-up rates for index insurance products are often low (Cole *et al.*, forthcoming).

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. Rainfall realized on the farm may not perfectly correlate with the rainfall index measure because the number of existing rainfall stations used to calculate payout is limited, and the potential client population may be located far from rainfall stations on average. 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 fully insure.

In this paper we examine theoretically and empirically the impact of informal risk-sharing and basis risk on the demand for index insurance, and also the effects of insurance purchase on subsequent risk-taking. The theoretical framework combines the Arnott-Stiglitz cooperative risk-sharing framework, in which informal risk sharing can lower risk taking, with Clarke's model of basis risk and the demand for index insurance. 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 potential 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, as informal networks can cover losses when the index insurance fails to provide coverage due to basis risk. The negative effects of basis risk on the demand for index insurance are possibly attenuated among those more informally insured.

The community groups we study are the Indian sub-caste (or *jati*). The *jati* is a well-defined, and the most important risk-sharing group in rural India (Munshi, 2011). It is a centuries-old institution whose salience is maintained over generations through strict rules on marital endogamy. The *jati* network is spatially dispersed across villages and districts, and it therefore has the potential to indemnify aggregate rainfall risk as well as individual losses. Our baseline data indicates that 59% of all financial transfers and informal loans are received from other members of the same *jati*, so the sub-caste is the relevant risk sharing network in this context. And 90% of these transfers and the majority of informal loans originate outside the villages of the respondents. While the Indian caste system offers a convenient and important setting to study risk sharing, there is similar risk-sharing along ethnic lines in West Africa (Grimard 1997, La Ferrara 2003). And recent papers have shown, using experimental evidence, that pre-existing informal networks play an important role in the demand for index-based weather insurance via the diffusion of information (Dercon *et al.,* 2011; Cai, de Janvry and Sadoulet 2012). No studies have empirically examined, however, the relationship between the demand for index insurance, the level of informal community-based risk mitigation and basis risk.

Using national survey data on *jati* membership, transfers, informal loans, individual losses from production shocks and rainfall histories for a large sample of rural Indian households, we first characterize each *jati* in terms of the extent to which the risk sharing network indemnifies individual (idiosyncratic) losses and losses from aggregate (rainfall) events. In particular we estimate how transfers and informal loans providing financial assistance differentially respond to both individual and aggregate (rainfall in the village) shocks with respect to *jati*-characteristics (average wealth, occupational diversity, etc) and household characteristics.

Next we conduct a randomized experiment where we market index insurance to a sample of *jati* members for whom we have estimated the *jati*-specific indemnification rates against idiosyncratic and aggregate shocks. We first study how informal risk sharing affects formal insurance take-up, and then how the random offer of index insurance (intent-to-treat) affects subsequent risk-taking.

In addition to randomizing the offer of and price of the index product, we randomly placed automatic rainfall stations in a subset of the sampled villages. Contract payouts are based on rainfall measured at these stations, so a household's distance from a rainfall station is a major determinant of basis risk. We show the existence of basis risk in our sample by estimating the relationship between the rainfall recorded at the stations and individual farmer's per-acre output. We use the distance variation to directly estimate (a) the effect of basis risk on index insurance demand, and (b) whether *jati*-based idiosyncratic risk sharing attenuates the negative effects of basis risk on formal insurance demand, as is consistent with the theory. We also adduce evidence that distance to the rain station, while proxying basis risk, is not a determinant of trust in the insurance product.

Our analysis of both risk-taking and of basis risk takes advantage of randomized variation generated from the field experiments, while the attributes of informal risk sharing networks are identified on the basis of each caste's responsiveness to idiosyncratic and aggregate shocks. Schulhofer-Wohl (2012) and Mazzocco and Saini (forthcoming) have argued that if individual losses reflect individual preferences for risk, tests of risk sharing that correlate income and consumption movements may be mis-specified. In contrast to this literature, we use data on transfers in response to shocks to estimate the degree of risk sharing directly, rather than indirectly inferring on the basis of consumption movements. As discussed in greater detail in a section on identification, endogenous formation of risk sharing networks may still constitute a threat to our method of identifying risk sharing, but our focus on *jati* networks that rural Indians can join only by birth, and whose membership is maintained through strict penalties on entry and exit, assures that such endogenous network formation is not a concern in our setting.

This paper contributes to the nascent experimental literature on constraints limiting the adoption of insurance products in developing countries (Giné *et al.*, 2008; Cole *et al.*, forthcoming; Giné and Yang, 2009; Cai *et al.*, 2009; Hazell and Hess 2010; Dercon *et al* 2011; Cai *et al.* 2012). It also contributes to the substantial literature on the economic implications of risk sharing and insurance (Ligon et al 2002, Dubois et al 2008, Karlan et al 2012, Chandrasekhar et al 2012, Morten 2012). These two strands of literature have remained separate, and we are the first to empirically explore how the degree of informal risk sharing affects the market 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.

In section II we describe the 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 survey data. Section V discusses the estimates of the caste-level determinants of indemnification of idiosyncratic and of aggregate losses. We estimate how these caste characteristics and basis risk affect the demand for formal insurance in section VI. In section VII we assess the effects of informal and formal index insurance on risk taking as measured by the yield and drought-resistance properties of the portfolio of rice varieties planted by farmers in Tamil Nadu. Section VIII concludes with implications for policy.

## II. Theory

### a. Informal Insurance Model with Monitoring

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 based on the cooperative-risk-sharing model of Arnott and Stiglitz (1991). Our goal in this section is to establish the relationship between informal group-based risk sharing and risk taking by group members. As in Arnott and Stiglitz (1991) we represent the behavior of the group as a two-member game with identical partners. Each 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 $\delta$ from her partner as long as the partner does not also incur a loss. Thus, she also pays out $\delta$ if the partner incurs a loss and she does not.

Partners behave cooperatively, choosing $e$ and $\delta$ 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 $\delta$ 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 $\delta$ (denoted $\delta^*$) 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.

### b. Introducing Formal Index Insurance with Basis Risk

We now introduce an additional aggregate risk factor and formal index insurance. Let *q* be the exogenous probability that an adverse weather event causes a loss *L* for both partners. This aggregate risk *q*, which is uninsurable by the group, is assumed to be independent of *P*. The index insurance contract pays out to both group members a portion of the loss *a* when an index passes some threshold value.[1] We assume this payout occurs with exogenous probability *r*. *r* and *q* may not coincide. Following Clarke (2011), we define a basis risk parameter $\varrho$ 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 $\varrho$ as an increase in basis risk, without any change in the marginal probabilities *r* or *q* characterizing the index and weather events.

We assume that the providers of index insurance charge a premium *rmaL*. 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.[2] The expected utility of the informally-insured group facing idiosyncratic, aggregate and basis risk from taking on the index contract is then:

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

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

(5) $$E(U) = (r - \varrho)[U_0(1 - P)^2 + U_1P^2 + (1 - P)P(U_2 + U_3)] + \varrho[u_0(1 - P)^2 + u_1P^2 + (1 - P)P(u_2 + u_3)] + (q + \varrho - r)[U_4(1 - P)^2 + U_5P^2 + (1 - P)P(U_6 + U_7)] + (1 - q - \varrho)[u_4(1 - P)^2 + u_5P^2 + (1 - P)P(u_6 + u_7)],$$

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

The group chooses the amount of coverage *a*, conditional on its ability to defray losses from idiosyncratic events *δ*, by maximizing (5). The FOC for *a* in this model is

(6) $$(1 - qm)\{(r - \varrho)[U_0'(1 - P)^2 + U_1'P^2 + (1 - P)P(U_2' + U_3')] + (q + \varrho - r)[U_4'(1 - P)^2 + U_5'P^2 + (1 - P)P(U_6' + U_7')]\} = qm\{\varrho[u_0'(1 - P)^2 + u_1'P^2 + (1 - P)P(u_2' + u_3')] + (1 - q - \varrho)[u_4'(1 - P)^2 + u_5'P^2 + (1 - P)P(u_6' + u_7')]\}$$

Clarke (2011) shows that in this model of index insurance without community risk-sharing of idiosyncratic risk, increases in basis risk lower the optimal amount of coverage *a** purchased, as do increases in administrative costs (price) in most cases.[3] It is easy to show that these results carry through if there is community risk-sharing of idiosyncratic risk, as here, and the demand for index insurance is independent of the level of *δ*. From (6) we can also establish the following propositions:

**Proposition 1**: *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

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

[3] Changes in the price of insurance have income and substitution effects so that there is the possibility that index insurance is a Giffen good.

for which the only solution is $a^* = 1$, irrespective of the value of $\delta$.[4]

**Proposition 2**: *If index insurance is actuarially fair but there is basis risk, the index is informative, and some index insurance is purchased, then the decision on how much index insurance to purchase (a*) is no longer independent of δ, the group's ability to indemnify idiosyncratic losses.*

The simple Arnott-Stiglitz model yields an optimal level of informal risk sharing, but that model ignores limited commitment, hidden income or liquidity constraints, all of which may limit the ability of partners to attain the informal insurance optimum (Kinnan 2011). To derive this proposition, we examine the comparative static effect on the demand for index insurance $a$ of an exogenous change in $\delta$ (the extent of informal risk sharing) below the optimum level of $\delta$.[5]

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

$$\text{(8)} \quad da^*/d\delta = \{(1 - P)P\{(r - \varrho)(1 - q)(U_3'' - U_2'') - \varrho q(u_3'' - u_2'') + (q + \varrho - r)(1 - q)(U_7'' - U_6'') - (1 - q - \varrho)q(u_7'' - u_6'')\}/\Theta,$$

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

Expression (8) 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). For example, given that $\delta<d/2$ (less than optimal) and declining absolute risk aversion, the term in (8) associated with

[4] 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.

[5] The theoretical method underlying this exercise was developed in Tobin and Houthakker (1950) to study the effect of goods rationing on the demand for unrationed commodities in households, and this method has been applied in several studies of the effects of fertility variation on labor supply and child schooling (e.g., Rosenzweig and Wolpin 1980, Rosenzweig and Zhang 2009).

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 (8) is negative. These non-zero terms indicate that the demand for formal insurance when there is basis risk is no longer independent of the extent of informal risk sharing, although it is not possible to unambiguously sign the direction of the relationship.

Expression (8) also shows that the relationship between index insurance and informal risk sharing varies with basis risk, $\varrho$, as the derivative of (8) with respect to $\varrho$ is also non-zero. For example, the index contract worsens utility in the worst state due to basis risk (a loss of $L$ without the contract versus a loss of $L(1 + a)$ with it), but informal risk sharing helps mitigate this worst state. Greater basis risk makes this state more likely, and the positive term associated with informal risk sharing described above becomes larger. In addition, the negative term (a smaller utility gain from the contract when idiosyncratic loss is indemnified) is smaller the larger the basis risk $\varrho$, since the index contract is not as valuable to begin with when it carries a lot of basis risk. While both of these terms move in the direction of making informal risk sharing and index insurance more complementary when there is greater basis risk, there may be offsetting effects where informal risk-sharing worsens the gains from index insurance the higher is $\varrho$.

Finally, the model suggests that subsidizing index insurance with basis risk increases the coverage $a^*$ for a given $\delta$, 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 of government programs designed to channel credit and fertilizer, and promote new seed varieties during the green revolution. The 2006 listing provides information on caste and sub-caste (*jati*), landholdings, and the household head's occupation and age for every household in 202 of those original villages. 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 Gujarat, 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. Our analysis only includes 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 both the village- and the 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. The REDS survey also provides information on financial transfers and loans by source and type for the crop year 2005-06.[6] We use remittances and "assistance received at the time of difficulty" to construct our measure of caste-based indemnification of losses, and exclude gifts for festivals and marriage as well as all transfers from formal sources such as charitable or religious

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

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.[7]

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, 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 aggregate (village level) weather shocks. Importantly, the estimates of the nature and extent of informal risk are based on data collected five years prior to our insurance marketing, and these shocks and behaviors 10 years prior cannot be affected by the randomized experiment.

### 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 how that index insurance in turn affects risk-taking, we conducted a controlled marketing experiment selling index insurance to households drawn randomly from the

[7] 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.

REDS listing villages. Conducting the experiment in these villages allows us to relate the product purchase decisions to the rich characterization of informal risk sharing within 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. The sampling frame for the marketing experiment was listing households in all 63 REDS villages in three large states: Uttar Pradesh (UP), Andhra Pradesh (AP) and Tamil Nadu (TN). 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. We can study agricultural investment decisions, input choices and risk taking among cultivator households.

We restrict the experiment sampling frame to only castes that have 50 or more households represented in the REDS listing. This 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 TN, AP and 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 farmers are over-represented in this sample.

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 state then marketed the product in the project villages. These activities were entirely independent of those of the survey firms subsequently contracted to collect data. The rainfall insurance policy we designed is a "Delayed Monsoon Onset" index-based insurance product, which insures against agricultural losses due to delayed rainfall. AICI first defines 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 agricultural universities. Monsoon onset is defined as a certain level of rainfall accumulation (varied between 30-40mm). The monsoon 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 and managerial calculations.

The insurance policy was not crop specific, thus providing broad coverage for monsoon onset. The 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.

<u>c.3. Experiment Design and Randomization of Treatments</u>. 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. The main treatments randomly varied the price of the insurance product using on the

spot lotteries for premium discounts at each household.[8] However, we will simply use the randomized offer of an insurance product at any price (i.e. Intent to Treat) to study the effect on subsequent risk taking. The exogenous variation in prices and discounts identify demand parameters in the insurance demand equation, and is useful to verify that the choices were sensible.

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.[9]

Appendix Table A2 and Appendix Figure A1 present summary statistics on insurance take-up at the different (randomly assigned) price points. Overall, roughly 40% of all households purchased some insurance. Of those, 38% purchased multiple units of insurance, with 17% purchasing 5 units or more. Figure A1 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.

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

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[8] 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. Appendix Table A1 provides the exact numbers. 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.

[9] We 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. An appendix provides detailed descriptions of the scripts. We do not discuss in this paper the effects of script variation, which were minimal.

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 built and maintained these rainfall gauges. All respondents were informed about the location of the nearest weather station as part of insurance marketing. This 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 perception of 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 (after the harvest), we conducted one additional round of follow-up surveys in Tamil Nadu in order to track household behavior following insurance purchase. All farmers in the Tamil Nadu sample were rice-growers in the *Kharif* season. The risk characteristics of the crops chosen thus reflect output rather than price risk, facilitating our examination of risk-taking based on the "crop choice" made by farmers amongst alternative varieties of rice. We asked farmers detailed questions about their seed 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 the rice varieties that they knew about. This allows us to create measures of the riskiness and yield characteristics of the crop portfolios of treated and non-treated rice farmers. The Tamil Nadu sample used for the risk analysis is comprised of baseline households that we re-visited, plus an additional "control sample" of 648 households from villages where no insurance product was marketed.

## 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 characterize the ability of individual *jatis* to indemnify losses using the information on transfers and informal loans. In particular, we estimate the determinants of informal indemnification $\delta_j$ for each caste group *j,* distinguishing between individual household losses and shocks that members of the caste experience jointly, which we measure using the village-specific rainfall time-series. Caste members are distributed across 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 rainfall shock are not subject to control by any members of the group. Indemnification by the caste group of the village shock thus is similar to index insurance. Village-level shocks are insurable by the group as long as such shocks are not perfectly correlated across villages inhabited by caste members, who are spread across a state.

We assume that the transfer payment $\delta_{ijk}$ 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 $\zeta_{kj}$ is given by

$$\delta_{ijk} = \eta_{ij}(d_{ijk} + d_j) + \iota_{ij}\zeta_{kj} + \boldsymbol{X}_j\boldsymbol{\beta} + \boldsymbol{X}_{ij}\boldsymbol{\gamma} + \mu_j + \varepsilon_{ijk}, \tag{9}$$

where $\boldsymbol{X}_{ij},$ is a vector of household characteristics, $\boldsymbol{X}_j$ is a vector of caste characteristics, $\mu_j$ contains all unmeasured characteristics of the caste including the village- and individual-level losses and shocks experienced by other caste members, and $\varepsilon_{ijk}$ 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 the $\eta_{ij}$ and $\iota_{ij}$ - the household-specific indemnification rates - depend on the caste's ability to indemnify household-specific losses and village shocks, and thus on a vector of both caste characteristics, and household characteristics, so that $\eta_{ij} = \eta(\boldsymbol{X}_j, \boldsymbol{X}_{ij})$ and $\iota_{ij} = \iota(\boldsymbol{X}_j, \boldsymbol{X}_{ij})$. Linearizing the indemnification functions, we obtain

(10) $$\delta_{ijk} = (\Sigma\eta^j_n X_{jn} + \Sigma\eta^{ij}_m X_{ijm})(d_{ijk} + d_j) + (\Sigma\iota^j_n X_{jn} + \Sigma\iota^{ij}_m X_{ijm})\zeta_{jk} + \Sigma\beta^j_n X_{jn} + \Sigma\gamma^j_m X_{ijm} + \mu_j + \varepsilon_{ijk},$$

where the $\eta^j_n$ and the $\iota^j_n$ are parameters of the caste-level indemnification functions, and the terms associated with them in equation (10) are summed over $n$ caste-level characteristics, $X_{ijm}$ 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 (10) using OLS is that the common component of household loss levels $d_j$ may be correlated with caste level unobservables $\mu_j$ determining payments, as the cooperative model indicates that the group's indemnification of individual losses is jointly determined with group- level risk choices (moral hazard). To obtain consistent estimates of the $\eta^j_n$ and $\iota^j_n$ and the $\eta^{ij}_m$ and $\iota^{ij}_m$ we thus employ caste-level fixed effects, which remove the caste-level linear variables, the unobservable fixed effect $\mu_j$ and the common and endogenous component of the household losses $d_j$.[10] This yields consistent estimates of $\eta^j_n$, $\iota^j_n$, $\eta^{ij}_m$ and $\iota^{ij}_m$ if individual shocks to payments $\varepsilon_{ijk}$ are uncorrelated with individual losses $d_{ijk}$ net of the caste fixed effect. The equation we estimate examines how responsive informal financial assistance is to individual and aggregate losses:

(11) $$\delta_{ijk} = (\Sigma\eta^j_n X_{jn} + \Sigma\eta^{ij}_m X_{ijm})d_{ijk} + (\Sigma\iota^j_n X_{jn} + \Sigma\iota^{ij}_m X_{ijm})\zeta_{kj} + \Sigma\gamma^j_m X_{ijm} + u_j + \varepsilon_{ijk},$$

where $u_j$ is the caste fixed effect.

[10] The caste fixed effect controls for all observed and unobserved caste-level characteristics that may affect the levels of transfers, such as the caste-average level of risk aversion or how close knit the community is. As a consequence we cannot estimate the effects of observed caste characteristics on the levels of transfers across the *jatis*.

Prior studies assessing the success of group risk-sharing exploit household- and group-specific times-series of consumption and incomes to estimate the relationships between consumption and income net of group consumption.[11] Schulhofer-Wohl (2012) and Mazzocco and Saini (forthcoming) have argued that individual losses may reflect individual preferences for risk, and this biases such tests. Unlike this literature, we use direct data on transfers rather than income-consumption co-movements to estimate informal risk sharing. The major threat to the identification of the *jati*-specific indemnification parameters that we estimate, given that we employ *jati* fixed-effects to absorb heterogeneity across castes in risk-behavior, is that the *jati* is unable to perfectly control individual risk-taking within the group, in contrast to the model. In that case there may be a positive correlation between transfer shocks and individual losses due to moral hazard, which will bias the estimates of the $\eta^j_n$.

Bias due to imperfect individual monitoring of risk-taking by the *jatis* and individual risk aversion heterogeneity are not a relevant concern for the estimates of the relationship between the rainfall shocks $\zeta_{kj}$ and transfers.[12] Moreover, the coefficients estimated, given the use of *jati* fixed effects, are those associated only with the interactions between both types of shocks and household and aggregate caste characteristics. With imperfect monitoring, the individual errors would have to be correlated systematically with these characteristics interactions. If risk-sharing networks form endogenously, then certain aggregate caste-characteristics (e.g. occupational diversification) may be correlated with more variable individual patterns of risk aversion within a network.[13] However, households are born into their caste, and network membership is maintained through strict penalties

[11] Cochrane (1991), Mace (1991), Townsend (1994), Udry (1994), Nelson (1994), Townsend (1995), Attanasio and Davis (1996), Hayashi et al (1996), Deaton (1997), Dynarski and Gruber (1997), Munshi and Rosenzweig (2009).

[12] Land markets are thin and permanent migration by households low in India so an individuals' propensity to face village-rainfall shocks is likely unrelated to moral hazard and risk preferences.

[13] This could happen with, say, negative assortative matching – a highly risk averse and a highly risk tolerant person would pair up in a risk sharing network, and take advantage of the gains from trade in providing mutual insurance.

on entry and exit. Endogenous network formation is therefore not an important concern in this setting.

Our model and the existing literature on risk-sharing networks is not informative about how the aggregate characteristics of communities affect the degree to which they can overcome the commitment, monitoring and other problems that limit first-best risk-sharing at the community level. Moreover, 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. Guided by the literature on risk sharing (Coate and Ravallion, 1993; Ligon *et al.*, 2002, Munshi and Rosenzweig, 2010), we assume that the wealth position of individual households within the community, measured by their landholdings and whether or not they own land, and their occupation affect their individual indemnification rates and are thus used to measure the $\boldsymbol{X}_{ij}$. Moreover, we assume the group's ability to indemnify risk and avoid moral hazard depends on the group's level of resources, its ability to agree on common actions, its ability to diversify risk, and its ability to monitor.[14] Accordingly we include in the set of *jati* $X_{jn}$ covariates the mean level of landholdings of the caste and the proportion of landless households as reflecting caste resource capacity. Since group inequality may lead to disagreement and division (Foster and Rosenzweig, 2002), we also include the standard deviation of caste landholdings in the indemnification function. To reflect the diversification of income sources, we include in the $\boldsymbol{X}_{jn}$ vector the proportion of caste household heads in professional and technical occupations.[15] Finally, we assume that larger caste population in the village is positively associated with monitoring capacity. Accordingly we expect

[14] 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.

[15] 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.

that a caste's ability to indemnify individual losses caused by aggregate shocks, $\eta_j$ and $\iota_j$, will be positively associated with mean caste landholdings, non-agricultural occupations, 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 $\zeta_k$ we use the deviation of crop-year rainfall in 05/06 from its 7-year village mean. $\delta_{ijk}$ 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. Approximately 24% 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.[16]

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 3 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 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 $\delta$ is less than half for almost all households. Informal

[16] None of our results are sensitive to conditional logit versus linear fixed-effects specifications.

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 4 reports the ML conditional logit estimates of (11) excluding household-level characteristics. We cluster standard errors by caste. 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. Moreover, the patterns of coefficient signs on the caste-level variable are very similar across the responses to both village-level rainfall shocks (which are not subject to moral hazard) and individual household losses.

Individual household characteristics 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 also affect the responsiveness of informal assistance to shocks, a second specification adds 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. The majority of the caste-level coefficients are statistically significant. For both specifications, the table reports the computed marginal effects on the probability of assistance.

## 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 1 and 2 using the experiment sample (drawn from the REDS listing) in three states that were randomly offered the index insurance product. 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 three (the "structural" logit coefficients) and column four (the marginal effects) of Table 4: $\widehat{\eta}_j = \Sigma \eta^j{}_n X_{jn}$ and $\widehat{\iota}_J = \Sigma \iota^j{}_n X_{jn}$.

Summary statistics on the sample estimates of $\widehat{\eta}_j$ and $\widehat{\iota}_J$ based on the marginals (log-odds) are provided in Table 2. We use the structural logit coefficients, which are invariant to the values of caste characteristics, but the results are not sensitive to this choice. The estimating equation is

$$i_{ij} = \varkappa_1 \widehat{\eta}_j + \varkappa_2 \widehat{\eta}_j D_i + \varkappa_3 D_i + \varkappa_4 \widehat{\iota}_J + \mathbf{x}_{ij} \varkappa_5 + \varsigma_{ij}, \qquad (12)$$

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 automatic weather station (AWS) as reported by the respondent; $\mathbf{x}$ is vector of respondent and randomly-varied index product characteristics; and $\varsigma_{ij}$ is an error term.

Randomization ensures that none of the right hand side variables reflect the determinants of the supply of insurance. Thus the $\kappa$ parameters identify demand relationships only. A key assumption of our analysis is that $D_i$ is positively related to basis risk $\varrho_i$. We can verify whether basis risk exists in our sample and whether distance to the rainfall station is a good proxy for basis risk using data we collected data on agricultural output from farmers in Uttar Pradesh (where we randomly assigned the location of rainfall stations) and in Andhra Pradesh (where we also collected data on distance to rainfall stations). In Table 5, we report estimates of the effect of rainfall per day over the *Kharif* season measured at the nearest AWS on the log value of farmers' output per acre from two specifications, the first linear in rainfall and the second where we allow the rainfall effect to vary by distance to the rainfall station. The first two columns show results for UP (where the location of the station was randomly assigned), and the last two columns aggregate UP and AP.

In both the randomized and the combined samples, increases in rainfall measured at the rain stations on average increase farmer output. However, the effect of rainfall dissipates the farther the rain gauge is from the farmer. The point estimates suggest that rainfall measured 14km away is uncorrelated with farm output. These estimates indicate that basis risk exists in our sample and that distance to the station is a reasonable proxy for basis risk.[17]

The theory therefore suggests that $\kappa_3$ (coefficient on distance to the nearest rainfall station) should be negative when informal risk-sharing is absent. Furthermore, Proposition 1 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. If informal risk-sharing reduces the impact of basis risk when there is

[17] We consider below whether the rain gauge distance variable may also be correlated with other factor that affect insurance take-up.

basis risk, $\kappa_2>0$: as distance to the weather station increases, the caste's ability to indemnify idiosyncratic risk will enhance (lower) the demand for index insurance. However, we also expect that, if a caste group is already insuring on the basis of weather variation (higher $\iota_j$), 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. Because the specifications include the estimated regressors $\widehat{\eta}_j$ and $\widehat{\iota_j}$ we report *t*-statistics based on bootstrapped standard errors clustered by caste. Standard errors are bootstrapped in all subsequent tables that include $\widehat{\eta}_j$ and $\widehat{\iota_j}$, using 1,000 replications for each specification.

As noted, distance to weather stations was not recorded in the sample of respondents in Tamil Nadu. The first column of Table 6 reports the estimates of equation (12), 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 $\hat{\eta}_j$ 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 rainfall variation 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, 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 AWS and the interaction between distance and $\hat{\eta}_j$, and the sample is therefore limited to the two states where distance information was collected. 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 ($\eta_j$=0), negatively affects take-up. The statistically significant negative coefficient on distance ($\kappa_3$) 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 $\eta_j$ and index insurance demand, $\kappa_1$=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 $\eta_j$ is positive and statistically significant ($\kappa_2$>0).

The measures of informal protection $\widehat{\eta}_j$ and $\widehat{\iota}_j$ are caste-level variables that may be correlated with unmeasured caste variables that also affect the demand for index insurance. We can add a caste fixed effect to the specification that will absorb all caste-level characteristic effects. 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-$\widehat{\eta}_j$ interaction coefficient is robust to the comprehensive control of caste characteristics. Column 4 of Table 6 reports the caste fixed effect estimates. As can be seen, the interaction coefficient changes little and retains its statistical significance. The findings that the level of basis risk reduces the demand for index insurance and informal indemnification of idiosyncratic risk increases the gains from index insurance the greater is basis risk are robust to omitted caste-level variables.

In the last specification, still including the caste fixed-effect, we add interaction terms (i) between weather station distance and the informal indemnification of aggregate losses by castes ($\iota_j$) and (ii) between weather station distance and the indicator variable for agricultural laborers. 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, as 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.[18] 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. 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 interaction coefficient, however, is not statistically significant.

### A. Is it Basis Risk or Lack of Trust?

We have shown using rainfall data measured at the rainfall stations and per-acre output value that the distance of a farmer to the rainfall station used to determine his insurance payout is a good proxy for the basis risk he faces. An alternative explanation for the relationship between AWS

[18] 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.

distance and insurance take-up, however, is that distance affects trust in the product, which is another commonly cited reason for low insurance demand (Cole *et al.*, forthcoming; Karlan *et al.,* 2012; Cai, de Janvry and Sadoulet 2012). Farmers not proximate to an AWS, and thus who cannot readily monitor the index determining payouts, for example, may be reluctant to purchase the insurance product if they lack complete trust in the insurance company.

This sub-section analyzes the possibility that our rainfall station placement experiment provides evidence on the role of trust rather than basis risk. We can address this directly because all our subjects who refused to purchase the product were asked in the survey about the reasons they chose not to purchase, with "do not trust insurance" offered as a potential response. Table 7 shows the distribution of responses to this question. Lack of trust accounts for 14% of non-purchases among cultivators, and 10% among agricultural laborers. Trust thus appears to be a relatively minor issue (lack of liquidity accounts for half of all non-purchase), but not so trivial that we are not inspired to further investigate its relationship to distance from the rainfall station.

Examining the relationship between AWS distance and the probability of refusing the purchase on the basis of trust among those who refused would not provide an appropriate test, as it would be based on a selected sample of refusers. Instead we divide up the choice set among all respondents offered the insurance product including separate refusal categories, plus the decision to purchase as another category. In particular, we estimate a multinomial logit regression of the determinants of three reasons for non-purchase: (1) "do not trust insurance", (2) "do not understand product", and (3) monetary concerns (where "too expensive", "not holding cash", and "no need" are aggregated into this one category), with "Purchased Insurance" serving as the omitted category. We estimate the specification implied by our model, which mirrors the (linear) specification estimated in column 3 of Table 6 and includes the characteristics of the village, the respondents, the caste and the interactions between the caste ability to indemnify individual losses and AWS distance.

Appendix Table A3 reports all multinomial logit coefficients. Table 8 reports the marginal effects, derived from the logit coefficients, associated with each independent variable on the probability of purchasing insurance in the first column and on the propensity to cite "lack of trust" as the reason for not purchasing in column two. The first column in Table 8 verifies that this non-linear multinomial logit specification produces the same set of results we have already seen: proximity to the rainfall station, subsidies, lower prices and rainfall volatility all increase the demand for insurance, while basis risk (i.e. increased distance to the station) makes informal risk sharing and formal insurance complements. In the second column, we see that distance has no statistically significant effect on respondent's propensity to cite "lack of trust" as the reason for not purchasing insurance. The coefficient on the interaction term between distance and informal insurance is also small and statistically insignificant. A chi-squared test of the joint significance of these two distance variables indicates that distance to rainfall station is not a significant predictor of "lack of trust" as the reason for not purchasing insurance. In contrast, the distance variables, which we have shown correspond to basis risk, are jointly significant determinants of the probability of rainfall insurance purchase. These results suggest that it is unlikely that the distance to the rainfall station proxies for trust in insurance rather than basis risk.

Finally, it may be the mere placement in the village of an AWS as part of our experiment made the prospect of rainfall risk more salient to respondents or might have suggested that their village may be especially risky. In our sample, the weather station was located in the respondents' villages only for a randomly-selected subset of the Uttar Pradesh villages. To see if village AWS presence is driving our results, we estimated the same specification as in Table 6 with and without caste fixed-effects but only including respondents located in the random subset of Uttar Pradesh villages without an AWS and the complete set of Andhra Pradesh villages, in which no AWS was located in a village (not reported). For this subsample, the distance and distance/indemnification coefficients retain their joint and individual statistical significance and sign. Distance does not therefore appear to proxy risk salience.

## VII. Insurance and Risk-Taking

We now examine the relationship between index insurance and risk-taking. The model predicted that formal index insurance should increase *ex ante* risk-taking, even in the presence of informal risk sharing. In this section we use data from our follow-up experimental sample of rice farmers in Tamil Nadu[19] to estimate the effect of offering formal insurance on initial crop variety choice in the *Kharif* season.

Farmers in Tamil Nadu were asked to rate the yield, drought tolerance, disease resistance, and insect resistance of individual rice varieties they had planted in the 2010 *Kharif* season (prior to the experiment) using a three-category ordinal scale. There were 94 different varieties planted across the sample and Table 9 reports the rating distributions. These show 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) $$I_{li} = \Sigma a_{is}\sigma_{ls}/\Sigma a_{is},$$

[19] 97% of the farmers in the Tamil Nadu sample were exclusively cultivating rice in the Kharif crop season.

where $l$ indicates whether the characteristic is drought resistance or yield, $\sigma_{ls}$=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 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

$$I_{li} = g_{\omega l}\omega_i + \mathbf{x_{ij}g} + g_j + \varepsilon_{ij}, \tag{13}$$

where $\omega_i$=1 if the index insurance product was offered to the farmer, $g_j$ is the caste fixed effect, and $\varepsilon_{ij}$ 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.

Table 10 reports the caste fixed effects estimates of equation (13). 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 evidently increases agricultural risk-taking. In becoming less conservative, farmers shift to higher-yield varieties, which should be good for income growth.

## 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. 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, may enhance the benefits from formal index insurance contracts. The index contract in turn permits increased risk-taking, in contrast to informal risk-sharing networks, which in fact may reduce risk-taking if the network primarily indemnifies against idiosyncratic risk.

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.

In addition to finding a more nuanced relationship between the demand for formal index insurance and informal community risks-haring, we also assessed the effects of formal index insurance on risk taking. In cooperative models of risk sharing incorporating moral hazard such as the one we use in this paper indemnification of losses may come at a cost: optimal levels of risk-taking may be reduced compared to a setting with no risk-sharing. In contrast, index insurance has the promise of permitting increased risk. 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 offsetting idiosyncratic 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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**Tables**

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 ($\eta_j$) | 0.336 | 0.149 |
| Caste's village-level insurance index ($\iota_j$) | 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
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 4
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 | P | Log-Odds | P |
|---|---|---|---|---|
| Adverse village rain deviation in 05/06 | -0.00183 | -0.00046 | -0.00179 | 0.00045 |
| | [2.41] | [2.41] | [2.35] | [2.35] |
| ×Caste's mean land holdings | 0.000256 | 0.00006 | 0.000274 | 0.00007 |
| | [1.64] | [1.64] | [1.71] | [1.71] |
| ×Caste's proportion landless | 0.00139 | 0.00035 | 0.00165 | 0.00041 |
| | [1.35] | [1.35] | [1.68] | [1.68] |
| ×Caste's proportion hh's with non-ag. occupations | 0.0206 | 0.00513 | 0.0207 | 0.0052 |
| | [3.29] | [3.29] | [3.32] | [3.32] |
| ×Caste's standard deviation of land holdings (x$10^{-3}$) | -0.00232 | 0.000579 | -0.00426 | 0.0011 |
| | [0.18] | [0.18] | [0.32] | [0.32] |
| ×Number of same-caste households in village (x10-3) | 0.00109 | -0.000273 | 0.00114 | 0.00028 |
| | [0.90] | [0.90] | [0.93] | [0.93] |
| Any individual household loss from distress event in 05/06 | -0.833 | -0.204251 | -0.794 | -0.195 |
| | [2.49] | [2.61] | [2.38] | [2.48] |
| ×Caste's mean land holdings | 0.144 | 0.036024 | 0.165 | 0.0412 |
| | [1.68] | [1.68] | [1.98] | [1.98] |
| ×Caste's proportion landless | 1.37 | 0.341520 | 1.22 | 0.305 |
| | [2.40] | [2.40] | [2.01] | [2.01] |
| ×Caste's proportion hh's with non-ag. occupations | 3.05 | 0.761193 | 3.25 | 0.81 |
| | [1.47] | [1.47] | [1.53] | [1.53] |
| ×Caste's standard deviation of land holdings (x10-3) | -16.5 | -4.1194 | -18.8 | -4.69 |
| | [1.84] | [1.84] | [2.12] | [2.12] |
| ×Number of same-caste households in village (x10-3) | 1.77 | 0.4415 | 1.73 | 0.00043 |
| | [2.38] | [2.38] | [2.37] | [2.37] |
| Household own land holdings | 0.00211 | 0.000524 | 0.0064 | 0.00159 |
| | [0.23] | [0.23] | [0.76] | [0.76] |
| Household landless | 0.325 | 0.080487 | 0.3 | 0.0744 |
| | [3.47] | [3.54] | [2.98] | [3.03] |
| Number of persons in hh in non-ag. occupations | -0.135 | -0.033785 | -0.159 | -0.0395 |
| | [1.29] | [1.29] | [1.39] | [1.39] |
| Include interactions with household variables | N | N | Y | Y |
| Caste fixed-effects | Y | Y | Y | Y |
| N | 4,660 | 4,660 | 4,660 | 4,660 |

Absolute values of asymptotic t-ratios in brackets, clustered at the caste level. The second specification (columns 3 and 4) includes interactions between household-level characteristics and the two shocks, but those coefficients are not reported in the table.

Table 5

Testing for basis risk: effects on log of output value per acre

| Variable | Uttar Pradesh | | Two States (UP and AP) | |
|---|---|---|---|---|
| Rain per day | 0.16516 | 0.30169 | 0.13937 | 0.23606 |
| | [1.32] | [2.2] | [1.4] | [2.09] |
| Distance to aws (km) | | 0.12483 | | 0.08460 |
| | | [2.4] | | [1.92] |
| Rain per day x Distance to aws | | -0.02231 | | -0.01673 |
| | | [3.53] | | [2.81] |
| N | 945 | 936 | 1,459 | 1,418 |

Absolute values of t-ratios in brackets, clustered at the village level. Two state regressions include state fixed effects. Sample includes all cultivators.

Table 6

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

| | Three States | Two States (AP and UP) | | | |
|---|---|---|---|---|---|
| Variable/Est. Method | FE-State | | | FE-Caste | |
| $\eta_j$ | 0.125 | 0.151 | 0.0228 | - | - |
| | [0.56] | [0.61] | [0.07] | | |
| $\eta_j$ × Distance to aws | - | - | 0.151 | 0.139 | 0.157 |
| | | | [3.42] | [2.55] | [2.31] |
| $\iota_j$ | -198 | -209.6 | -209.7 | - | - |
| | [1.71] | [1.28] | [0.94] | | |
| $\iota_j$ × Distance to aws | - | - | - | - | -18.6 |
| | | | | | [-0.528] |
| Distance to aws (km) | - | - | -0.0254 | -0.0246 | -0.019 |
| | | | [3.50] | [2.63] | [1.50] |
| Agricultural laborer | -0.0343 | -0.0341 | -0.028 | -0.0238 | -0.0379 |
| | [2.19] | [2.13] | [1.58] | [1.49] | [1.43] |
| Agricultural laborer × Distance to aws | - | - | - | - | 0.00333 |
| | | | | | [0.797] |
| Actuarial price | -0.00143 | -0.00159 | -0.00167 | -0.00154 | -0.00157 |
| | [2.07] | [2.07] | [2.40] | [2.14] | [2.14] |
| Subsidy | 0.389 | 0.355 | 0.35 | 0.376 | 0.372 |
| | [3.38] | [2.86] | [3.10] | [3.26] | [3.20] |
| Owned land holdings | 0.000405 | 0.000445 | 0.000648 | 0.00353 | 0.0035 |
| | [0.14] | [0.14] | [0.20] | [1.42] | [1.42] |
| Village coefficient of variation, rainfall | 0.523 | 0.751 | 0.747 | 0.874 | 0.908 |
| | [2.16] | [2.89] | [2.77] | [2.92] | [3.04] |
| N | 4,260 | 3,338 | 3,338 | 3,338 | 3,338 |

Absolute values of t-ratios in brackets, clustered at the caste level. Standard errors are bootstrapped to account for the fact that $\eta_j$ and $\iota_j$ are estimated regressors. Specifications also include scheduled tribe or caste indicator and whether non-Hindu

Table 7

Reasons Given for Not Purchasing Marketed Insurance, by Cultivator Status

| Variable | Cultivator (%) | Non-cultivator (%) |
|---|---|---|
| Too expensive | 2.26 | 1.32 |
| Currently not holding cash | 45.4 | 49.7 |
| No need | 35.5 | 38.8 |
| Do not trust insurance/payout unlikely | 13.8 | 9.62 |
| Do not understand | 3.02 | 0.62 |

Table 8

Marginal Effects from Multinomial Logit Regression of Reasons for not Purchasing Insurance

| | Purchased Insurance | Lack of Trust |
|---|---|---|
| $\eta_j$ | -0.034 | 0.080 |
| | [0.23] | [1.64] |
| $\eta_j$ × Distance to aws | 0.200 | 0.007 |
| | [3.40] | [0.55] |
| $\iota_j$ | 213.879 | 14.481 |
| | [1.30] | [0.33] |
| Distance to aws (km) | -0.036 | 0.000 |
| | [3.67] | [0.08] |
| Agricultural laborer | -0.034 | -0.021 |
| | [2.04] | [2.51] |
| Actuarial price | -0.002 | 0.000 |
| | [3.47] | [1.74] |
| Subsidy | 0.326 | -0.003 |
| | [2.66] | [0.12] |
| Owned land holdings | 0.003 | 0.001 |
| | [0.91] | [1.89] |
| Village coefficient of variation, rainfall | 1.126 | -0.773 |
| | [3.91] | [5.55] |
| Uttar Pradesh dummy | 0.054 | -0.014 |
| | [1.02] | [0.99] |
| Schedule | 0.013 | -0.030 |
| | [0.35] | [3.04] |
| Non-Hindu | 0.072 | 0.009 |
| | [1.00] | [0.37] |
| $\chi^2$ test of joint significance of distance variables | 29.11 | 2.18 |
| Prob > $\chi^2$ | 0.0001 | 0.3354 |

The table reports marginal effects of each independent variable on two of the four categories of responses ("Purchased Insurance", and "Did not Purchase because I do not Trust Insurance Contract") from the Multinomial Logit regression in Appendix Table A3. z-statistics based on robust standard errors clustered by Caste in brackets.

Table 9

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 | | |

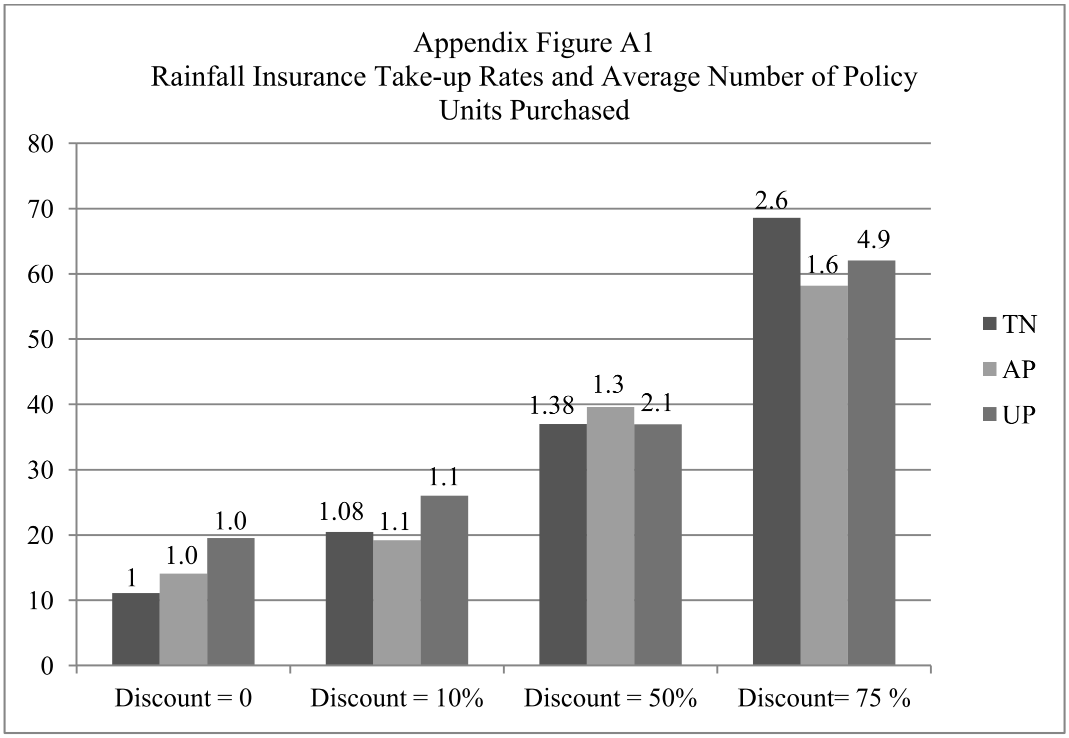
Table 10

Intent-to-Treat Caste Fixed-Effects 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) | (1) |
| Offered insurance | -0.0593 | 0.0519 |
| | [2.67] | [1.93] |
| Owned land holdings | 0.0000934 | 0.00056 |
| | [0.02] | [0.12] |
| Village coefficient of variation, rainfall | 0.351 | -0.516 |
| | [0.88] | [0.81] |
| N | 325 | 325 |

Absolute values of t-ratios in brackets, clustered by caste/village (because the randomized insurance treatment was stratified at the caste/village level).

**Appendices**


Appendix Figure A1
Rainfall Insurance Take-up Rates and Average Number of Policy Units Purchased
80
70
60
50
40
30
20
10
0
1
1.0
1.0
1.08
1.1
1.1
1.38
1.3
2.1
2.6
1.6
4.9
Discount = 0
Discount = 10%
Discount = 50%
Discount= 75 %
TN
AP
UP

Appendix Table A1
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 |

Appendix Table A2
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% |

Appendix Table A3
Multinomial Logit Regression of Reasons for Not Purchasing Insurance

| | Money/Liquidity Issues | Do not Understand | Do not Trust |
|---|---|---|---|
| $\eta_j$ | 0.071 | -6.264 | 1.478 |
| | [0.12] | [2.29] | [1.43] |
| $\eta_j$ × Distance to aws | -0.903 | 0.782 | -0.370 |
| | [3.45] | [1.68] | [1.41] |
| $\iota_j$ | -934.932 | -2679.109 | -280.942 |
| | [1.40] | [2.10] | [0.26] |
| Distance to aws (km) | 0.159 | -0.176 | 0.085 |
| | [3.71] | [2.00] | [1.47] |
| Agricultural laborer | 0.189 | -0.164 | -0.298 |
| | [2.60] | [0.42] | [1.73] |
| Actuarial price | 0.010 | 0.021 | 0.011 |
| | [3.26] | [1.78] | [3.27] |
| Subsidy | -1.435 | 0.738 | -0.866 |
| | [2.72] | [0.33] | [1.46] |
| Owned land holdings | -0.014 | 0.040 | 0.014 |
| | [1.16] | [2.34] | [1.00] |
| Village coefficient of variation, rainfall | -3.593 | 7.907 | -16.304 |
| | [3.02] | [3.97] | [5.00] |
| Uttar Pradesh dummy | -0.227 | 1.119 | -0.380 |
| | [0.99] | [1.37] | [1.32] |
| Scheduled Caste | 0.009 | -1.240 | -0.625 |
| | [0.05] | [2.88] | [3.18] |
| Non-Hindu | -0.323 | -1.031 | -0.015 |
| | [1.10] | [1.49] | [0.03] |
| Constant | 0.039 | -6.595 | -1.093 |
| | [0.06] | [3.46] | [1.16] |
| N | | 3,330 | |

Omitted Category is Purchased Insurance. Robust Standard Errors Clustered by Caste Reported underneath multinomial logit coefficients.