How Does Risk Management Influence Production Decisions? Evidence from a Field Experiment*

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Rainfall variability is an important source of risk in much of the developing world. We test whether the provision of insurance against this risk affects investment and production decisions by small- and medium-scale farmers. Our empirical strategy involves randomized provision of rainfall insurance amongst a sample of landowner farmers in a semi-arid area of India. While we find little effect on total expenditures, increased insurance induces farmers to substitute production activities towards high-return but higher-risk cash crops, consistent with theoretical predictions. Our results support the view that financial innovation may help ameliorate costs associated with weather variability and other types of risk.

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The Green Revolution introduced high-yield crop varieties, chemical fertilizer and other modern cultivation practices that led to a tremendous increase in global agricultural productivity. Yet, the impact of these new technologies on farming practices and output has been uneven. In many areas, traditional farming practices still predominate, and take-up of new agricultural technologies and practices remains limited, despite their high expected rates of return (see Duflo, Kremer and Robinson, 2008 and Suri, 2009).

Credit constraints and limited access to information are often proposed as explanations for low investment and technology adoption in the developing world (e.g., Feder, Just and Zilberman, 1985). An additional explanation, however, which has also drawn significant attention, is that low agricultural investment may be a response to the riskiness of these investments (Lipton, 1989). Although key farm inputs increase average agricultural profitability, there is significant variation in their return on investment. For example, the returns to fertilizer in semi-arid areas are positive only if there is sufficient rainfall, an event that is beyond the household's control. Consequently, risk-averse households may be unwilling to bear income fluctuations associated with these investments and may decide not to adopt them, or instead to shift towards lower-risk, lower-return strategies. Morduch (1995) refers to these as "income-smoothing" activities, and estimates that income-smoothing behavior may significantly reduce household incomes in developing countries.

Fundamentally, income smoothing behavior arises from the inability of households to insure themselves ex-post against income shocks, such as fluctuations in monsoon rainfall. These local rainfall shocks are, to a first approximation, non-systemic sources of risk: they are approximately uncorrelated with global aggregate asset returns. With complete and frictionless financial markets, households would be able to insulate consumption from the effects of these shocks, and thus invest in activities with the highest expected return (adjusted only for systematic risk). But in developing countries, insurance markets are typically incomplete or altogether absent. For example, government-run crop insurance schemes are often poorly designed, difficult to obtain, or reach only a small fraction of the population (Sinha, 2004).

This paper reports on a randomized evaluation of the effect of providing a substantial amount of rainfall insurance coverage to rainfed farmers in a rural semi-arid area of India on farmers' investment and production decisions. We build on a series of field experiments and surveys that we have conducted since 2004 in Andhra Pradesh, India (see Giné, Townsend and

Vickery, 2008, and Cole et al. 2011). This previous work has primarily studied determinants of the demand for rainfall insurance, rather than the impact of insurance on behavior.

The insurance policy we study provides cash payouts based on measured cumulative rainfall during the planting phase of the monsoon season. A significant theoretical advantage of the insurance design is that, since payouts are based on measured rainfall, they can be calculated and disbursed quickly and automatically without the need for households to formally file a claim.

By design, rainfall insurance only covers deficit rainfall, thus leaving the farmer exposed to other risks such as pest infestation, disease and so on. However, in a survey conducted both in 2004 and 2006, 90% of the sample ranked weather variability as the single most important source of risk they face, suggesting that formal rainfall insurance has the potential to significantly reduce overall income risk in our study regions and other semi-arid areas.

To preview our main empirical results, we find little effect of insurance provision on *total* agricultural expenditures. However, we find significant evidence of substitution *between* different production activities. In particular an increase in expenditures on cash crops (castor and groundnut); these crops produce higher expected returns but are more sensitive to deficient rainfall. This prediction closely mirrors theoretical predictions, as we illustrate through a simple model. These findings are economically as well as statistically significant – the fraction of farmers choosing to invest in cash crops is 13% higher in the insurance treatment sample than in the control group. Our results also suggest that the effect of insurance provision is non-linear, having a larger effect amongst farmers with smaller cash crop investments.

The rest of the paper is organized as follows. We first motivate our experiment by discussing the theoretical underpinning of risk-coping strategies used by households in rural areas of developing countries use. Section 2 describes the rainfall insurance product in detail, and describes our experimental design. Section 3 describes the sample and presents summary statistics. Section 4 contains our main empirical results. Section 5 summarizes and concludes.

1. Theoretical considerations

The key hypothesis tested in this paper is that the provision of insurance that reduces income risk leads households to shift towards higher-return, higher-risk production activities. Below we review existing evidence on this research question. In the Appendix we also present a simple model illustrating our main prediction.

A. Income smoothing and consumption smoothing

Households and firms select among income-generating activities by considering both expected returns and risk. Previous research emphasizes the point that households can reduce consumption volatility both by ex post *consumption smoothing* (e.g. through borrowing and savings, or formal insurance), and by ex ante *income smoothing*, that is, by selecting production activities that generate a less volatile income stream, generally at the cost of lower average income (Morduch, 1995; Walker and Ryan, 1990; Alderman and Paxton, 1994; Dercon, 2002).

Income smoothing and consumption smoothing decisions are tightly linked – the greater the availability of risk-coping mechanisms to insure consumption ex post, the less the need for households to smooth income ex ante (Eswaran and Kotwal, 1990; Morduch, 1995). While ex post consumption smoothing has been shown to be surprisingly good in many cases (Townsend, 1994; Udry, 1994; Paxson, 1991), a substantial body of evidence suggests it is incomplete, especially for spatially covariate shocks such as rainfall. See Cole et al. (2011) for a more complete discussion of this issue and references to further literature.

A parallel literature in corporate finance makes a similar prediction, that improvements in risk management will increase firm investment (Froot and Stein, 1998). The key difference is that aversion to production risk is driven by financial constraints (due to moral hazard or enforceability problems) rather than by household risk aversion. In the context of entrepreneurial firms such as the landowner farmers we study, incentives to manage production risk are likely to be driven by both household risk aversion and financial constraints.

For farmers, income smoothing strategies include intercropping amongst crops with different levels of drought tolerance, spatial separation of plots, shifting the timing and staggering of planting, moisture conservation measures such as bunds, furrows and irrigation, and diversifying household income amongst agricultural and non-agricultural sources. Consistent with income smoothing behavior, Rosenzweig and Stark (1989) find that households with more volatile farm profits are more likely to have a household member engaged in steady wage employment, while Morduch (1995) find households whose consumption is close to subsistence (and are therefore vulnerable to income shocks) devote a larger share of land to safer crop varieties. Dercon (1996) finds Tanzanian farmers with a large stock of liquid assets engage in higher risk agricultural activities. Dercon and Christiaensen (2007), using a panel of rural

Ethiopian households, find that fertilizer purchases are lower among poorer households, in part due to their inability to cope ex-post with adverse shocks.

Researchers have estimated considerable efficiency losses associated with ex ante risk mitigation. Rosenzweig and Binswanger (1993) estimate that a one standard deviation increase in the variability of monsoon onset would result, through reduced risk-taking, in a 15 percent drop in agricultural profits for their median household, and a 35 percent drop in profits for households at the 25th percentile. Morduch (1995) concludes that given moderate levels of risk aversion, farmers should be willing to give up at least 16 percent of their income to achieve perfect consumption smoothing.

This paper is also related to the literature of the effect of climate change on agricultural activity. For example, Guiteras (2009) uses historic rainfall variation to estimate the impact of weather on agricultural productivity, taking into account farmers endogenous risk-management strategies. He finds that predicted climate change from 2010-2039 will reduce major crop yields by 4.5 to 9 percent. While rainfall insurance will of course not have any effect on the climate, it can certainly help smooth consumption shocks. Moreover, it may enable farmers to continue to produce risky crops in the face of increasing climate variability, thus lessening the real impact of climate change.

This paper makes at least two contributions to this prior research on the link between the efficacy of ex post consumption smoothing and ex ante production decisions. One, we consider an experimental setting, in which we enforce exogenous variation in the quality of ex-post consumption insurance. This eliminates concerns about omitted variable biases, which are a concern in many of the studies cited above. Two, we consider a particular mechanism for smoothing ex post income and consumption, namely a rainfall index insurance product. This type of micro-insurance has recently drawn significant attention in developing countries, and our findings can help assess how this type of insurance product can improve average incomes and welfare.[2]

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[2] Our earlier research studies the determinants of rainfall insurance demand (Cole et al. 2009, Giné and Yang, 2009, and Giné et al., 2008). While we adopt an experimental approach, generating random variation in insurance participation, uptake has been too limited to allow an assessment of its impact on real decisions. Also related, two laboratory experiments conducted in the field by Boucher and Carter (2008) and Hill and Visceisza (2009) suggest that, over time, subjects learn the benefits of insurance and capitalize on it.

B. A simple framework

To help fix ideas, in Appendix A we present a simple model of insurance and production decisions that illustrates our main prediction, that changes in the availability of ex post insurance that smoothes consumption against production risk will lead to greater ex ante investment in risky production decisions. The intuition for this result is simple: for a risk-averse farmer, greater insurance makes risky activities more attractive, because it reduces the volatility of returns on such activities.

Formally in the model we show that investment in risky production activities is: (i) decreasing in the cost of insurance, or the basis risk of the insurance, (ii) decreasing in the riskiness of the production activity, and increasing in its expected return, (iii) decreasing in the farmer's risk aversion. In our simple CARA-normal setup, we present a simple closed-form expression that illustrates each of these results. However, these basic predictions are much more general than our model, and will obtain in almost any model with risk-averse agents and production risk.

In our empirical setting, we consider a number of dimensions of risky production decisions. One is the total level of agricultural investments. A second is the fraction of investments in risky cash crops, particularly castor and groundnut. As we discuss, these crops are more rain-sensitive than subsistence crops, but generate higher expected income. A third dimension is the timing of planting. In a setting where there is uncertainty about the quality of the monsoon, farmers have incentives to delay planting when the first rains fall, to reduce the possibility of crop failure. The cost of delaying may be to reduce output if the monsoon turns out to be of high quality (see Giné, Townsend and Vickery, 2011 for a model and evidence on this tradeoff, and how farmers' expectations about the monsoon affect the timing of planting).

II. Rainfall Insurance in India[3]

A. Product description

The rainfall insurance policies studied here are an example of "index insurance," that is, a contract whose payouts are linked to a publicly observable index like rainfall, temperature or a

[3] This section draws heavily on Section I.A of Cole et al. (2011).

commodity price. Index insurance policies have several important advantages over traditional crop insurances.[4] The fact that insurance payouts are linked to an exogenous, publicly observable index avoids the classic problems of moral hazard and adverse selection. Perhaps just as important, relative to an indemnity-based product, index insurance offers much lower transaction costs, as no claims verification process is required. Finally, traditional insurance may be very difficult for the insurer to price: there are no good historical data on the extent of crop damage experienced by farmers. Climate models are relatively well understood (at least more so than models of human behavior), and many localities offer thirty to forty years of historical rainfall data, making pricing much simpler for insurance companies.

Rainfall insurance also has several important shortcomings. It is complicated, and farmers and NGOs may have difficulty evaluating the value of the product. Unlike crop insurance, it does not cover other types of loss, such as pestilence. Rainfall insurance may also involve significant basis risk if the household is located too far from the relevant weather reference station. [Note: Most villages in our sample are located within 10km of the reference weather station –given the relatively flat terrain in our study areas, this suggests basis risk is likely to be relatively low, at least for our sample].

An index-based design has at least three notable advantages, which render the product commercially viable: it solves problems of moral hazard and adverse selection, and substantially reduces transaction costs. There is, however, an important drawback: basis risk inherent in an index-based product limits the value of the product. Further complicating BASIX's decision is the low level of financial literacy of its clients: few have purchased insurance before, and, as will become clear as the class develops, the proposed index product is not particularly simple.

Index insurance markets are expanding in many emerging market economies (World Bank, 2005; Skees, 2008). The first Indian rainfall insurance policies were developed by ICICI Lombard, a large general insurer, with technical support from the World Bank. Policies were first offered on a pilot basis in the state of Andhra Pradesh in 2003. Today, rainfall insurance is offered by several firms and sold in many parts of India. See Giné, Menand, Townsend and

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[4] In India, government crop insurance is available at subsidized rates, however few farmers purchase it voluntarily (it is required for farmers obtaining formal bank loans). Unlike rainfall insurance, crop insurance is not commercially viable; indeed, we are aware of no commercially sustainable crop insurance product in the developing or developed world. One disadvantage is that government insurance company often pays claims late, as late as two years after the harvest time has passed.

Vickery (forthcoming) for a non-technical description of this market and further institutional details.

Contract details. – Appendix Table A1 presents details for the contracts offered to farmers in 2009. The policies were underwritten by ICICI Lombard, one of India's leading private insurance companies. Payoffs are calculated based on measured rainfall at a nearby government rainfall station or an automated rain gauge operated by a private third-party vendor. ICICI Lombard policies divide the monsoon season into three contiguous phases of 35-45 days, corresponding to sowing, flowering, and harvest.[5] Separate policies are sold for each phase at a premium between Rs. 80 and Rs. 120 ($2-3 US).[6] A policy covering all three phases (column "Combined Premium") costs Rs. 260 to Rs. 340 ($6-8 US), including a Rs. 10 discount. Households in both regions were free to purchase any whole number of policies as desired.

Each insurance contract specifies a threshold amount of rainfall, designed to approximate the minimum required for successful crop growth. The date of the start of the policy is dynamically determined. Starting from June 1, when cumulative total rainfall reaches 50 mm, the index calculation begins. From that date forward, any additional rainfall (beyond the triggering 50 mm) counts towards the index. Payouts occur if rainfall is low. As an example, the Phase I ICICI Lombard policy in Mahabubnagar pays zero when cumulative rainfall during the 35-day coverage phase exceeds the strike of 70mm. Payouts are then linear in the rainfall deficit, at Rs. 10 per mm deficit, relative to this threshold, and jump to Rs. 1000 when cumulative rainfall is below the exit of 10mm, meant to correspond approximately to a point of crop failure.
The exception to this basic structure is the Phase III, which cover the harvest period. These pay off when rainfall is excessively high, rather than excessively low, to insure against flood or excess rain that damages crops prior to harvest.

Marketing and sales. – Microfinance institutions or non-government organizations (NGOs) typically sell rainfall policies on behalf of insurance companies, and handle payout disbursals. An important advantage of rainfall insurance is that payouts are calculated automatically by the insurer based on measured rainfall, without households needing to file a claim or provide proof of loss. This significantly reduces administrative expenses.

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[5] Since monsoon onset varies across years, the start of the first phase is defined as the day in June when accumulated rainfall since June 1 exceeds 50mm. If <50mm of rain falls in June, the first phase begins automatically on July 1.
[6] As a point of reference, the average daily wage for agricultural laborers in our survey areas at the time of the study is around Rs. 50, although incomes for landed farmers or more skilled workers are significantly higher.

In Andhra Pradesh, insurance is sold to households by BASIX, a microfinance institution with an extensive rural network of local agents known as Livelihood Services Agents (LSAs). These LSAs have close, enduring relationships with rural villages and sell a range of financial services including microfinance loans and other types of insurance.

Actuarial values, observed payouts and pricing. – Giné et al., 2007 calculate actuarial values of these policies. Setting aside the time value of money, calculated expected payouts range from 33% to 57% of premiums, with an average of 46%. Consistent with the generally higher price of financial services in developing countries, these levels are below those of U.S. auto and homeowner insurance contracts, where the payout ratios average 65-75%.[7] Giné et al. (2007) also show that the distribution of insurance returns on ICICI Lombard rainfall insurance contracts is highly skewed. Policies produce a positive return in only 11% of phases. The maximum return, observed in about 1% of phases, is 900%.

In Andhra Pradesh, every policy paid out at least once between the beginning of marketing and 2008. Some payouts were quite modest (Rs. 40 in 2006 for the Atmakur policy), while others were large (Rs. 1,796 in 2004 near Narayanpet). Using administrative data for all policies sold by BASIX in Andhra Pradesh from 2003 to 2009, Giné et al. (forthcoming) find an average ratio of total insurance payouts to total premiums of 138%. The difference between this figure and our historical estimated return may reflect unusual shocks such as the severe drought of 2009, or structural changes such as greater monsoon volatility (B.N. Goswami et al., 2003). Given the limited history of existing rainfall data and the skewness of the insurance return distribution, however, statistical tests of structural change are not likely to be powerful.

III. Sample Selection, Study Design, and Summary Statistics

A. *Study Population*

Our sample includes approximately 1,500 households drawn from 45 villages in two districts, Mahabubnagar and Anantapur, in Andhra Pradesh, India. The households were selected in two phases. In 2004, Giné et al. conducted village censuses of land-owning households in 37

[7] US insurance premiums data were generously provided by David Cummins of Temple University, based on the 2007 Best's Aggregates and Averages. The ratio of aggregate claims to premiums is 76.2% for private passenger auto liability insurance, 68.4% for private passenger auto physical damage, and 64.7% for homeowners insurance. The ratio for earthquake insurance is much lower, 20.4%, but this may reflect the relatively small number of recent earthquake events.

villages, and drew a stratified random sample of 1,063 from this sampling frame. In 2009, to improve statistical power for the study in this paper, an additional 500 households were drawn from these 37 villages as well as 8 other nearby villages. Rainfall insurance has been offered by BASIX in these villages as early as 2003. Most villages had witnessed significant payouts prior to the year of our intervention.

B. Study Design

Each household received a visit to their home in June 2009, prior to the onset of the 2009 monsoon season. During the visit, an enumerator first conducted a short survey about farming practices, and then explained the recommended fertilizer dosages for castor and groundnut, the two main rain-fed cash crops in the area. The enumerator then explained the concept of insurance to the household, and gave specific details about the policies offered by BASIX.

Each household was then given a scratch card (similar to the format of a scratch-off lottery ticket in the United States), which they could scratch to reveal two different treatments. The key treatment for the purposes of this paper is the assignment of the household to either an "insurance" or a "control" group. The insurance group received 10 Phase-I weather insurance policies, underwritten by ICICI. The structure of these policies was similar to those sold in the region in previous years (as described in Section II). The "control" group were promised a fixed future cash payment equivalent to the expected payouts of these 10 policies, roughly Rs. 300.

The intention of this survey design was to insure that any observed differences in behavior between the insurance and control groups were driven by the state-contingent nature of the insurance product, rather than wealth effects due to differences between the expected value of the insurance and the value of the non-contingent cash payment given to the control group. The fixed cash payment was promised to the household at the same time that insurance payouts were distributed to households, so that differences in behavior would not be driven by differences in the timing of payments.

The second treatment offered each household three coupons for a fertilizer discount of 25, 100, or 175 rupees on a 50 kg bag of locally appropriate fertilizer (DAP in Anantapur, NP fertilizer in Mahabubnagar), upon provision of a receipt from a government store. (Note: Due to operational problems, the implementation of this second treatment was not entirely successful in the field – see Section 4 for more details).

The cash versus insurance treatment and fertilizer coupons were applied randomly and independently across households. The use of scratch cards ensured that neither the respondent nor the enumerator was aware of the household's treatment status while the survey was being conducted. All farmers in all of the study villages also had the option to purchase additional insurance policies, of Phase I, II, or III, but few did so in practice.

A few weeks after the ICRISAT team completed the visits in a given village, respondents were contacted by telephone to inform them of the upcoming visit of ICRISAT enumerators and BASIX agents to verify the purchase of fertilizer and honor the vouchers. To minimize fraud, farmers were required during the verification visit to produce a receipt from an input supplier in their names and the coupon serial numbers had to match ICRISAT's administrative records. As it turned out, 97% of farmers who purchased fertilizer had valid receipts at the time of the visit.

In November 2009, after the growing season, ICRISAT team visited each study household, and conducted a follow-up survey. In addition to standard demographic information, the survey collected information on livestock, financial assets (including savings, loans, and insurance), agricultural investments and production decisions during the monsoon, as well as attitudes towards and expectations of weather and insurance payout, and risk-coping behavior.

No payouts had been made by the time of the follow-up survey. Rainfall was however clearly below exit levels in two of the five rainfall stations included in the study for phase I, and by the time of the follow-up survey, many farmers clearly expected to receive a payout in the future. Figure I plots cumulative total rainfall (blue line) and cumulative "index" rainfall (measured from when the policy starts). The gold horizontal lines represent the strike (top) and exit (bottom) levels of rainfall for each rainfall station. For example, in Naryanpet, rainfall was very low in the month of June, never reaching the trigger amount of 50 mm necessary for the policy to start. Thus, the policy started automatically on July 1st. Rainfall levels quickly cross the exit (5mm) level, but never exceeded 16 mm. Each policy therefore triggered a payout of Rs. 10 * (50-16), or Rs. 340. Since each treatment farmer received ten policies, this meant each farmer was eligible for a total payout of Rs. 3,400. Farmers in Anantapur received payouts of (30-10)*10 = 200 * 10 = Rs. 2,000. In Hindupur, no rainfall fell in the month of July, triggering the 'exit', and farmers each received a payout of 10 x 1,000=Rs. 10,000. This amount is significant: it represents twice the average household savings in our sample.

Both insurance and the control group payouts were made in December 2010 and January 2011. Notably, this timing was well after one might have expected, given that the policies indicate a settlement date of "thirty days after the data release by data provider and verified by Insurer." However, the timing was relatively consistent with previous monsoon seasons. The long timeframe for payment of insurance payouts reflected both slow release of the data by the relevant collectors and slow processing by the insurance provider.

(Following these payouts, a follow-up survey to measure consumption and subsequent re-investment was conducted in the spring and summer of 2010. These data are not yet available for analysis.)

C. Summary Statistics

Table I presents summary statistics for the entire sample, based on the baseline survey conducted at the start of the 2009 monsoon season. Logistical constraints precluded conducting an extremely detailed baseline survey, however detailed historical planting and demographic data are available for the households that were included in earlier studies. For the households added to the sample in 2009, additional demographic details were also collected in the November follow-up survey.

Panel A provides basic demographic information. The average household has 5.2 members with a 49.6-year old household head; most household heads (91%) are male. During the *previous year's* planting season (i.e. the 2008 Kharif), households cultivated 4.3 acres of land on average. The 10th percentile of land cultivated was 1 acre, and the 90th percentile of land cultivated was 9 acres. About 92% of households grew cash crops in 2008. These basic household characteristics are similar to the general sample selected for previous work (e.g. see the summary statistics presented in Cole et al. 2011, which are based on a 2006 survey instrument).

In Panel B we report total household expenditure for all crops on a range of agricultural inputs including seeds, fertilizer, manure, irrigation, hired labor, and so on. Panel C reports the same statistics for cash crops, only for those households that had grown cash crops during Kharif 2008.

Given that assignment to either the insurance treatment or control groups was random, we would not expect to observe statistically significant systematic differences between the characteristics of households offered insurance ("treatment") and those offered cash equivalent ("control"). Confirming this expectation, of the 29 means comparisons presented in Table 1, in only one case is there a statistically significant difference between treatment and control groups: treatment households use slightly less DAP fertilizer.

In Table 2, we report agricultural investment decisions from the year prior to our intervention, the summer of 2008. An overwhelming majority (92%) of farmers planted cash crops in 2008: treatment and control groups were perfectly balanced. Fertilizer usage was also similar in the two groups.

These results suggest that the randomization between insurance treatment and control groups was implemented successfully. We observe no systematic differences in household characteristics between the treatment and control groups.

IV. Results

In this section, we discuss our empirical results. We first analyze questions about farmers' perception of their own behavior in response to risk of rainfall fluctuation. We then evaluate the effect of randomly assigned rainfall insurance on agricultural investment decisions. Finally, we discuss the experiment designed to tease out the elasticity of demand for fertilizer.

A. Self-reported risk coping strategies

We begin by analyzing farmers' views of their own risk-management behavior, using question asked during the pre-planting baseline survey. Table 2 reports farmers' answers to three general qualitative questions about risk-coping behavior. We first ask generally whether households felt they made any decisions that would reduce risk, at the cost of lower expected returns. 74% of households responded "yes" to this question, consistent with the idea that households are not fully insured against idiosyncratic income variation.

Second, households were asked more specifically: *"For example, one strategy might be to use a lower seed rate, or use less fertilizer or hired labor. This would provide less profit if the rains are good, but less loss if the rains are bad. Do you adopt any of these strategies"*. In this case a substantially smaller fraction of households, 24%, replied in the affirmative. Finally, we asked the farmers if they adopted strategies that provide less profit if the rains are good, but less loss if the rains are bad. 39% of all respondents agreed, with slightly more answering yes in the treatment group.

The use of multiple similar questions is a common technique to validate survey responses: in this case, the answers to the final two questions appear somewhat inconsistent. While household responses seem sensitive to the way the question is posed, overall these responses appear consistent with the proposition that a significant fraction of households alter their production decisions as a way to reduce exposure to risk.

Finally, we note that the fraction of households answering "yes" to any these questions is statistically identical across the insurance treatment and control groups, again validating the randomization approach used.

In Table 3, we ask the insured sample whether (and how) the provision of insurance affected their investment behavior. The responses here may provide guidance for where to look for an effect when comparing treatment and control groups. Using data from the follow-up survey in November 2009 (which was written and conducted before we had analyzed the results of the baseline survey), we ask treatment respondents, who each had ten insurance policies, whether they changed their behavior in response to having insurance. A majority of respondents reported using more fertilizer, while only 14% reported using less fertilizer. More generally, a larger fraction of respondents indicated that they used more seeds, more pesticide, more hired labor, and borrowed more, in comparison with those who reported "used less", though some of these differences are quite modest. The only input of which farmers said they were influenced to use less on average was bullock labor.

Regarding the timing of planting, 26% of households reported that they planted earlier in response to receiving insurance. As discussed in greater detail in Giné et al. (2010), the timing of planting can be viewed through the lens of an irreversible investment or real options framework. Planting early involves greater risk due to the chance that the crop may fail before the monsoon arrives. However, if the monsoon does arrive promptly following the initial planting, then the crop has a longer period in which to grow. In theory, Phase I policies provide an attractive hedge against the risk of failure, because households may receive swift payouts, facilitating replanting. (In practice, as described above, payments may be delayed for months). We find that 26% of households report planting earlier as a result of the provision of insurance.

B. Insurance and Investment Decisions: Baseline results

Table 4 presents our main baseline results. In this table, we regress a range of measures of agricultural investment (measured in rupees) on an indicator variable for whether the household received the insurance treatment. For completeness, we also include dummies for the size of the fertilizer discounts received, although as described in section D below, for operational reasons the implementation of this treatment did not generate meaningful variation in the amount of fertilizer used by farmers.

Panel (A) examines the amount spent on agricultural production activities across all crops. This includes cash crops (castor and groundnut) and lower-risk, low-return subsistence crops such as sorghum. Notably, we find no significant effect of the insurance treatment on expenditures across any of these categories.

In contrast, panel (B) examines expenditures on the subset of risky cash crops. This analysis is motivated by our theoretical model, which predicts that farmers with greater access to insurance will shift a greater share of production into riskier activities. The dependent variable in Panel B, column (11) is an indicator variable for whether the household spent any money on cash crops. This is likely to be measured with relatively little noise. We find a large and positive effect (significantly different from zero at a p-value of 0.051). The share of households planting a cash crop rises from 48.6% in the control group to 55.0% in the treatment group. This is an economically large effect, particularly in light of conventional wisdom that rural farmers with low levels of education are slow to adopt farming practices. (Recall from Table 1 that we observe no statistically significant difference between the treatment and control groups in the likelihood of planting a cash crop in the year prior to the intervention.)

This effect is corroborated by two alternative measures. First, farmers receiving the insurance treatment report using significantly more inputs for cash crops (castor or groundnut). Column (7) under Panel B presents the results of a regression of ln(1+value of inputs used for cash crops) on the insurance treatment dummy and the size of the fertilizer discount. The point estimate, 0.366, is economically large and statistically significant at the 10% level, although estimated somewhat imprecisely. (A treatment effect as small as 0.1 cannot be ruled out at the 10% level based on our confidence bounds.)

Another way of viewing this relationship is to plot the cumulative density function of investment in cash crops by insurance treatment status. In Figure 2, it becomes clear that the effect is quite non-linear. A sizeable number of households are pushed from not growing cash crops into growing cash crops. However, for those farmers in the top part of the distribution, who are relatively more wealthy, insurance has little effect on investment. (They are already investing a large absolute amount in cash crops.)

Secondly, column (8) within Panel B presents a regression of the natural log of (1+ total number of acres planted in cash crops). Here, the effect is again quite large, representing approximately an 8 percentage point increase in the area of land devoted to cash crops. Consistent with the general tenor of our results, however, we find no effect of the insurance treatment on the total land cultivated (Column (3) of Panel A). This result is perhaps not surprising given the frictions in land markets within rural India.

In columns (6) of Panel A and (4) of Panel B, we test whether the insurance caused farmers to plant earlier, amongst the subset of farmers who do plant. Many farmers use a traditional method of keeping track of dates. "Kartis" roughly represent a two-week period of time. We do not find any statistically significant effect on time of first planting. The confidence interval is relatively narrow, around 0.3 of a Kartis, or approximately four days.

C. Heterogeneous treatment effects

In Table 5, we test for heterogeneous treatment effects along three dimensions. First, we examine whether the initial wealth mediates the effect of insurance. The prediction is not clear. On the one hand, wealthier households may be able to self-insure themselves better against adverse shocks, so that they are less likely to respond to rainfall insurance. On the other hand, they may be in a better position to adjust their agricultural practices in response to a shift in the risk-return frontier introduced by insurance. In fact, we find weak evidence that the insurance product had a stronger effect on wealthier households. Column (4), a Tobit specification of the value of inputs used for cash crops, finds a positive relationship between wealth index and cash crop expenditures.

In columns (2) and (5), we test whether those more likely to have purchased insurance in the past behave differently. We focus on exogenous likelihood of having purchased insurance, using randomly assigned marketing treatments from prior years (described in Cole et al., 2011) to predict a probability of purchase. It may be the case that those more experience with the insurance product trust the product, and are hence more likely to change behavior. We do not find any differential effect among those who were more likely to have purchased insurance.

Finally, in columns (3) and (6) we test whether there is any "demonstration effect" of a village having been paid out in the past. Stein (2011) shows that in villages in which payouts have occurred before, farmers are subsequently more likely to purchase policies in the future. Similarly, farmers who had already witnessed a payout may be more likely to change farming practices, since they may have a higher level of trust in the insurance policy. Since we are comparing across villages, we have significantly less statistical power. We find no heterogeneous effects by village.

D. Price Elasticity of Demand for Fertilizer

A hypothesis motivating the design of this study was that fertilizer use was low among farmers. Earlier rounds of surveys had indicated fertilizer usage rates well below the amounts recommended by agricultural experts. Fertilizer use is relatively easy to measure and recall (number of bags used). An estimate of the price elasticity of fertilizer use might therefore be helpful in calibrating any measured effects of insurance on fertilizer use. We thus measure the elasticity of demand by exploiting random variation in the price of fertilizer generated by our experimental design.

Table 6 presents results from the fertilizer experiment. In column (1), we regress the number of coupons redeemed by an individual on a constant, plus dummies for a Rs. 100 and Rs. 175 discount coupon. The constant indicates the fraction of coupons redeemed by households who received the smallest coupon, Rs. 25.

We find a statistically significant positive relationship between the size of the discount and the number of coupons redeemed: reducing the price of fertilizer from Rs. 475 (Rs. 500 price with a Rs. 25 discount) to Rs. to 400 increases the number of coupons redeemed by 0.32. A further reduction in price to Rs. 325 per bag (with a Rs. 175 coupon) increases the number of coupons redeemed by an additional 0.437 minus 0.323 = 0.124. These numbers, however, should be taken with some caution: even those receiving the smallest coupon redeemed 2.1 coupons, meaning that there was relatively little margin for variation in coupon usage. Moreover, the modal respondent redeemed all three coupons.

The results in column (2), moreover, provide further evidence that the experiment was not correctly calibrated in terms of the number of coupons offered. In this column, we regress the total number of bags of fertilizer purchased, as reported by households in the follow-up survey on the dummies of fertilizer coupons. The average among those receiving the smallest coupon is 5.9 (not reported), well more than the three coupons we provided. This suggests that coupon usage was generally inframarginal. The coefficients on coupon size confirm this: while they are positive and not trivial in size (the point estimates suggest those with larger coupons purchased 0.52 more bags of fertilizer in total than those with the smallest coupon), they are not statistically distinguishable.

V. Discussion and conclusions

We find evidence that insurance against an important source of risk influences production decisions by rural households. Interestingly, this change in behavior appears to occur through a substitution effect. Namely, we find little evidence of a change in total agricultural expenditures by households; however, we do find substitution in expenditures away from less-risky subsistence crops towards higher-risk, higher-return cash crops.

While our results are preliminary, we tentatively view these results as being consistent either with the presence of fixed short-run production factors (e.g. a given amount of land, which cannot be easily adjusted in the short run), or the presence of financial constraints. These factors would tend to make it difficult for households to adjust total expenditures or total land sown.

Through the lens of corporate finance, our results appear consistent with models predicting an interaction between risk management and production decisions (e.g. Froot and Stein, 1998). From a development economics perspective, they suggest that incomplete insurance may be an important constraint on development.

Finally, our results present evidence that financial innovations can influence real decisions. To date, the promise of rainfall insurance to dramatically improve welfare has remained that: a promise. Cole et al. (2011), in a systematic review of the literature, find no evidence from any study that index insurance has an impact on investment, consumption-smoothing, or welfare. Of course, this absence of evidence does not constitute evidence of absence of an effect. While it has certainly been difficult to rule out the hypothesis that rainfall insurance is ineffective, there are a number of reasons it may be particularly difficult to identify a causal chain between access to insurance and outcomes.

First, take-up has been relatively modest, even in the face of significant subsidies. Cole et al (2010) explore reasons for this in great detail. However, there are also examples of higher levels of take-up. Cole, Stein, and Tobacman (2010) find increasing levels of take-up in Gujarat, and in regions of India, commercial sales have been quite high. Still, we are aware of no data set in which farmers have close to as much coverage as those in this study.

Second, much of the impact of rainfall insurance may come after a drought. Most insurance policies are (correctly) designed to pay large amounts during these rare events. But by definition, field studies will only occasionally view rare events.

The results presented in this paper are important because they demonstrate that when a population has substantial levels of risk coverage, they will adjust their investment decisions towards more profitable, albeit riskier, crops. While the insurance was not purchased, it was delivered by the sales agents, in a market setting, to a population that was accustomed to the product.

Here, we point out that it is worth highlighting the differences between income-smoothing behavior and risk-coping behavior. The theoretical distinction is clear: the former occurs before rainfall is realized, in order to reduce variance, and in particular limit downside in the worst states of the world. The latter occurs after a shock is realized. This paper focuses on the former effects, though we cannot with certainty rule out that our estimates represent a combination of both effects.

In our view, these results do not represent a "magic bullet" vindicating rainfall insurance. However, they do provide evidence that farmers can change farming practices remarkably quickly when offered a product that manages financial risk. Precise welfare calculations are difficult when only one outcome is realized. Nevertheless, the results suggest that allocative efficiency and farmer income could be significantly improved by the introduction of innovative financial instruments.

Just as importantly, these results will help us quantify the real cost of ex-ante rainfall risk to farmers. These costs can, for example, be combined with climate change models to better understand the costs that increased weather variability will impose on small-scale farmers.

References

Binswanger, H. P., 1980, Attitudes towards risk: experimental measurement in rural India, American Journal of Agricultural Economics, 62(8): 395-407.

Binswanger, H. P., 1981, Attitudes towards risk: theoretical implications of an experiment in rural India, The Economic Journal, 91(9): 867-889

Binswanger, H. P. and D. A. Sillers, 1984, Risk Aversion and Credit Constraints in Farmers' Decision Making: A Reinterpretation, Journal of Development Studies, 20:5-21.

Cole, Shawn, Xavier Giné, Jeremy Tobacman, Petia Topalova, Robert Townsend and James Vickery, 2011, Barriers to Household Risk Management: Evidence From India. Online at http://ssrn.com/abstract=1374076.

Cole, Shawn and Gauri Shastry, 2009, Smart Money: The Effects of Education, Cognitive Ability, and Financial Literacy on Financial Market Participation, Working Paper, Harvard Business School.

Cole, Shawn, Thomas Sampson, and Bilal Zia, 2010, Prices or Knowledge? What Drives Demand for Financial Services in Emerging Markets? Journal of Finance, forthcoming.

Dercon, S. and L. Christiaensen, 2007, Consumption risk, technology adoption and poverty traps: Evidence from Ethipia. World Bank Policy Research Working Paper 4257.

Duflo, Esther, Michael Kremer and Jonathan Robinson, 2008, How High are Rates of Return to Fertilizer? Evidence from Field Experiments in Kenya, American Economic Review Papers and Proceedings 98 (2): 482-388.

Feder, Gershon, Richard Just and David Zilberman, 1985, Adoption of Agricultural Innovations in Developing Countries: A Survey, Economic Development and Cultural Change, University of Chicago Press, vol. 33(2), pp. 255-98.

Giné, Xavier, Lev Menand, Robert Townsend and James Vickery, forthcoming, Microinsurance: A Case Study of the Indian Rainfall Index Insurance Market, in Ghate, C. (ed) Handbook of the Indian Economy, Oxford University Press.

Giné, Xavier, Robert Townsend and James Vickery, 2007, Statistical Analysis of Rainfall Insurance Payouts in Southern India, American Journal of Agricultural Economics, 89, 1248-54.

Giné, Xavier, Robert Townsend and James Vickery, 2008, Patterns of Rainfall Insurance Participation in Rural India, World Bank Economic Review, 22, 539-566.

Giné, Xavier and Dean Yang, 2009, Insurance, Credit and Technology Adoption: Field Experimental Evidence from Malawi, Journal of Development Economics, 89(1), 1-11.

Goswami, B. N., V. Venugopal, D. Sengupta, M.S. Madhusoodanan, and Prince K. Xavier, 2003, Increasing Trend of Extreme Rain Events Over India in a Warming Environment. 314(5804):1442-1445.

Guiteras, Ray, 2009. "The Impact of Climate Change on Indian Agriculture," manuscript, University of Maryland.

Hill, Ruth Vargas and Angelino Viceisza, 2009, An Experiment on the Impact of Weather Shocks and Insurance on Risky Investment. Mimeo, IFPRI.

Horowitz, J. and E. Lichtenberg, 1993, Insurance, Moral Hazard, and Chemical Use in Agriculture, American Journal of Agricultural Economics 75 (November): 926-935.

Lamb, R., 2003, Fertilizer Use, Risk and Off-Farm Labor Markets in the Semi-Arid Tropics of India, American Journal of Agricultural Economics 85(2): 359-371.

Morduch, Jonathan, 1995, Income Smoothing and Consumption Smoothing, Journal of Economic Perspectives, 9, 103-114.

Rosenzweig, Mark R. and Hans P. Binswanger, 1993, Wealth, Weather Risk and the Profitability of Agricultural Investment, Economic Journal, 103, 56-78.

Sinha, S., 2004, Agriculture Insurance in India: Scope for Participation of Private Insurers, Economic and Political Weekly, June 19th: 2605-2612.

Skees, Jerry, 2008, Innovations in Index Insurance for the Poor in Lower Income Counties Agricultural and Resource Economics Review, 37:1-15.

Suri, Tavneet, 2009, Selection and Comparative Advantage in Technology Adoption, mimeo, MIT Sloan School of Management.

Townsend, Robert, 1994, Risk and Insurance in Village India, Econometrica, 62(3), 539-591.

Walker, T. and J. Ryan, 1990, Village and Household Economics in India's Semi-Arid Tropics, John Hopkins University Press, Baltimore, Maryland.

World Bank, 2005, Managing Agricultural Production Risk: Innovations In Developing Countries, World Bank Agriculture and Rural Development Department, World Bank Press.

Appendix A: Model of insurance and production decisions

This Appendix presents a simple illustrative model of an agricultural entrepreneur to highlight the interaction between production decisions and insurance provision. The key result is that for a risk-averse farmer, investment in risky production activities is increasing in their access to insurance against production risk. Note that, while we assume a very simple setting to build intuition, the basic results we derive extend to a much more general class of models.

A. Basic setup and timing

Consider a one-period model of a farmer with initial wealth W_0 and constant absolute risk aversion (CARA) utility. The farmer has access to a risky production activity or project (e.g. sowing cash crops, or applying fertilizer), and decides at the start of the period what fraction of their wealth to devote to this risky activity. The remainder of their wealth is invested in a safe activity, which we assume for simplicity produces a real return of zero.

We denote the amount invested in the risky production activity by α. The net return on investment (per rupee invested) is given by $\overline{R} + e$, where $\overline{R}$ is the expected return and e is a zero-mean normally distributed error term: $e \sim N(0, \sigma^2_e)$.

The farmer can partially hedge the production risk associated with the risky activity by purchasing insurance. We denote the amount spent on insurance premia by φ. The insurance payout is negatively correlated with the return on investment, but not perfectly (i.e. there is some basis risk). Net of the initial premium, the net payout on the insurance (per rupee of premium) is given by: $-e + u - \mu$, where $u \sim N(0, \sigma^2_u)$. The higher is σ^2_u, the greater the basis risk. We generally assume that $\mu > 0$, which means that the expected insurance payout net of the premium is negative (i.e. the insurance is not actuarially fair).[9]

To summarize the timing: at the start of the period the farmer chooses how much to invest (α) and how much insurance to purchase (φ). At the end of the period, the return on the risky production activity and the insurance payout are realized. The farmer then consumes their initial wealth W_0 plus their net income from the investment and from insurance.

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[9] This could be because of imperfect competition amongst insurers, administrative costs of providing the insurance, or a compensation for the risk borne by the insurer.

We assume the farmer faces an interior solution in equilibrium (i.e. the fraction of their wealth invested in the risky project, inclusive of any insurance purchased, is between zero and one). Finally we assume that $\mu < \overline{R}$. This ensures that insurance demand is positive in equilibrium.

B. Optimal investment in the presence of insurance

The farmer's objective is to maximize expected end-of period utility $E[u(W_1)]$. End of period wealth (W_1) is given by the law of motion:

$$\begin{aligned} \text{End of period wealth } (W_1) &= \text{initial wealth } (W_0) + \text{investment return (Y)} + \text{insurance payout (IP)} \\ &= W_0 + \alpha(\overline{R} + e) + \varphi(-e + u - \mu) \end{aligned}$$

Given our exponential-normal setup, and denoting the farmer's coefficient of absolute risk aversion by γ, the farmer's problem can be written as:

$$\max_{\alpha, \varphi} E[u(W_1)] = \max_{\alpha, \varphi} \{E(W_1) - \tfrac{1}{2}\gamma \, var(W_1)\} \qquad [A.1]$$

where:

$E(W_1) = W_0 + \alpha \overline{R} - \varphi\mu$

$var(W_1) = (\alpha - \varphi)^2\sigma^2_e + \varphi^2\sigma^2_u$

Taking first order conditions of [A.1] with respect to α and φ, and solving the resulting simultaneous equations, the optimal investment level is given by the following expression:

$$\alpha^* = \frac{1}{\gamma}\left[\frac{\overline{R} - \mu}{\sigma^2_u} + \frac{\overline{R}}{\sigma^2_e}\right] \qquad [A.2]$$

An alternative and similar expression can be derived if we assume that the level of insurance φ is assigned exogenously to the household, rather than being a decision variable. (This is the setting that corresponds most exactly to the design of our field experiment). In this case, optimal investment is given by the simpler expression:

$$\alpha^* = \frac{1}{\gamma}\frac{\bar{R}}{\sigma_e^2} + \varphi$$

C. Comparative statics

Inspecting expression [A.2] yields the following comparative statics results for the farmer's equilibrium level of investment in the risky production activity:

Proposition 1: Investment and insurance. In equilibrium, the farmer's investment in the risky activity (α^*) is:

A. *decreasing in the expected per-unit net cost of insurance (μ).*
B. *decreasing in the basis risk of the insurance (σ^2_u)*
C. *decreasing in the variance of investment returns (σ^2_e)*
D. *decreasing in risk aversion (γ)*
E. *increasing in the expected return on investment ($\bar{R}$)*

<u>Proof</u>: By taking first derivatives of [A.2] with respect to each parameter.

The same comparative statics results apply to the alternative expression for optimal investment assuming that insurance is assigned exogenously. The only difference is that part A of the Proposition instead states that investment in the risky production activity (α^*) is increasing in the exogenously determined level of insurance, φ, rather than being decreasing in the cost of insurance.

The key result of this Proposition is that an improvement in access to insurance – either an increase in the amount of exogenously provided insurance, a reduction in the cost of the insurance, or an improvement in the quality of the insurance while keeping the cost fixed – increases investment in the risky activity.

The simple intuition for these results is that the farmer's optimal level of investment trades off the high expected return of the investment against its risk. Improving access to insurance against production risk allows the farmer to reduce the background risk associated with any given investment level (i.e. to shift this risk-return frontier outwards), allowing the farmer to invest more in equilibrium. Given these results, it is also straightforward to verify that the farmer's expected income and expected utility are decreasing in the expected per-unit net cost of insurance (μ), and the basis risk of the insurance (σ^2_u), so that improving access to insurance increases expected income and welfare.

Note that since we assume exponential utility, there are no wealth effects in the model presented here. In reality, provision of insurance may affect behavior both through its risk-management benefits and because it increases household wealth. To control for this, in our field work we compare two groups, one of which receives insurance for free, the other of which is promised the actuarial value of the insurance for free. In other words we effectively hold fixed the wealth of the household between the treatment and control groups.

Figure 1: Cumulative Rainfall during Kharif 2009, for Phase 1 Policies

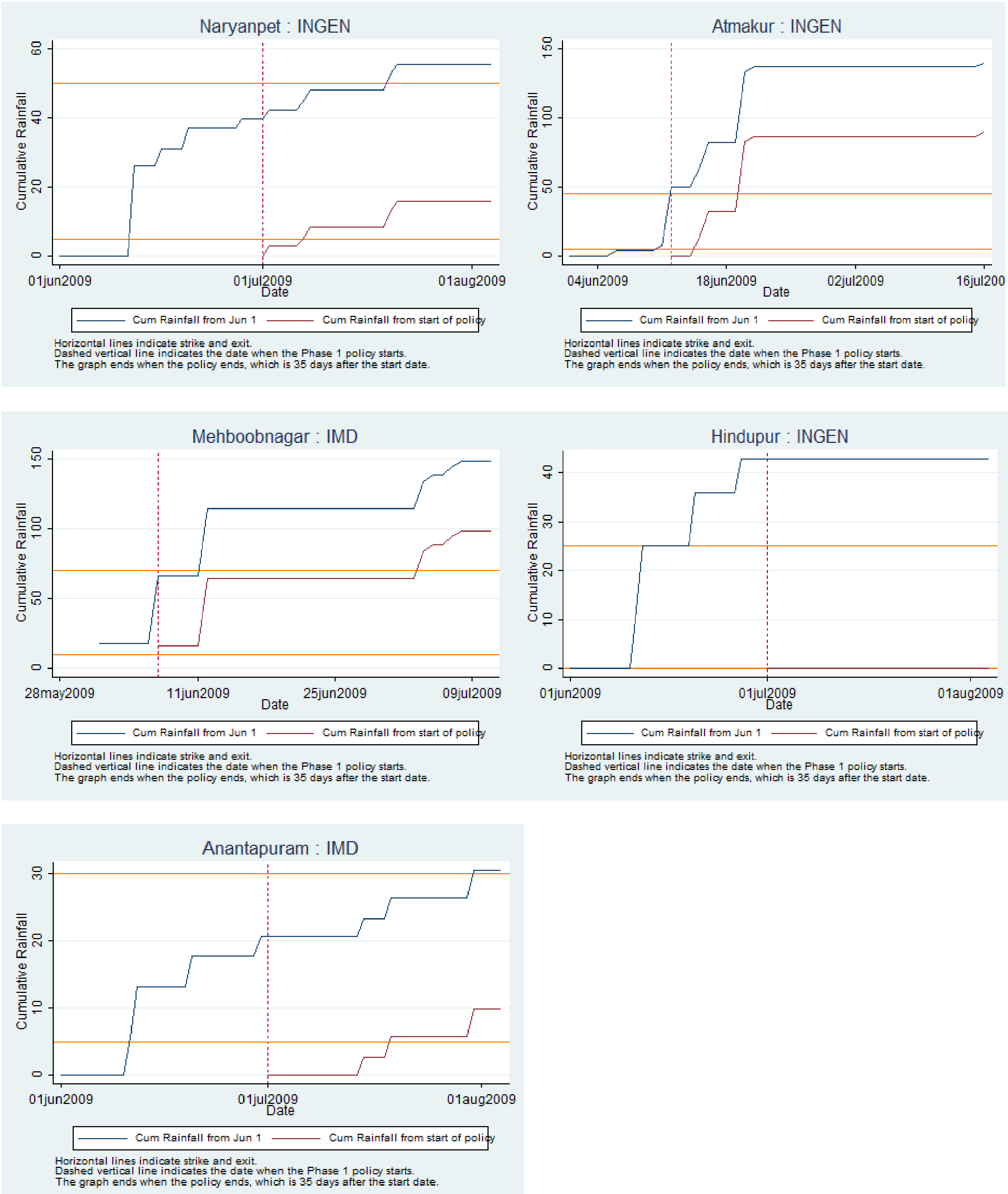

Figure 2: CDF of Investment in Cash Crops, Treatment vs. Control

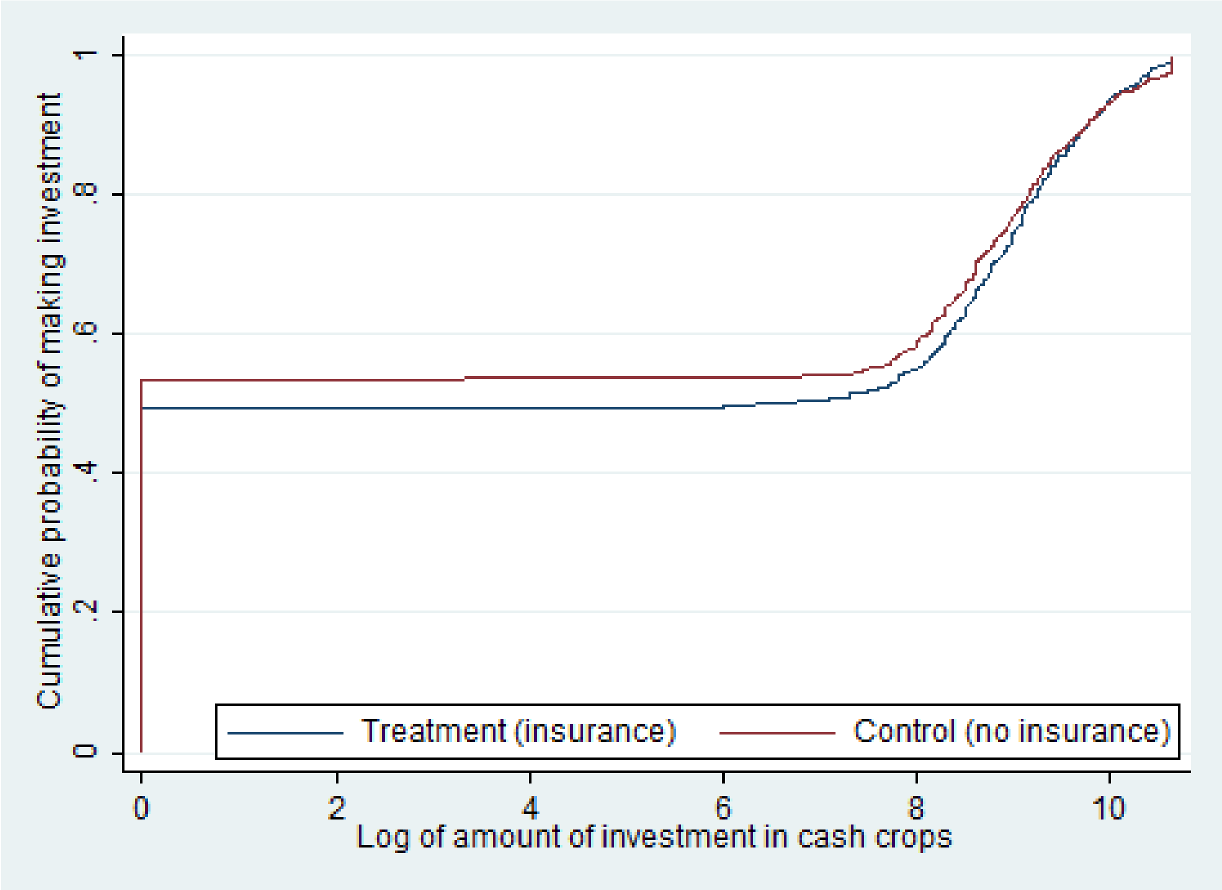

Table 1: Summary Statistics for 2009 Baseline Survey

Variable	N	Mean	SD	10th pcntile	Median	90th pctile	Treatment Mean	Control Mean	Difference	Robust p-value
Household demographics										
HH Size	1490	5.15	2.05	3	5	8	5.12	5.18	-0.06	0.55
Male HH Head	1490	0.91	0.29	1	1	1	0.92	0.9	0.02	0.29
Age of HH Head	1490	49.34	12.99	34	50	65	49.61	49.06	0.55	0.41
Respondent Unschooled	1490	0.55	0.5	0	1	1	0.56	0.54	0.02	0.33
Investment in All Crops during Kharif 2008										
Spending on hybrid seeds	1498	843.4	2177.8	0	0	2400	845.0	841.8	3.2	0.98
Spending on improved seeds	1498	4380.3	6991.7	0	2000	12000	4377.3	4383.2	-5.9	0.99
Spending on fertilizer	1498	3266.1	3925.6	400	2000	7000	3273.9	3258.3	15.6	0.94
Spending on manure	1498	2205.5	3139.2	0	1200	5500	2074.0	2337.7	-263.7	0.1
Spending on irrigation	1498	151.2	884.3	0	0	175	119.1	183.5	-64.5	0.16
Spending on hiring tractor/other implements	1498	2670.2	3597.9	0	1950	6000	2715.2	2624.9	90.3	0.63
Spending on manual labor	1498	4964.2	5318.2	200	3800	10000	5027.8	4900.3	127.6	0.64
Spending on bullock labor	1498	1585.8	2470.4	0	1000	3500	1576.5	1595.1	-18.6	0.88
Area (acres) of land cultivated	1498	4.3	3.93	1	3.5	9	4.37	4.23	0.14	0.51
Bags of DAP/complex used per acre	1498	1.45	1.75	0	1	2	1.35	1.55	-0.20	0.03
Bags of gypsum used per acre	1498	0.06	0.54	0	0	0	0.05	0.08	-0.03	0.32
Bags of urea used per acre	1498	0.71	1.42	0	0	2	0.7	0.72	-0.02	0.84
Investment in Cash Crops during Kharif 2008										
Planted cash crop	1498	0.92	0.27	1	1	1	0.92	0.92	0.00	0.68
Spending on hybrid seeds	1498	440.8	1052.7	0	0	1200	456.1	425.3	30.8	0.57
Spending on improved seeds	1498	4008.5	6016.8	0	1800	10600	4016.9	4000.1	16.8	0.96
Spending on fertilizer	1498	2290.7	2249.4	500	1600	5000	2287.5	2293.9	-6.4	0.96
Spending on manure	1498	1844.7	2828.3	0	1000	5000	1762.4	1927.4	-165.0	0.26
Spending on irrigation	1498	30.9	320.9	0	0	0	22.3	39.6	-17.4	0.3
Spending on hiring tractor/other implements	1498	2019.0	2194.3	0	1500	4500	2086.8	1950.9	135.9	0.23
Spending on manual labor	1498	3884.4	3998.1	500	3000	8000	3886.5	3882.2	4.3	0.98
Spending on bullock labor	1498	1400.6	2106.2	0	800	3000	1397.2	1404.1	-6.9	0.95

Area (acres) of land cultivated	1498	3.4	2.83	1	3	6	3.49	3.32	0.17	0.23
Bags of DAP/complex used per acre	1498	1.39	1.06	1	1	2	1.4	1.38	0.02	0.8
Bags of gypsum used per acre	1498	0.03	0.19	0	0	0	0.03	0.03	0.00	0.75
Bags of urea used per acre	1498	0.24	0.64	0	0	1	0.25	0.22	0.03	0.31
Miscellaneous										
Savings in deposits, cash at home, and other kinds	1498	5448.0	9130.6	0	2800	13200	5744.2	5150.3	593.9	0.21
Bags of fertilizer purchased since Bharani 2009	1490	6.21	6.18	2	4	13	6.14	6.29	-0.15	0.64

Notes:

1. This table reports summary statistics from the 2009 baseline survey (conducted in June 2009), and tests the random assignment of insurance treatment.
2. Kharif is the summer planting period. All monetary values are in Indian rupees.
3. *** statistically significant at 1% level; ** significant at 5% level; * significant at 10% level.

Table 2: Risk-coping Strategies, 2009 Baseline

Variable	N	Mean	SD	10th Percentile	Median	90th Percentile	Treatment Mean	Control Mean	Difference	Robust p-value	
Planted cash crop last Kharif (summer 2008)	1498	0.92	0.27	1	1	1	0.92	0.92	0.01	0.68	
Fertilizer use for cash crops last Kharif											
Used recommended amount of fertilizer	1380	0.6	0.49	0	1	1	0.61	0.59	0.02	0.44	
Used more than recommended amount	1380	0.39	0.49	0	0	1	0.38	0.4	-0.01	0.62	
Used less than recommended amount	1380	0.01	0.12	0	0	0	0.01	0.02	-0.01	0.24	
Self-report investment strategy											
Invests less to cope with risk	1498	0.24	0.43	0	0	1	0.24	0.24	0	0.95	
Makes decisions that lower risk as well as return	1498	0.73	0.44	0	1	1	0.74	0.73	0.01	0.72	
Adopts strategy that reduces sensitivity to rain	1498	0.39	0.49	0	0	1	0.41	0.37	0.04	0.1	*

Notes:

1. This table compares fertilizer use and investment strategy across the treatment and control groups, with data from the 2009 baseline survey.
2. "*Fertilizer use for cash crops* " only considers farmers who planted cash crops last Kharif. The recommended amount of fertilizer is 1bag per acre.
3. The p-values reported correspond to a test of significant difference across the treatement and control groups, with robust standard errors.
   *** statistically significant at 1% level; ** significant at 5% level; * significant at 10% level.

Table 3: the Effect of Rainfall Insurance on Agricultural Investment, 2009 Follow-up

N = 749

The effect of rainfall insurance on	More	Change	Less
the amount of			
Fertilizer used	50%	36%	14%
Seeds used	41%	43%	16%
Pesticides used	32%	41%	27%
Bullock labor used	23%	48%	29%
Hired labor	35%	42%	23%
Funds borrowed to finance agricultural inputs	26%	52%	22%
the timing of initial planting			
Planted earlier	26%		
No change	69%		
Planted later	5%		
the decision whether to abandon crops			
Influenced against abandoning	26%		
No change	67%		
Influenced toward abandoning	7%		

Notes:

1. This table reports self-reported investment decisions among farmers who were provided rainfall insurance. with data from a follow-up survey conducted in November 2009.

Table 4: the Effect of Rainfall Insurance on Agricultural Investments, 2009 Follow-up

Part I: All Crops	(1)	(2)	(3)	(4)	(5)	(6)
Variable	Log of amount spent	Log of market value used	Log of area of land used	Log of amount spent on fertilizer	Log of market value used on fertilizer	Calendar Kartis when planting started
Insurance treatment	0.038	0.066	0.026	-0.024	-0.011	-0.070
	(0.078)	(0.086)	(0.032)	(0.091)	(0.102)	(0.126)
Discount	0.000	0.001	0.000	0.001	0.001	-0.001
	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)
N	1490	1490	1490	1490	1490	1351
R-squared	0.114	0.124	0.107	0.101	0.154	0.206
Mean of Dep Var	9.544	9.475	1.394	7.400	7.249	15.724

Part II: Cash Crops	(7)	(8)	(9)	(10)	(11)
Variable	Log of market value used	Log of area of land used	Log of market value used on fertilizer	Calendar Kartis when planting started	Dummy: any input on cash crop
Insurance treatment	0.366*	0.079**	0.265	-0.025	0.057*
	(0.194)	(0.034)	(0.165)	(0.108)	(0.029)
Discount	-0.000	-0.000	-0.000	-0.001	-0.000
	(0.002)	(0.000)	(0.001)	(0.001)	(0.000)
N	1490	1490	1490	680	1416
R-squared	0.345	0.348	0.312	0.556	--
Mean of Dep Var	4.392	0.688	3.499	15.281	0.477

Notes:

1. All regressions include a control for fertilizer discounts and 43 village dummies on the right-hand side.

2. Regressions (1)-(10), OLS regressions; regression (11), probit. All regressions with robust standard errors.
 *** statistically significant at 1% level; ** significant at 5% level; * significant at 10% level.

Table 5: Heterogeneous Effects of Rainfall Insurance on Agricultural Investments, 2009 Follow-up

Variable	Dummy: any input on cash crop Probit (marginal effects)			Log of market value used on cash crop Tobit		
	(1)	(2)	(3)	(4)	(5)	(6)
Insurance treatment	0.057*	0.039	0.044	0.769**	0.727	0.863
	(0.029)	(0.051)	(0.056)	(0.387)	(0.935)	(1.080)
Wealth index	-0.023			-0.322		
	(0.018)			(0.290)		
(Insurance treat) * (wealth index)	0.036			0.642*		
	(0.024)			(0.380)		
Predicted probability		0.081			1.425	
		(0.100)			(1.847)	
(Insurance treat) * (predicted probability)		-0.010			-0.206	
		(0.139)			(2.505)	
Past payout in village			0.064			1.405
			(0.044)			(0.872)
(Insurance treat) * (past payout in village)			-0.003			-0.137
			(0.063)			(1.208)
Constant				5.611***	5.144***	-0.329
				(1.340)	(1.218)	(0.903)
Village dummies	Yes	Yes	No	Yes	Yes	No
Dummy for 2006 sample	Yes	No	No	Yes	No	No
N	1416	975	1490	1490	1000	1490

Notes:

1. (1) The dependent variable in Regressions (4)-(6) is the log of the total market value of inputs used for cash crop since Bharani (around April 2009).
   (2) The independent variable "wealth index" is based on a 2006 survey and is the first component of the PCA score for a set of dummies, each of which indicates whether a household owned a certain type of asset.
   (3) "predicted probability" is also based on the 2006 survey, and is obtained by linearly predicting the probability that a household would buy at least one rainfall insurance policy in 2006 using treatments from an experiment conducted in 2006 (Cole et al . 2010).
   (4) "past payout in village" is a dummy whether the village where a HH was living had received any insurance payout since 2004.
2. All regressions control for fertilizer discounts.
3. Robust standard errors. *** statistically significant at 1% level; ** significant at 5% level; * significant at 10% level.

Table 6: Elasticity of Demand for Fertilizer, 2009 Follow-up

Variable	(1) Number of coupons redeemed (admin data)	(2) Number of bags of fertilizer bought (admin data)	(3) (2), winsorized top & bottom 2%	(4) Number of bags of fertilizer bought (self-report)	(5) (4), winsorized top & bottom 2%
Discount = Rs. 100	0.323***	0.471**	0.382***	0.385	0.211
	(0.074)	(0.194)	(0.132)	(0.390)	(0.329)
Discount = Rs. 175	0.437***	0.474***	0.519***	0.487	0.371
	(0.069)	(0.154)	(0.129)	(0.372)	(0.320)
Constant	2.324***	3.067***	2.976***	5.921***	5.821***
	(0.059)	(0.121)	(0.099)	(0.244)	(0.222)
N	1389	1387	1387	1490	1490
R-squared	0.032	0.007	0.013	0.001	0.001
Mean of dep var	2.582	3.386	3.281	6.212	6.015

Notes:

1. This table reports farmers' response to fertilizer coupons. These coupons carried different values and were randomly offered to farmers so that each farmer received either 3 coupons of 25 rupees (Rs), 3 coupons of 100 rupees, or 3 coupons of 175 rupees.
2. Regressions (1)-(3) use administrative data, while Regression (4)-(5) use data from the 2009 follow-up survey.
3. OLS regressions with robust standard errors.

*** statistically significant at 1% level; ** significant at 5% level; * significant at 10% level.