AGRICULTURAL DECISIONS AFTER RELAXING CREDIT AND RISK CONSTRAINTS[*]

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Abstract

The investment decisions of small-scale farmers in developing countries are conditioned by their financial environment. Binding credit market constraints and incomplete insurance can limit investment in activities with high expected profits. We conducted several experiments in northern Ghana in which farmers were randomly assigned to receive cash grants, grants of or opportunities to purchase rainfall index insurance, or a combination of the two. Demand for index insurance is strong, and insurance leads to significantly larger agricultural investment and riskier production choices in agriculture. The binding constraint to farmer investment is uninsured risk: When provided with insurance against the primary catastrophic risk they face, farmers are able to find resources to increase expenditure on their farms. Demand for insurance in subsequent years is strongly increasing with the farmer's own receipt of insurance payouts, with the receipt of payouts by others in the farmer's social network and with recent poor rain in the village. Both investment patterns and the demand for index insurance are consistent with the presence of important basis risk associated with the index insurance, imperfect trust that promised payouts will be delivered and overweighting recent events.

Keywords: agriculture, insurance markets, credit markets, risk, underinvestment, misallocation

JEL: C93, D24, D92, G22, O12, O13, O16, Q12, Q14

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1. Introduction

Incomplete markets shape the investments of firms. In the rural areas of developing countries, financial market imperfections are pervasive, and there are broad regions in which almost every household manages farmland, operating effectively as a firm. In these contexts, households facing constrained access to credit or insurance may choose to invest less, or differently, on their farms than they would under perfect markets. Agricultural policy, particularly in Africa, focuses on increasing investment levels by farmers. Policies have commonly focused on reducing risk or increasing access to capital, with implicit assumptions of market failures in one or more such domains.

Before this study began, we asked smallholder farmers in northern Ghana about their farming practices in a series of qualitative focus groups. Discussions were guided toward identifying constraints to further investment. Farmers most often cited lack of capital as the reason they had not intensified farm investment, but farmers also understood the risk of unpredictable rainfall and claimed to reduce their farm investment because of it. Thus, we seek to test the importance of capital constraints and uninsured risk, separately and together, as financial market imperfections hindering optimal investment by smallholder farmers. We do this with a multi-year, multi-arm randomized trial with cash grants, rainfall insurance grants and rainfall insurance sales in northern Ghana.

The welfare gains from improving financial markets could be large for three reasons. First, if either risk or limited access to credit is discouraging investment, the marginal return on investments may be high. Existing evidence from fertilizer in northern Ghana suggests that these returns are indeed high.[1] Yet the median farmer in northern Ghana uses no chemical inputs.[2] Second, agriculture in northern Ghana is almost exclusively rainfed. Thus, weather risk is significant and rainfall index insurance has promise. Third, we have strong regional evidence that rainfall shocks translate directly to consumption fluctuations (Kazianga and Udry 2006). Thus, mitigating the risks from rainfall should lead to not just higher yields but also smoother consumption. More broadly stated, poverty is about both the level of consumption and vulnerability. Households are especially vulnerable when they face risks that are large relative to their incomes (as is typically the case for poor farmers) and when these risks affect entire communities simultaneously (as is the case for rainfall risk). Farmers, keenly aware of this, may hold back on investment and thus miss out on opportunities for higher income. This then can generate poverty traps.

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[1] Experiments on farmers' plots across 12 districts of northern Ghana in 2010 with inorganic fertilizer in northern Ghana showed for an additional expenditure of $60 per acre (inclusive of the additional cost of labor), fertilizer use generates $215 of additional output per acre (Fosu and Dittoh 2011).

[2] This fact is derived from the control group of farmers in the first year of our survey, described in section 3 below.

To understand how capital and risk interact, and under what circumstances underinvestment occurs, we experimentally manipulate the financial environment in which farmers in northern Ghana make investment decisions. We do so by providing farmers with cash grants, grants or access to purchase rainfall index insurance or both. Using rainfall index insurance rather than crop insurance eliminates moral hazard and adverse selection because payouts depend only on observable rainfall realizations. This is beneficial for theoretical and research reasons, in that it allows us to isolate the impact of risk on investment decisions, and is relevant for policy reasons, given the historical challenges of crop insurance (Hazell, Pomareda, and Valdés 1986) and recent policy attention to index insurance.

The experiments are motivated by a simple model which starts with perfect capital and perfect insurance markets, and then shuts down each. Farm investment is lower than in the fully efficient allocation if either market is missing (and land markets are also shut down, given the restrictions of the land tenure system in northern Ghana (Yaro and Abraham 2009)). If credit constraints are binding, then provision of cash grants increases investment, but the provision of grants of insurance reduces investment. In contrast, when insurance markets are incomplete, provision of cash grants has a minimal impact on investment, but investment responds positively to the receipt of an insurance grant.

To test these predictions, we turn to a three-year multi-arm randomized trial.[3] In year one, we conducted a 2x2 experiment. Maize farmers received (a) either a cash grant of $85 per acre or no cash grant (average grant of $420 per farmer), and (b) either a rainfall insurance grant with an actuarially fair value of $47 per acre or no rainfall insurance grant. In year two, we conducted another cash grant experiment but only offered rainfall insurance for sale at randomly varied prices ranging from one eighth of the actuarially fair price to market price (i.e., actuarially fair plus a market premium to cover servicing costs) rather than giving some out for free as in year one. In year three, we did not conduct another cash grant experiment, but the insurance-pricing experiment continued.

Four elements distinguish our data and experiments: (1) We randomly provide cash grants to measure the effect of capital constraints on investment and agricultural income (most of the existing complementary research is on the insurance component), (2) We provide free insurance in order to observe investment effects on a full population of maize farmers rather than just those willing to buy (Cole et al. (2011) is a notable complementary study with grants of free insurance to farmers in India), (3) Our experiment takes place over multiple years, allowing us to examine the impact on demand in subsequent years to treatments and events in prior years, and (4) We estimate a demand curve from

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[3] Conducted as a “natural field experiment” in the sense that all grants and insurance were offered through an NGO, and although after the first year individuals obviously knew that researchers were conducting surveys, the grants and insurance were presented as those of an NGO, not researchers.

barely positive prices to approximate market prices. The randomized pricing also allows for testing the local area treatment effects (LATE) at different prices because using price as an instrument can generate different investment behaviors at each price. This thus makes an important methodological and policy point, cautioning one not to extrapolate treatment estimates too far if generated using price as an instrument for takeup, unless the differential selection into treatment is well understood.

We find strong responses of agricultural investment to the rainfall insurance grant, but relatively small effects of the cash grants. We consider both of these results striking. Our main result is that uninsured risk is a binding constraint on farmer investment: When provided with insurance against the primary catastrophic risk they face, farmers are able to find resources to increase expenditure on their farms. This result is important in two dimensions: First, it demonstrates the direct importance of risk in hindering investment. Second, the fact that farmers came up with resources to increase investment merely as a consequence of getting rainfall insurance shows that liquidity constraints are not as binding as typically thought.[4] Thus, the strongest evidence on capital constraints comes not from the capital grant treatment estimate, but rather from the insurance-only results compared to control. Furthermore, as we will discuss later, the treatments are not directly comparable, as one needs assumptions of perfect markets in order to compare the intensity of the two, and obviously a key lesson from this and similar research is that there are not perfect capital and insurance markets in this type of setting. This second fact, combined with the lack of a large response to cash grants, suggests that agricultural credit market policy alone will not suffice to generate higher farm investment. This is an important result, given the large emphasis throughout the world in agricultural credit policy.

We also show that there is sufficient demand to support a market for rainfall insurance and will discuss in more length below the ensuing policy and market issues in Ghana. We find that at the actuarially fair price, 40 to 50 percent of farmers demand index insurance, and they purchase coverage for more than 60 percent of their cultivated acreage. Patterns of insurance demand are consistent with farmers being conscious of the important degree of basis risk associated with the index insurance product. But there are important frictions, such as trust and recency bias (i.e., overweighting of recent events), in the insurance market. Farmers do not seem to have complete trust that payouts will be made when rainfall trigger events occur, so the demand for index insurance is quite sensitive to the experience of the farmer and others in his social network with the insurance product. Demand increases after either the farmer or others in his network receive an insurance payout, and demand is lower if a farmer was

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[4] This does not mean that there are never liquidity constraints, since individuals could still be constrained partially on the farm, or in other domains of their life. These farmers are very poor, and the prospect of potentially binding liquidity constraints in the future strengthens the responsiveness of investment to insurance, as discussed in Section 2.

previously insured and the rainfall was good, so no payout was made. The irony is unfortunate: Insurance offers its largest benefit for low-probability high-loss events, yet rare payouts harm demand. This could easily lead to insurance market failures if not addressed in the design of policies.

2. Investment and the Financial Environment

In an environment with well-functioning markets, including markets for insurance and capital, the standard neoclassical separation between production and consumption holds and a farmer's input choices on a particular plot are independent of his or her wealth and preferences. Investment in inputs maximizes the present discounted value of the (state-contingent) profits generated by those investments. Where insurance markets are imperfect or credit constraints bind, separation no longer holds and the randomized provision of capital grants or insurance that pays off in certain states may influence farmers' investment choices. The model is in the appendix.

Figure 1 summarizes the core predictions, conditional on different financial market imperfections, of a model of investment response to capital grants and/or the provision of insurance. We start with complete credit markets and full risk-pooling. In such an environment (row 1), farm investment is independent of resources and preferences: Investment is fully determined by profit maximization, which depends only on the probabilities of rainfall outcomes and the physical characteristics of the production function. Thus, neither a capital grant nor an insurance policy has any influence on farm investment.

Next, we introduce imperfect capital markets (row 2). This is straightforward and standard theoretically: With imperfect capital markets, a cash grant leads to an increase in investment (in both a risky and hedging asset). Investments in fertilizer or cultivating a larger plot would be typical examples of the risky asset; investment in irrigation (were it feasible in northern Ghana) would be an example of a hedging asset. However, a grant of insurance decreases the expected marginal utility of future consumption. Thus, the farmer reduces investment in both risky and hedging assets in order to consume more now relative to the future. If a farmer receives both the capital and insurance grant, then naturally the net effect of the positive and negative impacts will depend on the expected value of the insurance grant in the future relative to the value of the cash grant. In our case, the expected value of the insurance grant was always considerably smaller than the value of the cash grant. Thus, the net prediction is to increase investment in both the risky and hedging assets, but not as much as with the capital grant only.

Next, we examine an environment with perfect capital markets but imperfect risk markets (row 3). The capital grant increases investment in the risky asset but only via a wealth effect for those with decreasing absolute risk aversion. Symmetrically, the capital grant reduces investment in hedging assets, again only via a wealth effect for those with decreasing absolute risk aversion. The effect of the insurance grant is intuitive: Investment will increase in the risky asset and fall in the hedging asset. Given that both insurance and capital grants yield the same predictions, if a farmer receives both the capital and insurance grants, the investment response for both risky and hedging assets will be stronger.

Last, we examine an environment with imperfections in both capital and risk markets. The effect of binding capital constraints dominates the effect of imperfect risk markets. Thus, the predictions are the same in row 4 (imperfect markets in both) as they are in row 2 (imperfect capital markets and perfect risk markets). In a more general model than this, it would be possible for the effect of imperfect risk markets to offset that of binding capital constraints, making the effect of an insurance grant on investment in the risky asset ambiguous.

The model in the appendix is stark in its simplicity. We have distinguished sharply between the risky and hedging inputs and between these inputs and a risk-free asset in a model with only a good and a bad state. In fact, farmers have access to a portfolio of input and investment choices with an array of varying payoffs in a vast set of possible states of the world. In rainfed northern Ghana, almost all agricultural activities require investment in inputs which have a higher return in good rainfall conditions than they do in years of drought or flood and correspond to a greater or lesser degree to the risky investment. Households may in addition have access to some limited activities (discussed below) that provide relatively good returns in poor years, corresponding to the hedging investment.

The restriction of the model to two periods sharpens the contrast between the implications of binding capital constraints and those of imperfect insurance. With an extended time horizon, a farmer with no access to insurance markets can use his access to credit markets to smooth transitory rainfall shocks.[5] Our choice of a short time horizon amounts to the assumption that farmer decisions are conditioned by the possibility of binding capital constraints in the near future. This would occur, for example, in the event of a drought (which we do not observe during our sample period).[6] All risk is realized in period 2 in the model, abstracting from the possibility that aggregate rainfall risk affects the interest rate on the safe asset. This kind of price effect would reduce the ability of farmers with access to credit markets to smooth consumption in the face of aggregate transitory rainfall shocks, reinforcing the impact of grants of index insurance when insurance markets are incomplete.

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[5] In a dynamic model in which farmers have no safe asset (in contrast to our model), de Nicola (2012) shows that the introduction of index insurance can reduce risky agricultural investment, because farmers have less need to accumulate assets as a hedge against risk. This result is reversed when farmers have alternative, safe assets.

[6] In section 3.5 we point out that the rainfall risk faced by these farmers is high relative to their observed wealth and thus the relevance of the short horizon of the model. Median harvest value is $950, which is the amount at risk from a drought, while mean livestock plus grain stock holding is $880.

3. The Setting, the Interventions and Data Collection

3.1 Year One: Sample Frame and Randomization for Grant Experiment

Appendix Figure 1 provides a timeline of all data collection activities and experimental treatments.

In order to have a rich set of background data on individuals and a representative sample frame, we used the Ghana Living Standards Survey 5 Plus (GLSS5+) survey data to form the initial sample frame. The GLSS5+ was conducted from April to September 2008 by the Institute of Statistical, Social and Economic Research (ISSER) at the University of Ghana - Legon in collaboration with the Ghana Statistical Service. The GLSS5+ was a clustered random sample, with households randomly chosen based on a census of selected enumeration areas in the 23 Millenium Development Authority (MiDA) districts[7]. From the GLSS5+ sample frame, we then selected communities in northern Ghana in which maize farming was dominant. Then, within each community, we selected the households with some maize farming but no more than 15 acres of land. Within each household, we identified the key decisionmaker for farming decisions on the main household plot, which was typically the male head of household (except in the case of widows). Our sample frame is over 95% male as a result. This yielded a sample of 502 households. We refer to this as Sample Frame 1, and it is used for the Grant Experiment (i.e., the provision of unconditional cash). (Appendix Table I provides an overview of our sample frames, survey completion rates, and observations used for each table in the analysis.)

We randomly assigned the 502 households to one of four cells: 117 to cash grant, 135 to insurance grant, 95 to both cash grant and insurance grant, or 155 to control (neither cash grant nor insurance grant).[8] The unit of randomization was the household, and the randomization was conducted privately, stratified by community. We did not have the GLSS5+ data prior to the randomization and thus were not able to verify *ex ante* the orthogonality between assignment to treatment and other observables. When cash and rainfall insurance grants were announced to farmers, they were presented not as part of a randomized trial but rather as a service from a research partnership between IPA and the local nongovernmental organization Presbyterian Agricultural Services (PAS).[9]

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[7] Ghana has 170 districts in total, twenty of which are located in the Northern Region. MiDA is the Ghanaian government entity created to lead the programs under the compact between the US Government Millennium Challenge Corporation (MCC) and the Ghanaian government. Although the sample frame for this study was generated from the GLSS5+, the interventions described here were independent of MiDA and MCC.

[8] Since the budget for this research included the cost of the intervention and since the size of the sample frame was not fixed, we optimized statistical power by increasing the size of the control group relative to the treatment groups. However, since the exact formula for optimal power depended not just on the relative cost but also on any change in variance, we did not solve this analytically but rather approximated.

[9] The script for the field officers for the insurance grant, for example, was as follows: "I am working for NGOs called Innovations for Poverty Action and Presbyterian Agriculture Services. We are trying to learn about maize farmers in

Table I shows summary statistics, mean comparisons of each treatment cell to the control, an F-test from individual regressions of each covariate on a set of three indicator variables for each treatment cell (Column 7) and an F-test from a regression of assignment to each treatment cell on the full set of covariates (bottom row). No covariates show any statistically significant differences across treatment assignment in the aggregate F-test. In pairwise comparisons of each treatment and the control, out of 70 tests we only reject equality for one pairwise combination for year one, whereas for year two, eight out of 24 reject equality. Note that the imbalance, if not merely sampling variation, indicates a trend towards *larger* farms in the control group in year two (e.g., larger cultivated acreage, higher total costs of investments), compared to the treatment groups, particularly those sold insurance at a price of GHC 4 per acre. Thus, if this introduced bias, it would lead to an underestimate of our treatment effects.

3.2 Year One: Insurance Grant Design

We designed the insurance grant in collaboration with the Ghanaian Ministry of Food and Agriculture (MoFA) Savannah Agricultural Research Institute (SARI) and PAS and secured permission from the Ghana National Insurance Commission to research the effects of a non-commercial rainfall index insurance product. We held focus groups with farmers to learn about their perception of key risks and about the types of rainfall outcomes likely to lead to catastrophically low yields. While rainfall data for Ghana were available from 1960 onwards from the Ghana Meteorological Service (GMet), equivalent data were not available for crop yields. Given the limitations of this historical data, our decision about the trigger rainfall amounts for insurance payouts was made on the basis of our qualitative discussions with our Ghanaian partners and farmers. The value of per acre insurance payouts in case of catastrophically low yields was set to be equal to mean yields in the GLSS5+. We reduced product complexity to enhance farmer understanding and acknowledge that the simplicity came at the expense of increased basis risk.[10] The trigger for payouts was determined based on the number of dry or wet days in a month (where either too much or too little rainfall triggered a payout). The maximum payout amount was chosen in order to approximately cover 100% of a full loss, or roughly $145 per acre of maize grown.

We used five rainfall gauges in 2009. Appendix Table II provides summary statistics on distance to farmer homesteads in our sample and rainfall for each gauge, and Appendix Figure 2 provides a map of the area and location of communities and rain gauges in the study. The Ghana Meteorological

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the Northern Region, and in (Tamale Metropolitan / Savelugu-Nanton / West Mamprusi) district. As part of this research, you are invited to participate in a free rainfall protection plan called TAKAYUA Rainfall Insurance, which I would like to tell you about." Control group households were informed that others in their community had received grants but that limited resources did not allow everyone to receive one, and that the selection was random and thus fair to everyone.

[10] See Hill and Robles (2011) for an analysis and innovative approach using laboratory experiments to assess farmer perception of basis risk and insurance fit.

Association (GMet) provided rainfall data at all steps of the process: to inform development of both the NGO and private products and to provide close to real-time access to rainfall data.[11] The timing of payouts may also be critical, both to provide farmers needed cash to adjust their farming decisions based on rainfall realizations (Fafchamps 1993), as well as to generate trust in the insurance institutions. IPA had systems in place to receive the incoming rainfall data and check automatically for trigger events. In the case that a trigger event occurred, payouts were made no more than three to four week days after the data were available. Details of the insurance policy are provided in Appendix Table III.

Around March of 2009, we sent insurance marketers to visit individually with those farmers selected to receive the insurance offer. Each farmer was offered a grant of insurance coverage for the number of acres they reported farming maize in the GLSS5+ baseline. The marketers described the insurance policy, left a copy of the policy document with each farmer and informed the farmer he would have approximately two weeks to decide whether to take up the offer. Marketers returned to each farmer two weeks after this visit and issued a certficate to those farmers agreeing to take up the product. In this case, where the product was offered at no cost, 100 percent of farmers took it up.

A total of 230 policies were issued to farmers free of cost, covering a total of 1,159.5 acres, for an average of about five acres per farmer. One payout was made to 171 farmers in July of 2009 at $85 per acre. The average payout was $350 per farmer, conditional on receiving a payout.

3.3 Year One: Cash Grant Design

For those in the cash grant treatment, we first announced the grant and explained similarly as the insurance grant: a collaboration between IPA and PAS to help smallholder farmers and learn more about farming in northern Ghana. We made three key design decisions concerning the cash grant treatment: the amount, the timing and whether to transfer in-kind goods or cash. The grant was fixed at $85 per acre which is the average harvest value per acre for farmes less than 15 acres in the GLASS5+ baseline, and averaged $420 per recipient. We determined the amount with MoFA as the per acre cost of inputs and labor of the MoFA recommended maize farming practices in order to avoid any issues of possible nonconvexities in the production function at levels of inputs lower than the recommended practice.

For the timing, we decided to individualize delivery of the grant based on farmers' stated preferences and intentions about use of the grant. Thus, if they reported half would go to seed and half to labor for harvest, half the cash would be delivered before the planting period and half before harvest. Beyond

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[11] All rain gauges were managed by unbiased GMet employees, who recorded daily rainfall measurements on paper that were converted into electronic datasets by the main GMet office. Electronic rainfall data arrived in 10-day (dekad) chunks, typically 10-20 days after they had been recorded.

timing the cash to coincide with their stated use, we did nothing to impose compliance, i.e., we did not tell them they must use it for what they said, nor did we verify or tell them we would verify the purchases. Of course, we cannot control what they thought or how they thought their behaviors might influence possible future grants. Finally, we decided to give grants in cash rather than in kind. This was done in order to allow the farmers to use the resources in what they considered their highest return activities, regardless of what they initially said they would do with the funds. Due to budget constraints, we were unable to randomize the implementation of the grant in order to test the effect of the various options on amount, timing and cash vs. in-kind delivery.

3.4 Year Two: Expanded Sample Frame for Insurance Product Pricing Experiment

For year two, we expanded the sample frame in order to conduct an insurance pricing experiment. The second year insurance coverage was also redesigned and renamed to *Takayua* (which means “umbrella” in the local Dagbani language) and calibrated to trigger per-acre payouts after seven or more consecutive “wet” days (over 1mm of rainfall) or after twelve or more consecutive “dry” days (1mm or less rainfall). Payouts under *Takayua* were promised to be delivered two weeks after the dry or wet spell had been broken. We used rainfall data from the prior 33 years to determine pricing, although 10 of those 33 years did not have complete rainfall data for all rainfall gauges.

The pricing experiment included the grant experiment sample from year one, as well as two new samples: new households drawn from the grant experiment communities (Sample Frame 2) and entirely new communities (Sample Frame 3). The price was randomized at the community level in order to facilitate communication and avoid confusion that would result from offering insurance at different price levels within a single community, but every community also had control group farmers without access to the insurance. This randomization was at the household level.

For Sample Frame 2, the expansion in communities already part of the Grant Experiment, we first conducted a census in order to select additional households for the sample. Using our census, we applied the same filter as in the Grant Experiment (maize farmers with fewer than 15 acres). This yielded 676 additional households. We then randomly assigned each community to be sold the insurance product at a price of either GHC 1 or GHC 4 ($1.30 or $5.25) and then randomly drew 867 of the 1,178 in Sample Frame 1 and 2 to be sold the insurance. We put the remaining 311 in a control group of individuals not offered the insurance.[12] Both prices represent considerable subsidies, as the actuarially

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[12] Throughout the paper, we use the PPP exchange rate of 0.6953 Ghana Cedi (GHC) to US$1 for 2009, 0.7574 for 2010, and 0.7983 for 2011 (World Bank, 2011).

fair price was about 7.65 GHC ($9.58) per acre.[13] Offers were made in November 2009, and we sold 402 out of 475 offered at 1 GHC and 261 out of 392 offered at 4 GHC.

For Sample Frame 3, we expanded to new communities and used this sample frame to test actuarially fair and market-based prices for the same insurance product. First, we randomly selected 12 new communities from maps of the areas that delineated all communities within 30 kilometers of one of the rain gauges. We then completed a census in each community and filtered the sample using the same criteria as the grant experiment (maize farmers with fewer than 15 acres). We drew 228 households (19 per community) into the sample. We then randomly assigned each community to receive insurance marketing at near the actuarially fair price (GHC 8 or GHC 9.5, equivalent to $10.50 or $12.50, depending on the rain gauge to which the community was assigned) or the estimated price in a competitive market (GHC 12 or GHC 14, equivalent to $15.85 or $18.50, depending on the rain gauge).[14] Offering the insurance product at several prices, including at the estimated actuarially fair and competitive market prices, allowed us to measure demand for the product at different prices and to further refine a demand curve for rainfall index insurance in the region. Offers were made in March 2010. Each farmer was visited up to four times as part of the marketing. During the first visit, a marketer educated individual respondents about the *Takayua* product and its price. If the farmer was interested in purchasing, during the second visit a marketer returned to sign contracts and collect premiums. During the third visit, a marketer issued a physical policyholder certificate, including details on the policyholder and acreage covered. During the fourth visit, an auditor from IPA verified understanding of the terms and conditions of *Takayua* with about 10 percent of farmers who tookup the product.[15]

3.5 Year One Followup Survey /Year Two Baseline Survey

In January through March 2010, we attempted to survey 1,178 farmers, the union of the 502 households in Sample 1 (the Grant Experiment) and 676 households in Sample 2 (the year two Pricing Experiment

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[13] Thus the actuarially fair value of a unit of insurance decreased considerably from year one to year two. The main benefit of lowering the actuarial value is that it provides farmers more variation to choose (since the unit of an acre is the smallest unit sold, for marketing and simplicity purposes). However, also note that because insurance in the first year grant experiment had a price of zero, the actuarially fair value of a unit of that insurance is arbitrary; only the aggregate value of what we gave matter, not whether the policy is more (less) generous for fewer (more) acres. This is a result of index insurance not being tied to actual plots (as opposed to crop insurance).

[14] We discuss more on distribution costs in the discussion, but this is close to the load factor of 70% found in the India market (Giné, Townsend, and Vickery 2007).

[15] To better understand farmers' comprehension of the policies and learn about their perceptions of basis risk, we also conducted a post-harvest survey with 672 of 729 *Takayua* policyholders after the year two harvest. 97.9 percent of the treatment group indicated willingness to purchase the product again for the 2011 farming season.

farmers that were from existing communities).[16] We completed 1,087 of 1,178 surveys for an overall response rate of 92 percent.

These households are poor. For the control group, the median value of livestock holdings is about $450 and that of formal savings is zero. The value of grain stocks ranges from about $430 just after harvest to $0 before harvesting begins. Almost 70 percent state that they have missed meals over the past year because their family could not afford enough food.[17] Median harvest value is about $950; this is the amount at risk to crop failure in the event of a drought.

3.6 Year Two: Cash Grant Experiment

In the year two cash grant experiment conducted between May and June 2010, we repeated the cash grant to a newly randomized treatment group of 363 (out of 676) farmers from Sample Frame 2 (i.e., thus there was no overlap with those in the year one capital grant experiment). The cash grant was $462 per household, regardless of acreage, and the entire amount was given to the farmers at a single time.

3.7 Year Two: Insurance Payouts

Two of five rainfall stations triggered payouts totaling just over $100,000 in 2010. The Tamale (Pong) station measured eight consecutive wet days in late August, triggering a payout of $26 per acre to 125 individual farmers with 785 acres. The second payout was made when the Walewale station recorded 11 consecutive wet days in late September, triggering a payout of $66 per acre to 225 individual farmers with 1,254 acres. These payouts were made within two weeks of the trigger event.

3.8 Year Two: Follow-up Survey

In February and March 2011, we conducted a second follow-up survey targeting 1,406 households, the union of Sample 1 (the year one grant experiment), Sample 2 (the year one pricing experiment on households from villages in the Grant Experiment) and Sample 3 (the year one pricing experiment on households from new villages, i.e., no overlap with the Grant Experiment). We reached 1,252 of the 1,406 households, for an overall response rate of 89 percent.

In order to ensure data quality, the survey instrument was programmed to ask for confirmation of and updates to the previous year's data through preloading data about household members, plots,

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[16] The product pricing experiment in new communities took place immediately after this survey was completed, thus Sample 3 is included in the 2011 followup survey but not here. We dropped four farmers between years due to administrative error.

[17] For the subset of households that were observed in the GLSS5+ we observe that mean consumption per adult equivalent is about $2.05.

employment, assets, livestock and loans. The survey also asked for new data on areas, including harvests, crop storage and sales, chemical use, seed sources, ploughing, livestock, income, expenditures, assets, loans, agricultural processing, education, health, household enterprise and formal employment.

3.9 Year Three: Commercial Product and Pricing Experiment

In May 2011, we negotiated a partnership with the Ghana Agricultural Insurance Programme (GAIP) to market GAIP's commercial drought-indexed insurance product, a product reinsured by Swiss Re and endorsed officially by the National Insurance Commission. Due to the increased complexity of the commercial product (compared to the original non-commercial product from years one and two), individual marketing scripts and protocols emphasized transparency about the product, named *Sanzali*, the Dagbani word for "drought." *Sanzali* was divided into three stages based on the maize plant's growth stage, and each stage included one or two types of drought triggers (cumulative rainfall levels over 10-day periods, or consecutive dry days). The *Sanzali* product was offered at an actuarially fair price of $7.90 per acre, as well as a subsidized price of $4.00 per acre and a market price of $11.90 per acre. The pricing assignments were randomized by community, with 23 communities (31.9 percent) in the market price cell, 23 communities (31.9 percent) in the actuarially fair and 26 communities (36.2 percent) in the subsdized price cell. Control farmers were randomized individually.

The same farmers from the year two pricing experiment were included in this year three pricing experiment. We offered insurance to 1,095 farmers and sold a total of 655 policies (59.8%). As with year two, each farmer was visited up to four times. Demand was 63.9% at the subsidized $4.00 per acre price, 55.6% at the actuarially fair GHC $7.90 per acre price and 40.0% at the market price GHC $11.90 per acre.

As with the second year, three to seven days after the marketing visit, IPA staff conducted audit visits with ten percent of the insurance group to test their comprehension of the product. Audit reports confirm that farmers had a clear understanding of the product, including complex ideas such as cumulative rainfall per dekad. IPA also conducted informal interviews to gain insight into how smallholders financed their insurance purchase, finding that smallholders made their purchases through informal loans, produce sales, gifts or small ruminant sales.

3.10 Year Three: Insurance Payout

The insurance product in year three (2011) did not trigger any payouts.[18]

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[18] Not reported in this paper, we conducted a notification experiment and harvest survey with the 572 *Sanzali* policyholders after the realization that there would be no payout, due to concern that silence may lead to longer

4. Capital Grants, Insurance and Investment

Figure 2 summarizes the consequences for farm investment of the randomized grant of either capital grants, rainfall index insurance or both.[19] The top left panel of Figure 2 shows that the CDF of total expenditures on the farms of households who received free insurance (with or without capital) is strongly shifted to the right of that of control group farmers and the capital-grant-only farmers.[20] The effects of insurance grants on total expenditure are not those that one would expect to see for farmers facing binding credit constraints. Farmers in the insurance group were promised future resources in some states of the world and given nothing up front. With binding credit constraints, this would have induced farmers to reduce investment on farming activities. Instead, we see a dramatic increase.

The top right panel of Figure 2 documents increased expenditures on farm chemicals, primarily fertilizer. Here both the insurance-only and capital-only treatments lead to similar shifts, and the treatment with both capital and insurance is roughly additive in the two components. For each of the three treatments, we can reject the hypothesis ($p<0.03$) that the treatment and control distributions are the same.

In the bottom left panel of Figure 2, we see that insurance also has a positive effect on the acres cultivated by farmers (the step pattern is driven by clustering at unit values of reported cultivated acres), but that there is no difference between the CDFs of area cultivated by the control and capital grant groups. The difference between the distributions is statistically different for the insurance and insurance plus capital groups versus the control group ($p<0.04$).

Harvests, shown in the bottom right panel of Figure 2, are higher for the group that received insurance than for the control group, but the difference is relatively small (about $120 at the 25th percentile, off a control group base of $475) and not statistically significant at conventional levels. However, the group that received both insurance and capital does have a CDF of harvest values that is distinctly shifted to the right of that of the control group ($190 at the 25th percentile). The Kolmogorov-Smirnov D statistic is 0.16 ($p=0.07$). We will discuss this pattern further below, where we argue that it and other evidence may reflect the salience of both basis risk and the impact of the capital grants on policyholders'

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term mistrust. Some policyholders were notified individually and others as part of a group about rainfall measurements recorded at their nearest rain gauge and about insurance outcomes.

[19] Note we restrict attention here to year one (Sample Frame One), when the insurance was granted. This allows for a straightforward interpretation of the CDF, whereas including year two would add complications because not all bought the insurance. In Section 6 we report the investment response in both years and show that it is similar.

[20] A Kolmogorov-Smirnov test rejects the equality of the insurance grant and control distributions ($p=0.05$).

expectations that insurance payouts will be made when trigger events occur. In none of the treatments is the increase in the value of output larger than the increase in total expenditures.

The index insurance product we designed had the feature that payouts would be made within three weeks of the realization of a trigger. Thus, some payouts happened midseason, not post-harvest. This leads to the natural question: Do the observed investment responses simply reflect the insurance payouts and not a behavioral response upon receiving the insurance contract? The bottom left panel of Figure 2 is important in this respect because cultivated area is determined during the plot preparation stage of the farming season, before any insurance payouts could be made. Thus, although we cannot rule out *any* later investments happening with the insurance proceeds from negative shocks, we do clearly observe behavioral response prior to any cash infusion.

5. Modeling the Demand for Insurance and Investment

In years two and three, we provided access to insurance at randomized prices for a random set of farmers. In year two, this insurance pricing experiment was crossed with the capital grants experiment The empirical results above lead us to focus the model on an environment in which farmers are not confronted with binding credit constraints but do face incomplete insurance. The second part of the model in the appendix shows how farmers in such an environment respond to treatments of (a) access to insurance at varying prices, (b) grants of capital and (c) their interaction.

First, we consider the demand for insurance and the average response of investment to access to insurance and to capital grants. If the index insurance product has no basis risk, farmers with access to actuarially fair insurance will fully insure and then invest in the risky and hedging inputs at the profit-maximizing level. At prices higher than actuarially fair, farmers will purchase less than full insurance, invest less in the risky input and invest more in the hedging input. As long as the demand for insurance is positive, access to the insurance market implies a neoclassical separation result in which investment in the risky and hedging inputs is independent of farmer preferences and wealth. This implies that investment is the same for those who receive a capital grant in addition to access to index insurance at a given price as for those who only receive access to insurance. At higher prices of insurance, demand falls to zero, at which point the separation result fails and the capital grant has the additional impact of increasing (decreasing) investment in the risky (hedging) input. We discuss more in sections 6.1 and 6.2.

Second, we examine the heterogeneous treatment effect of access to insurance at varying prices. The effect on investment of access to insurance for a given farmer varies with the insurance price: At higher prices for insurance, the demand for the risky input increases less and the demand for the hedging input decreases less. If farmers vary in their characteristics (e.g., if some are more risk averse than others), then making insurance available at a higher price induces a different set of farmers to purchase insurance than making insurance available at a lower price. In this case, the treatment effect at a given price varies across these different types. For the case of heterogeneous risk aversion, as the price of insurance rises, the set of farmers demanding insurance becomes more risk averse on average. At a given price of insurance, the effect of access to insurance on investment is larger for more risk-averse farmers. Therefore, the selection effect of the higher price offsets its direct demand effect. In the appendix, we show that the net treatment effect of varying price is ambiguous because it depends on the distribution of risk aversion in the population. In section 6.3 we examine the local average treatment effect of access to insurance at varying prices. This is an important point for treatment effect analysis that relies on random price variation to generate differential participation of any product or service.

The model then introduces basis risk and (mis)trust---two realistic aspects of actual index insurance products. Both introduce a divergence between insurance payouts and the realization of bad states. With basis risk, there is a state with a bad outcome for which there is no payout of the index insurance. With mistrust there is a bad state in which the realization of the index is such that a payout is obligated but not made. In either case, even actuarially fair insurance does not permit the farmer to achieve full insurance. We show that with constant absolute risk aversion, investment remains invariant to a capital grant even if there is basis risk or mistrust. However, with DARA, investment in the risky (hedging) input increases (decreases) with the capital grant. At any price of insurance, and for any conventional risk averse preferences, a decrease in basis risk or an increase in the farmer's trust that payouts will be made increases the demand for insurance, increases investment in the risky input and reduces investment in the hedging input.

Farmers may have varying degrees of trust that the insurance will make payouts in bad states of nature. Farmers with greater trust will experience larger treatment effects of access to insurance at any given price. At higher insurance prices, farmers with less trust that payouts will be made will disproportionately drop out of the pool of insurance purchasers. The qualitative process of selection is the same for heterogeneity in trust in the insurance product as we saw for risk aversion. In section 6.4, we examine two sources of information that might induce a change in trust: one's own experience with the index insurance and the experience of individuals in one's social network with the insurance.

6. Demand, Investment and Social Interactions

6.1 The Demand for Rainfall Index Insurance in Ghana

The random variation in the price at which farmers were eligible to purchase rainfall index insurance permits us to examine in a straightforward way the demand for this product. Figure 3 shows the fraction of farmers purchasing insurance as a function of the price of the insurance. The actuarially fair price of the insurance product was between 6 and 9 GHC per acre (depending upon the specific rainfall station). In contrast to Cole et al. (2012), we find demand did not drop off dramatically when a token price of 1 GHC per acre was charged. Even at actuarially fair prices, 40 percent to 50 percent of farmers purchased insurance. Demand falls to 10 percent to 20 percent of farmers at higher rates of 12 to 14 GHC per acre. Again in contrast to Cole et al. (2012), farmers are purchasing more than token amounts of insurance. On average, farmers who purchased insurance (at a price greater than zero) purchased coverage for more than 60 percent of their acreage. Figure 4 shows the fraction of acreage for which insurance was purchased at every price (including 0 for those who did not purchase insurance).

Column 1 of Table II is the regression analogue of Figure 6. The dependent variable is an indicator variable for obtaining insurance coverage. The regression includes all three years of data and, in addition to indicator variables for treatment status (the various prices and prices/capital grant combinations), includes indicator variables for year effects and year-sample stratification categories. The general pattern observed in Figure 3 is replicated.

There are two insurance prices (p=1 and p=4) at which some farmers received capital grants and others did not. At p=4, the quantity demanded is higher among those who received the capital grant (78 percent versus 70 percent, p-value = 0.01 from joint test of equality of coefficients at p=1 and p=4, reported at bottom of table). This contradicts the conclusion of section 5.2 above: With CARA preferences, insurance demand at a specific price should be independent of the capital grant. If farmers have decreasing absolute risk aversion, then the demand for insurance at a fixed price should be *smaller* for those farmers who received the capital grants.

A more encompassing theory is required to understand the higher demand for insurance by those with the capital grant than by those without the capital grant. First, insurance demand may increase with the capital grant if there are unobserved informal insurance mechanisms that guarantee a minimum consumption level. This would work through a wealth effect from the cash grant: The cash grant reduces the likelihood that this limited liability feature of the consumption allocation comes into play, thus increasing the effective risk aversion of farmers who are recipients of the capital grants. However, in

Table II, Column 2 we show that the demand for insurance, conditional on the insurance price, is uncorrelated with baseline household non-land wealth. We divide our measure of wealth by 250 GHC so that wealth is measured in “capital grant units” to ease comparison across Columns 1 and 2, and the result is a point estimate of 0.00 and a standard error of 0.001. We return to this combination of results (that insurance demand increases with the receipt of a capital grant but is not correlated with household wealth) in section 6.4. Second, although the grants had not been paid at the time of insurance purchase, the expectation of the grant may have made individuals more likely to use available cash for the insurance, rather than investment in the farm. This seems implausible to explain the result, however, given the low cost of insurance (1 or 4 GHC per acre) relative to expenditures on risky inputs. Third, an “experimenter (or NGO) effect” may have occurred, in which individuals who received the grant were more likely to buy the insurance in order to reciprocate to the NGO for giving them the capital grant. Finally, if the receipt of a capital grant increases recipient farmers’ trust that payouts will be made on the index insurance when a trigger event occurs, then insurance demand will be higher at any price for those who receive a grant.

In Table II Columns 2-4, we limit the sample to the first two years of the data because those are the years for which we have information on farmer investment. In columns 1, 2 and 3, the dependent variable is equal to 1 if farmer *i* has insurance in year t and 0 otherwise. In column 4, the dependent variable is an indicator variable for whether the farmer has both insurance and a capital grant in year t. Columns 3 and 4, therefore, report the first stage estimates for the instrumental variables regressions we implement below. The instrumental variable specification requires one key assumption regarding the exclusion restriction: that the mere offer of insurance did not constitute a conveyance of information, such that even those who did not accept the offer of insurance shifted their existing beliefs regarding the marginal returns to agricultural investment. As the marketing of insurance was not delivered alongside any technical assistance on farming, we believe this is a reasonable assumption to make.

6.2 Investment and Insurance

Table3 presents estimates of the regression analogues of Figures 1-4, using the two years of data for which we have information on farmer investments. The regressions are

$$Y_{it} = \alpha_0 + \alpha_I I_{it} + \alpha_B I_{it} \cdot K_{it} + \alpha_K K_{it} + \alpha X_{it} + \varepsilon_{it}, \tag{1}$$

where I_{it} is an indicator variable that farmer i has rainfall index insurance in year t and K_{it} is an indicator that the farmer has a capital grant only in year t. X_{it} is a vector which includes indicator variables for the second year, the sampling strata and interactions of these. I_{it} is endogenous because it depends on farmer demand for insurance. We instrument using the randomized prices of insurance, interacted with an indicator of receiving a capital grant, as shown in Table II.

In Table III, we present the outcomes roughly chronologically, i.e., investment decisions that are *ex ante* with respect to rainfall realization then investments that are *ex post.* The ordering of columns 1-5 also corresponds to our *a priori* judgment of the extent to which these investments correspond to the risky input in our model. Columns 1 and 2 are unambiguously *ex-ante*: land preparation costs (largely tractor rental) and the number of acres cultivated. These are the investments for which the return likely is most sensitive to later rainfall realizations. For both, the insurance leads to large increases relative to the means of the control group farmers. Expenditure on chemicals (mostly fertilizer) is somewhat ambiguous with respect to timing of rainfall, as early-season rainfall is realized before fertilizer is applied. As with land preparation and number of acres cultivated, we observe a large increase relative to the control group mean. The timing of labor input is more temporally diffuse and may be more flexibly used depending on rainfall realization. The impact on wages paid to hired labor (Column 4) and the opportunity cost of family labor (Column 5, priced at gender-community-season- specific wages) is not significant statistically, but also large and similarly sized relative to the control group.[21] We do find one effect from the capital grant alone: Farmers who receive a capital grant alone have higher expenditures on chemicals compared to control group farmers ($56, se = 17), which is 13% of the average capital grant amount of $420. We also find an additive effect but just for chemical investments: Those who receive the capital and insurance invest $66 (se = 16) more than those who receive just the insurance. These increases in expenditure on chemicals associated with the capital grant are consistent with the model in section 2.2 for farmers with decreasing absolute risk aversion, although the magnitudes are strikingly large. We return to these results in section 6.4.

Farmers with insurance invest more in cultivation. Column 6 shows that total cultivation expenditure, inclusive of the value of household and exchange labor (valued at community-gender-season-specific wages), is $266 (se=134) higher for farmers with insurance than for farmers in the control group. Mean expenditure in the control group is $2058, so the magnitude of the increase associated with insurance is quite large. The point estimate of the additional investment associated with receiving a capital grant along with the insurance is positive but not statistically significantly different from zero ($72, se = 139). The point estimate of the joint effect of insurance and the capital grant is to increase investment by $338 (p-value = 0.02, reported in the final row of the table). The capital grant alone has no significant effect on investment ($2, se = 149). These results are consistent with those shown in Figure 2 and are

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[21] The measurement of family labor used on farms remains a significant empirical challenge for an annual retrospective survey. Future field work aims to address this more.

inconsistent with the presence of binding credit constraints. Farmers with insurance are able to find the resources to increase investment in their farms.

Column 7 reports that the total value of production may be higher for households with insurance, but the estimate is not statistically significant ($104, se = 81). The joint effect of insurance and a capital grant is large and significant ($234, p-value=0.01, from a control group mean of 1177). Even if statistically significant, the increase in the value of output is not sufficiently large to generate additional profits. In no group can we reject the hypothesis that the higher value of output after treatment is equal to the increase in total expenditure.

There are two important issues to keep in mind when interpreting results on farm profits (e.g., subtracting the effects in column 6 from those in column 7). First, the most important component of total costs is the value of household labor. But the market for hired labor is thin, and it is not clear that this observed wage is the appropriate opportunity cost of family labor.[22] This may be the most important reason for the observation that profits are typically negative in this and similar data from rural West Africa. (In our data, profits turn positive only at the 60th percentile of realized profits in the control group when family labor valued at gender-community-season specific wages, whereas profits turn positive at the 15th percentile of realized profits in the control group when family labor is valued at zero.) Second, we have data for only two years of cultivation outcomes, and the effect of additional investment in farm inputs on output depends upon the realization of aggregate weather shocks. The increase in harvest value that we observe with insurance and capital grants is conditional on this realization and may be higher or lower in other rainfall conditions (See Rosenzweig and Udry 2013).[23]

We conclude the discussion of Table III with a comparison of the treatment effect point estimates for insurance and capital. They are difficult to compare except through the lens of cost-effectiveness in a program evaluation. However, such a lens is not exactly right for insurance, since as we discuss in section 7.1 below there is demand for insurance at commercially viable prices. A similar point could be made regarding capital: A lending market, if viable, could alleviate capital constraints, but obviously a lending market would likely lead to less behavior change than giving out grants. Note that in a world in which both capital and insurance are fully subsidized, the cost of the rainfall insurance is an order of magnitude less than the cost of the capital grant, while the consequential behavior change is an order of

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[22] Similar results are found with respect to cows in India, where profits are positive only if family labor is valued at zero. See Anagol, Etang and Karlan (2013)

[23] In Table IV, we see that there is some variation in rainfall across the five rainfall gauges in our survey area, but this additional source of variation is modest because of the geographical proximity of all the stations.

magnitude more.[24] Hence the cost effectiveness is unambiguous and striking: If using subsidy money to generate higher farm investments, rainfall insurance grants are far more cost-effective than cash grants.

Next, in Table IV, we examine the riskiness of investment. We do this by using the same specification as in Column 7 of Table III, but adding independent variables for total rain and the interaction of total rain with treatment assignment. A positive coefficient on the interaction term, when predicting harvest value, implies farmers made investments that were more sensitive to rainfall if they had insurance. Table IV Column 1 shows that indeed this is the case: Insurance alone at zero rainfall leads to -$1,069 (se=596) lower output, and for each millimeter of rainfall the output increases by $157 (se=76) more for those with insurance than for those in the control group. With rainfall data in the range of 6 to 9 hundred millimeters, this implies that the impact of insurance on harvest value goes from -$127 to $344 from the low end range of rainfall to the high end. The increase in responsiveness of output to rainfall in the capital grant is less precisely estimated ($125, se = 84). Thus, it is difficult to draw similar conclusions for the shift in riskiness for those in the capital group. The additive effect for both insurance and capital over the direct effects of each is also imprecisely estimated but oppositely signed, creating an imprecisely estimated net null effect.

Column 2 of Table IV shows that insured farmers shifted the mix of their crops to highly rainfall-sensitive maize, the crop for which the insurance product was designed. Insured farmers increased the share of their land planted to maize by 9 percentage points (se=3, relative to a mean maize acreage of 31 percent in the control group). Capital grant recipients increased the share of their land planted with maize by 12 percentage points (se=3.4). Those who received both capital and insurance, however, did not shift more into maize production than those who received insurance alone (4 percentage points, se = 2.9).

Columns 3-6 of Table IV examine the responsiveness of investments in less risky inputs, corresponding to the hedging input in the model, to the insurance and capital grant treatments. In Column 3 we show that insured households reduce their income from fruit crops (primarily mango in this region) by $1.16 per week (se $0.66, mean weekly income in the control group is $1.84). Mango, the most important such crop, is very drought-resistant and yields badly when there is abundant rain due to fungal disease and pests (Sthapit and Scherr 2012). Columns 4-6 examine nonfarm enterprises, the returns from which may be less sensitive to rainfall risk than are the returns to rainfed agriculture itself. Column 4 shows that insured households that do not receive a capital grant are 6 percentage points less likely to have

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[24] If we use fertilizer as the outcome of interest (chosen also to be conservative, since we do find a positive treatment effect from the capital grant on fertilizer investment), then we find that a subsidy for rainfall insurance generates $2.49 more in fertilizer investment for every dollar of subsidy, whereas a subsidy of capital generates $0.22 (95% confidence interval is $0.09 to $0.36) more in fertilizer investment for every dollar of subsidy.

any non-farm income generating activity (se = 3.3 percentage points, relative to a mean of 26 percent in the control group). Likewise, Column 5 shows that insured households that do not receive a capital grant have on average 0.11 fewer members engaged in nonfarm occupations (se = 0.06, relative to a mean of 0.4 in the control group). Insured farmers shift the overall portfolio of their activities to take on more risk, specifically risk along the dimension covered by the rainfall index insurance.

In Table V we examine aggregate farm outcomes and household welfare outcomes. Column 1 reports the impact on the value of harvest (including own-consumed production), plus the value of any insurance payouts (net of the cost of the insurance premiums). Total revenue is $285 higher for farmers who are insured (se = $83, relative to mean of $1179 in the control group). There is no significant additional effect for those who received the capital grant as well as insurance, nor any effect for those who received the capital grant alone. Column 2 examines the postharvest liquid real assets of farmers, which are comprised of the value of their livestock holdings and the value of their stocks of grain.[25] Postharvest assets are $529 higher for insured farmers (se = $231, relative to mean of $1761 in the control group). Farmers who received the capital grant hold $620 more assets in the postharvest period than the control group (se = $267). There is no significant additional effect for those farmers who received the capital grant as well as insurance.

For household welfare outcomes, we observe important changes in ability to absorb shocks (meals missed), and we do observe some of the capital grant money being used for utilities and reduced borrowing. Specifically, Column 4 reports 23 percent of control group respondents or another adult in their household having missed meals over the past 12 months because they could not afford enough food. This proportion is reduced by 8 percentage points (se = 3.3) among those who are insured, 8 percentage points among those who received a capital grant (se = 3.7) and by an additional 3 percentage points among those who received both (se = 3). We do not have a complete expenditure survey for the household, but Column 4 does aggregate what we do have: construction or housing improvement, clothing and footwear, ceremonial expenses, community levies and utilities. We do not find any statistically significant impact on this aggregate measure of household welfare. Examining three specific outcomes, utility expenditures (Column 5), school expenditures (Column 6) and borrowing (Column 7), we only find effects for the capital grant and insurance treatment group, with large increase in utility expenditures (p-value=0.023), school expenses (p-value = 0.159) and reduction in borrowing (p-

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[25] Both formal and informal financial borrowing and saving is unimportant in the study area, and because of its sensitivity we have approximately 200 nonresponses to questions on these. Replicating column 9 adding financial saving minus debt yields very similar estimates: postharvest assets are $631 (se=$260) higher for insured farmers and $702 (se=$298) higher for farmers who received the capital grant. There is no significant additional effect for those who received the cash grant along with insurance ($379, se=$252).

value=0.0003). The borrowing results for the insurance-only treatment group also tell us that the presence of the insurance did not itself generate higher demand for or supply of credit.

Table VI shows the heterogeneous effects of insurance and the capital grants across four key household characteristics. First, we consider pretreatment wealth. The interquartile range of wealth is approximately \$380. The effect of being insured on investment is approximately \$95 larger for a household at the 25th percentile of the wealth distribution than it is for a household at the 75th percentile. With decreasing absolute risk aversion, the introduction of insurance is associated with a larger increase in investment for households with a lower level of wealth. Similarly, we find that the impact of a capital grant is less as wealth increases, although this result is not statistically significant.

Three more interactions are explored in Columns 2-4. For the quarter of households headed by someone who can read, insurance is associated with a much larger but also imprecisely estimated investment than for the other three quarters of households in the sample (\$514, se = 251). Interpretation of this interaction is speculative, of course, but it may have something to do with the household's ability to understand the insurance product or with the level of communication and trust established between the insurance sales agents and the household head. Farm investments by older household heads are also less responsive to insurance than those of younger heads (-\$12, se=6.6, per year). This also may reflect the trust established with the young sales agents or greater confidence in financial innovations among younger household heads. There is no evidence of differential impacts of insurance according to the size of the household. In Column 5, we simultaneously examine all four of these interactions. The wealth and age interactions with insurance both remain approximately as large and retain their statistical significance.[26]

6.3 The Insurance Market, Heterogeneity, and Separation

In Table VII, we examine the effects of differential selection into the insured pool as the price changes as discussed in section 5.1, as well as the separation implications of the availability of insurance (see the model in the appendix). Recall that for a given farmer, the treatment effect on investment of the availability of insurance is smaller when the insurance is sold at a higher price. However, at higher prices, more risk-averse farmers differentially remain in the insured pool, and the treatment effects on investment of insurance availability are larger for these farmers. We show in Table VII that there is no strong evidence that one of these effects outweighs the other. To simplify the presentation, we consider

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[26] Appendix Table IV shows the same heterogeneity analysis as in Table VI, except just for the two unambiguously *ex-ante* investment decisions, land preparation costs and number of acres cultivated. Results are similar, with the exception of age, for which we do not find a statistically significant result from insurance, but we do from capital.

a binary classification of prices into “low” (price less than or equal to GHC 4) and “high” (greater than GHC 4). With a strict threshold at 90 percent, only for family labor can we reject the null hypothesis that the impact of insurance is the same at high prices and at low prices (p=0.05; the $\chi^2(1)$ test statistic for the equality of the effect at low and high prices is reported for each investment in the final row of the table). However, three other results are close: land preparation costs (p-value = 0.104) and hired labor (p-value = 0.151) and ultimately harvest value (p-value = 0.134). The treatment heterogeneity with respect to insurance prices apparently is different for these different inputs: increasing in price for land preparation costs and for hired labor but decreasing in price for family labor.

In one of the years of our intervention, capital grants were randomly allocated to some households who also had access to (randomly priced) insurance. Where there is no basis risk, investment choices are independent of preferences and wealth. Conditional on the insurance price and the physical characteristics of the farm, investment should also be orthogonal to household wealth, household demographics, lagged shocks to profits, off-farm employment or any other household characteristic. The concern is that such variables might be correlated with unobserved dimensions of land quality, which might affect the responsiveness of investment. The randomization of the capital grant ensures that in expectation there is no such correlation here. We show in column 3 that for those who purchase insurance at a low price, receipt of a capital grant is associated with a large and statistically significant increase in expenditure on farm chemicals ($66, se=16). This violates the separation result, underscoring the importance of basis risk for these farmers’ investment decisions.

We showed in section 5 that if households have CARA preferences, investment will be invariant to the capital grant even if there is basis risk. However, for more general preferences we can expect investment to be increasing in the capital grant when the farmer has access to insurance but there is basis risk. For example, with CRRA preferences investment will increase with the receipt of a capital grant. However, this increase is observed only for chemical purchases.

6.4 Learning, Social Interactions and the Demand for Insurance

We are motivated to explore an alternative hypothesis associated with the trustworthiness of insurance by our observation (Column 1 of Table II, test at bottom of table, F-stat = 5.939, p-value =0.003) that insurance purchases at a given price are higher for those farmers who received a cash grant (but *not* higher for wealthier households (Column 2)). This result is consistent with the hypothesis that farmers are not entirely confident that the promised insurance payouts will be made when trigger events occur (in the notation of 5.2, $\pi_N > 0$). If this concern is mitigated by the provision of the capital grant, then insurance demand and investment would respond as well.

There are alternative mechanisms that could increase the confidence of purchasers of insurance that π_N is small or zero. The two most obvious are one's own (good) experience with the insurance product or one's friends and neighbor's experience with the product. Therefore, we estimate

$$\begin{aligned} I_{it} = {} & \gamma_{IP} I_{i.t-1} Pay_{i,t-1} + \gamma_{NP} I_{i,t-1}(1 - Pay_{i,t-1}) + \gamma_{SP} S(Pay)^{j}_{i,t-1} + \gamma_{SNP} S(NoPay)^{j}_{i,t-1} \\ & + \gamma_{SK} S(Capital)^{j}_{i,t-1} + \gamma_{Pay} Pay_{i,t-1} + \gamma_{SN} Num^{j}_{i,t-1} + \gamma_{P} P_{it} + X_{it}\gamma + \nu_{it} \end{aligned} \quad . \tag{2}$$

$\mathrm{I}_{\mathrm{it-1}}$ is an indicator variable that farmer *i* had insurance in *t-1*. $\mathrm{Pay}_{\mathrm{i,t-1}}$ is an indicator variable that rainfall in the community of farmer *i* in *t-1* was such that there would have been an insurance payout in the community. $\mathrm{Num}^{j}_{i,t-1}$ is the number of individuals in farmer *i*'s social network of type *j* in *t-1*. $\mathrm{S(Pay)}^{j}_{i,t-1}$ is the fraction of members of that network who were insured and received a payout in *t-1*. $\mathrm{S(NoPay)}^{j}_{i,t-1}$ is the fraction of members of that network who were insured and did not receive an insurance payout in *t-1*. $\mathrm{S(Capital)}^{j}_{i,t-1}$ is the fraction of members of that network who received a capital grant in *t-1*. P_{it} is the price at which i is offered insurance. X_{it} is a vector which includes indicator variables for the second year, the sampling strata and interactions of these.

The interactions of $\mathrm{I}_{i,t-1}$ and $\mathrm{Pay}_{i,t-1}$ are instrumented with interactions of the randomized prices at which *i* was offered insurance in period *t-1* and whether a payout trigger event occurred for *i*. $\mathrm{S(Pay)}^{j}_{i,t-1}$ and $\mathrm{S(NoPay)}^{j}_{i,t-1}$ depend on the insurance demands of individuals within *i*'s network. They are instrumented with the share of individuals within *i*'s network (of type *j*) who were offered insurance at each of the randomized prices, times the occurrence of a payout trigger event.

Estimates of (26) are presented Table VIII. Each pair of columns represents estimates using a different definition of the social network. In the first, links are defined by pairs who have ever lent to or borrowed from each other; in the second, links are based on family relationships; and in the third, links are based on sharing advice regarding farming. For each network type, results are presented using first the number of acres worth of insurance purchased and second using a binary indicator of insurance take up.

The first notable pattern is that current demand for insurance is strongly associated with an individual's lagged experience with payouts. A farmer who had insurance in the previous year and received a payout purchases 0.61 to 0.88 acres more insurance than a farmer who did not have insurance in the past year (the mean amount of insurance purchased conditional on purchasing some insurance is 5.5 acres and is 2.5 acres unconditionally). The result is similar but less statistically significant for the binary outcome of take-up (Columns 2, 4 and 6; 4 to 5 percentage point increase in takeup over a mean take up rate of 44 percent among those offered insurance). Furthermore, and with important (and disturbing) implications for market development, a consistent and negative pattern is found for farmers who had insurance the prior year but did *not* receive a payout. These farmers purchased insurance for between 1.05 and 1.22 *fewer* acres than did farmers who did not have insurance in the previous year, and their take up of insurance was between 17 and 18 percentage points lower (all results significant with p-values < 0.01).

Our interpretation of this result is that farmers who receive a payout in *t-1* revise downward their estimate of π_N, the probability that a state will occur in which they should be paid but in which the insurer reneges, and that farmers who were insured but who do not receive a payout revise π_N upward. Similarly, farmers may be updating their priors (whether correctly or not) regarding the extent of basis risk in the contract. Unfortunately, it is difficult to examine variation in basis risk in this study. We do not have randomized placement of the rainfall gauges, as Mobarak and Rosenzweig (2012) do, and proximity to a rainfall gauge is correlated with market access, road quality and distance to cities, since the gauges are in principal towns in each area.[27]

The second notable pattern is that insurance demand is influenced by the payout experience of others within an individual's social network. For each of the three network definitions, an increase in the number of an individual's network members who had insurance and a payout last year is associated with an increase in the amount of insurance demanded and an increase in the take up of insurance. These effects are statistically and economically significant, but not as large as the effect from one's own experience. The number of acres purchased increases by 0.48 (se=0.23), 0.15 (se=0.07) and 0.13 (se=0.07) for each credit, familial relationship and farming peer who receives a payout, respectively. Similar effects are found when examining the probability of buying any insurance (Column 2, 4 and 6). However, we observe no deleterious effects of peers not receiving a payout: An increase in the number of peers who are insured and who do *not* receive a payout does not lower an individual's demand for insurance. It is possible that there is less discussion about the absence of payouts in these social networks than there is about the receipt of payouts.

There is also an increase in the demand for insurance associated with the share of one's extended family and farming information networks that received a capital grant in the previous year. This finding is in

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[27] Farmers in northern Ghana appear cognizant of this type of basis risk. With 675 households offered insurance in year two, we conducted a supplementary survey partly to assess their understanding of basis risk and the correlation of their rainfall with the rainfall of the nearest gauge. Ninety percent of the household heads listed too much or too little rain as the cause of most of their crop damage. Among those whose assigned rainfall station was within 10 miles of their farm, 51 percent thought that the rainfall pattern at the rainfall station is similar or very similar to the rainfall on their plots. But for households with plots further from the rainfall station, only 39 percent thought that the rainfall pattern at the station is similar to that on their plots.

accord with our earlier result (Table II) that one's own receipt of a capital grant increases demand for insurance. We interpret this pattern, as we did with one's own experience with the insurance, as providing evidence that there is not complete trust that payouts will be made and that the extent of this mistrust is influenced by the experience a farmer and his social network have had with the product.

Two alternative interpretations exist: an income effect and a behavioral recency bias. With incomplete insurance, farmers who received a payout last year could have a lower income than farmers who did not have insurance, and farmers who did not receive a payout could have a higher income than uninsured farmers. With increasing absolute risk aversion, that pattern could translate into changes in insurance demand with the signs we observe in Table VIII. This logic carries over to realizations within social networks, provided that there is (unobserved to us) risk-sharing within these networks.[28] The income effect interpretation, however, is not consistent with the finding that capital grants in one's social network increase insurance demand: unobserved transfers should reduce insurance demand.

A second possible alternative interpretation of these results is behavioral. Rainfall patterns in the semi-arid tropics of West Africa exhibit no serial correlation (Nicholson and Palao 1993). However, our results so far are consistent with farmers who act otherwise. The results are consistent with "recency bias," in which farmers who experienced a trigger event last year overestimate the probability of its reoccurrence this year and similarly farmers who did not experience a trigger event underestimate the probability of a payout this year.[29] The effect of community-level payout trigger events reported in Table VIII provides evidence that recency bias is indeed playing a role in insurance demand. This variable is an indicator equal to one if a rainfall event occurred last year that would have triggered an insurance payout to anyone with insurance in the respondent's community. We see that demand for insurance is significantly higher for individuals in communities that would have received a payout in the previous year. However, even conditional on trigger events occurring last year, both own experience with the insurance product and the experience of members of one's social network remain important determinants of insurance demand. Thus, both recency bias and the evolving degree of trust that payouts will be made when trigger events occur are important for the demand for index insurance.

This result can help explain why rainfall insurance markets are scant. Given the importance of basis risk, the main promise of rainfall insurance is to protect from the rare disasters, i.e., low-probability high-loss

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[28] We have data on informal transfers, and there is no evidence of transfers associated with the realization of insurance payouts. However, it is possible that there are transfers that are not recorded in our data. There is qualitative evidence from focus group discussions and informal conversations with respondents of the importance of informal transfers: narratives on the intervention say that some farmers finance insurance with loans from informal networks.

[29] Data from the United Stated, e.g., find such a bias for the purchase of flood insurance (Browne and Hoyt 2000).

events. Yet when payouts are rare, demand is harmed. This could partially explain why insurance firms have not historically offered rainfall index insurance. However, this should inspire experimentation (such as small payouts for less extreme outcomes) and other trust-building mechanisms.

7. Discussion of Results and Market Development

Combining our results with lessons from complementary research provides us with some guidance on the mechanisms driving rural financial markets and their failures. This helps companies, governments and other stakeholders who seek prescriptions for improved policies and for researchers who seek a better understanding of developing country agricultural capital and risk markets.

7.1 Demand

Prior studies have highlighted the rainfall insurance demand conundrum: Why is demand low, despite the evidence that risk shapes farmer behavior? In one of the first studies on the demand for rainfall insurance, Giné and Yang (2009) shows that when rainfall insurance is bundled with credit (and priced at the actuarially fair rate plus costs), demand for the credit actually falls. Their initial hypothesis was that the rainfall insurance should have made farmers *more* likely to take on risk, which would thus motivate higher levels of borrowing to invest in a new crop. To explain their finding, the authors conjecture that borrowers already had implicit insurance, in that they could default on their loan with bad rainfall shocks. Thus, the bundled insurance was actually overinsuring farmers, which likewise depressed demand for the bundled credit. More recent studies show that many factors drive demand, such as trust (Cole et al. (2012)), social networks (J. Cai 2012a), provision of financial literacy on insurance (J. Cai 2012a) and simple framing and marketing of the insurance (Cole et al. (2012)).

Price is a consistent driver of insurance demand and not simply due to liquidity. Mobarak and Rosenzweig (2012), the closest study to ours in terms of completeness of the range of prices tested, finds strikingly similar demand curves. They find 15 percent (versus 11 percent in our study) purchase at market prices; 38 percent (versus 42 percent in our study) purchase at a 50 percent discount (roughly actuarially fair prices); and 60 percent (versus 67 percent in our study) purchase at a 75 percent discount. Cole et al (2012) also find steep elasticities, although on a smaller range of prices.

The steep elasticity at prices above actuarially fair[30] suggests several areas for further research and policy exploration. We need to examine whether liquidity could explain the steep demand curve. The cash grant came *after* the insurance sales. This, combined with the fact that wealthier individuals do not

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[30] The mid-point arc elasticity from actuarially fair (p=8) to market price (p=14) is -2.0

exhibit flatter demand curves and the fact that the insurance-only treatment group in the Grant Experiment managed to increase investment substantially, suggests liquidity is not the driving factor.[31]

Given the evidence that experience and trust matter as well as price, there is a trade-off between products that provide payouts only in rare adverse events (and are thus lower price) and products that pay out frequently (and thus help resolve the problem of farmers dropping insurance due to rare payouts). Such approaches are not uncommon in developed countries either. For example, car insurance companies often reduce premiums when no claims have been made. (However, this pricing strategy also likely deals with adverse selection, not merely trust.)

7.2 Investment Response

The existing literature is light on evidence on investment response. Three exceptions to our knowledge in the recent literature are able to focus on investment response, and all find results similar to ours, i.e., that risk-taking and investment increase even absent any capital infusion. Cole et al. (2012) employs the same approach we do in the first year of our study, providing insurance at zero price. Thus, as long as individuals trust the insurance provider and basis risk is not too high (two nontrivial conditions, see Mobarak and Rosenzweig (2012) for evidence that basis risk matters), such grants provide an estimate of the impact on behavior from reducing risk with respect to rainfall on a general population, not just those who take-up at a positive price. H. Cai et al. (2010) similarly finds in China that insurance for sows leads to higher investment in sows for those who are willing to buy the insurance, and J. Cai (2012b) finds an increase in production area and borrowing, and a reduction in diversification and savings, for tobacco farmers from a government weather insurance program in China. We find that aggregate farm investment responds strongly positively to the insurance treatment, and that the mix of investment shits towards inputs that have returns that are highly correlated with the index that is insured. The availability of index insurance could have the opposite effect on aggregate investment in an environment in which farm investment is strongly weighted towards risk reduction (e.g., irrigation).

Despite the typical research and policy focus on capital constraints for smallholder farmers, we find weaker evidence that such constraints bind. There is a strong investment response from the insurance

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[31] Cole et al (2012) finds evidence that liquidity does matter (at least in combination with a mental accounting story in which transfers by an NGO “stick” to that context and such proceeds are more likely to be used when the NGO then offers to sell an item). Their survey payment drives up the demand for the insurance: when cash paid for survey completion equals the premium price, the take-up rate increased by 40 percentage points.

treatment even with no capital grant. The capital treatment does lead to a modest increase in cash expenditures but no overall increase in investment.[32]

Our results do not mean that capital constraints do not bind; they may mean that the risk-adjusted returns to investment in farming without insurance are lower than returns outside agriculture. Furthermore, the fact that the farmers respond so much to the insurance-only treatment implies that they anticipate an inability to smooth over time in the event of the realization of an adverse aggregate transitory rainfall shock (as explained in section 2.3). This implies capital and savings constraints bind when such shocks occur, although these were not realized during our study period.

7.3 Returns to Capital

We are not able to use our experiment to estimate the returns to capital, since labor inputs shift along with the provided capital. In the de Mel et al. (2008) capital grant experiment, labor inputs do not change, thus allowing an interpretation that they measure returns to capital. Here, labor inputs do change. Our lack of a separate instrument for labor means we cannot identify separately the return to labor and capital (similar to Beaman et al. (2013)). Even if the labor quantity remained the same, we would be concerned that the labor quality might change with the grant. Thus, our capital grant should be thought of as testing how investment behavior changes when capital constraints are relaxed.

7.4 Market Development

The insurance products and marketing processes evolved over the duration of the study, based on both observed farmer preferences and increasing national interest in growing a sustainable weather insurance industry. The distribution costs we employed here high, and not intended to be a demonstration of the potential supply-side model of delivery. The pricing was set using typical load factors in insurance markets (Giné, Townsend, and Vickery 2007), with recognition and expectation that if demand was shown to exist, the insurance marketing firms would determine the most cost effective marketing and distribution channels upon scale-up. This is indeed the rough path in which this market has been developing, with the newest channel of mobile money offering the lowest cost and thus likely most scalable opportunity for mass marketing.

Starting in year three, the partnerships with Ghana Agricultural Insurance Programme (GAIP) and Ghana Insurers Association (GIA), along with modifications to the product, have allowed for expanded market

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[32] This is a striking contrast to capital grant studies that have focused on businesses outside agriculture: e.g., de Mel et al (2008; 2009), which find a large investment response, although only an increase in profits for men, not women; Fafchamps et al (2011), which finds large investment response, but only with in-kind grants, and less so for cash grants; and Karlan et al (2013), which finds large investment response, but either no impact or negative impact on profits.

coverage. The year four product (i.e., after the results reported herein) differed, and only about 5 percent purchased. The year four implementation differed in several ways: (1) The product had higher expected payouts. (2) Marketing was done to entire communities with interactive sessions (thus avoiding the costly one-on-one marketing that was used in the first years of the study). (3) In order to test whether the presence of prior years' activities (and thus institutional trust) mattered, we expanded to new areas. (4) Due to operational constraints, the product was marketed later in the season than we believe optimal. As a result, by the time the product was offered, some rains had already begun and farmers had lowered their perceived likelihood of drought.

Year five is now beginning. Of particular concern to all stakeholders is the availability of good quality, real-time rainfall data. Due to the growing public and private interest in weather insurance in Ghana, GIA and GAIP are piloting two new approaches to data collection: automated weather stations and satellite data. Three automated weather stations have been installed in the study area and will be available for indexing. The associations have also partnered with the TAMSAT group (Tropical Applications of Meteorology using Satellite data and ground-based observations) at the University of Reading in order to determine the feasibility of satellite rainfall data. Both automated weather stations and satellite rainfall data are promising innovations for capturing high-quality real-time rainfall data and further reducing the cost of administering insurance and thus the premiums for smallholder farmers.

8. Conclusion

Risk matters. Of course, we are not the first to discuss this in theory or to show evidence of this. The market for rainfall insurance is rapidly advancing. For example, in India, over 9 million farmers have rainfall insurance, as part of a mandatory-for-borrowers and subsidized program (Dercon et al. 2012). The results we discuss in this paper advance our knowledge by looking at both capital and risk constraints for smallholder farmers. By tying the lessons to a model, we are able to understand more fully the underlying market failures that wreak havoc with the ability and willingness of the poor to invest more in their farms and increase their expected farm profits.

This paper also has an important lesson for the microcredit community, both researchers and practitioners. Although microcredit has traditionally focused on entrepreneurs, any lending in rural areas undoubtedly involves smallholder farmers. We learn here, however, that capital constraints alone are not the problem. Rather, risk is a key hindrance to investment and thus improved income and growth. Microcredit networks and infrastructure could be used to build better risk management tools. Although there has been some attempt at this, it has traditionally been life insurance, not rainfall or agricultural insurance of some sort. We learn here that mitigating risk alone, without an infusion of capital, leads to higher investment. Thus, the lesson should not be to simply bundle rainfall insurance with loans but rather to use the delivery infrastructure and perhaps the trust that microfinance institutions or banks may have in the community, in order to market and distribute rainfall insurance.

We (and others) focus on rainfall insurance because it does not have the adverse selection and moral hazard issues that are potentially problematic for crop or pest insurance. But index insurance necessarily involves basis risk. Further research is needed to understand how to overcome adverse selection and moral hazard problems in more general crop insurance. Forty years ago many conjectured that adverse selection and moral hazard made credit markets impossible to succeed for the poor, yet decades of innovation in microcredit has shown these to be mostly solvable problems. Similar innovation on business processes, monitoring system, and delivery vehicles to reduce information asymmetries and transaction costs might make possible more comprehensive insurance and thus dramatic welfare improvements for the poor. Here we have shown that risk, in general, hinders investment, and thus we conjecture that reducing other non-rainfall agricultural risk should lead to similar improvements in investment.

For rainfall or other index insurance, we note several key lessons and areas for further research. First, it is important to better understand the extent and implications for welfare of basis risk, and to improve product design and data infrastructure in order to improve the connection between insurance payouts and shocks to farm profits. Second, trust is a key issue, and this can be tackled through product design (increasing states of the world with payouts), proper linkage with trusted institutions and proper regulation. Third, and this is partly a research methods question that also has policy implications, we need to understand whether mental accounting is a key factor or not in the decision to purchase insurance. Understanding how “nudges” like framing, timing and bundling with other processes affect the decision to purchase insurance has implications for how insurance is sold (Thaler and Sunstein (2009)). Further tests could help illuminate this, for example by separating the liquidity shock entirely both in name (i.e., have it come from a separate entity) and in timing. Further ideas could involve bundling the insurance premium with input costs or selling through mobile operators in ways similar to existing sales of life insurance (“Tigo” 2012).

Ultimately, we see large investment responses to relaxing risk constraints. Thus, we conjecture that the rewards can be larger than the obstacles from a societal perspective. To have evidence rather than conjecture, we need further work that helps understand whether the impacts on farm profits are low due to measurement issues, heterogeneity, suboptimal investment decisions or additional constraints in complementary markets.

From a policy perspective, several important lessons come out of this study, and the progression of the market in Ghana we believe is enlightening. The new product is fully commercialized, underwritten and reinsured by Swiss Re, and the market pricing confirms that what we had put forward as market prices in the experiments reported in this paper were accurate. We see this work as demonstrating a proof of concept: that risk matters and thus products that help reduce risk will lead to higher investment. The next challenge is operational: to bring down costs of delivery and lower basis risk. Work is under way by the insurance companies to do just that, with distribution through mobile money and improvements in product design using remote sensing and more rainfall gauges.

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Appendix 1: The Model

Part One: The Grant Experiment

We provide a simple model that permits us to use the investment response to capital grants and/or the provision of insurance to draw conclusions about farmers' financial environments. A minimal model sufficient for this purpose includes two periods, production, risk and the appropriate financial markets. Preferences over consumption in the first period (c^0) and in the various states of the second period (c_s^1), with probability of state *s* equal to π_s and a discount factor β, are

$$u(c^0) + \beta \sum_{s \in S} \pi_s u(c_s^1). \tag{3}$$

We start with an environment with a perfect credit market and complete risk pooling. The household (with exogenous cash on hand *Y*) has access to a market on which it can buy (or sell) a risk-free asset (*a*) which earns (or pays) interest *R* $(= \frac{1}{\beta}$, to simplify notation later). The household is also a member of an informal risk sharing group which permits the efficient *ex-post* pooling of all risk. This informal risk sharing operates such that every household consumes the expected value of its second period consumption in any realized second period state.

The farmer has a concave production technology that provides second period output equal to $f_s(\mathbf{x})$ in state *s* after a vector of inputs ***x*** are committed in the first period. To simplify some of the notation which follows, we let there be only two states $s \in \{G, B\}$. We also assume that there are two types of inputs, x_r and x_h, such that the marginal product of a "risky" input (x_r) is lower in state B than in G, while the converse is true of the '"hedging" input (x_h.). To simplify and sharpen the contrast between risky and hedging investments, we make the extreme assumptions that the marginal return on x_r is zero in the bad state (B) and similarly for x_h in the good state (G), but this is not essential for any of our results. Thus, we assume that $f_G(\mathbf{x}) = A_G f(x_r)$ and $f_B(\mathbf{x}) = A_B f(x_h)$ with $A_G > A_B$.

Our empirical focus will largely be on the risky inputs, which comprise the inputs into farm production in northern Ghana. These include field preparation, fertilizer and pesticide use, weeding and cultivation activities, all of which have a higher return when growing conditions like rainfall are good.[33] This of course need not be the case for all agricultural investments in all parts of the world: Irrigation would be

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[33] The assumption that these inputs have a lower return in the low state corresponds to farmer accounts of their practices in northern Ghana, and there is agronomic support as well. See Amujoyegbe et al. (2007).

the archetypical hedging investment, i.e., a higher payoff in state B than in G, but there is no irrigation in our sample.

In anticipation of our two-pronged intervention, let *k* denote a cash grant provided to the farmer in the first period, and k_s denote a state-contingent payout promised if *s* occurs in the second period. *k* and k_s correspond to our experimental interventions providing grants of, respectively, capital and rainfall index insurance. We are not concerned here with changes in the price of inputs, so we choose units so that the price of each input is 1. Thus, the household maximizes (3) subject to

$$\begin{aligned} c^0 &= Y - x_r - x_{\mathrm{h}} - a + k \\ c_L^1 = c_H^1 = c^1 &= \sum_{s\in S} \pi_s \left(f_s(\mathbf{x}) + Ra + k_s \right) \\ \mathbf{x} &\geq 0 \end{aligned} \tag{4}$$

We have assumed that the risk pooling group is sufficiently diverse that there is no aggregate risk.[34] This extreme assumption serves to focus on the implications of binding credit constraints in the absence of any risk-based motivation for moving resources across periods. The household chooses i_s and x_s so that farm investment satisfies

$$q_G A_G \frac{\partial f(x_r)}{\partial x_r} = q_B A_B \frac{\partial f(x_h)}{\partial x_h} = 1 \tag{5}$$

for the inputs x_r and x_h. (We assume the Inada condition on $f(x_s)$ so that the non-negativity constraint on ***x*** never binds.)

With complete credit markets and full risk-pooling, farm investment is independent of resources (*Y*) and preferences: Investment is fully determined by equation (5), which depends only on the price of the state-contingent securities and the physical characteristics of the production function. Neither a capital grant nor an insurance policy has any influence on farm investment:

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[34] Thus all the rainfall risk is fully pooled: If a farmer realizes poor rainfall, he receives a transfer from the pool equal to $\left[\pi_H(f_H(\boldsymbol{x})+k_H)+\pi_L(f_L(\boldsymbol{x})+k_L)\right]-\left[f_L(\boldsymbol{x})+k_L\right]$. If the same farmer realizes good rainfall, he makes a transfer to the pool equal to $\left[f_H(\boldsymbol{x})+k_H\right]-\left[\pi_H(f_H(\boldsymbol{x})+k_H)+\pi_L(f_L(\boldsymbol{x})+k_L)\right]$. This is, of course, an idealized representation of risk pooling, but it corresponds to one particular Pareto efficient allocation of risk and is akin to the moral economy described by Scott (1976).

(6) $$\frac{dx_r}{dk} = \frac{dx_r}{dk_s} = \frac{dx_h}{dk} = \frac{dx_h}{dk_s} = 0.$$

We now introduce, in turn, capital constraints and incomplete insurance markets.

Capital Constraints

Suppose that borrowing is not possible: Add the constraint $a \geq 0$ to the constraint set. We will consider situations in which this constraint binds. Informal consumption pooling remains complete, so every household consumes the expected value of its consumption in any state. With $a \geq 0$ binding, the first order conditions become

(7) $$u'(c^0) > u'(c^1)$$

and

(8) $$u'(c^0) = \beta u'(c^1)\pi_G \frac{\partial f_G(x)}{\partial x_r} = \beta u'(c^1)\pi_B \frac{\partial f_B(x)}{\partial x_h}.$$

The implicit function theorem immediately implies

(9) $$\frac{dx_r}{dk}, \frac{dx_h}{dk} > 0 > \frac{dx_r}{dk_B}, \frac{dx_h}{dk_B}.$$

The capital grant reduces the shadow price of the binding borrowing constraint, raising the relative value of consumption in the future and therefore inducing higher investment in **x** (i.e., both x_r and x_h). In contrast, the promise of future resources, even in the bad state L, increases that shadow price and lowers the relative value of consumption in the future. Hence, investment in any input in **x** falls with promised contingent payments.

Imperfect Insurance

In the extreme, there is no informal risk pooling, so $c_s^1 = f_s(\boldsymbol{x}) + Ra + k_s$. The household chooses x_r such that

(10) $$R\left[\frac{\pi_B}{\pi_G}\frac{u'(c_B^1)}{u'(c_G^1)}+1\right]=\frac{\partial f_G(\boldsymbol{x})}{\partial x_r};$$

chooses x_h so that

(11) $$R\left[\frac{\pi_G}{\pi_B}\frac{u'(c_G^1)}{u'(c_B^1)}+1\right]=\frac{\partial f_B(x)}{\partial x_h};$$

and chooses *a* such that

(12) $$u'(c^0)=\pi_B u'(c_B^1)+\pi_G u'(c_G^1).$$

First, note that when insurance is absent and $f_G(\boldsymbol{x}) > f_B(\boldsymbol{x})$, then

(13) $$\pi_G\frac{\partial f_G(x)}{\partial x_r} > R > \pi_B\frac{\partial f_B(x)}{\partial x_h} \ .$$

Relative to (5) with complete markets, there is overinvestment in the hedging input and underinvestment in the risky input. Farmers will invest less than the profit maximizing amount in cultivated area, labor use and fertilizer, all examples of inputs that (to varying degrees) correspond to the risky input in this model. In contrast, farmers will invest more than the profit maximizing amount in hedging inputs like irrigation or drought resistant varieties (neither of which is available to farmers in our sample) or in orchards or nonfarm activities.

Let $\{a^*, x_r^*, x_h^*\}$ solve (10), (11) and (12) when k=0. If u(.) is CARA, then investment in either the risky input x_r or the hedging input x_h is invariant with respect to the capital grant *k,* but the amount invested in the risk-free asset *(a)* increases with the capital grant *k,* i.e., $a^{*k} > a^*$. $\{a^{*k}, x_r^*, x_h^*\}$ is optimal when $k>0$ because

$$c_G^1 - c_B^1 = f_G(\boldsymbol{x}^*) - k_B$$

and thus the ratios of marginal utilities in (10) and (11) are unaffected by *k*. In contrast, increases in promised payouts in the bad state decrease (increase) the LHS of (10) (the LHS of (11)). Therefore, with CARA preferences, the absence of informal insurance implies that $0=\frac{dx_r}{dk}<\frac{dx_r}{dk_B}$. Conversely, with

CARA preferences $0 = \frac{dx_h}{dk} > \frac{dx_h}{dk_B}$. The extreme conclusion that $\frac{dx_r}{dk} = \frac{dx_h}{dk} = 0$ relies on the CARA assumption. For the more reasonable case of decreasing absolute risk aversion, $\{a^{*k}, x_h^{*k}, x_r^{*k}\}$ with $x_r^{*k} > x_r^*$ and $x_h^{*k} < x_r^*$ solves (10)-(13) for $k > 0$ because the absolute degree of risk aversion falls as c_B^1 increases (and c_B^1 increases with a^{*k}). Thus, with imperfect insurance and decreasing absolute risk aversion we have

$$\frac{dx_r}{dk}, \frac{dx_r}{dk_B} > 0 > \frac{dx_h}{dk}, \frac{dx_h}{dk_B}. \tag{14}$$

Different mechanisms underlie the positive responses of risky investment in agriculture in response to the cash grant and the grant of index insurance. The cash grant increases cash on hand, saving in the safe asset and thus consumption in either state of the second period. With decreasing absolute risk aversion, this implies more investment in the risky input. Index insurance directly increases consumption in the low state of period 2, which implies greater investment in the risky input and less investment in the safe input.

Capital Constraints and Imperfect Insurance

With $a \geq 0$ binding, the marginal utility of consumption in period *0* remains strictly greater than the expected marginal utility in period *1* and the analogue to (8) remain first order conditions for **x**. Since $a = 0$, $c^0 = Y - x_h - x_r + k$ and $c_s^1 = f_s(\boldsymbol{x}) + k_s$. The implicit function theorem implies

$$\frac{dx_r}{dk}, \frac{dx_h}{dk} > 0 \geq \frac{dx_r}{dk_s}, \frac{dx_h}{dk_s}. \tag{15}$$

Part Two: The Demand for Insurance and Investment

The results of section 4 lead us to focus on an environment in which farmers are not confronted with binding credit constraints, but in which they do not have access to complete informal insurance mechanisms. We continue to consider a world with two states and examine the demand for rainfall index insurance at price *p* that pays off in state *B*. The household's budget constraints are now

$$c^0 = Y - a - x_r - x_h - pI \tag{16}$$

$$c_G^1 = f_G(\boldsymbol{x}) + Ra \tag{17}$$

$$c_B^1 = f_B(\boldsymbol{x}) + Ra + I\ . \tag{18}$$

In addition to non-negativity constraints on *c*, c_G, c_B, x_r and x_h, short sales of *I* are not feasible:

$$I \geq 0. \tag{19}$$

If the non-negativity constraints are not binding, the first order conditions for *I*, *a* and ***x*** are

$$\frac{u'(c^0)}{u'(c_B^1)} = \frac{\beta\pi_B}{p} \tag{20}$$

$$u'(c^0) = \pi_G u'(c_G^1) + \pi_B u'(c_B^1) \tag{21}$$

$$u'(c^0) = \beta\pi_G u'(c_G^1)\frac{\partial f_G(\boldsymbol{x})}{\partial x_r} \tag{22}$$

$$u'(c^0) = \beta\pi_B u'(c_B^1)\frac{\partial f_B(x)}{\partial x_h}. \tag{23}$$

If $p = \frac{\pi_B}{R}$ then the insurance is actuarially fair, (19) will not bind and we have the familiar result that $c^0 = c_B^1 = c_G^1$. In such a case, consumers demand full insurance and the expected return to investment in the risky agricultural activity is equal to R. However, index insurance is rarely actuarially fair, unless subsidized. Rather, it sells at a premium to cover the transaction and operations costs for the company if the market is competitive and also economic profits if non-competitive. When $p > \frac{\pi_B}{R}$, i.e., above actuarially fair, households demand less than full insurance and $c_B^1 < c^0 < c_G^1$. Therefore,

$$\pi_B \frac{\partial f_B(x)}{\partial x_h} < R < \pi_G \frac{\partial f_G(x)}{\partial x_r}. \tag{24}$$

Farm investment in the risky input is lower than it would be in the case of actuarially fair insurance, because the investment pays off more in the state in which resources are less valuable (and of course the converse for the hedging input). However, as long as insurance demand is positive, there is a separation result. Combining (20)-(23) we have for the risky input

$$\frac{R}{1-Rp} = \frac{\partial f_G(\boldsymbol{x})}{\partial x_r}. \tag{245}$$

Despite the fact that there is not full insurance and households are risk averse, production decisions are separable from preferences, wealth and from the riskiness of the farmer's land.[35] There is of course a $p^* > \frac{\pi_B}{R}$ such that insurance demand is zero and (19) binds for all $p \geq p^*$. In this case, the household equalizes the marginal utility of investing in inputs and in *a:*

$$\pi_G \frac{\partial f_G(\boldsymbol{x})}{\partial x_r} u'(c_G^1) = R\left(\pi_G u'(c_G^1) + \pi_B u'(c_B^1)\right) = \pi_B \frac{\partial f_B(\boldsymbol{x})}{\partial x_h} u'(c_B^1)$$

and the optimal choice of *x* depends upon household preferences and wealth. Separation of production decisions occurs only for households that purchase insurance.

Selection and Heterogeneous Treatment Effects

Consider a set of farmers characterized by varying coefficients of absolute risk aversion θ_i but otherwise identical. Let $x_r(\theta_i, p)$, $x_h(\theta_i, p)$ and $I(\theta_i, p)$ denote the input choices and insurance demand of type *i* at price *p*, respectively, and $x_r(\theta_i, c)$ and $x_h(\theta_i, c)$ be the input choices by type *i* without access to insurance (*c* for "control"). The treatment effect on the risky investment of access to insurance at price *p* for type *i* is

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[35] The analogous condition for the hedging input is $\frac{1}{p} = \frac{\partial f_B(\boldsymbol{x})}{\partial x_h}$.

$$T(\theta_i, p) = x_r(\theta_i, p) - x_r(\theta_i, c). \tag{26}$$

From (245), $T(\theta_i, p_1) \geq T(\theta_i, p_2)$ for $p_1 < p_2$, and the inequality is strict if $I(\theta_i, p_1) > 0$. That is, the treatment effect on risky farm investment by a specific farmer of making insurance available at a high price is (weakly) less than that of making insurance available at a lower price, although it is nonnegative at any price.

However, making insurance available at a higher price induces a different set of farmers to purchase insurance than making insurance available at a lower price, and the treatment effect at a given price varies across these different types. From (20)-(23) we have

$$\frac{u'(c_G^1)}{u'(c_B^1)} = e^{-\theta[f_G(x)-(f_B(x)-I)]} = \frac{\pi_B}{\pi_G}\frac{1-Rp}{Rp}. \tag{27}$$

If $\theta_1 > \theta_2$, and both types of farmers are purchasing insurance at price *p*, then $x_r(\theta_1, p) = x_r(\theta_2, p)$ and $I(\theta_2, p) > I(\theta_1, p)$. Unsurprisingly, the more risk-averse farmer purchases more insurance at every price *p*. Since this holds at every price, the price at which (19) binds for type *1* is greater than that for type *2*: $p_1^* > p_2^*$.

Consider treatment effects at p_{low} with $p_{low} < p_2^* < p_1^*$; at this price both types of farmer demand insurance when it is available. Since $x_r(\theta_1, c) < x_r(\theta_2, c)$ and $x_r(\theta_1, p_{low}) = x_r(\theta_2, p_{low})$, $T(\theta_1, p_{low}) > T(\theta_2, p_{low})$. If the population of farmers consists of these two types, an empirical estimate of the treatment effect at the low price will lie in between, depending upon the population shares of the two types.

Suppose $p_2^* < p_{med} < p_1^*$, so that only type *1* purchases insurance. In this case, $T(\theta_1, p_{med}) < T(\theta_1, p_{low})$, as argued above, i.e., the risky investment response of type *1* farmers is less if they gain access to insurance at a higher price. But this response may be greater than the response of type *2* farmers to insurance at a lower price. $T(\theta_1, p_{med}) > T(\theta_2, p_{low})$ if

$$x_r(\theta_2, c) - x_r(\theta_1, c) > x_r(\theta_2, p_{low}) - x_r(\theta_1, p_{med}) = x_r(\theta_1, p_{low}) - x_r(\theta_1, p_{med}),$$

which for given θ_1, θ_2 will be satisfied for $p_{med} - p_{low}$ sufficiently small. In this case, we have $T(\theta_2, p_{low}) < T(\theta_1, p_{med}) < T(\theta_1, p_{low})$, and the LATE estimate of the treatment effect of availability of insurance at the low price can be higher or lower than the LATE estimate of the treatment effect of insurance at the high price. The selection effect of the higher price can offset its direct demand effect, so the net treatment effect of varying price is ambiguous.

We have illustrated this heterogeneity with respect to variation in risk aversion across farmers. Similar results based on analogous reasoning can be obtained for other dimensions of heterogeneity. For example, farmers with land that is differentially risky will select into insurance differently. The selection process into insurance with respect to land heterogeneity will depend upon the form of the production function and in particular on how the marginal product of ***x*** varies with the riskiness of the land. We know of no evidence on this relationship; hence we have focused on heterogeneous risk aversion.

Basis Risk and Trust

Basis risk and (mis)trust are essential aspects of any actual index insurance product. Both introduce a divergence between insurance payouts and the realization of bad states. We introduce these ideas by adding a state *N* in which there is no payout, even though the bad state is realized. We suppose that $f_N(\boldsymbol{x}) = f_B(\boldsymbol{x})$. Thus, N can represent either basis risk (the risk the payout is not made due to differences between the farmer's realized rainfall and the rainfall measured by the insurer) or mistrust (the risk that the insurer reneges on his obligation to pay the farmer). $(1-\pi_G-\pi_B)=\pi_N$ is a measure of either the extent of basis risk or the degree of distrust in the insurance. Consumption in that state is

$$c_N^1 = f_N(\boldsymbol{x}) + Ra. \tag{28}$$

Given our assumption on f_N, we have $c_B^1 - c_N^1 = I > 0$. If the insurance is actuarially fair, $c^0 = c_B^1 > c_N^1$. The choice of the safe asset is governed by

$$u'(c^0) = \pi_G u'(c_G^1) + \pi_B u'(c_B^1) + (1-\pi_G-\pi_B)u'(c_N^1). \tag{29}$$

If the insurance is actuarially fair, then we have

$$c_G^1 > c^0 = c_B^1 > c_N^1 .$$

Farm investment in the risky input satisfies

$$\pi_G \frac{\partial f_G(\boldsymbol{x})}{\partial x_r} = \frac{Ru'(c^0)}{u'(c_G^1)} > R , \tag{30}$$

and x_r is lower than when there is no basis risk or mistrust.

With CARA preferences, investment in either the safe or risky input remains invariant to capital grants, even in the presence of basis risk or mistrust. The FOCs for x_r, x_h, *I* and *a* are (22), (23), (20) and (29). Consider a farmer's choices when offered alternative capital grants k^a or k^b with $k^b > k^a$. If $\{\mathbf{x}(k^a), I(k^a), a(k^a)\}$ satisfy the budget constraints ((16), (17), (18), (28)) and the FOCs, then $x_r(k^b) = x_r(k^a)$, $x_\mathrm{h}(k^b) = x_\mathrm{h}(k^a)$, $I(k^b) = I(k^a)$ and $a(k^b) = \dfrac{k^b - k^a}{R-1}$ are optimal for grant k^b. With decreasing absolute risk aversion, as in section 2, x_r increases (and x_h decreases) with larger capital grants.

Holding constant π_G, an increase in π_B represents an increase in a farmer's trust that a payout will be made in a bad state, either because basis risk falls or because trust increases. Consider a price such that insurance demand is positive. Since from (20)

(31) $$\frac{d\left(\dfrac{u'(c^0)}{u'(c_B^1)}\right)}{d\pi_B} = \frac{\beta}{p} > 0,$$

(29) implies

$$\frac{d\left(\dfrac{u'(c^0)}{u'(c_G^1)}\right)}{d\pi_B} < 0.$$

Hence, from (22),

(32) $$\frac{dx_r}{d\pi_B} > 0.$$

At any price of insurance, and for any conventional risk-averse preferences, a decrease in basis risk or an increase in the farmer's trust that payouts will be made increases investment. The decline in basis risk (increase in trust) *a fortiori* increases purchases of insurance: $c_G^1 - c_B^1$ declines as π_B increases, and $c_G^1 - c_B^1 = f_G(\mathbf{x}) - f_B(\mathbf{x}) + I$. The demand for insurance increases more than $f_G(\mathbf{x})$ as π_B increases.

Farmers may have varying degrees of trust that the insurance will make payouts in bad states of nature. If this is so, then the analysis in section 5.1 regarding heterogeneous treatment effects applies in this dimension as well. Farmers with greater trust will experience larger treatment effects of access to insurance at any given price (by (32)). At higher insurance prices, farmers with less trust that payouts will be made will disproportionately drop out of the pool of insurance purchasers (from (31)). The qualitative process of selection is the same for heterogeneity in trust in the insurance product as we saw for risk aversion. In section 6.4, we examine two sources of information that might induce a change in π_B : one's own experience with the index insurance and the experience of individuals in one's social network with the insurance.

FIGURE 1 SUMMARY OF IMPLICATIONS OF MARKET IMPERFECTIONS

	Market Environment		Predicted Change in Investment					
	Perfect Capital Markets	Perfect Risk Markets	Capital Grant Treatment Only		Insurance Grant Treatment Only		Capital & Insurance Grant Treatment	
			Risky Asset	Hedging Asset	Risky Asset	Hedging Asset	Risky Asset	Hedging Asset
1	Yes	Yes	0	0	0	0	0	0
2	No	Yes	++	++	-	-	+	+
3	Yes	No	+ [36]	- [37]	++	- -	++	- -
4	No	No	+	+	-	-	?	?

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[36] Small and positive via wealth effect, if DARA; zero if CARA.

[37] Small and negative via wealth effect, if DARA; zero if CARA.

Figure 2: Effect of Insurance and Cash Grants on Total Investment

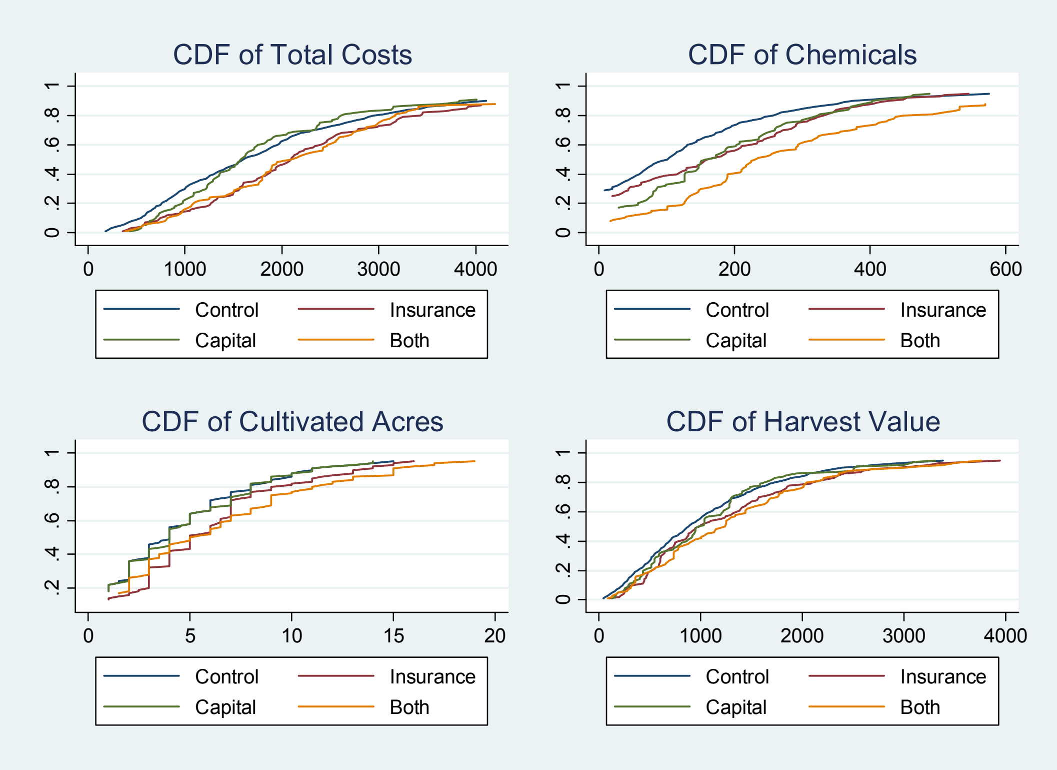
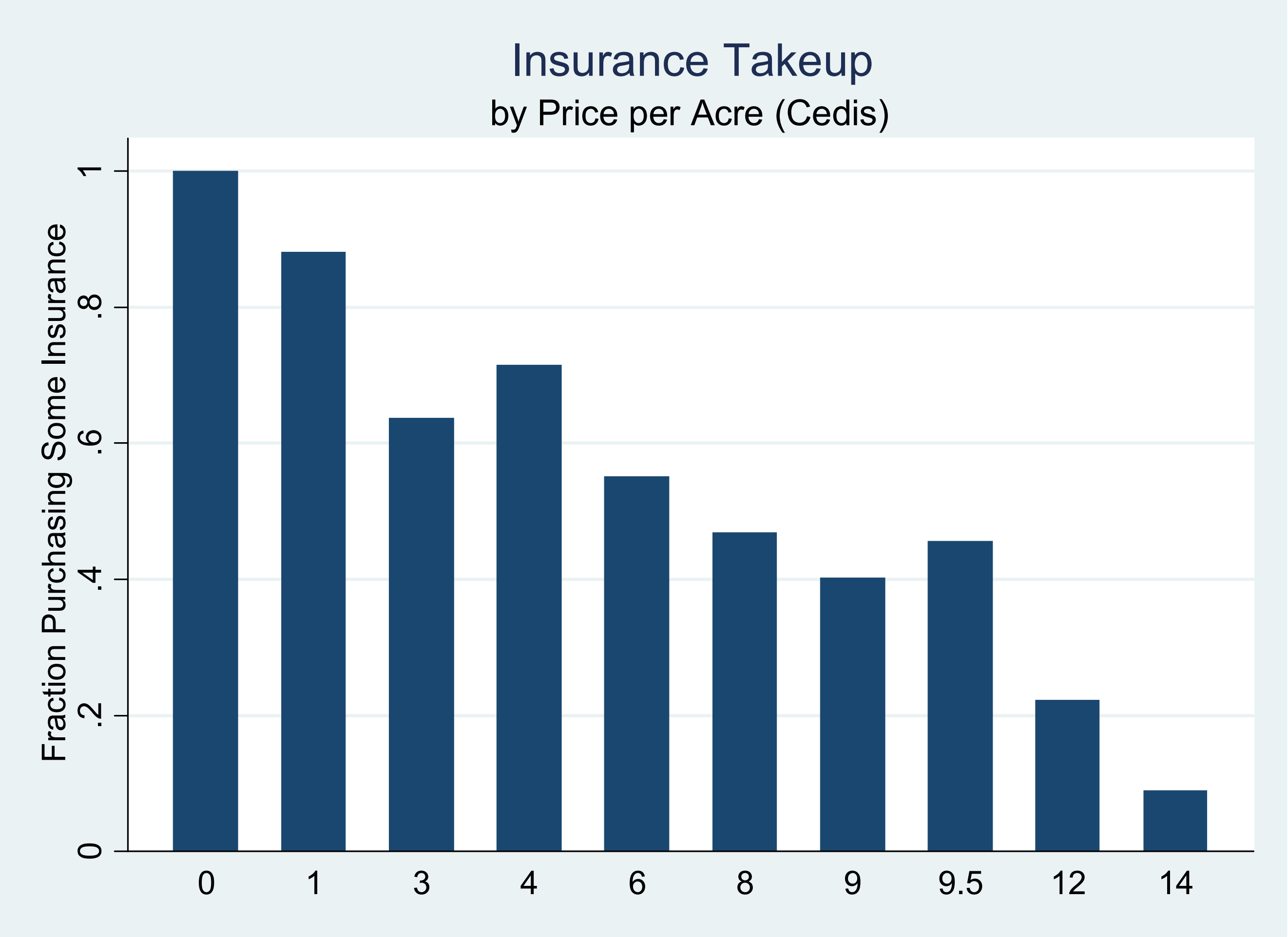
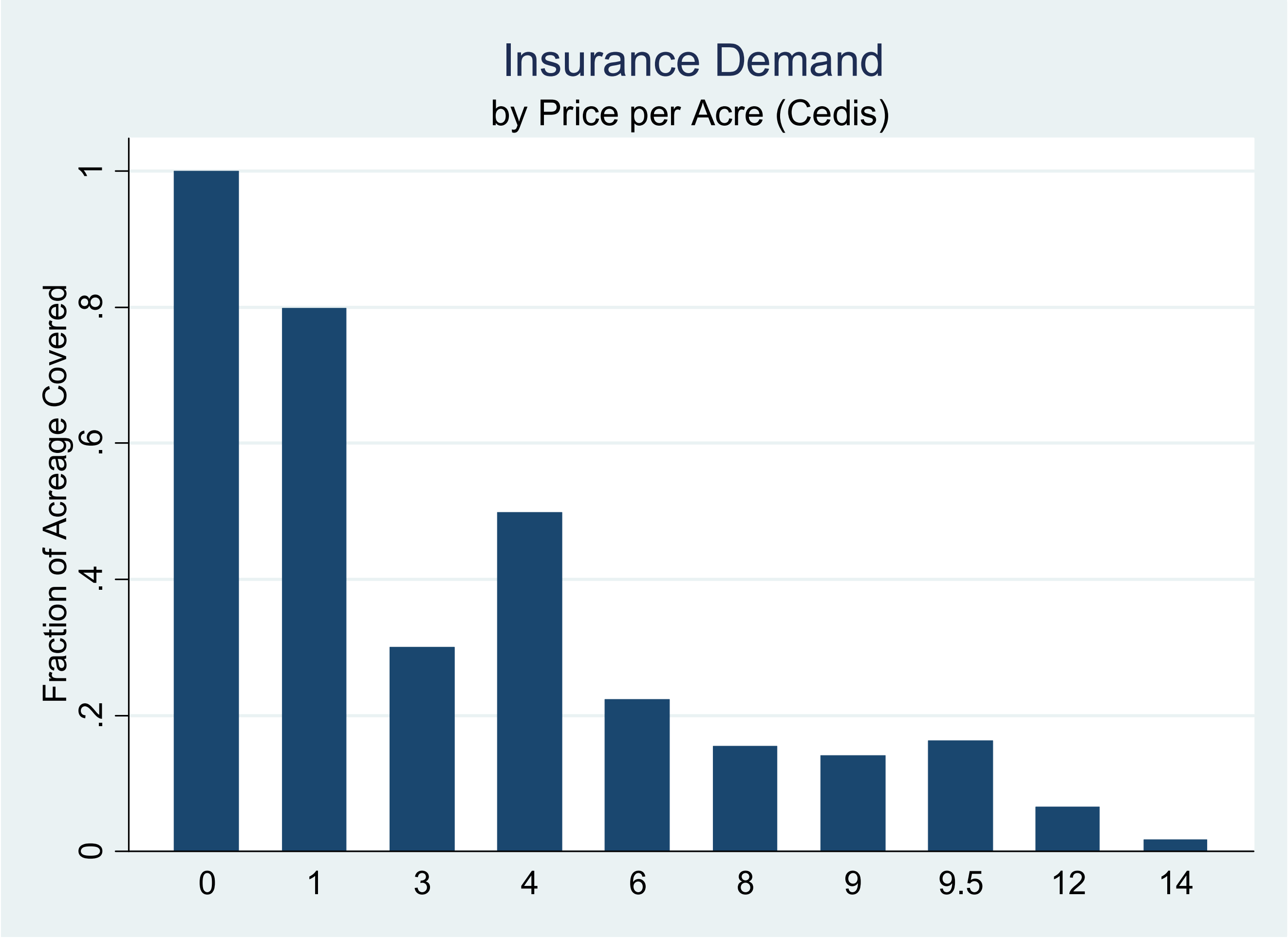


Figure 3: Insurance Take-up



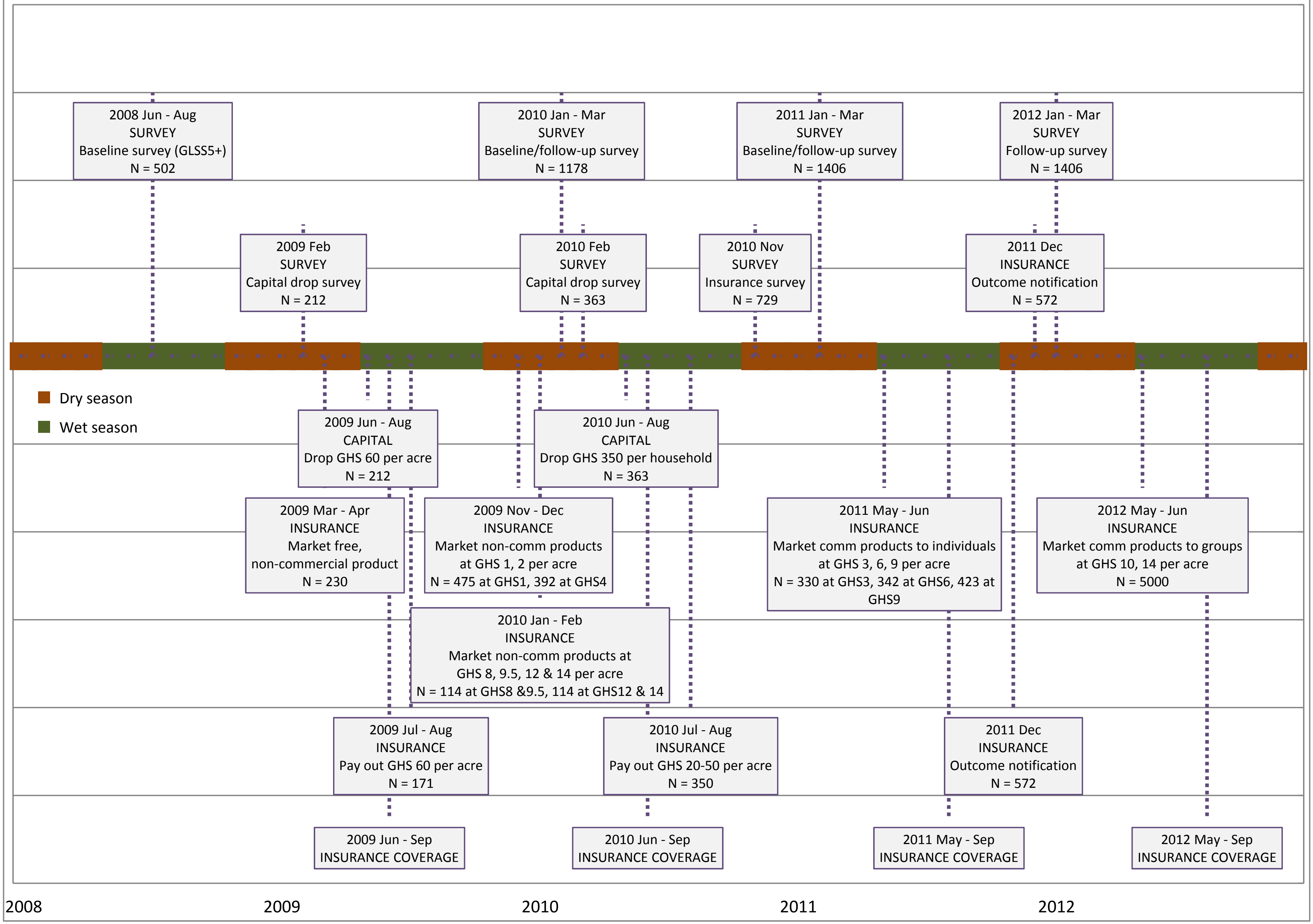
Note: Includes results from all three sample frames and years.

Figure 4: The Demand for Acres Insured



Note: Includes results from all three sample frames and years.

Appendix Figure 1: Timeline



Appendix Figure 2: Northern Ghana Map with Rainfall Gauges and Farms in Study

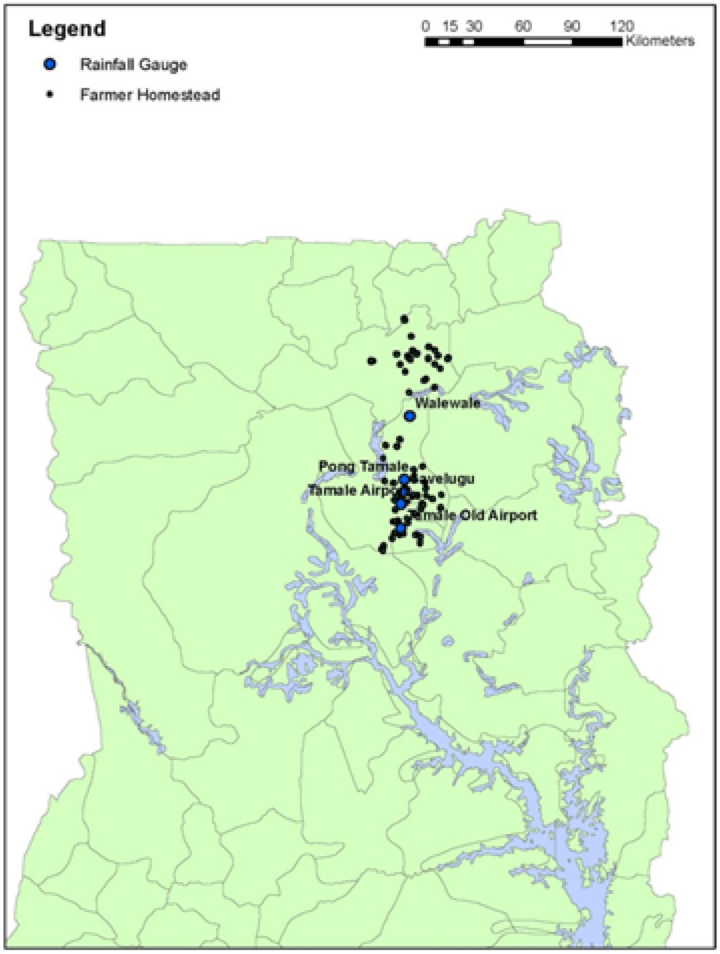


Table I: Baseline Statistics and Orthogonality Tests

Mean (standard errors)

	(1)	(2)	(3)	(4)	(5)	(7)	(8)	(9)	(10)	(11)
Data Source:	GLSS5+ (Baseline for Year 1 Grant Experiment)						Year 1 Followup Survey (Baseline for Year 2 Price Experiment)			
Year of Experiment:	Year 1						Year 2			
	All	Both Capital and Insurance	Capital	Insurance	Control	F-test (p-value) from regression of var on both, capital & insurance	Offered insurance @ 1 cedi	Offered insurance @ 4 cedis	Control	F-test (p-value) from regression of var on p=1/p=4
Household size	6.45	6.12	6.40	6.47	6.66	0.39	6.31	6.35	6.60	0.35
	(0.17)	(0.38)	(0.36)	(0.33)	(0.33)	(0.76)	(0.23)	(0.21)	(0.31)	(0.71)
Total acreage	7.80	8.44	7.33	8.17	7.43	1.49	6.26	5.03	6.29	2.78
	(0.21)	(0.67)	(0.37)	(0.39)	(0.35)	(0.22)	(0.44)	(0.37)	(0.57)	(0.06)
Cultivated acreage	7.02	7.31	6.75	7.17	6.91	0.40	4.59	4.17	5.00	1.00
	(0.19)	(0.53)	(0.36)	(0.32)	(0.33)	(0.75)	(0.36)	(0.36)	(0.43)	(0.37)
Total cost							1320	1118	1430	2.65
							(94)	(71)	(127)	(0.07)
Harvest value	234	301	182	226	238	1.97	794	647	764	2.07
	(16)	(55)	(22)	(22)	(30)	(0.12)	(62)	(44)	(62)	(0.13)
Chemical value	65	81	67	58	60	0.90	90	88	114	1.65
	(5)	(15)	(12)	(7)	(9)	(0.44)	(9)	(9)	(14)	(0.19)
Hired Labour							213	209	307	1.02
							(37)	(35)	(88)	(0.36)
Family Labour							901	720	883	2.24
							(77)	(52)	(76)	(0.11)
Head literate	0.15	0.15	0.15	0.13	0.18	0.58				
	(0.02)	(0.04)	(0.03)	(0.03)	(0.03)	(0.63)				
Head age	47.79	47.42	48.68	47.93	47.21	0.23				
	(0.68)	(1.55)	(1.45)	(1.31)	(1.22)	(0.88)				
F-test from regression of each treatment		1.49	0.71	0.46	1.03		1.59	1.48	0.70	
assignment on all above covariates		0.17	0.66	0.86	0.41		0.12	0.16	0.69	
Observations	502	95	117	135	155		268	258	150	

Standard errors in parentheses. Total cost, hired labour and family labour data not available from GLSS5+ survey. Note that the number of observations in columns 8-10 varies, depending on missing data for each row. Also, not reported, for Year 1, t-tests for all pairwise comparisons of each covariate (rows above) for any treatment versus control (1 test), each individual treatment versus control (3 tests) and each treatment against each other treatment (6 tests), for a total of 10 t-tests per covariates, and 70 tests in total. Of these 70 tests, only one tests rejects the null hypothesis of equality at the 10% statistical significance level: harvest value of Both Capital and Insurance versus Capital (p=0.03). Similarly, for Year 2, each covariate has 3 pairwise t-tests (p=1 vs p=4; p=1 vs control; p=4 vs control). Out of these 24 t-tests, eight fail: total acreage (1 vs 4, p=0.03; 4 vs control, p=0.05), total costs (1 vs 4, p=0.09, 4 vs control, p=0.02); harvest value (1 vs 4, p=0.06); chemical values (4 vs control, p=0.1); family wages (1 vs 4, p=0.05; 4 vs control, p=0.07)

Table II: Take-up of Insurance (First Stage)
OLS

	(1)	(2)	(3)	(4)
Dependent variable:	Insurance Takeup = 1	Insurance Takeup = 1	Insurance Takeup = 1	Insurance and Capital Takeup = 1
Insurance Price = 0	1.00***	1.00***	1.00***	
	(0.000)	(0.001)	(0.000)	
Insurance Price = 1	0.84***	0.89***	0.84***	
	(0.020)	(0.018)	(0.020)	
Insurance Price = 3	0.59***			
	(0.029)			
Insurance Price = 4	0.63***	0.70***	0.63***	
	(0.029)	(0.029)	(0.029)	
Insurance Price = 6	0.51***			
	(0.029)			
Insurance Price = 8	0.45***	0.47***	0.45***	
	(0.081)	(0.084)	(0.081)	
Insurance Price = 9	0.36***			
	(0.024)			
Insurance Price = 9.5	0.41***	0.42***	0.41***	
	(0.057)	(0.058)	(0.057)	
Insurance Price = 12	0.18***	0.17**	0.18***	
	(0.063)	(0.070)	(0.063)	
Insurance Price = 14	0.08**	0.09**	0.08**	
	(0.031)	(0.034)	(0.031)	
Insurance Price = 0 AND Capital Grant Treatment	1.00***	1.00***	1.00***	1.00
	(0.000)	(0.001)	(0.000)	(.)
Insurance Price = 1 AND Capital Grant Treatment	0.88***	0.88***	0.88***	0.87***
	(0.028)	(0.028)	(0.028)	(0.028)
Insurance Price = 4 AND Capital Grant Treatment	0.79***	0.78***	0.79***	0.78***
	(0.038)	(0.038)	(0.038)	(0.038)
Wealth at baseline (units = GHC wealth / average capital grant per household)		0.00		
		(0.001)		
Observations	3,314	1,801	1,908	1,908
R-squared	0.711	0.837	0.807	0.860
F-test: (insurance price=1)=(insurance price=1&CapitalGrant) & (insurance price=4)=(insurance price=4&CapitalGrant), i.e. whether demand differs at price = (1,4) for insurance with capital grant compared to demand at price = (1,4) without capital grant	5.941			
p-value	0.003			

Standard errors in parentheses, clustered at community-year (i.e., unit of randomization of insurance prices). Column 1 includes 3 years of demand data, whereas Columns 2-4 include only years 1 and 2 of demand data. Column 2 drops 107 observations due to missing wealth information. All specifications include controls for full set of sample frame and year interactions (thus no constant). *** p<0.01, ** p<0.05, * p<0.1.

Table III: Impact on Investment and Harvest

IV

Dependent variable:	(1) Land Preparation Costs	(2) # of Acres Cultivated	(3) Value of Chemicals Used	(4) Wages Paid to Hired Labor	(5) Opportunity Cost of Family Labor	(6) Total Costs	(7) Value of Harvest
Insured	25.53**	1.02**	37.90**	83.54	98.16	266.15**	104.27
	(12.064)	(0.420)	(14.854)	(59.623)	(84.349)	(134.229)	(81.198)
Insured * Capital Grant Treatment	15.77	0.26	66.44***	39.76	-52.65	72.14	129.24
	(13.040)	(0.445)	(15.674)	(65.040)	(86.100)	(138.640)	(81.389)
Capital Grant Treatment	15.36	0.09	55.63***	75.61	-130.56	2.44	64.82
	(13.361)	(0.480)	(17.274)	(68.914)	(92.217)	(148.553)	(89.764)
Constant	169.38***	8.12***	171.70***	201.88***	1,394.58***	2,033.11***	1,417.52***
	(10.603)	(0.399)	(13.804)	(45.383)	(84.786)	(124.294)	(90.635)
Observations	2,320	2,320	2,320	2,320	2,320	2,320	2,320
R-squared	0.017	0.143	0.041	0.005	0.006	0.009	0.012
Mean for Control	189.1	5.921	158.3	327.9	1302	2058	1177
Chi2-test of Insured and Insured + Capital Grant Treatment	8.889	7.125	36.15	3.136	0.239	5.091	6.618
p value	0.003	0.008	0.000	0.077	0.625	0.024	0.010

Robust standard errors in parentheses. "Insured" instrumented by full set of prices (Table 2, Column 1 presents first stage regressions). Total Costs (Column 6) includes sum of chemicals, land preparatory costs (e.g., equipment rental, but not labor), hired labor, and family labor (valued at gender/community/year specific wages). Harvest value includes own-produced consumption, valued at community-specific market value. All specifications include controls for full set of sample frame and year interactions. *** p<0.01, ** p<0.05, * p<0.1

Table IV: Reallocation of Investments

IV

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	Value of Harvest	Proportion of Land Planted with Maize	Average Weekly Orchard Income	Household Has Non-Farm Income Generating Activity (binary)	# of HH Members Working in Non-Farm Income Generating Activity	Average Weekly Enterprise Income
Insured	-1,069.13*	0.09***	-1.59*	-0.06*	-0.11*	-8.64
	(596.208)	(0.031)	(0.876)	(0.033)	(0.061)	(7.151)
Insured * Capital Grant Treatment	1,324.48	0.04	0.65	0.07**	0.16**	3.77
	(821.152)	(0.029)	(0.776)	(0.033)	(0.062)	(9.126)
Capital Grant Treatment	-879.77	0.12***	-0.19	-0.04	-0.08	-2.83
	(642.233)	(0.034)	(0.926)	(0.038)	(0.066)	(4.530)
Insured * Total Rainfall	156.82**					
	(76.291)					
Insured * Capital Grant Treatment * Total Rainfall	-155.36					
	(105.649)					
Capital Grant Treatment * Total Rainfall	124.95					
	(83.589)					
Total Rainfall (hundreds of millimeters)	2,247.39***					
	(624.545)					
Total Rainfall Squared	-146.65***					
	(40.970)					
Constant	-7,154.76***	0.23***	2.42***	0.17***	0.22***	5.79
	(2,375.086)	(0.016)	(0.613)	(0.027)	(0.038)	(4.363)
Observations	2,320	2,782	2,316	2,320	2,320	2,350
R-squared	0.021	0.090	0.001	0.007	0.010	0.007
Chi2 Test of Joint Effect of Insurance and Insurance + Capital	0.138	15.52	0.906	0.132	0.388	0.449
p value	0.710	8.16e-05	0.341	0.717	0.534	0.503
Mean for Control	1177	0.309	2.587	0.261	0.405	6.604

(Column 1) includes sum of chemicals, land preparatory costs (e.g., equipment rental, but not labor), hired labor, and family labor (valued at gender/community/year specific wages). Columns 4, 5 and 6 (regarding non-farm income) are derived from a survey question which asks if each person in the household "spent the most time during the past 12 months" (and if so, how many months) on fishing, construction, working as a hired agricultural laborer, working in non-farm labor, self-employed, employed in a household enterprise, or salaried regular employment. Harvest value includes own-consumed production, valued at community-specific market value. All specifications include controls for full set of sample frame and year interactions. *** p<0.01, ** p<0.05, * p<0.1

Table V: Income and Household Welfare
IV

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variable:	Total Farm Revenue (including insurance payouts, net of premiums)	Post Harvest Assets (livestock + grain)	Household Reports Having Missed a Meal in Past 12 Months (binary)	Total Expenditure in 12 Months	Utility Expenses in Past 12 Months	School Expenses in Past 12 Months	Borrowed in Past 12 Months from Any Source (binary)
Insured	284.98***	530.74**	-0.08**	46.39	0.36	-0.71	-0.00
	(82.991)	(230.839)	(0.033)	(58.767)	(7.102)	(15.872)	(0.025)
Insured * Capital Grant Treatment	109.13	310.66	-0.03	2.44	19.96**	25.83	-0.13***
	(84.446)	(229.150)	(0.030)	(58.568)	(8.444)	(16.111)	(0.033)
Capital Grant Treatment	66.93	606.12**	-0.08**	7.14	10.30	24.04	-0.06
	(90.585)	(266.636)	(0.037)	(61.540)	(8.268)	(18.841)	(0.040)
Constant	1,386.17***	1,782.29***	0.37***	470.10***	37.72***	107.94***	0.46***
	(91.209)	(223.471)	(0.035)	(43.073)	(5.768)	(12.632)	(0.035)
Observations	2,320	2,265	2,304	2,316	2,316	1,940	3,756
R-squared	0.023	0.007	0.013	0.015	0.050	0.032	0.203
Chi2 Test of Joint Effect of Insurance and Insurance + Capital	17.97	10.68	9.830	0.581	5.192	1.984	13.39
p value	0.0000225	0.00108	0.00172	0.446	0.0227	0.159	0.000253
Mean for Control	1179	1756	0.229	585.6	41.93	115.2	0.313

Robust standard errors in parentheses. "Insured" instrumented by full set of prices (Table 2, Column 1 presents first stage regressions). Column 4, total expenditures, includes the construction or housing improvement, clothing and footwear, ceremonial expenses, community levies, and utilities. All specifications include controls for full set of sample frame and year interactions. *** p<0.01, ** p<0.05, * p<0.1

Table VI: Investment Response, Heterogeneity with respect to Socioeconomic Covariates
IV

	(1)	(2)	(3)	(4)	(5)
Dependent Variable:	Total Farm Costs	Total Farm Costs	Total Farm Costs	Total Farm Costs	Total Farm Costs
Insured	403.45***	134.39	815.32***	274.53	583.28
	(144.513)	(144.590)	(312.240)	(259.810)	(366.383)
Insured * Capital Grant Treatment	-26.05	105.20	-293.93	150.82	-208.20
	(159.086)	(156.459)	(404.963)	(317.762)	(495.209)
Capital Grant Treatment	81.60	-92.89	670.04	-104.99	253.16
	(160.577)	(168.094)	(439.846)	(335.402)	(525.588)
Wealth * Insured	-0.25*				-0.22*
	(0.143)				(0.117)
Wealth * Insured * Capital Grant Treatment	0.15				0.17
	(0.171)				(0.141)
Wealth * Capital Grant Treatment	-0.17				-0.10
	(0.159)				(0.159)
Wealth	0.37***				0.27***
	(0.088)				(0.087)
Head of Household Can Read * Insured		513.73**			450.89*
		(250.582)			(247.289)
Head of Household Can Read * Insured * Capital Grant Treatment		-189.52			-142.59
		(322.897)			(325.800)
Head of Household Can Read * Capital Grant Treatment		303.82			224.09
		(277.620)			(264.053)
Head of Household Can Read		-76.70			0.02
		(119.606)			(117.837)
Head of Household Age * Insured			-12.00*		-11.90*
			(6.551)		(6.508)
Head of Household Age * Insured * Capital Grant Treatment			7.90		11.39
			(8.598)		(8.753)
Head of Household Age * Capital Grant Treatment			-14.98		-12.19
			(9.433)		(8.892)
Head of Household Age			10.72***		3.76
			(3.546)		(3.447)
Household Size * Insured				0.68	31.54
				(32.262)	(32.966)
Household Size * Insured * Capital Grant Treatment				-8.97	-42.12
				(43.019)	(43.713)
Household Size * Capital Grant Treatment				17.72	38.73
				(45.485)	(43.809)
Household Size				132.15***	115.83***
				(15.500)	(16.341)
Constant	2,002.98***	2,059.20***	1,637.39***	1,068.18***	990.09***
	(124.703)	(132.364)	(194.400)	(159.855)	(212.122)
Observations	2,318	2,320	2,289	2,289	2,288
R-squared	0.029	0.012	0.013	0.074	0.090
25th percentile of covariate	94.15	0	30	4	
Mean of covariate	458.0	0.283	43.34	6.846	
75th percentile of covariate	474.0	1	53	9	

Robust standard errors in parentheses. Sample size varies because of different number of missing values for each of the interaction covariates. "Insured" instrumented by full set of prices (Table 2, Column 1 presents first stage regressions). Total Costs (Column 1) includes sum of chemicals, land preparatory costs (e.g., equipment rental, but not labor), hired labor, and family labor (valued at gender/community/year specific wages). Harvest value includes own-consumed production, valued at community-specific market value. All specifications include controls for full set of sample frame and year interactions.*** p<0.01, ** p<0.05, * p<0.1

Table VII: Heterogeneous Investment Response Conditional on Selection Effects from Different Insurance Prices

	IV						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variable:	Land Preparation Costs	# of Acres Cultivated	Value of Chemicals Used	Wages Paid to Hired Labor	Opportunity Cost of Family Labor	Total Farm Costs	Value of Harvest
Insured at Low Price	22.52*	1.02**	37.79**	70.81	131.47	277.13**	132.83
	(12.371)	(0.428)	(15.118)	(61.057)	(85.847)	(136.950)	(81.910)
Insured at High Price	122.36**	1.10	40.95	447.09*	-856.22*	-47.91	-714.07
	(60.157)	(2.151)	(78.139)	(254.552)	(491.599)	(662.127)	(559.616)
Insured at Low Price * Capital Grant Treatment	16.97	0.26	66.46***	44.46	-65.05	68.05	118.58
	(13.158)	(0.446)	(15.700)	(65.224)	(86.343)	(139.018)	(81.473)
Constant	142.05***	8.10***	170.79***	98.72	1,665.24***	2,121.88***	1,649.33***
	(17.897)	(0.693)	(24.592)	(64.550)	(166.538)	(204.233)	(191.932)
Observations	2,320	2,320	2,320	2,320	2,320	2,320	2,320
F-test Insured at Low price = Insured at high price	2.643	0.00122	0.00158	2.066	3.917	0.231	2.242
p-value	0.104	0.972	0.968	0.151	0.0478	0.631	0.134

Robust standard errors in parentheses. "Insured at Low/High" instrumented by full set of low (0, 1 or 4) or high (above 4) prices . Total Costs (Column 1) includes sum of chemicals, land preparatory costs (e.g., equipment rental, but not labor), hired labor, and family labor (valued at gender/community/year specific wages). Harvest value includes own-consumed production, valued at community-specific market value. Controls included for capital grant treatment group and full set of sample frame and year interactions. *** p<0.01, ** p<0.05, * p<0.1

Table VIII: Dynamic Effects of Prior Year Experience and Social Networks

IV

	(1)	(2)	(3)	(4)	(5)	(6)
Social network definition:	Borrowed or Lent	Borrowed or Lent	Related	Related	Farming Advice Given or Received	Farming Advice Given or Received
Dependent variable:	# of Acres Insurance Purchased	Purchased Any Insurance	# of Acres Insurance Purchased	Purchased Any Insurance	# of Acres Insurance Purchased	Purchased Any Insurance
Insured * Received Payout in Prior Year	0.88***	0.05*	0.69**	0.04	0.61*	0.04
	(0.334)	(0.030)	(0.344)	(0.029)	(0.340)	(0.029)
Insured * Did Not Receive Payout in Prior Year	-1.22***	-0.18***	-1.11***	-0.17***	-1.05***	-0.17***
	(0.268)	(0.033)	(0.260)	(0.033)	(0.261)	(0.033)
# Insured in Social Network that Received Payout in Prior Year	0.48**	0.06***	0.15**	0.01	0.13**	0.01**
	(0.227)	(0.017)	(0.066)	(0.007)	(0.067)	(0.006)
# Insured in Social Network that Did Not Receive Payout in Prior Year	-0.14	-0.00	-0.01	-0.00	-0.07*	-0.00
	(0.128)	(0.017)	(0.041)	(0.005)	(0.039)	(0.005)
Eligible for Payout in Prior Year	0.89***	0.09***	0.77***	0.08***	0.72***	0.08***
	(0.172)	(0.022)	(0.179)	(0.023)	(0.179)	(0.023)
# in Social Network that Received a Capital Grant in Prior Year	0.28	0.04	0.27**	0.03**	0.16	0.04***
	(0.333)	(0.029)	(0.125)	(0.013)	(0.136)	(0.013)
Constant	4.14***	0.72***	4.26***	0.69***	4.22***	0.70***
	(0.346)	(0.039)	(0.372)	(0.043)	(0.364)	(0.042)
Observations	2,189	2,189	2,189	2,189	2,189	2,189
R-squared	0.362	0.291	0.363	0.299	0.366	0.298
Mean of Dependent Variable	2.467	0.444	2.467	0.444	2.467	0.444

Robust standard errors in parentheses. Includes demand data from years 2 and 3. "Insured" instrumented by full set of prices (Table 2, Column 1 presents first stage regressions). "# in Social Network Insured" instrumented by # of individuals in the network offered insurance at each price. All specifications Include control for current year price, current year price squared, capital grant treatment status, acreage owned by household, control group in prior year, household size reported in prior year, size of social network, and sample frame and year interactions. *** p<0.01, ** p<0.05, * p<0.1

Appendix Table I: Sample Frame Summaries
Observation Counts

Panel A: Experimental Cells	Sample Frame 1	Sample Frame 2	Sample Frame 3	Total
Communities:	Original communities	New households in same communities as SF1	New communities	
Year 1 Grant Experiment				
Capital grant	117	0	0	117
Insurance Grant	135	0	0	135
Capital + Insurance Grant	95	0	0	95
Control	155	0	0	155
Total	502	0	0	502
Year 2 Insurance Product Pricing Experiment				
p=1 (PPP $US 1.30)	207	268	0	475
p=4 (PPP $US 5.25)	134	258	0	392
p=8/9.5 (PPP $US 10.50/12.50)	0	0	114	114
p=12/14 (PPP $US 15.85/18.50)	0	0	114	114
Control	161	150	0	311
Total	502	676	228	1406
Year 2 Capital Grant Experiment				
Treatment	0	363	0	363
Control	0	313	0	313
Total	0	676	0	676
Year 3 Insurance Product Pricing Experiment				
p=3 GHC (PPP $US 4.00)	105	168	57	330
p=6 GHC (PPP $US 7.90)	110	175	57	342
p=9 GHC (PPP $US 11.90)	126	183	114	423
Control	161	150	0	311
Total	502	676	228	1406
Panel B: Surveys				
Year 1 Followup/Year 2 Baseline				
Targeted	502	676	0	1178
Completed	481	587	0	1068
Year 2 Followup Survey				
Targeted	502	676	228	1406
Completed	465	579	208	1252
Panel C: Sample Size Explanations for Each Table				
Table 2: First Stage & Takeup				
Column 1: yr 1 and 2 and 3	1506	1352	456	3314
Column 2: yr 1 and 2, non-missing wealth	970	623	208	1801
Column 3: yr 1 and 2	1004	676	228	1908
Column 4: yr 1 and 2	1004	676	228	1908
Table 3: IV Agric Investment/outcomes				
All columns	946	1166	208	2320
Table 4: Reallocation of Investments and Welfare Impacts				
Columns 1, 4, 5, 6 & 8	946	1166	208	2320
Column 2	988	1338	456	2782
Column 3	946	1163	207	2316
Column 7	944	1154	206	2304
Column 9	935	1134	196	2265
Table 5: Interactions				
Column 1: wealth	946	1165	207	2318
Column 2: household head reads	946	1166	208	2320
Column 3: household head age	946	1155	188	2289
Column 4: household size	946	1155	188	2289
Column 5: joint	946	1154	188	2288
Table 6: Heterogeneity with respect to prices	946	1166	208	2320
Table 7: Dynamic Effects & Social Networks	682	1051	456	2189

Appendix Table II: Homestead to Rainfall Gauge Distance Summary Statistics in 2009 & 2010

Gauge Location	(1) Mean Distance (km)	(2) Standard Deviation (km)	(3) Number of Farmers	(4) 2009 Mean Rainfall Amount (decimeters)	(5) 2010 Mean Rainfall Amount (decimeters)
Savelugu	8.36	7.15	264	6.74	-
Tamale Old Airport	6.69	3.56	171	7.02	-
Pong Tamale	11.98	6.42	392	6.12	6.05
Tamale Airport	13.37	7.64	469	7.44	5.97
Walewale	32.77	8.38	389	5.18	5.60

Appendix Table III: Summary of Insurance Product Terms

	Year One 2009 product	Year Two 2010 product	Year Three 2011 product	Post-Study Year 2012 product
Insurance Underwriter/Reinsurer	NGO	NGO	Reinsurance Company	Reinsurance Company
Product name	Takayua ("umbrella")	Takayua ("umbrella")	Sanzali ("drought")	Sapooli/Awor ("shortage of rain")
Actuarial price (s) per acre	GHC 33 (USD 47.45)	GHC 7.65 (USD 9.58)	GHC 6 (USD 7.90)	GHC 12 (USD 15.00)
Premium(s)per acre	GHC 0 (USD 0.00)	GHC 1 (USD 1.30)	GHC 3 (USD 4.00)	GHC 10 (USD 12.50)
		GHC 2 (USD 5.25)	GHC 6 (USD 7.90)	GHC 14 (USD 17.50)
		GHC 8 (USD 10.50)	GHC 9 (USD 11.90)	
		GHC 9.50 (USD 12.50)		
		GHC 12 (USD 15.85)		
		GHC 14 (USD 18.50)		
Max payout per acre	GHC 100 (USD	GHC 100 (USD	GHC 70 (USD 87.70)	GHC 100 (USD
Actual payout(s) per acre	GHC 20 (USD 28.75)	GHC 20 (USD 26.40)	GHC 0 (USD 0.00)	GHC 26.80 (USD 33.55)
	GHC 60 (USD 86.30)	GHC 50 (USD 66.00)		
Coverage window	June-September	June-September	May-September	May-September
Covers drought?	Yes	Yes	Yes	Yes
Covers flood?	Yes	Yes	No	No
Product detail (simplified)	Payout for 8 or fewer dry days, or 18 or more wet days, per month	Payout for 12 or more consecutive dry days, or 7 or more consecutive wet days, during coverage window	Payout for 13-16 or more consecutive dry days during germination stage, 12-16 or more dry days during crop growth stage, or fewer than 125 cumulative mm rainfall during flowering stage	Payout for 12-16 or more consecutive dry days during germination stage, 12-16 or more dry days during crop growth stage, or fewer than 125 cumulative mm rainfall during flowering stage

Column 4, the 2012 product, was not part of the empirical results in the paper but is included here as it is discussed in the Conclusion of the paper. We use the PPP exchange rate of GHS 0.6953 to USD 1 for 2009, 0.7574 for 2010, and 0.7983 for 2011 (World Bank, 2011). The World Bank's 2012 PPP exchange rates have not yet been released, so we use the 2011 rate for year 2012.

Appendix Table IV: Investment Response, Heterogeneity with respect to Socioeconomic Covariates

IV

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Dependent Variable:	Land Preparation Costs	Land Preparation Costs	Land Preparation Costs	Land Preparation Costs	Land Preparation Costs	# of Acres Cultivated	# of Acres Cultivated	# of Acres Cultivated	# of Acres Cultivated	# of Acres Cultivated
Insured	37.05***	13.19	48.45*	34.86	26.82	1.38***	0.48	1.76*	0.70	0.68
	(14.026)	(13.472)	(28.549)	(21.342)	(31.348)	(0.453)	(0.466)	(1.021)	(0.712)	(1.103)
Insured * Capital Grant Treatment	5.95	21.58	71.81*	-6.40	65.88	-0.18	0.50	1.14	-0.53	0.91
	(14.601)	(15.105)	(40.175)	(29.837)	(46.736)	(0.491)	(0.513)	(1.352)	(0.893)	(1.529)
Capital Grant Treatment	24.91	21.45	92.06**	10.45	79.77*	0.31	0.30	3.55**	0.31	3.05**
	(15.197)	(16.527)	(37.979)	(23.883)	(41.808)	(0.535)	(0.598)	(1.429)	(0.871)	(1.408)
Wealth * Insured	-0.02				-0.01	-0.00				-0.00
	(0.018)				(0.015)	(0.000)				(0.000)
Wealth * Insured * Capital Grant Treatment	0.01				0.01	0.00				0.00
	(0.018)				(0.017)	(0.001)				(0.000)
Wealth * Capital Grant Treatment	-0.02				-0.01	-0.00				-0.00
	(0.017)				(0.017)	(0.001)				(0.001)
Wealth	0.03***				0.02**	0.00***				0.00***
	(0.009)				(0.008)	(0.000)				(0.000)
Head of Household Can Read * Insured		48.80**			52.37**		1.98***			1.90***
		(22.139)			(21.724)		(0.741)			(0.710)
Head of Household Can Read * Insured * Capital Grant Treatment		-25.82			-42.30		-0.91			-1.22
		(29.555)			(29.740)		(1.010)			(0.995)
Head of Household Can Read * Capital Grant Treatment		-16.43			-23.35		-0.48			-0.87
		(22.793)			(22.000)		(0.778)			(0.722)
Head of Household Can Read		-15.90			-14.31		-1.53***			-1.33***
		(10.244)			(10.135)		(0.325)			(0.311)
Head of Household Age * Insured			-0.51		-0.18			-0.02		-0.02
			(0.601)		(0.613)			(0.021)		(0.021)
Head of Household Age * Insured * Capital Grant Treatment			-1.24		-1.40*			-0.02		-0.02
			(0.832)		(0.848)			(0.029)		(0.029)
Head of Household Age * Capital Grant Treatment			-1.74**		-1.54**			-0.08***		-0.07**
			(0.759)		(0.731)			(0.029)		(0.027)
Head of Household Age			0.31		-0.53*			0.03**		-0.01
			(0.314)		(0.300)			(0.012)		(0.011)
Household Size * Insured				-2.17	-0.54				0.04	0.11
				(2.835)	(3.006)				(0.095)	(0.098)
Household Size * Insured * Capital Grant Treatment				3.63	2.61				0.13	0.04
				(4.481)	(4.544)				(0.128)	(0.131)
Household Size * Capital Grant Treatment				0.31	2.23				-0.03	0.06
				(3.040)	(3.155)				(0.116)	(0.117)
Household Size				12.99***	12.53***				0.53***	0.48***
				(1.423)	(1.510)				(0.049)	(0.052)
Constant	166.54***	174.63***	158.14***	72.74***	100.72***	8.03***	8.61***	7.08***	4.08***	5.24***
	(10.828)	(11.386)	(16.526)	(13.971)	(18.506)	(0.402)	(0.424)	(0.647)	(0.474)	(0.663)
Observations	2,318	2,320	2,289	2,289	2,288	2,318	2,320	2,289	2,289	2,288
R-squared	0.034	0.021	0.020	0.084	0.106	0.186	0.153	0.150	0.245	0.283
25th percentile of covariate	94.15	0	30	4		94.15	0	30	4	
Mean of covariate	458.0	0.283	43.34	6.846		458.0	0.283	43.34	6.846	
75th percentile of covariate	474.0	1	53	9		474.0	1	53	9	

Robust standard errors in parentheses. Sample size varies because of different number of missing values for each of the interaction covariates. "Insured" instrumented by full set of prices (Table 2, Column 1 presents first stage regressions). Total Costs (Column 1) includes sum of chemicals, land preparatory costs (e.g., equipment rental, but not labor), hired labor, and family labor (valued at gender/community/year specific wages). Harvest value includes own-consumed production, valued at community-specific market value. All specifications include controls for full set of sample frame and year interactions.*** p<0.01, ** p<0.05, * p<0.1