$$\pi_H \frac{\partial f_H(x)}{\partial x} u'(c_H) = R\left(\pi_H u'(c_H) + \pi_L u'(c_L)\right)$$

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

5.1 Selection and Heterogeneous Treatment Effects

Consider a set of farmers characterized by varying coefficients of absolute risk aversion θ_i but otherwise identical. Let $x_i(p)$ and $I_i(p)$ denote the farm investment and insurance demand of type *i* at price *p*,respectively, and $x_i(a)$ be the farm investment by type *i* without access to insurance. The treatment effect of access to insurance at price *p* for type *i* is

(21) $$T_i(p) = x_i(p) - x_i(a).$$

From (20), $T_i(p_1) \geq T_i(p_2)$ for $p_1 < p_2$, and the inequality is strict if $I_i(p_1) > 0$. That is, the treatment effect on 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 (17)-(19) we have

(22) $$\frac{u'(c_H)}{u'(c_L)} = e^{-\theta[f_H(x)-(f_L-I)]} = \frac{\pi_L}{\pi_H}\frac{1-Rp}{Rp}.$$

If $\theta_1 > \theta_2$, and both types of farmers are purchasing insurance at price p, then $x_1(p) = x_2(p)$ and $I_2(p) > I_1(p)$. Unsurprisingly, the more risk averse farmer purchases more insurance at every price *p*. Since this holds at every price, the price at which (16) binds for type *1* is greater than that for type *2*: $p_1^* > p_2^*$.

Consider treatment effects at $p_L < p_2^* < p_1^*$; at this price both types of farmer demand insurance when it is available. Since $x_1(a) < x_2(a)$ and $x_1(p_L) = x_2(p_L)$, $T_1(p_L) > T_2(p_L)$. 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 $p_2^* < p_H < p_1^*$, so that only type 1 purchases insurance. $T_1(p_H) < T_1(p_L)$, as argued above, the 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. $T_1(p_H) > T_2(p_L)$ if

$$x_2(a) - x_1(a) > x_2(p_L) - x_1(p_H) = x_1(p_L) - x_1(p_H),$$

which for given $\theta_1, \ \theta_2$ will be satisfied for $p_H - p_L$ sufficiently small. In this case we have $T_2(p_L) < T_1(p_H) < T_1(p_L)$, 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, but similar results based on analogous reasoning can be obtained for other dimensions of heterogeneity as discussed below.

5.2 Basis Risk

An essential aspect of any actual index insurance product is basis risk. Insurance payouts are not identical with the realization of bad states. We introduce basis risk by adding a state *N* in which there is no payout. We suppose that $f_N(x) = f_L(x)$; this is not necessary for the analysis but is convenient for reasons that will become apparent in the next subsection. Consumption in that state is

(23) $$c_N = f_N(x) + Ra.$$

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

(24) $$u'(c) = \pi_H u'(c_H) + \pi_L u'(c_L) + (1 - \pi_H - \pi_L) u'(c_N).$$

If the insurance is actuarially fair, then, we have

$$c_H > c = c_L > c_N \ .$$

Farm investment satisfies

(25) $$\pi_H \frac{\partial f_H(x)}{\partial x} = \frac{Ru'(c)}{u'(c_H)} > R$$

and *x* is lower than when there is no basis risk.

With CARA preferences, investment remains invariant to capital grants even in the presence of basis risk. The FOC for *x*, *I* and *a* are (17), (24) and (19). Consider farmers *0* and *1* with $k^1 > k^0$. Then if x^0, I^0, a^0 satisfy the budget constraints ((13), (14), (15), (23)) and the FOC for farmer *0*, then $x^1 = x^0$,

$I^1 = I^0$ and $a^1 = \dfrac{k^1 - k^0}{R-1}$ are optimal for farmer *1*. With decreasing absolute risk aversion, as in section 2, *x* increases with capital grants.

5.3 Trust

The introduction of a new insurance product is associated with a problem of trust. Why should a farmer believe a financial institution that promises a contingent payout if state *L* occurs in the future? To consider this question, suppose state *N* is a state identical to state *L*, but in which the promised insurance payout is not made. $(1-\pi_H-\pi_L)$ is now a measure of *distrust* in the insurance. Holding constant π_H, an increase in π_L represents an increase in a farmer's trust that a payout will be made in a bad state. Consider a price such that insurance demand is positive. Since from (17)

(25)
$$\frac{d\left(\dfrac{u'(c)}{u'(c_L)}\right)}{d\pi_L} = \frac{\beta}{p} > 0,$$

(24) implies

$$\frac{d\left(\dfrac{u'(c)}{u'(c_H)}\right)}{d\pi_L} < 0.$$

Hence, from (19),

(25)
$$\frac{dx}{d\pi_L} > 0.$$

At any price of insurance, and for any conventional risk averse preferences, an increase in the farmer's trust that payouts will be made increases investment. The increase in trust *a fortiori,* increases purchases of insurance: $c_H - c_L$ declines as π_L increases, and $c_H - c_L = f_H(x) - f_L + I$. The demand for insurance increases more than $f_H(x)$ as π_L 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 (25)). At higher insurance prices, farmers with less trust that payouts will be made will disproportionately drop out of the pool of insurance purchasers (from (25)). 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_L : one's own experience with the index insurance, and the experience of individuals in one's social network with the insurance.

6. The Demand for Index Insurance, 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 5 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 8 and 9.5 cedis per acre (depending upon the specific rainfall station). In contrast to Cole et al. (2010), demand did not drop off radically when a token price of 1 cedi per acre was charged; even at the actuarially fair price, 40 percent to 50 percent of farmers purchased insurance. Demand falls to 10% to 20% of farmers at higher rates of 12 to 14 cedis per acre. Again in contrast to Cole et al. (2010), 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 6 shows the fraction of acreage for which insurance was purchased at every price (including 0 for those who did not purchase insurance).

Table 2, Column 1 is the regression analogue of Figure 5. 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 5 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% versus 70%, p-value from joint test of equality of coefficients at p=1 and p=4 = 0.01, 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 (say, because they have CRRA preferences) then the demand for insurance at a fixed price should be *smaller* for those farmers who received the capital grants.

Several factors however could in a more encompassing theory lead to higher demand for those with the capital grant than for those without the capital grant. First, 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. Second, 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 2, 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 cedis 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. Third, although the grants had not been made 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 the investment costs. Finally, an experimenter or “NGO” effect may have occurred, in which individuals who receive the grant were more likely to buy the insurance in order to reciprocate to the NGO for giving them the capital grant.

In columns 3 and 4 of Table 2 we limit the sample to the first two years of the data because those are the years for which we currently have information on farmer investment. In column 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 that 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 insurance did not get delivered alongside any technical assistance on farming, we believe this is a reasonable assumption to make.

6.2 Investment and Insurance

Table 3 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

$$Y_{it} = \alpha_0 + \alpha_I I_{it} + \alpha_B B_{it} + \alpha_K K_{it} + \alpha X_{it} + \varepsilon_{it} \qquad (26)$$

where I_{it} is an indicator variable that farmer i has rainfall index insurance in year t, B_{it} is an indicator that farmer i has both rainfall index insurance and a capital grant 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} and B_{it}, of course, are endogenous because they depend on farmer demand for insurance. These are instrumented using the randomized prices of insurance, interacted with an indicator of receiving a capital grant, as shown in 2.

Farmers with insurance invest more in cultivation. 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 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 1 and are inconsistent with the presence of binding credit constraints. Farmers with insurance are able to find the resources to increase investment in their farms.

Columns 2-4 of Table 3 show that the primary cash expenditures on cultivation are higher for insured farmers. Expenditure on chemicals (mostly fertilizer), land preparation (largely tractor rental) and hired labor are all higher for farmers who are insured. Similarly in column 6 we show that the area cultivated by farmers with insurance is higher. These are all large and statistically significant increases, relative to the means of these items for control group farmers. 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. 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.

In column 5, we see that there are no statistically significant changes in value of family labor (which we price at gender-community-season specific wages) among farmers who receive any of the treatments. The measurement of family labor used on farms remains a significant empirical challenge for an annual retrospective survey.

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 = 82). The joint effect of insurance and a capital grant is large and significant ($233, 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 is an important issue to keep in mind when interpreting results on farm profits (e.g., subtracting the effects in column 1 from those in column 7). 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 (similar results are found with respect to cows in India, where profits are positive only if family labor is valued at zero, see Anagol et al 2012). This may be the most important reason for the observation that profits are typically negative in this and similar data from rural west Africa (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).

Next, in Table 4, we examine not just the level of investment (as we did in Table 3), but the riskiness of investment. We do this by using the same specification as in Table 3, 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 4 Column 8 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 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, thus create an imprecisely estimated net null effect.

Columns 1 indicates that insured households invest more in total in their farms when rainfall is better (Column 2-6 indicate the breakdown, and we see more sensitivity of chemical use than others, which is intuitive as this is an input that can be more reactive over time to changes in weather conditions). The models of sections 2 and 5, in which *x* is determined before the realization of the state, therefore, miss an important dimension of agricultural activity in this region. As Fafchamps (1993) showed, agricultural production is a process that unfolds gradually as the seasonal weather realization is revealed. A fundamental characteristic of rainfall index insurance is that payouts are independent of farmer actions. This does not imply, however, that farmer actions in response to the realization of rainfall shocks are unaffected by insurance. These effects from the insurance only group are particularly strong for purchased inputs – chemicals and hired labor; the estimates are too noisy to see any effect on the amount of family labor. The capital only group does increase its investment in chemicals and family labor as rainfall increases (although as noted above, the aggregate measure is not significant statistically).[13]

Finally, Column 7 of Table 4 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, control group farmers planted maize on 31% of their cultivated acres). 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).

Table 5 shows the heterogeneous effects of insurance and the capital grants across four key household characteristics. First we consider 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

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[13] The differential sensitivity of input application to early season rainfall by insurance status raises interesting questions about dynamic production decisions over the farming season that are beyond the scope of the current paper, but that are accessible given the data we have collected.

significantly less for a wealthier than for a less wealthy household, 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 in 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.

6.3 The Insurance Market, Heterogeneity, and Separation

In Table 6, we examine the effects of differential selection into the insured pool as the price changes as discussed in section 5.1, and also the separation implications of the availability of insurance, as derived in equation (20). 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 6 that there is no strong evidence that one of these effects outweighs the other. To simplify the presentation, we consider 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%, 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, two other results are close: land preparation costs (p-value of 0.104) and hired labor (p-value of 0.151), and ultimately harvest value (p-value 0.134).

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 2 that conditional on purchasing 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, s.e.=16). There is no statistically significant effect of receipt of a capital grant at a low insurance price for any other input, nor for total farm investment (or output).

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 $\frac{u'(c)}{u'(c_H)}$ will decline with the receipt of a capital grant and thus investment will increase. 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 2, test at bottom of table, F-test 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

$$\begin{aligned}(27)\qquad I_{it} &= \gamma_{IP} I_{i.t-1} Pay_{i,t-1} + \gamma_{NP} I_{i,t-1}(1-Pay_{i,t-1}) + \gamma_{SP} S(Pay)^{j}_{i,t-1} + \gamma_{SNP} S(NoPay)^{j}_{i,t-1} \\ &+\gamma_{SK} S(Capital)^{j}_{i,t-1} + \gamma_{Pay} Pay_{i,t-1} + \gamma_{SN} Num^{j}_{i,t-1} + \gamma_{P} P_{it} + X_{it}\gamma + \nu_{it}\end{aligned}$$

I_{it-1} is an indicator variable that farmer *i* had insurance in *t-1*. $Pay_{i,t-1}$ 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. $Num^{j}_{i,t-1}$ is the number of individuals in farmer *i*'s social network of type *j* in *t-1*. $S(Pay)^{j}_{i,t-1}$ is the fraction of members of that network who were insured and received a payout in *t-1*. $S(NoPay)^{j}_{i,t-1}$ is the fraction of members of that network who were insured and did not receive an insurance payout in *t-1*. $S(Capital)^{j}_{i,t-1}$ 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 $I_{i,t-1}$ and $Pay_{i,t-1}$ 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*.

$S(Pay)_{i,t-1}^{j}$ and $S(NoPay)_{i,t-1}^{j}$ 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 (27) are presented Table 7. 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 0.83 to 1.18 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 2.5 acres unconditionally). The result is similar for the binary outcome of take-up (Columns 2, 4 and 6; 8 to 11 percentage point increase in takeup over a mean take up rate of 43 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 2.33 and 2.53 *fewer* acres than did farmers who did not have insurance in the previous year, and their take up of insurance was between 35 and 38 percentage points lower (all results significant with p-value < 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.

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 substantively significant, but not as large as the effect from one's own experience. The number of acres purchased increases by 0.73 (se=0.23), 0.18 (se=0.06) and 0.15 (se=0.06) for each credit, familial relationship, and farming peer who receives a payout, respectively. Similar learning effects are found when examining the probability of buying any insurance (Column 2, 4 and 6). However, we observe no deleterious effects as we did for the direct effect of 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 family relationship and farming information networks that received a capital grant in the previous year. This finding is in accord with our earlier result (Table 2) that one's own receipt of a capital grant increases demand for insurance.

We interpret this pattern, as with that we find for 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 7. This logic carries over to realizations within social networks, provided that there is (unobserved to us) risk sharing within these networks.[14] The income effect interpretation, however, is not consistent with the finding that capital grants in one's social network increase insurance demand: if there are unobserved transfers this should be associated with a decline in 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 1993). However, our results so far are consistent with farmers who act otherwise. The results are consistent with "salience", or "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. The effect of community level payout trigger events reported in Table 7 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. The available historical rainfall data for the region provide no support for the hypothesis that trigger events are serially correlated, so this appears to be an instance of recency bias. However, even conditional on trigger events occurring last year, both one's own actual 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.

7. Discussion

Several of these results resonate well with existing and ongoing research on agricultural risk markets and capital markets in other settings. Combining our results with lessons from complementary

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[14] 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.

research provides us with some clear guidance on the mechanisms driving agricultural markets (and their failures). Such an understanding is helpful for companies, governments and other stakeholders who seek prescriptions for improved policies, and for researchers who seek a deeper and more robust understanding of capital and risk markets for agriculture in developing countries, including lessons on behavioral responses by farmers to policy changes from firms and government.

We start first by discussing the demand component of rainfall insurance. We then discuss the behavioral response to receiving insurance and capital on investment decisions by farmers. And last we discuss the implications here, as they relate to other literature, on the returns to capital for smallholder farmers.

The elephant in the room from prior studies is lack of demand for rainfall insurance, despite the evidence that risk impedes investment, and that investment likely has large marginal returns. In one of the first studies on demand for rainfall insurance, Giné and Yang (2009) shows that when rainfall insurance is bundled with credit (and priced at actuarially fair plus costs, hence likely market prices), demand for the credit actually falls. Their hypothesis was that the rainfall insurance should have made farmers *more* likely to be willing to take out the loan to invest in a new technology. 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 them, and thus likewise depressed demand for the credit.

From existing literature we are learning that many factors drive demand, such as trust (Cole et al, 2011), social networks (Cai, 2012), provision of financial literacy on insurance (Cai, 2012; Giné, Karlan and Ngatia, 2012), and also just simple framing and marketing of the insurance (Cole et al, 2011).

Price is a consistent driver, and not simply due to liquidity. The closest study to ours in terms of completeness of the range of prices tested is Mobarak and Rosenzweig (2012), and they find strikingly similar demand curves: 15% purchase rate at market prices (versus 11% in our study); about 22% purchase rate when priced at a 10% discount off of market price (no comparable price point in our study); about a 38% purchase rate when priced at a 50% discount off of market price, thus about actuarially fair (versus 42% in our study at actuarially fair prices); and about a 60% purchase rate when priced at a 75% discount off of market price (versus 67% in our study when priced at about a 75% discount). Our additional price points are consistent, almost linear extrapolations, from the above. We are aware of one other study which randomized the price of rainfall insurance, Cole et al (2011). Although Cole et al tested a smaller range of prices, they found similarly steep elasticities.

The observed elasticity suggests several areas for further research, and policy exploration. First, we need to examine whether liquidity could explain the steep demand curve. In our setup the cash drop (and its announcement) came *after* the insurance sales, hence this, combined with the fact that wealthier individuals do not exhibit flatter demand curves, and combined with the fact that individuals in the insurance only treatment group in the Grant Experiment managed to increase investment substantially, suggests liquidity is not the driving factor. The exogenous variation in the Cole et al (2011) study does find important evidence that liquidity matters (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 if the NGO then offers to sell an item). The 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, a 150% increase in likelihood of take-up.

Given the strong evidence that price matters and that experience and trust matter as well, there are some clear paths forward for policy and research. First, insurance products may consider payout schemes that include high-probability events, not just extreme outcomes, or even insurance products that effectively have a savings component to it so that individuals get what they perceive as a payout in almost all states of the world. Such approaches are not uncommon in developing countries either, for example with car insurance policies that reduce future premiums when no claims are made (this also is a likely mechanism of dealing with adverse selection, not merely trust).

Second, and this is partly a research methods question, but also has policy implications, we need to determine whether mental accounting is a key factor or not in the purchase of insurance. 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. Third, if liquidity is the issue (despite the above points), financing schemes could increase demand at higher prices. One obvious idea is to link to harvest proceeds, however this may have issues regarding incentives to side-sell at harvest in order to avoid loan repayment (see Giné and Karlan, 2012). Thus contracting issues would need to be worked out with respect to avoiding moral hazard on the loan to finance the premiums. Furthermore, given the small size of the premiums, transaction costs on financing may prove costly. 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).

Given typically low take-up rates of the rainfall insurance, the complementary literature is light on investment response (statistical power issues make it difficult to detect, particularly given the difficulty in measuring many farm inputs precisely). Two exceptions to our knowledge in the recent literature are able to focus on investment response, and both find similar results as we do, that risk-taking and investment increase even absent any capital infusion. Cole et al (2012) employ 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 a major issue (two nontrivial conditions, see Mobarak and Rosenzweig (2012) for clear evidence that basis risk matters), such “insurance drops” provide an estimate of the impact on behavior from merely removing risk with respect to rainfall on a general population, not just those who understand and take-up at a positive price. Similar results from Cai et al (2010) find in China that insurance for sows leads to higher investment in sows for those who are willing to buy the insurance.

Although finding an investment response is important, we also lack clear evidence on the capital constraints being a key impediment to investment. Note that we are not able to use our experiment to precisely test returns to capital, since labor inputs shift along with the provided capital. In a similar experiment, de Mel et al (2008; 2009) provide cash grants to microentrepreneurs and find returns for men around 80% but near zero returns for women. In their setting they find little shift in labor inputs, thus conclude that their measure is a measure of the returns to capital. In our setting, we find significant shifts in labor, and have no instrument for labor apart from the provision of capital, thus we are not able to separately identify labor and capital. We also note that even if quantity of labor remained the same, the quality may shift. Measuring returns to capital is not easy with simply one instrument. Instead our capital drops should be thought of as testing how investment behavior changes when capital constraints are relaxed.

In the agriculture space, returns to capital no doubt are not homogeneous across farmers, and naturally effective policy on risk and capital markets must take into consideration not just the potential returns to farmers from relaxing capital or credit constraints, but also the heterogeneity in returns across farmers. Suri (2011) demonstrates this clearly: in Kenya, Suri finds that low adoption of hybrid maize is driven by heterogeneity in returns. Other research has sought as well to estimate returns to capital, but stated more conservatively has found considerable heterogeneity Further research to tackle the returns to capital question would be quite fruitful.

8. Conclusion

Risk matters. Of course, we are not the first to discuss this in theory, or to show evidence of this. This project advances our knowledge by its comprehensive approach to dealing with both capital constraints and risk constraints for smallholder farmers, and tying the lessons to a model to help understand more about 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 targets, whether directly or indirectly, smallholder farmers. We learn here however that capital constraints alone are not the problem, that risk is a key hindrance to investment and thus improved income and growth. Microcredit networks and infrastructure could be used to build in 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 do learn here that mitigating risk alone, without an infusion of capital, does lead to higher investment. Thus the lesson should not be to simply bundle rainfall insurance with loans (as we learn from Gine and Yang (2009), this depressed demand for the 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 adverse selection and moral hazard issues that are potentially problematic for crop or pest insurance. Further research is needed to understand whether such problems are solvable. 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 systems, and delivery vehicles to reduce information asymmetries and transaction costs could generate dramatic welfare improvements for the poor.

Lastly, for rainfall or other index insurance, we note several key lessons and areas for further research. First of all, we consider basis risk a critical and practical issue, and research indicates is a genuine and economically important impediment (and farmers understand the risk, at least qualitatively Mobarak and Rosenzweig (2011)). Furthermore, 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, as well as proper regulation. Ultimately we see large investment responses to relaxing both credit and capital constraints, thus we conjecture that the rewards are larger than obstacles from a societal perspective. To make that link complete, however, we also need further work on returns, to understand whether impact on farm profits are low due to measurement issues, heterogeneity, or suboptimal investment decisions.

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Figure 1: Effect of Insurance and Cash Grants on Total Investment

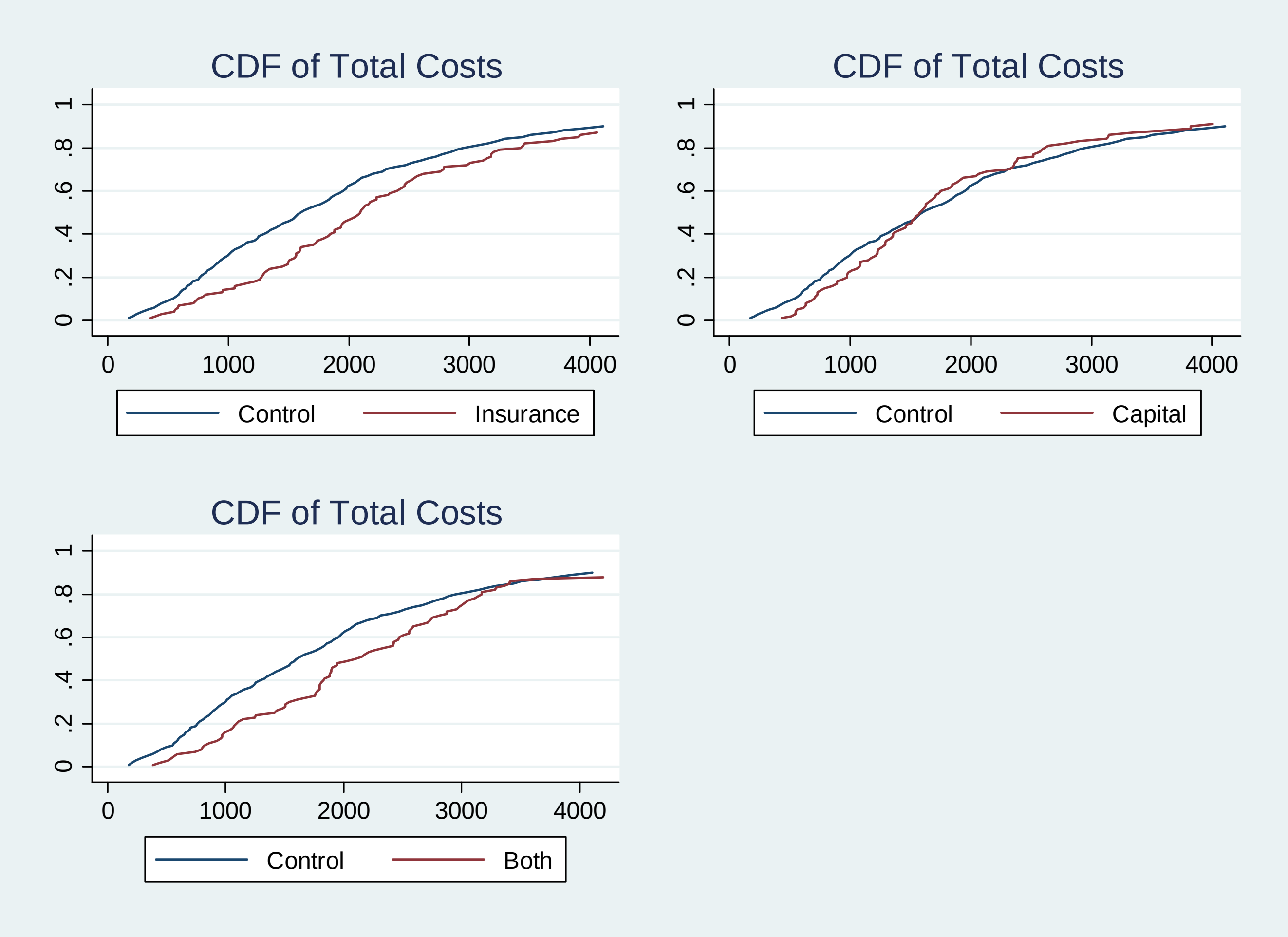


Figure 2: Effect of Insurance and Cash Grants on Chemical Expenditure

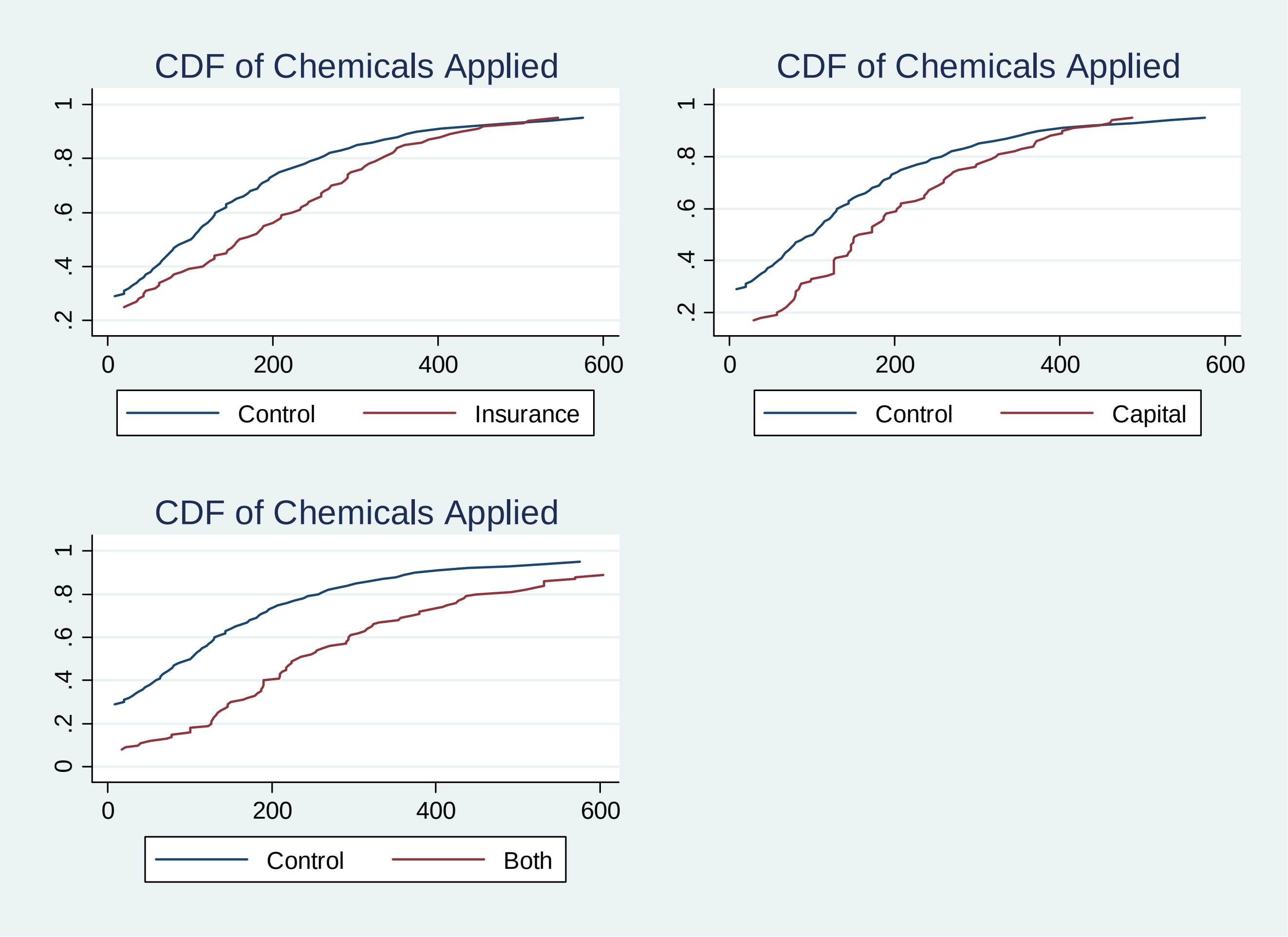


Figure 3: Effect of Insurance and Cash Grants on Area Cultivated

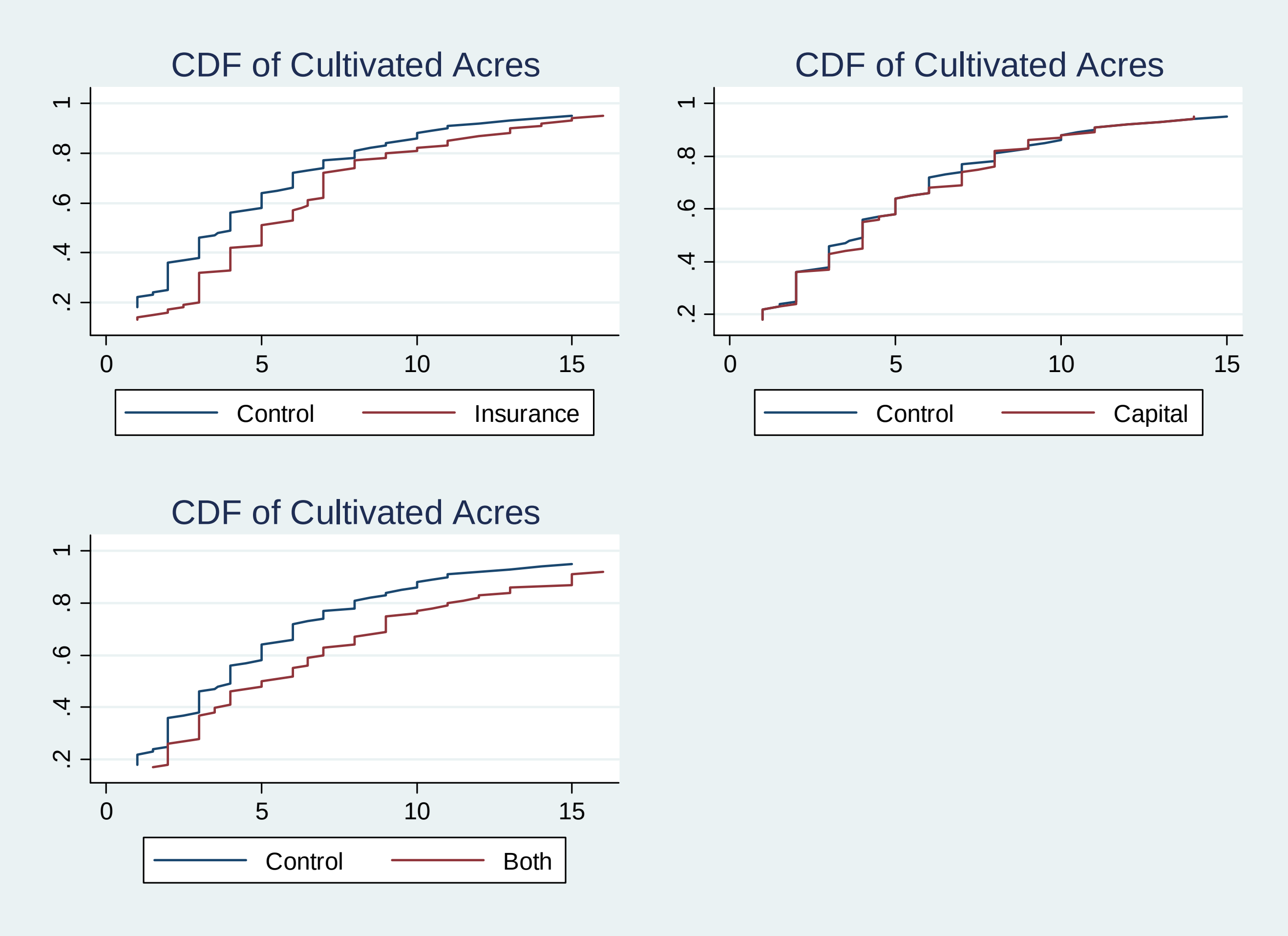


Figure 4: Effect of Insurance and Cash Grants on Value of Harvest

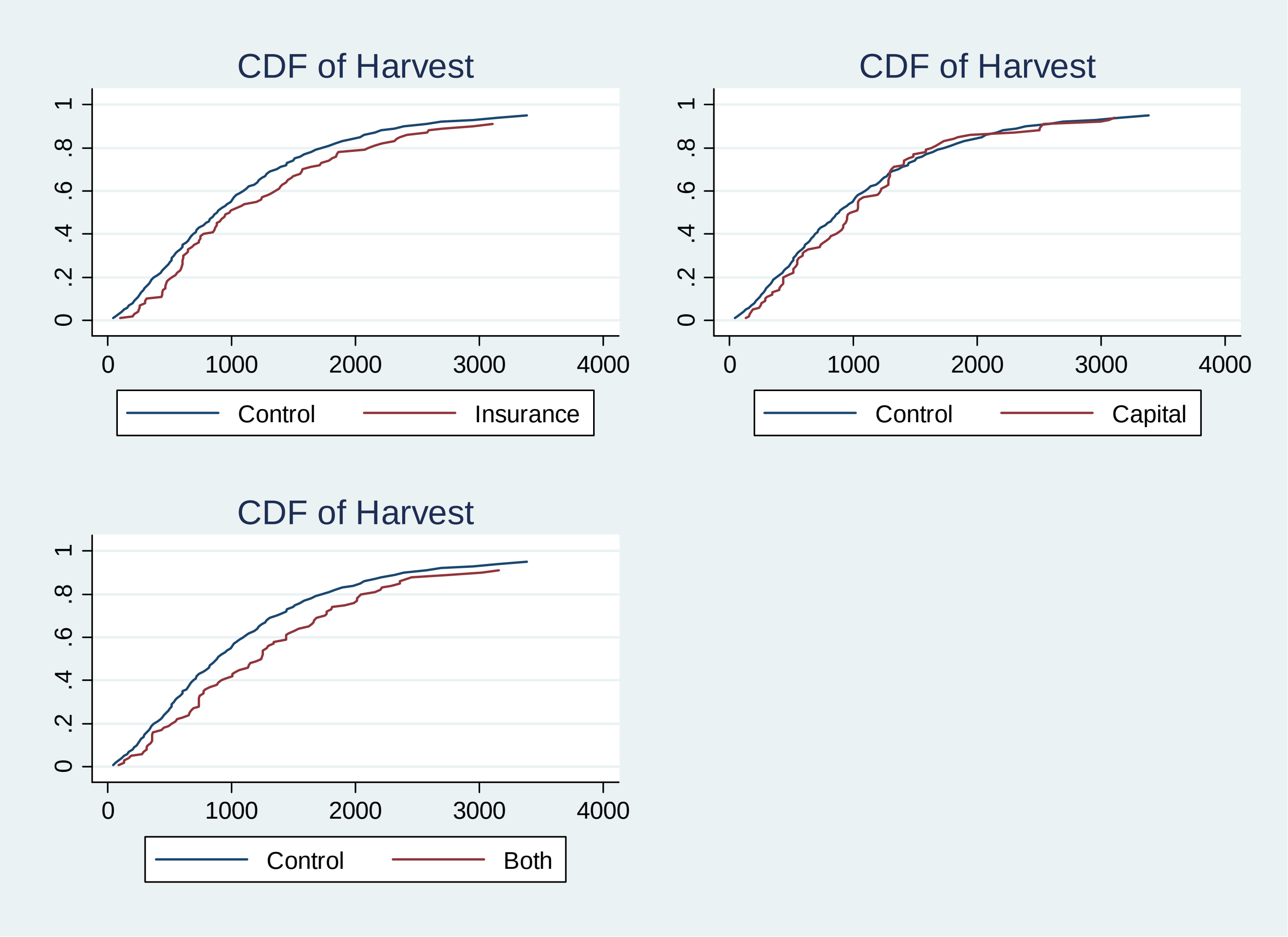


Figure 5: Insurance Takeup

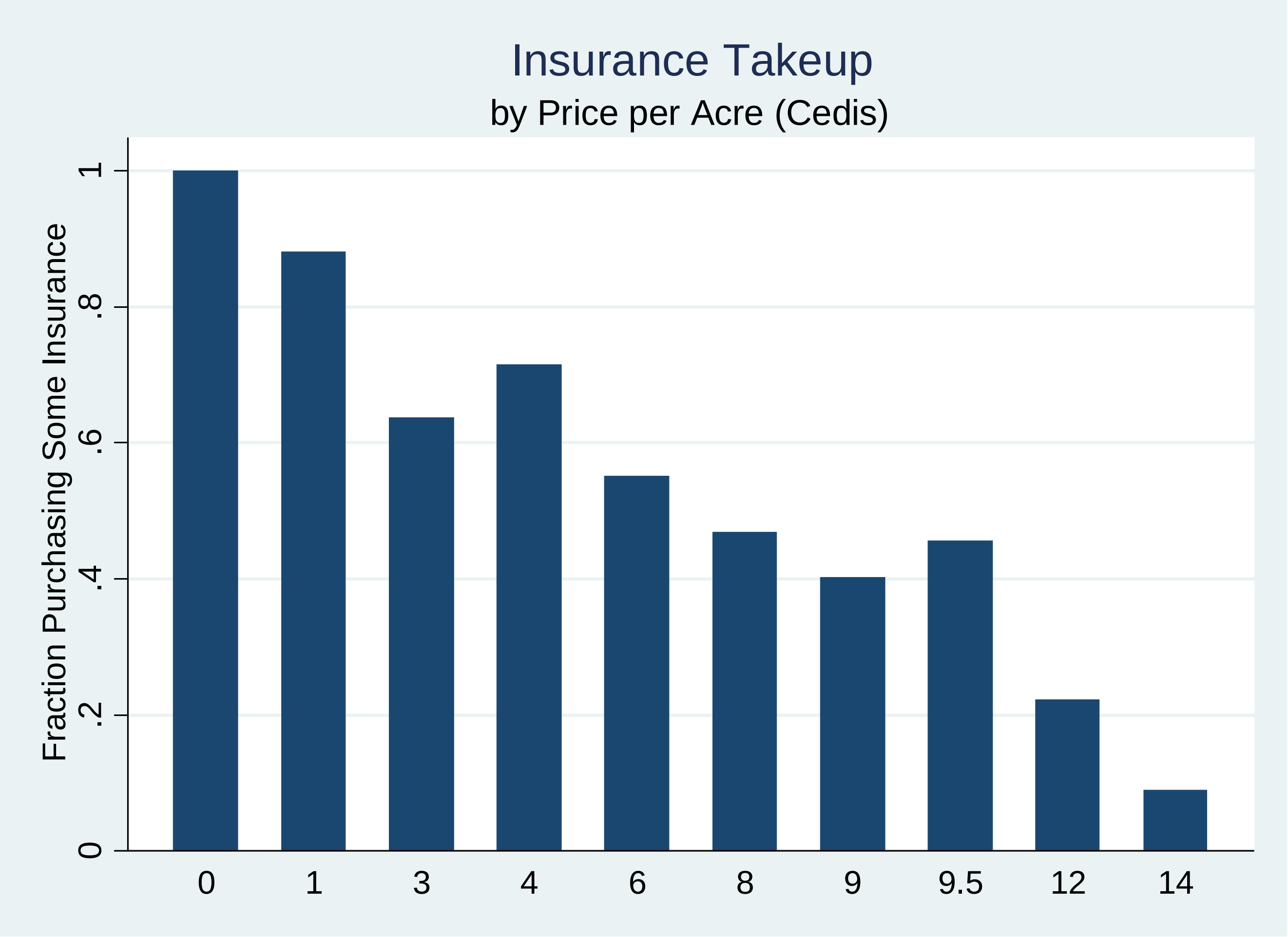


Figure 6: The Demand for Acres Insured

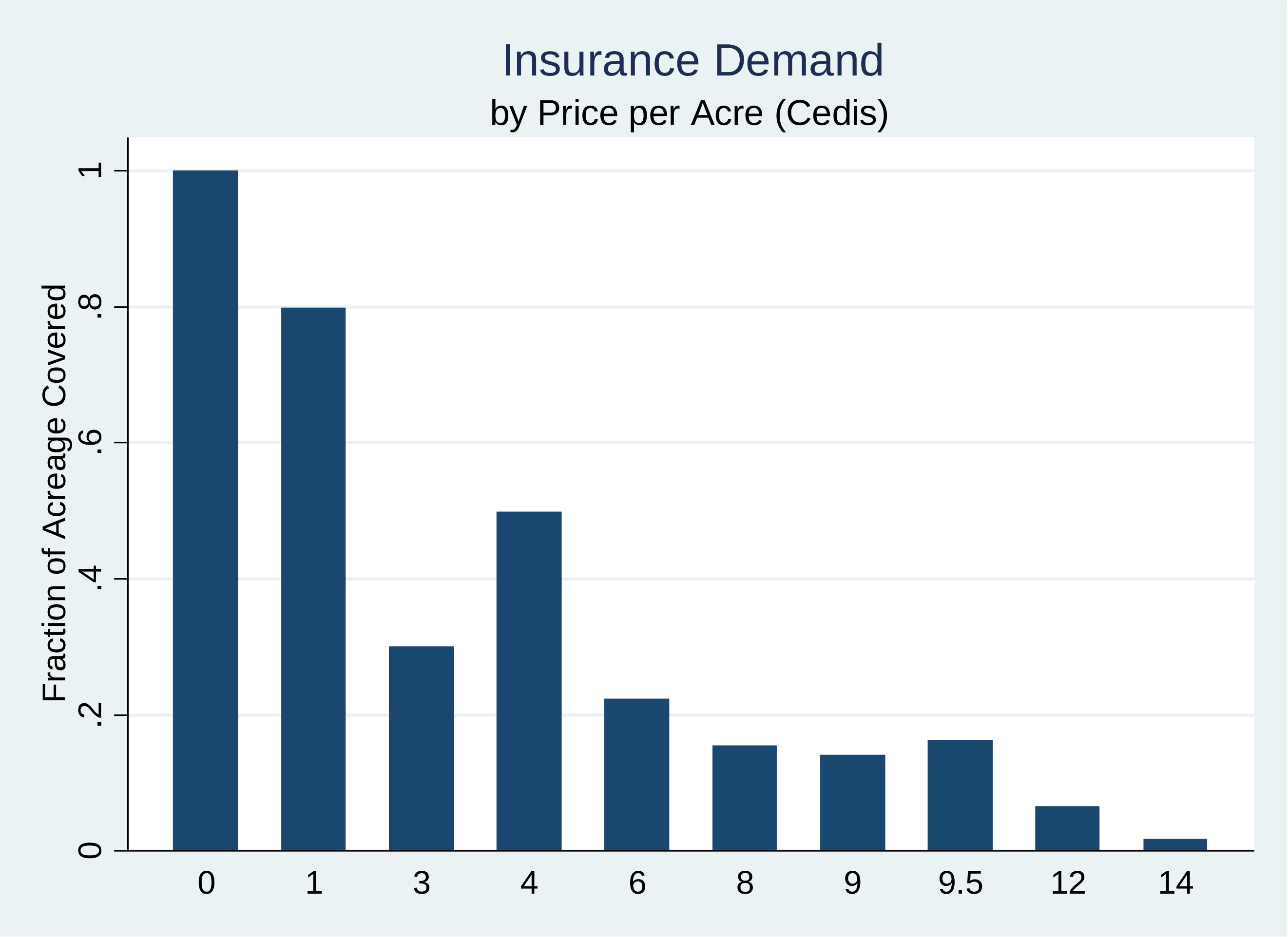
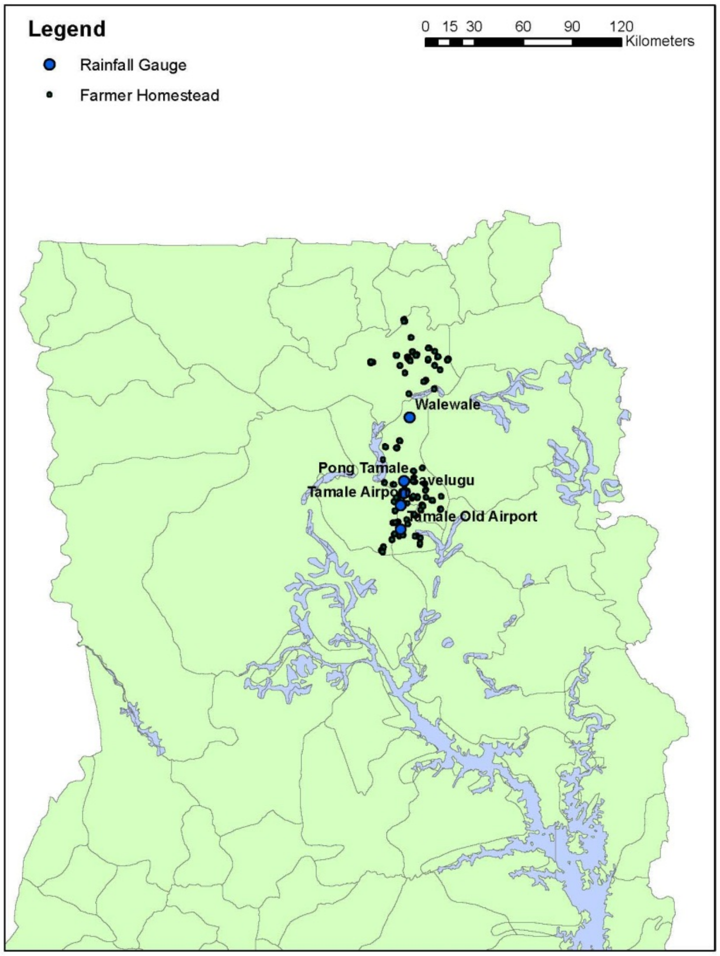


Figure 7: Northern Ghana Map with Rainfall Gauges and Farms in Study

Location of Communities and Rainfall Gauges in Northern Ghana



Appendix Figure 1

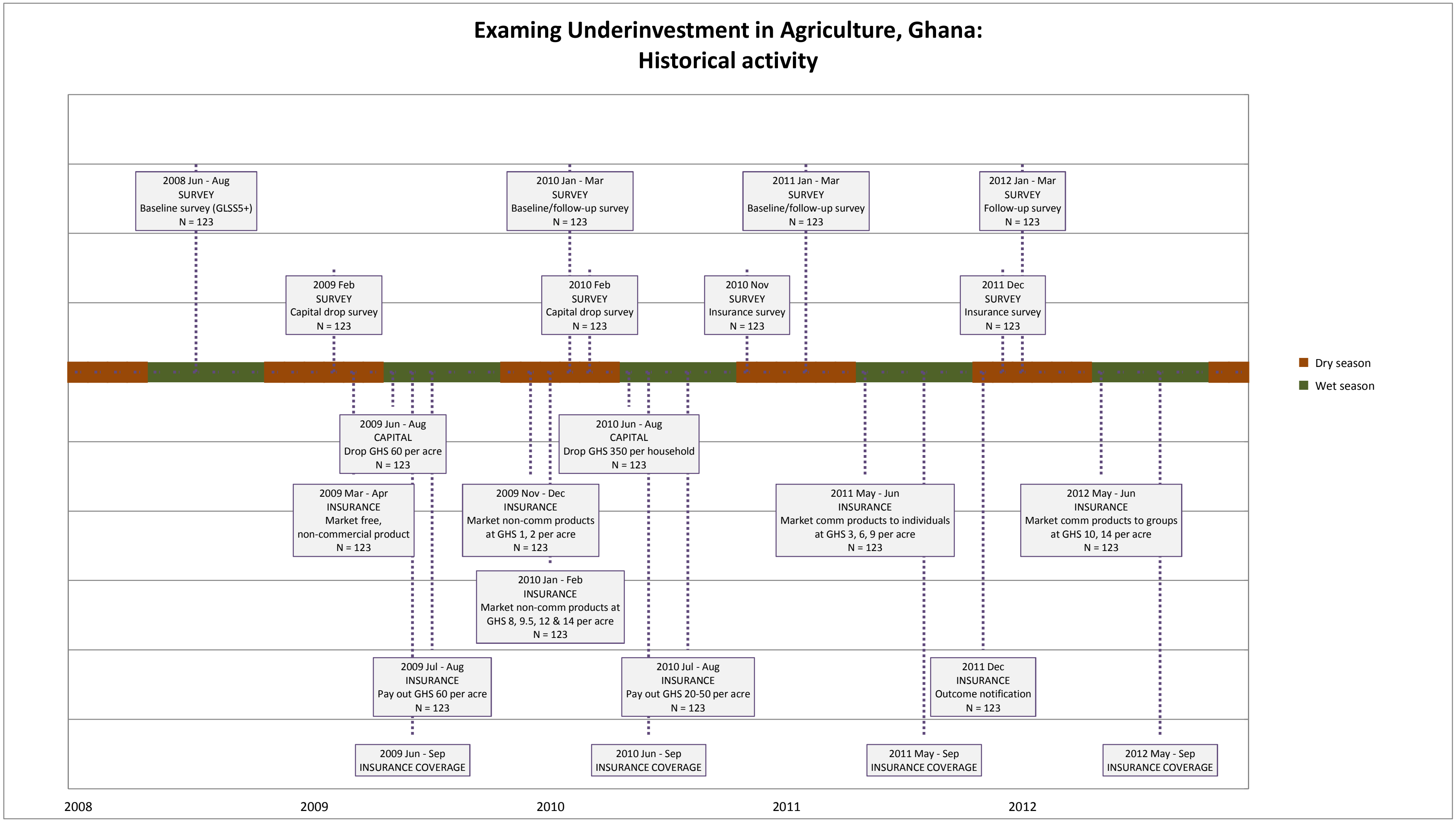


Table 1: Summary Statistics and Orthogonality

Mean (standard errors)

	(1)	(2)	(3)	(4)	(5)	(7)	(8)	(9)	(10)	(11)
Data Source:	GLSS5+						Year 1 Followup Survey			
	All	Both	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	6.4	6.47	6.66	0.39	6.31	6.35	6.6	0.35
	(0.17)	(0.38)	(0.36)	(0.33)	(0.33)	(0.76)	(0.23)	(0.21)	(0.31)	(0.71)
Total acreage	7.8	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
							(94.00)	(71.00)	(127.00)	(0.07)
Harvest value	233.67	300.66	181.86	226.36	238.07	1.97	794	647	764	2.07
	(15.96)	(54.70)	(22.02)	(21.86)	(29.91)	(0.12)	(62.00)	(44.00)	(62.00)	(0.13)
Chemical value	64.99	81.28	66.84	58.16	59.56	0.90	90	88	114	1.65
	(5.19)	(14.94)	(11.79)	(7.08)	(9.04)	(0.44)	(9.00)	(9.00)	(14.00)	(0.19)
Hired Labour							213	209	307	1.02
							(37.00)	(35.00)	(88.00)	(0.36)
Family Labour							901	720	883	2.24
							(77.00)	(52.00)	(76.00)	(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 treatment assignment on all above covariates		1.49	0.71	0.46	1.03		1.59	1.48	0.70	
		0.17	0.66	0.86	0.41		0.12	0.16	0.69	
Observations		95	117	135	155		587	587	587	

Standard errors in parentheses. Total cost, hired labour and family labour data not available from GLSS5+ survey.

Table 2: 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***	
	(0.001)	(0.001)	(0.001)	
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)	(0.030)	(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
	(0.001)	(0.001)	(0.001)	(.)
Insurance Price = 1 AND Capital Grant Treatment	0.88***	0.89***	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)
Capital Grant Treatment	0.00	0.00	0.00	0.00
	(0.003)	(0.002)	(0.003)	(.)
Wealth at baseline		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: (p=1)=(p=1&CapitalGrant) & (p=4)=(p=4&CapitalGrant), i.e. whether demand differs at p = (1,4) for insurance with capital grant compared to demand at p = (1,4) without capital grant	5.939			
p-value	0.00266			

Robust standard errors in parentheses. Column 1 includes 3 years of demand data, Columns 2-4 include years 1 and 2 of demand data. Column 2 drops observations with missing wealth. 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 3: Impact on Investment and Harvest
IV

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

IV

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variable:	Total Costs	Value of Chemicals Used	Land Preparation Costs	Wages Paid to Hired Labor	Opportunity Cost of Family Labor	# of Acres Cultivated	Proportion of Land Allocated to Maize	Value of Harvest
Insured	-1,444.90	-217.72**	32.76	-581.51	-535.56	1.25	0.09***	-1,069.13*
	(1,007.107)	(104.539)	(99.262)	(423.079)	(636.659)	(3.187)	(0.031)	(596.208)
Insured * Capital Grant Treatment	-1,418.68	116.49	248.21*	-92.00	-1,393.99*	1.69	0.04	1,324.48
	(1,221.387)	(154.222)	(147.360)	(554.052)	(789.219)	(4.616)	(0.029)	(821.152)
Insured * Total Rainfall	231.04*	33.44**	-0.17	89.99	86.55	-0.01		156.82**
	(128.855)	(13.358)	(12.502)	(55.632)	(79.978)	(0.401)		(76.291)
Insured * Capital Grant Treatment * Total Rainfall	190.56	-6.67	-30.10	15.60	172.79*	-0.19		-155.36
	(159.703)	(19.945)	(18.484)	(74.322)	(100.994)	(0.582)		(105.649)
Capital Grant Treatment	-1,419.02	-159.62	-12.84	363.82	-1,669.48**	-6.96*	0.12***	-879.77
	(1,042.954)	(121.387)	(108.595)	(444.460)	(670.159)	(3.737)	(0.034)	(642.233)
Capital Grant Treatment * Total Rainfall	189.60	28.03*	4.04	-35.30	202.11**	0.93*		124.95
	(133.680)	(15.650)	(13.695)	(57.148)	(85.670)	(0.475)		(83.589)
Total Rainfall (hundreds of millimeters)	5,156.68***	530.55***	233.91**	1,215.18**	3,306.62***	6.80**		2,247.39***
	(1,030.090)	(120.908)	(92.259)	(488.764)	(656.070)	(3.108)		(624.545)
Total Rainfall Squared	-342.29***	-34.50***	-15.79***	-74.82**	-225.95***	-0.49**		-146.65***
	(67.638)	(7.937)	(6.011)	(32.232)	(42.883)	(0.203)		(40.970)
Constant	-17,301.26***	-1,857.18***	-693.30**	-4,695.18**	-10,627.70***	-15.00	0.23***	-7,154.76***
	(3,912.114)	(458.888)	(353.617)	(1,846.393)	(2,505.944)	(11.893)	(0.016)	(2,375.086)
Observations	2,320	2,320	2,320	2,320	2,320	2,320	2,782	2,320
R-squared	0.024	0.057	0.022	0.021	0.023	0.154	0.090	0.021
Mean in Control	2058	158.3	189.1	327.9	1302	5.921	0.309	1177

Robust standard errors in parentheses. Columns 1-6 & 8: 2 years of agronomic data with nonmissing input data. Column 7 includes more observations because observations with missing input data are not dropped. "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. Rainfall ranges from 6 to 9 hundred millimeters. *** p<0.01, ** p<0.05, * p<0.1

Table 5: Investment Response, Heterogeneity with respect to Socioeconomic Covariates

IV

	(1)	(2)	(3)	(4)	(5)
Dependent Variable:	Total Costs	Total Costs	Total Costs	Total Costs	Total 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)
Insured * Wealth	-0.25*				-0.22*
	(0.143)				(0.117)
Insured * Capital Grant Treatment * Wealth	0.15				0.17
	(0.171)				(0.141)
Capital Grant Treatment	81.60	-92.89	670.04	-104.99	253.16
	(160.577)	(168.094)	(439.846)	(335.402)	(525.588)
Capital Grant Treatment * Wealth	-0.17				-0.10
	(0.159)				(0.159)
Wealth	0.37***				0.27***
	(0.088)				(0.087)
Insured * Head of Household Can Read		513.73**			450.89*
		(250.582)			(247.289)
Insured * Capital Grant Treatment * Head of Household Can Read		-189.52			-142.59
		(322.897)			(325.800)
Capital Grant Treatment * Head of Household Can Read		303.82			224.09
		(277.620)			(264.053)
Head of Household Can Read		-76.70			0.02
		(119.606)			(117.837)
Insured * Head of Household Age			-12.00*		-11.90*
			(6.551)		(6.508)
Insured * Capital Grant Treatment * Head of Household Age			7.90		11.39
			(8.598)		(8.753)
Capital Grant Treatment * Head of Household Age			-14.98		-12.19
			(9.433)		(8.892)
Head of Household Age			10.72***		3.76
			(3.546)		(3.447)
Insured * Household Size				0.68	31.54
				(32.262)	(32.966)
Insured * Capital Grant Treatment * Household Size				-8.97	-42.12
				(43.019)	(43.713)
Capital Grant Treatment * Household Size				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 varies with missing interaction variable. "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 6: Heterogeneity with Respect to Price of Insurance

IV

Dependent variable:	(1) Total Costs	(2) Value of Chemicals Used	(3) Land Preparation Costs	(4) Wages Paid to Hired Labor	(5) Opportunity Cost of Family Labor	(6) # of Acres Cultivated	(7) Value of Harvest
Insured at Low Price	277.13**	37.79**	22.52*	70.81	131.47	1.02**	132.83
	(136.950)	(15.118)	(12.371)	(61.057)	(85.847)	(0.428)	(81.910)
Insured at High Price	-47.91	40.95	122.36**	447.09*	-856.22*	1.10	-714.07
	(662.127)	(78.139)	(60.157)	(254.552)	(491.599)	(2.151)	(559.616)
Insured at Low Price * Capital Grant Treatment	68.05	66.46***	16.97	44.46	-65.05	0.26	118.58
	(139.018)	(15.700)	(13.158)	(65.224)	(86.343)	(0.446)	(81.473)
Constant	2,121.88***	170.79***	142.05***	98.72	1,665.24***	8.10***	1,649.33***
	(204.233)	(24.592)	(17.897)	(64.550)	(166.538)	(0.693)	(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	0.231	0.00158	2.643	2.066	3.917	0.00122	2.242
p-value	0.631	0.968	0.104	0.151	0.0478	0.972	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 7: Dynamics 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	1.18***	0.11***	0.92***	0.08***	0.83***	0.08***
	(0.300)	(0.028)	(0.321)	(0.028)	(0.316)	(0.028)
Insured * Did Not Receive Payout in Prior Year	-2.33***	-0.35***	-2.53***	-0.38***	-2.41***	-0.36***
	(0.654)	(0.078)	(0.641)	(0.078)	(0.628)	(0.077)
# Insured in Social Network that Received Payout in Prior Year	0.73***	0.06***	0.18***	0.01*	0.15**	0.02***
	(0.228)	(0.018)	(0.064)	(0.006)	(0.064)	(0.006)
# Insured in Social Network that Did Not Receive Payout in Prior Year	-0.11	-0.01	0.01	-0.00	-0.04	0.00
	(0.120)	(0.016)	(0.038)	(0.005)	(0.037)	(0.004)
Eligible for Payout in Prior Year	1.56***	0.14***	1.48***	0.14***	1.37***	0.13***
	(0.163)	(0.021)	(0.161)	(0.021)	(0.162)	(0.021)
# in Social Network that Received a Capital Grant in Prior Year	0.25	0.05	0.32***	0.04***	0.14	0.04***
	(0.319)	(0.030)	(0.120)	(0.012)	(0.126)	(0.012)
Constant	3.56***	0.67***	3.70***	0.64***	3.77***	0.67***
	(0.331)	(0.037)	(0.351)	(0.041)	(0.343)	(0.040)
Observations	2,189	2,189	2,189	2,189	2,189	2,189
R-squared	0.366	0.282	0.366	0.292	0.367	0.291
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 size of social network that received capital in the prior year. *** p<0.01, ** p<0.05, * p<0.1

Appendix Table 1: 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: Rainfall				
Columns 1-6, 8	946	1166	208	2320
Column 7	988	1338	456	2782
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 2: 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