# 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 $\pi_s$ and a discount factor $\beta$, 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 $x_{\mathrm{h}}$ 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

[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

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

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

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

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:

[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 $x_{\mathrm{h}}$ 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

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

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

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

## 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

(16) $$c^0 = Y - a - x_r - x_h - pI$$

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

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

In addition to non-negativity constraints on *c*, $c_G$, $c_B$, $x_r$ and $x_\mathrm{h}$, short sales of *I* are not feasible:

(19) $$I \geq 0.$$

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

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

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

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

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

If $p = \dfrac{\pi_B}{R}$ 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 $\theta_i$ 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

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

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

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

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

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 $\theta_1$, $\theta_2$ 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

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

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

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

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

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

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 $\left\{ \mathbf{x}(k^a), I(k^a), a(k^a) \right\}$ satisfy the budget constraints ((16), (17), (18), (28)) and the FOCs, then $x_r(k^b) = x_r(k^a)$, $x_h(k^b) = x_h(k^a)$, $I(k^b) = I(k^a)$ 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 $\pi_G$, an increase in $\pi_B$ 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

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

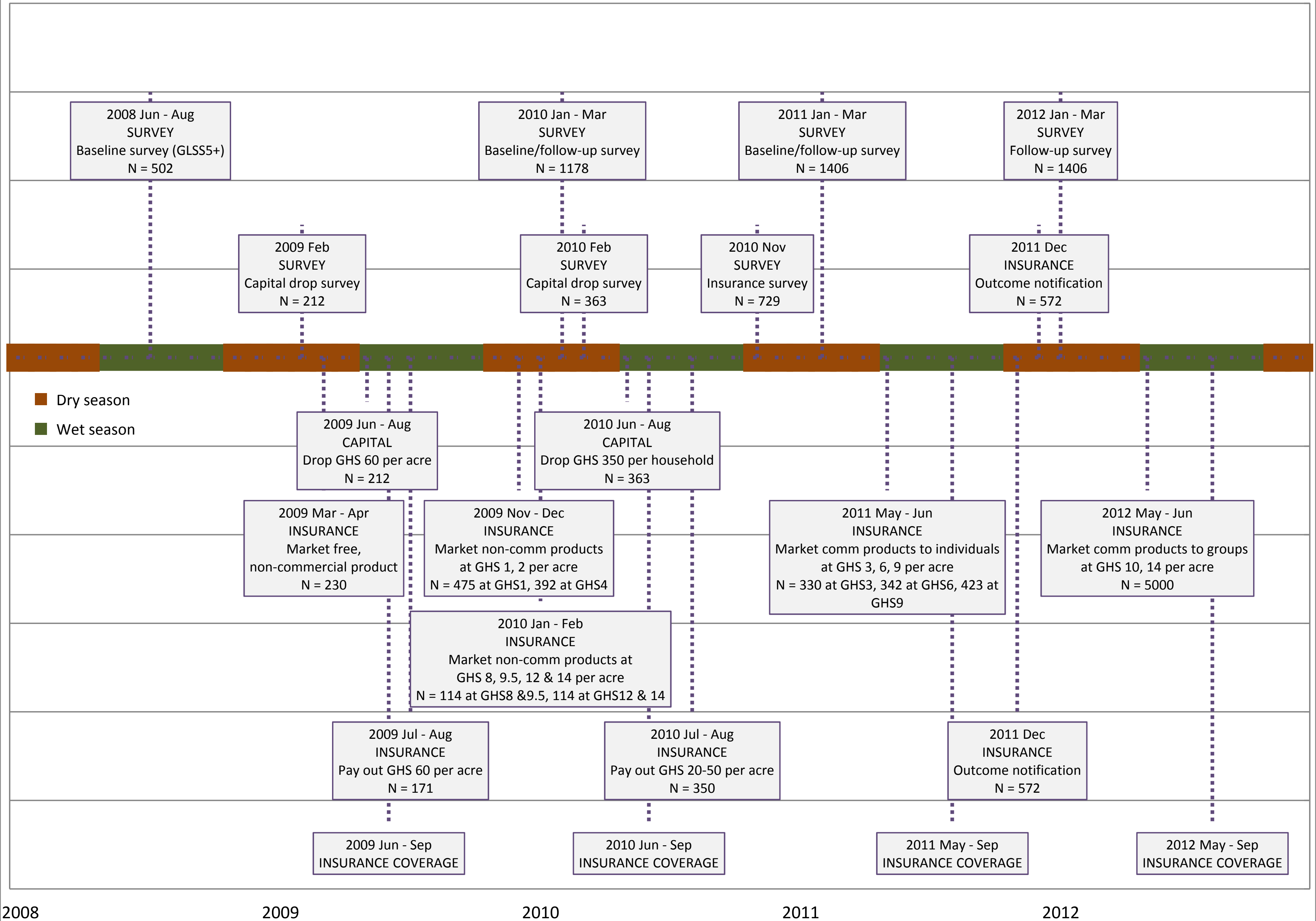
Hence, from (22),

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

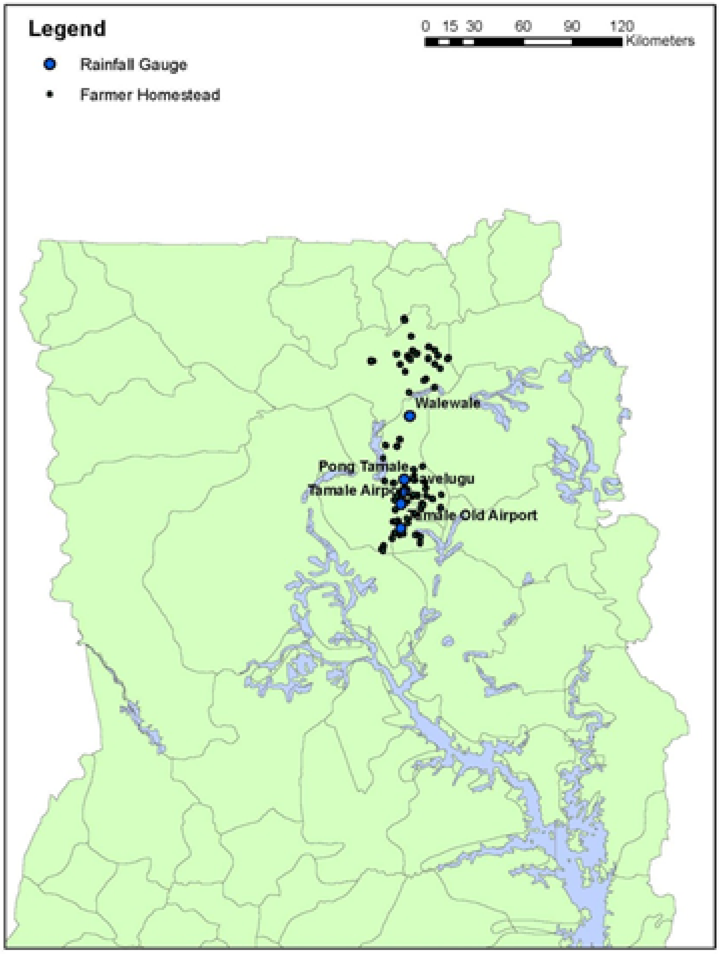
At any price of insurance, and for any conventional risk-averse preferences, a decrease in basis risk or an increase in the farmer's trust that payouts will be made increases investment. The decline in basis risk (increase in trust) *a fortiori* increases purchases of insurance: $c_G^1 - c_B^1$ declines as $\pi_B$ 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 $\pi_B$ 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 $\pi_B$ : one's own experience with the index insurance and the experience of individuals in one's social network with the insurance.

# Appendix Figure 1: Timeline



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



Appendix Table I: Sample Frame Summaries
Observation Counts

| Panel A: Experimental Cells | Sample Frame 1 | Sample Frame 2 | Sample Frame 3 | Total |
|---|---|---|---|---|
| | | New households in same communities as | | |
| Communities: | Original communities | 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<br>2009 product | Year Two<br>2010 product | Year Three<br>2011 product | Post-Study Year<br>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)<br>GHC 2 (USD 5.25)<br>GHC 8 (USD 10.50)<br>GHC 9.50 (USD 12.50)<br>GHC 12 (USD 15.85)<br>GHC 14 (USD 18.50) | GHC 3 (USD 4.00)<br>GHC 6 (USD 7.90)<br>GHC 9 (USD 11.90) | GHC 10 (USD 12.50)<br>GHC 14 (USD 17.50) |
| 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)<br>GHC 60 (USD 86.30) | GHC 20 (USD 26.40)<br>GHC 50 (USD 66.00) | GHC 0 (USD 0.00) | GHC 26.80 (USD 33.55) |
| 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