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A field experiment on the impact of weather shocks and insurance on risky investment

Ruth Vargas Hill · Angelino Viceisza

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Abstract We conduct a framed field experiment in rural Ethiopia to test the seminal hypothesis that insurance provision induces farmers to take greater, yet profitable, risks. Farmers participated in a game protocol in which they were asked to make a simple decision: whether or not to purchase fertilizer and if so, how many bags. The return to fertilizer was dependent on a stochastic weather draw made in each round of the game. In later rounds a random selection of farmers made this decision in the presence of a stylized weather-index insurance contract. Insurance was found to have some positive effect on fertilizer purchases. Purchases were also found to depend on the realization of the weather in the previous round. We explore the mechanisms of this relationship and find that it may be the result of both changes in wealth weather brings about, and changes in perceptions of the costs and benefits to fertilizer purchases.

Keywords Fertilizer purchases · Uncertainty · Insurance · Investment response · Field experiment · Ethiopia

JEL Classification C93 · D13 · D80 · O13

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R.V. Hill · A. Viceisza (✉)
International Food Policy Research Institute (IFPRI), 2033 K Street NW, Room 400, Washington, DC 20006, USA
e-mail: a.viceisza@cgiar.org

R.V. Hill
e-mail: r.v.hill@cgiar.org

1 Introduction

Many investment options available to individuals in the developing world have returns characterised by substantial uninsurable risk. Perhaps none more so than the decision made by farmers to invest in crop production that depends on the vagaries of weather. Markets for weather contingent securities to insure against this risk are limited and inaccessible to the majority of these farmers.

A rich theoretical literature considers how investment decisions of poor individuals are impacted by such uncertainty. Sandmo's seminal work proves that for a firm facing output price uncertainty an increase in the riskiness of the return to production activities or in the risk aversion of the firm will reduce the scale of production (Sandmo 1971). This model has been adapted for rural households by Finkelshtain and Chalfant (1991), Fafchamps (1992), Barrett (1996), Kurosaki and Fafchamps (2002) and others. These papers similarly show that, absent the special case of output risk positively correlated with consumption prices, increases in output risk and the risk aversion of farmers reduce the scale of risky crop production. These models thus predict that reductions in risk, such as those that would result from a weather-index based insurance contract, will increase investments that are susceptible to weather risk.[1]

Empirically testing this prediction has proved somewhat difficult. There are few instances of exogenous variations in risk which have allowed the impact of reductions in risk—such as those that would result from the development of weather insurance markets—to be assessed. Studies on the supply response of insurance provision have mainly focused on traditional yield and revenue insurance (and mainly for the US, for example Horowitz and Lichtenberg 1993; Ramaswami 1993; Smith and Goodwin 1996). However these insurance contracts differ significantly from the one considered in this paper in that they insure crop yields, which depended both on production investments and weather, and not returns to a given production investment. These traditional contracts are subject to considerable moral hazard which impacts the observed supply response. Furthermore, insurance in these studies was not an exogenous source of variation in risk, as farmers selected the amount of insurance coverage they would purchase. This made it difficult to separate the decision to purchase insurance from its impact on other production decisions, such as input purchases and the scale of operation.

Recently a number of experimental studies have been conducted that randomly allocate weather insurance to farmers, thereby allowing an empirical test of this hypothesis (Giné and Yang 2007; Giné et al. 2008). However, there has not been sufficient take-up, neither in the number of people accessing insurance nor the level of

[1]The special case holds when the source of output risk faced by a household is price risk of a crop that the household both produces and purchases. Fafchamps (1992) characterizes this case of positively correlated output revenues and consumption prices thus: "growing a crop whose revenue is positively correlated with consumption prices is a form of insurance. Consequently, more risk-averse farmers will seek to insure themselves against consumption price risk by increasing the production of consumption crops." He notes that this is only the case if the consumption effects outweigh the direct effect on income that arises as a result of switching the portfolio of crops, and if the covariance between crop price uncertainty and revenue uncertainty is large and positive.

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insurance purchased, to allow for an assessment of its impact (Cole et al. 2009). One exception is a recent study by Cai et al. (2009) which examined the impact of indemnity sow insurance on investment in sows in China. They use community level data on sow investments, and a randomized insurance marketing strategy to identify the impact of insurance.

While small scale field experiments (what Harrison and List 2004, refer to as framed field experiments) can be an interesting avenue to explore such impacts, particularly because they can rid the experiment of constraints such as credit and trust, such studies seem to have been rather limited. Most comparable experimental work has focused on willingness to pay or accept insurance. Recent work has explored willingness to partake in risk-sharing arrangements (Bone et al. 2004; Charness and Genicot 2009), willingness to pay for insurance against low probability catastrophic events (see, for example, Laury et al. 2009) and behaviour in experimental insurance markets (Camerer and Kunreuther 1989). The work that is closest to assessing the impact of insurance on investment behaviour in a small scale experiment is Carter (2008). He implements a framed field experiment with farmers in Peru to familiarize subjects with the concepts of basis risk and weather-index based insurance. He then observes farmers' decisions to purchase insurance and undertake risky investment. In our case, however, insurance was exogenously mandated for a random selection of farmers to allow a focus on the behavioural impacts of insurance. We also considered a case in which weather insurance was based on an external index for which there was no basis risk. We thus considered the impact of an ideal insurance contract—a contract that faces no adverse selection, moral hazard or basis risk.

Insurance reduces an individual's exposure to risk thereby reducing the variance of output. However, just as changes in the underlying stochastic process alter behaviour, changes in an individual's perception of the degree of risk to which they are exposed can also result in behavioural adaptation. In the face of imperfect information about the stochastic process determining output, individuals form beliefs about expected return and risk. These beliefs are updated as a result of realizations of the stochastic process. Whilst some posit Bayesian updating of beliefs (for example Viscusi 1985; Smith and Johnson 1988; McCluskey and Rausser 2001), there is a considerable and growing body of evidence that suggests individuals use heuristic tools in forming and updating beliefs (for example Tversky and Kahneman 1971, 1974; Kahneman and Tversky 1972, 1973; Grether 1980; Charness and Levin 2005; Rabin and Vayanos 2009). The use of these heuristic tools can result in individuals overweighing salient experiences—such as recent experiences or very good or bad experiences—in forming and updating beliefs. As such, it is possible that realizations of an uncertain process, such as the weather, result in a contemporaneous impact on wealth and on perceptions.

In particular we note that a considerable theoretical and empirical literature has documented one particular heuristic used by individuals when they observe a short sequence of independent and identically distributed draws from a time-invariant stochastic distribution. This is the belief in the law of small numbers as discussed in Rapoport and Budescu (1997); Rabin (2002); Rabin and Vayanos (2009). The law of small numbers dictates that individuals exaggerate the likelihood that a short sequence of draws will resemble the long run rate at which those draws should be produced. As a result individuals believe that draws that are not locally representative (in

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that they do not represent the long-run rate) are quite unlikely. A belief in the law of small numbers encourages an individual to think that early draws of one signal (such as good weather) increase the odds of subsequent draw of the other signals (such as bad weather).

To explore some of these issues in a controlled environment we conducted a framed field experiment in rural Ethiopia to observe investment decisions under uncertainty with and without mandated insurance. The investment decision considered was the decision to purchase fertilizer. Applying fertilizer and planting improved seeds are the main yield-increasing investments available to crop farmers in Ethiopia. Investing in fertilizer increases yields substantially when rains are good, but have little effect on yields when it rains less than expected. Seasonal credit for fertilizer is widely available in Ethiopia, reaching about four million farmers (Spielman 2009), yet fertilizer is applied to only 32% of cultivated area (Seyoum Tafesse 2009). There are a number of reasons that can be given for why this is the case, such as limited knowledge about fertilizer use (Asfaw and Admassie 2004), low returns to fertilizer (Dadi et al. 2004), and limited or untimely availability of fertilizer (Byerlee et al. 2007). However empirical work has highlighted that an additional reason for low fertilizer use is the increased net-income risk it brings. Even controlling for other household characteristics, households that are less able to manage income risk are less likely to apply fertilizer (Dercon and Christiaensen 2010). Dercon and Christiaensen show that fertilizer returns are high when the rainfall is good and negative when the rainfall is too low or too high. Combined with the fact that the main fertilizer application is made at planting, and that purchase orders for fertilizer are often made well in advance of this, this makes fertilizer a risky investment.[2]

In the framed field experiment farmers were asked to make a simple decision: whether or not to purchase fertilizer and if so, how many bags. The return to fertilizer was dependent on a stochastic weather draw made in each round of the game protocol. In later rounds of the game protocol a random selection of farmers made this decision in the presence of a stylized weather-index insurance contract.

Insurance was found to have some positive effect on fertilizer purchases. Purchases were also found to depend on the realization of the weather in the previous round. We explore the mechanisms which give rise to this relationship and find that it may be the result of both changes in wealth weather brings about, and its impact on the subjective probability of good weather next round.

In the next section the experimental game protocols are detailed and the survey site and implementation strategy are described. Section 3 discusses the empirical strategy, and Sect. 4 presents the empirical results. Section 5 concludes.

[2] In Ethiopia, fertilizer is largely purchased through cooperatives or from the local government agriculture office. Demand forms for fertilizer are filled in a number of months before application, and on the basis of these requests fertilizer is delivered to the farmer on credit for use during the planting season. Fertilizer is not commonly stored from one season to the next, so in effect the farmer makes his fertilizer investment decision prior to the planting season.

2 The experiments

Unexpected events that cause ill health, a loss of assets, or a loss of income play a large role in determining the fortunes of households in Ethiopia. Research on the potential impact of shocks and insurance on production decisions is appropriate in this context of high dependence of welfare on uninsured weather risk, which is why Danicho Mukhere kebele in Silte zone in southern Ethiopia was selected as the experimental site.

The kebele is located by the main road linking Addis Ababa to Soddo (Wolayita), about half way between Butajira and Hosannah. There are around 2,000 households living in Danicho Mukhere, in a relatively dispersed fashion. The kebele is comprised of 8 villages, some in the lowlands by the road and others in the highlands. The lowland villages are close to a road and a trading post (one of the villages, Wonchele-Ashekokola encompasses this trading area) whilst those in the highland areas have to be reached by foot and face substantial market access constraints. Four of the eight villages in the kebele were purposively selected to ensure a variety of agro-climatic and market-access conditions were covered. In this kebele there are a number of traditional insurance groups, called iddirs, that have been organically formed to insure households against the costs of funerals. However, at the time of the investigation, households had no means by which to insure the weather risk to which they were exposed.

2.1 The experimental design

We are mainly interested in the extent to which insurance provision affects ex ante risk-taking. Given our subject pool we found it important to construct a game protocol that was simple enough to elicit farmers' decision making under varying degrees of risk, but that farmers could also relate to their day-to-day decision making environment. We developed a framed game protocol in which farmers made fertilizer purchase decisions (as previously described, farmers are familiar with this decision) in the presence of weather risk, which led to income risk. We refer to this baseline environment as the investment in fertilizer game protocol (IFG).

To address the question of how insurance affects ex ante risk taking, we also considered a modified environment in which farmers made fertilizer decisions in the presence of insurance which led to a decrease in income risk. We refer to this treated environment as the *modified* IFG protocol (MIFG). Any given farmer participated either in the IFG or the MIFG, thus enabling a between-subjects design. Furthermore, since farmers in both environments (IFG and MIFG) started out making decisions without insurance, our design allows for a difference-in-difference comparison.

2.1.1 The IFG and MIFG protocols

The IFG protocol comprised the following steps:

1. At the beginning of the game ($t = 1$) the farmer was assigned a random initial endowment y_1.

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2. The farmer had to decide how many bags of fertilizer f_1 to purchase using this initial endowment. He could purchase zero, one or two bags of fertilizer at unit price p. Any fertilizer purchased was automatically applied as input to the production process. The farmer's return from fertilizer $r > 0$ was fully dependent on the weather θ_1 and the amount of fertilizer applied.
3. The weather was determined. It was good ($\theta_1 = 1$) with probability ρ and bad ($\theta_1 = 0$) with probability $1 - \rho$.
4. The farmer received income according to his choice of fertilizer and the draw of the weather. This additional income was determined as follows:

$$y_b + (a + rf_1)\theta_1. \tag{1}$$

In expression (1) y_b represents baseline income from production that the farmer received regardless of the state of the weather and a represents returns to good weather regardless of the amount of fertilizer applied. The other variables are as defined previously. Accordingly, the farmer's income at the beginning of round $t = 2$ was:

$$y_2 = (y_1 - pf_1 - k) + (y_b + (a + rf_1)\theta_1), \tag{2}$$

where k represents a consumption fee that the farmer had to pay regardless of the weather. The first component of expression (2) (indicated in the first parenthesis) represents the remainder of the farmer's initial endowment (after payments for fertilizer and consumption), whereas the second component represents production income, part of which is conditional on the amount of fertilizer applied and/or the weather.
5. Once the first round of the game was completed, steps 2 through 4 were repeated three additional times. Each repetition of steps 2 through 4 constituted an additional round of the game. So, the IFG protocol consisted of a total of four rounds. The farmer was only assigned a random endowment at the beginning of the first round. In subsequent rounds the farmer's wealth evolved according to his fertilizer choices and the realizations of the weather.

The MIFG was the same as the IFG, except that *the last two rounds* of the game protocol were played in the presence of *mandated* insurance. The cost of insurance was equal to $m > 0$ and insurance paid T in times of bad weather (insurance did not pay in times of good weather). Insurance was always actuarially fair such that the expected benefit of insurance was equal to the cost, i.e., $m = (1 - \rho)T$.

So, the farmer's income at the end of a given round t with insurance was:

$$y_{t+1} = (y_t - pf_t - k - (m - T)) + (y_b + (a + rf_t - T)\theta_t). \tag{3}$$

Note that if the weather was good ($\theta_t = 1$), expression (3) would reduce to $y_{t+1} = (y_t - pf_t - k - m) + (y_b + (a + rf_t))$ such that the insurance benefit would not increase the farmer's net income (relative to expression (2)). Meanwhile, if the weather was bad ($\theta_t = 0$), expression (3) would reduce to $y_{t+1} = (y_t - pf_t - k - m + T) + (y_b)$ such that the insurance benefit would take effect.

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2.2 Comparison with risk protocols

Our experiment protocol relates to experiments on choice under uncertainty, particularly, those that elicit preferences for risk using choices over monetary lotteries (see for example Binswanger 1980; Holt and Laury 2002, 2005; Cox and Harrison 2008; Harrison et al. 2010, and several others). For the sake of simplicity, we term these "risk protocols". However, there are also some crucial differences given our main question of interest. To draw the analogy between our protocol and risk protocols, we focus on the additional income the farmer receives in any given round t. This income is based on (1) the farmer's fertilizer choice f_t, (2) the weather draw θ_t and (3) the presence of insurance or not. In any given round, the farmer's choice of how much fertilizer to purchase can be seen as a choice over three lotteries as indicated in Table 1.

First, consider the case without insurance. Choosing one bag of fertilizer corresponds to lottery A, which pays y_b if the weather is bad and $y_b + a$ if the weather is good. Similarly, choosing two (three) bags of fertilizer corresponds to lottery B (C). Next, consider the case with actuarially fair insurance. In this case the choice between lotteries A'', C'' or B'' represents the choice between zero, one or two bags of fertilizer in the presence of insurance.

Viewed in this way, it becomes quite clear why we would expect a risk averse farmer to increase his fertilizer choice in a round with insurance holding wealth and expectation of the weather constant. Since insurance was actuarially fair, the farmer's expected payoff was the same with or without insurance. However, the risk associated with such payoff was lower due to the benefit of insurance (as exhibited by the range of possible payoffs across states).

While thinking about the choices in our experiments as choices over monetary lotteries is useful, it is important to note that the decision-making task in our experiments was framed quite differently from that in risk protocols. The farmer was assigned an initial endowment which he could use to purchase fertilizer. Typical risk protocols do not maintain such a procedure as subjects make decisions over monetary lotteries and those decisions become binding only at the end of the experiment—either through payment for all decisions or payment for a random set of decisions. So, typically the subject neither (physically) purchases nor receives payment for the lottery as the experiment progresses. As such the farmer faced a dynamic situation in which wealth carried over across periods. Furthermore, the farmer in the MIFG actually purchased an insurance contract that paid in times of bad weather.

2.3 External validity

We now discuss other components of our experimental design and how they affect the trade-off between power to test the main hypothesis and external validity of the game protocols. In actuality (i.e., the naturally occurring day-to-day environment), several socioeconomic factors affect whether a farmer chooses to buy fertilizer and the likely impact of insurance on fertilizer purchases.

First, consider the liquidity constraints a farmer faces. As is often the case in rural areas, subjects in the experiment sessions could be liquidity constrained or even go

Table 1 Round t choice of fertilizer in a lottery-choice framework

Lottery	Fertilizer (f_t)	Payoff if $\theta_t = 0$ $(1-\rho)$[a]	Payoff if $\theta_t = 1$ (ρ)	Expected payoff	Difference in payoff (across states)
Without insurance (high risk environment, IFG)					
A	0	y_b	$y_b + a$	$y_b + \rho a$	a
B	1	$y_b - p$	$y_b + (a+r) - p$	$y_b + \rho(a+r) - p$	$(a+r)$
C	2	$y_b - 2p$	$y_b + (a+2r) - 2p$	$y_b + \rho(a+2r) - 2p$	$(a+2r)$
With generally priced insurance (low risk environment)[b]					
A'	0	$y_b - (m-T)$	$y_b + a - m$	$y_b + \rho a + ((1-\rho)T - m)$	$a - T$
B'	1	$y_b - p - (m-T)$	$y_b + (a+r) - p - m$	$y_b + \rho(a+r) - p + ((1-\rho)T - m)$	$(a+r) - T$
C'	2	$y_b - 2p - (m-T)$	$y_b + (a+2r) - 2p - m$	$y_b + \rho(a+2r) - 2p + ((1-\rho)T - m)$	$(a+2r) - T$
With actuarially fair insurance (low risk environment, MIFG)					
A''	0	$y_b - (m-T)$	$y_b + a - m$	$y_b + \rho a$	$a - T$
B''	1	$y_b - p - (m-T)$	$y_b + (a+r) - p - m$	$y_b + \rho(a+r) - p$	$(a+r) - T$
C''	2	$y_b - 2p - (m-T)$	$y_b + (a+2r) - 2p - m$	$y_b + \rho(a+2r) - 2p$	$(a+2r) - T$

[a] $1-\rho$ varied across sessions (but was fixed within a session) from 1/3 to 1/4 to 1/5

[b] The general formulation that allows for insurance that is not actuarially fair is included for the sake of completion

bankrupt. As the experiment did not allow for borrowing, sufficient rounds of bad weather could lead some into a state of bankruptcy, that is, zero wealth. If this occurred, the subject had to sit out the "game" until he or she had sufficient resources to be able to continue making fertilizer purchases. Our assignment of random initial endowments made some subjects more likely to go bankrupt than others, which in turn may affect how subjects make their fertilizer choices (something we test by looking at changes in wealth). In reality, provision of insurance may open up access to credit for farmers. This has been identified as a distinct and potentially large impact of insurance provision on investment decisions and farmer welfare (Carter 2008). This is not something we consider here as we assess the impact of insurance without a commensurate change in access to credit. As a result our analysis is essentially a lower bound on the potential impact of insurance on investment decisions.

Second, consider social effects such as the influence of one's peers or social networks on fertilizer choices. Our game protocols mitigated peer effects by maintaining the following procedures which will be elaborated upon in Sect. 2.5. Farmers were separated during the decision making phase of the experiment using voting boxes. They were also instructed not to communicate with each other once the experiment began; any questions were to be directed to the experimenter (as opposed to peers). Furthermore, individual earnings were not made public, since each farmer was paid in private by the assistant experimenter. Whereas it may have been interesting to study peer effects, particularly since they have been shown to matter for social learning processes such as technology adoption (e.g., Munshi 2004), this was not part of the research question. Introducing peers' choices for a given subject to observe prior to making his or her own choice would have made the game protocol more complicated and lengthy, potentially reducing the power to test our main hypothesis. So we study individual choices in isolation from peers.

Finally, consider trust toward and understanding of the insurance product. Since insurance was mandated and introduced after two rounds of weather draws and realized earnings, failure to trust that insurance would actually pay in times of bad weather was of minimal relevance. Trust was further promoted by the fact that weather risk was resolved in a matter of minutes and, hence, insurance paid out (or not) quickly. This controls for a relatively important typical confound, namely, lack of trust. With regard to understanding, the experimenter spent considerable time explaining the costs and benefits of insurance to the subjects in order to relax this constraint (Sect. 2.5 elaborates on how the games were explained). To explore ex post variation in subject understanding and test whether improved understanding makes farmers more likely to respond to insurance, we also included a series of questions in the household survey, which 94 percent of subjects completed after participating in the experiment. Although in actuality trust and understanding may be lower than in our game protocols, it was important to control for those factors to gain power for testing the main hypothesis.

2.4 Expectation formation

The probability that good (bad) weather occurs, ρ $(1-\rho)$, is an important determinant of the level of fertilizer a farmer chooses to apply within the experiment. Subjects

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were informed of the stochastic process underlying the weather and thus, we could assume that ρ is common information to all farmers, and stays constant across time. In reality, however, farmers are likely to have different beliefs about the size of ρ. Farmers were told ρ but then observed a number of realizations of 1 (good weather) and 0 (bad weather) as they made their decision in repeated rounds of the game protocol. The law of small numbers would suggest that the more times the farmer observes 0, the less likely does he consider the possibility that he will draw 0 again in the next round, and likewise for repeated draws of 1. Although repeated rounds of 1 result in higher and higher levels of y_1 (causing a farmer to be more likely to purchase fertilizer), they also result in a higher and higher expectation by the farmer that the next round's draw will be 0. If we denote π as a farmer's subjective belief of the probability ρ, repeated rounds of 1 can be thought to decrease π and thus reduce the subjective expected return to fertilizer, $\pi(a + rf)$. Repeated rounds of 0 can be thought to increase π and thus increase the subjective expected return to fertilizer, $\pi(a + rf)$.

Experimental studies have quantified the biases brought about by a belief in the law of small numbers for the case of $\rho = 0.5$ (Rapoport and Budescu 1997; Rabin and Vayanos 2009) and theoretical work has modeled the impact of the law of small numbers for many values of ρ when an individual takes into account the draw in the previous round (Rabin 2002). Here we consider a case where $\rho \neq 0.5$ and the number of previous rounds considered ranges from 5 to 8 (the IFG and MIFG were each preceded by a set of willingness-to-pay for insurance protocols that lasted four rounds; this is further discussed in Sect. 2.5).

We chose not to explicitly elicit these expectations that are "internal" to the game protocol, since this would have considerably added to its length. So, our analysis controls for internal expectation formation using a proxy.

To proxy for the likely impact of the law of small numbers on subjective expectations formation we posit that $\pi = f(b, \rho)$ where b is the length of time since the last bad draw was realized and $\partial\pi/\partial b < 0$. In this formulation b is the main measure that proxies for the law of small numbers (or "local representativeness"). In particular the above formulation states that as a subject observes more rounds of good weather he believes good (bad) weather to be less (more) likely since the short-run sequence being observed should "balance" realization of draws proportionally to the population. We find b a fairly intuitive and simple proxy to capture the subject's evolution of beliefs given a relatively long history of draws (i.e., 5 to 8 rounds).

2.5 Implementation and procedures

We conducted twelve sessions during the course of seven days: six were IFG and six were MIFG. The average session comprised around 22 subjects. Half of the sessions offered 25% return on fertilizer and the other half offered 100% return. The probability of bad weather $1 - \rho$, which was drawn per round at the session level, was equal to $1/3$ during one session, $1/4$ during seven sessions and $1/5$ during four sessions. This probability was also held constant within the session. The $1/3$ session was significantly different from all other sessions, since it lead to very high realizations of bad weather, thus constraining individuals for several rounds of decision making. Therefore, we exclude it from our analysis. The consumption fee k was always set at 8 Birr

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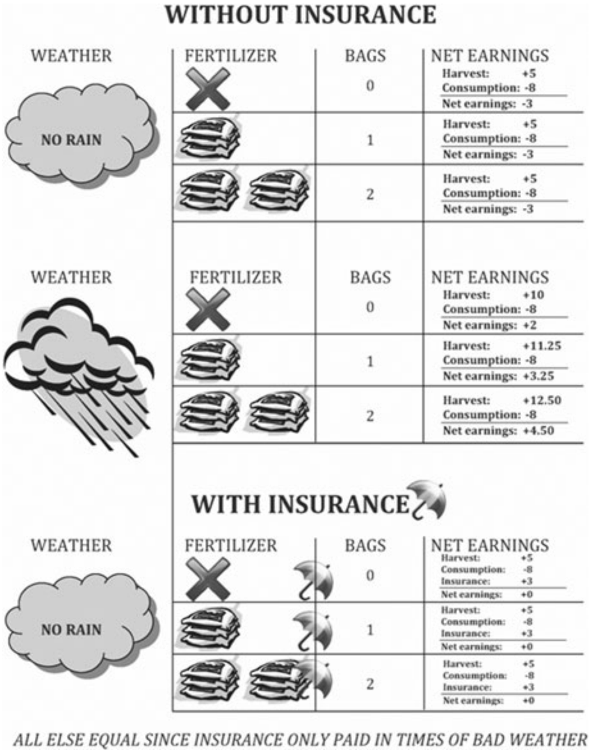

Fig. 1 Graphical display of IFG and MIFG protocols

("Birr" is Ethiopia's national currency). The initial endowment at the beginning of the game protocol y_1 varied randomly from 2 Birr to 16 Birr across individuals within a session. The additional income from production a and the minimum income from production y_b were both always set at 5 Birr. The price of fertilizer p was always set at 1 Birr and the price of insurance was actuarially fair, thus varying with the probability of bad weather (as above) and the benefit of insurance T, which was always equal to 3 Birr.

Each experiment session consisted of registration, instruction, practice, decision making and payment in private. Instructions were done orally (i.e., read aloud by the experimenter) and depending on which protocol was being addressed, parts of the graphic in Fig. 1 were displayed on the board to support the explanation. The subject instructions are available from the authors upon request. In summary the IFG proceeded as follows:

1. Each farmer's initial endowment was assigned only once at the beginning of the game protocol (i.e., at the beginning of the first round) in a white envelope.
2. Each farmer revealed his preference for fertilizer by placing the amount of money that corresponded to the value of the number of bags of fertilizer, pf_1, in his yellow envelope. This envelope was collected by the experimenter and handed to the assistant experimenter. The assistant experimenter recorded the farmer's choice and then replaced the amount of money in the yellow envelope with the corresponding number of fertilizer vouchers that represented bags of fertilizer. The

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experimenter returned each farmer's yellow envelope and the farmer confirmed the number of fertilizer vouchers that were in the yellow envelope. Envelopes were traced by the farmer's seat number, which was marked in the upper right-hand corner.

3. The probability of good (bad) weather was represented by distinct color pen tops in a black opaque bag. The experimenter called upon *a farmer* to draw the weather out of a bag. The weather drawn was for the entire session, i.e., all farmers faced the same good or bad weather.
4. Each farmer would then go to the assistant experimenter individually to receive payment for his additional earnings according to his choice, the weather and the consumption fee which had to be paid (recall expression (1)). The assistant experimenter paid each farmer behind dividers in order to maintain subject privacy.

Once the first period was conducted, steps 2 through 4 were repeated three additional times. During those periods, the farmer's wealth evolved according to his choices and weather shocks. There were no additional random shocks to the farmer's wealth except for the shocks provided by the weather. All earnings in the experiment were kept in the white envelope. This enabled the farmer to keep track of his wealth throughout the game protocol. Subjects were informed that whatever was in the white envelope at the end of the experiment session would be theirs to keep.

Whilst subjects were not informed of the length of the game protocol at the beginning of the session, the experimenter did announce the final round in some sessions if subjects inquired about it. Typically, this arose in sessions that took place later in the day because subjects had to return home to attend to their cattle prior to dusk. The direction of this effect on fertilizer choice in the final round is unclear; however, we do not necessarily see this as problematic since this issue arose both in some IFG and some MIFG sessions. Thus we expect our difference-in-difference analysis to control for this effect.

The MIFG sessions were similar to the IFG sessions, with the exception that the last two rounds of the game protocol were played in the presence of *mandated* insurance. Procedurally, these last two rounds differed from those in the IFG as follows. When revealing his preference for fertilizer (recall step 2), each farmer also had to place an amount equivalent to the cost of one unit of insurance m into the yellow envelope. In case of out-of-pocket insurance, this amount came from the white envelope. In case of granted insurance, the experimenter provided the farmer with the amount m. In addition to any fertilizer vouchers, the assistant experimenter placed an insurance voucher in the yellow envelope (recall step 3). Each farmer was paid according to his choice and the weather shock, but now in the presence of insurance (recall step 4). As in the IFG each farmer individually went to the assistant experimenter to receive payment for his additional earnings in private (recall expression (3)).

We note some final aspects of our experimental procedures that are important. First, we let farmers draw the weather in any given round, as opposed to having the experimenter control it, in order to foster additional transparency and credibility into the design of the experiment. At the same time, live drawing of the weather at the session level across a short sequence (i.e., number of rounds) gave rise to some relatively degenerate patterns of weather realizations. As a result, we need to control for this in the analysis.

Fig. 2 Typical experiment session

Second, in order to maintain a high degree of experimenter control, particularly over the explanation that was provided to subjects, the following measures were taken as per the norm in laboratory-like experimental sessions conducted in developed countries: (1) one of the authors served as the experimenter and the other author served as the assistant experimenter, (2) the same experimenter and assistant experimenter conducted all sessions and (3) since the experimenter did not speak the subjects' national language, Amharic, all sessions were conducted in English with live translation by a translator who also stayed constant across all sessions. This translator was trained on the protocols prior to the first session. This afforded the authors full control over the explanation of the game protocol that was given to the farmers, and full information on any questions that arose from the subject pool. It also allowed for a meaningful evaluation of subjects' understanding.

Third, to allow for subject privacy, the experiments were conducted in the library of the local school located at the center of Danicho Mukhere kebele, which was a large room with tables and chairs that were spaced out. Additionally subjects were separated by dividers (voting boxes). A picture of one of our sessions is indicated in Fig. 2.

Finally, each IFG or MIFG was preceded by a willingness-to-pay (WTP) for insurance protocol. The data elicited in the WTP protocol are not relevant for this study and were collected for other purposes; however, preceding the (M)IFG by the WTP protocol served one main purpose for the research question of this paper. It enabled subjects to familiarize themselves with the concept of insurance, in particular when insurance would pay out, before they had to make decisions that might be impacted by insurance. Since the WTP protocol also drew weather shocks, this furthermore adds a history (variation) of weather draws that can be used in identifying the role of previous shocks and expectations formation in determining fertilizer purchases. On average the complete session lasted 150 minutes and paid 27 Birr. This compares to one and a half days of casual farm labour wage in this area.

2.6 Sample selection

Each of the four selected villages from Danicho Mukhere kebele have a number of funeral insurance societies called iddir to which all households in the village belong. We used these organizations to list and sample participants. We randomly selected 6 iddirs in each village. Leaders and members of each of the selected iddirs were listed. Two leaders and ten members were randomly selected from each iddir and invited to participate in the experimental sessions. We stratified by leader/non-leader since it was important to ensure that leaders were also represented. Our aim was to have at least two leaders represented.

This gave rise to 288 sampled individuals, although our target number of individuals was 240 (10 from each iddir). We deliberately selected 12 people from each iddir in case some were not able to participate in the experiment (or arrived too late to participate), and in case some that had participated in the experiment were not able to undertake a household survey administered subsequent to the experiment. Of the 288 listed, 261 participated in the experiment sessions. This represents remarkably low attrition. Of these 261 individuals 241 were randomly selected to complete the household survey.

Table 2 presents some descriptive statistics on the individuals that participated in the experiment and survey. The majority of subjects (84%) were male and were engaged in farming as their main activity (91%). The majority of these farmers have very little education (the mean level of education is only 2.3 years).

Weather shocks are not unknown to these farmers. As Table 2 reports, nearly all farmers reported experiencing drought in the last 10 years. Subjective estimates of crop losses from the last occurrence of rain failure (reported as 2007 for most) suggest that the median farmer loses 75% of his crop when the rain fails (compared to a year in which rainfall is sufficient). Farmers view the probability of rainfall shortages in the coming season as quite high. Farmers perceptions of rainfall risk were elicited by asking them to place beans between two squares, rain failure and sufficient rain, in accordance with how likely they thought rain failure in the forthcoming season was (see Hill 2009, for use of a similar method to elicit perceptions of price risk). On average, farmers thought rain would fail with a probability of 0.25.

In the presence of quite considerable rainfall risk, Table 2 indicates that farmers have very little means at their disposal to deal with weather shocks when they do arise. In the last occurrence of drought 25% of farmers experienced losses in productive assets and/or income, and 64% reduced consumption in addition to experiencing losses in productive assets and/or income. Further assessment of farmers' access to credit and participation in risk-sharing networks, shows that, in general, farmers borrow from those who live in the same village and neighborhood as themselves, households that are members of the same iddirs and labour sharing groups. These are households with whom they have very strong ties, households that they have given to and received help from in the past, but households that are exposed to almost identical weather risk. The contextualization of the experimental game protocol as a situation of uninsured weather risk, was thus one that was very familiar and easily understood by these farmers.

In addition, the investment decision that farmers were asked to make was a familiar one. Fertilizer is the most commonly purchased input among these farmers: 50% had

Table 2 Descriptive statistics

	Statistic	All farmers	Insurance sessions	No insurance sessions	T-test of difference[a]
Socioeconomic Characteristics					
Gender (1 = Male)	Prop.	0.84	0.81	0.87	−1.04
Age (years)	Mean	45	45	45	−0.13
	Median	45	42	45	0.18
Years of Schooling	Mean	2.3	2.3	2.3	0.06
	Median	1	1	0	0.01
Farming as main activity	Prop.	0.91	0.90	0.92	−0.69
Housework as main activity	Prop.	0.06	0.07	0.05	0.07
Area of land owned (hectares)	Mean	0.61	0.55	0.66	−2.19**
	Median	0.50	0.50	0.50	1.26
Experience of weather risk					
Experienced drought in last 10 years	Prop.				
Prop. of crop lost last rain failure	Mean	0.76	0.78	0.75	1.36
	Median	0.75	0.81	0.75	3.06*
Perceived prob of rain failing	Mean	0.27	0.27	0.27	−0.02
	Median	0.25	0.25	0.25	0.00
Impact of drought on household welfare					
Lost productive assets/income	Prop.	0.25	0.24	0.26	
Reduced consumption	Prop.	0.11	0.07	0.15	
Both red. cons. and lost assets/inc.	Prop.	0.64	0.69	0.59	
Input use					
Used fertilizer last season	Prop.	0.50	0.50	0.50	−0.06
Bought seeds last season	Prop.	0.22	0.23	0.21	0.39
Hired farm labour last season	Prop.	0.09	0.09	0.08	0.23
Hired oxen last season	Prop.	0.15	0.18	0.12	1.24
Used fertilizer in last five years	Prop.	0.63	0.62	0.64	−0.28

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

[a] The continuity corrected Pearson $\chi^2(1)$ statistic is reported for tests of equality between medians

purchased fertilizer in the season prior to the experiment, and 63% had purchased fertilizer in the five years prior to the survey. In comparison, only 22% had purchased seeds in the season prior to participation and only 9% had hired labour and 15%, oxen.

Next we discuss the empirical strategy.

3 Empirical strategy

As discussed in the previous section, insurance was provided to farmers by randomly selecting half of the sessions to be an "insurance" session. And likewise when insurance was provided, the selection of granted and actuarially fair insurance was also

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random. The allocation of good and bad weather was also randomly assigned as live weather draws were made by subjects during the experimental sessions. In addition wealth and changes in wealth were varied across individuals within and between sessions by random allocation of initial wealth endowment and variations in return to fertilizer across sessions.

Randomization should result in no significant difference in the initial value of the outcome of interest or other covariates that may affect the outcome. In such cases a simple comparison of changes in fertilizer purchases before (rounds 1 and 2) and after (rounds 3 and 4) insurance should suffice. When repeated observations of individual behaviour are available, as in this case, the use of difference-in-difference estimators can provide a more robust estimator by additionally controlling for significant differences in the initial outcome of interest or covariates (Heckman and Robb 1985) or any learning effects, earnings effects or fatigue that may occur as rounds progress (which would contaminate simple before and after estimates). Given the presence of multiple rounds of data before and after the provision of insurance, we can estimate a fixed effects regression of the changes in fertilizer purchases, Δf_{it}. Namely,

$$\Delta f_{it} = \beta_0 + \beta_{\Delta I} \cdot \Delta I_{it} + \Delta u_{it}, \tag{4}$$

where I is a dummy taking the value of 1 when insurance is provided, and u_{it} is individual time specific errors.

However, as we discuss below, although there were few differences in individual characteristics across the sessions, the randomization of both weather and insurance across 44 rounds resulted in some important differences in round characteristics that need to be controlled for.

Table 2 presents summary statistics disaggregated by whether or not insurance was provided. There are no significant differences in both the mean and the median of these observable characteristics. The mean area of land owned does differ significantly between the treated and control groups, but not the median. Similarly although the mean yield loss from bad weather does not differ significantly across treatment and control sessions, the median does. This table suggests the randomization was successful in ensuring individuals with similar characteristics were in each session.

In Table 3 characteristics of the sessions are presented. As the weather was drawn live during the session, each session varied in the amount and timing of bad weather. Given this process was random, for a large enough number of sessions, the amount and timing of bad weather should be orthogonal to the provision of insurance in a given session. In Table 3, however, we see that this was not the case for the experimental sessions we conducted. The history of weather draws was quite different between sessions in which insurance was offered and which it was not.

Draws prior to the start of the insurance game (observed in the WTP game) were such that bad weather had been observed more recently in insurance sessions compared to no-insurance (control) sessions. This may have led participants to hold different beliefs about the likelihood of bad weather across the first round of insurance and no insurance sessions. If participants exhibit a belief in the law of small numbers, those in the no-insurance sessions would have assigned greater probability to the weather being bad in the first round relative to those in the MIFG sessions. This

Table 3 Session characteristics

	Round	All sessions	Insurance sessions	No insurance sessions	T-test of difference
Endowed wealth		7.5	7.7	7.4	0.60
Wealth (Birr on hand)	1	11.3	11.8	10.9	1.33
	2	12.9	12.4	12.5	0.94
	3	14.0	16.2	12.0	3.83***
	4	16.2	17.9	14.9	2.42**
Change in wealth (Birr)[a]	1 & 2	1.6	1.5	1.7	−0.29
	2 & 3	1.0	2.9	−0.6	9.68***
	3 & 4	2.3	1.6	2.9	−6.49**
Rounds since bad weather (*b*)	1	2.9	2.2	3.5	−7.43***
Good Weather occurred	1	0.81	0.80	0.82	−0.28
	2	0.72	1	0.48	11.12***
	3	0.91	0.81	1	−5.64***
	4	1	1	1	–
Fertilizer purchased (bags)	1	1.55	1.71	1.42	4.03***
	2	1.63	1.79	1.50	4.13***
	3	1.55	1.79	1.34	5.46***
	4	1.71	1.79	1.65	2.17**

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

[a] Change in wealth is calculated to include the premium of free insurance as a wealth transfer

is consistent with the finding that participants in the no insurance sessions exhibited lower initial levels of fertilizer purchases, given they expected lower returns to fertilizer due to higher expectations of the weather being bad.

There was also a difference in the experience of weather in round 2 (the round before insurance was provided) between treatment and control sessions. Sessions with insurance universally experienced good weather in this round, while half of the sessions without insurance experienced bad weather. This resulted in differences in the wealth levels of individuals in treatment and control sessions in rounds 3 and 4, the rounds in which insurance was provided. In these rounds individuals in treatment sessions were much wealthier even though wealth levels were not significantly different across insurance and no-insurance sessions in rounds 1 and 2. It may also have given rise to individuals holding very different perceptions of the risks and benefits of fertilizer purchases as they went into the final rounds of the game protocol. In round 3, only one session experienced bad weather, and this was a session in which insurance was offered.

In the analysis these differences in wealth, weather and expectation of weather draws are controlled for by adding these covariates in the regression analysis, and by matching on these covariates.

In the fixed effects analysis, we thus estimate the following:

$$\Delta f_{it} = \beta_0 + \beta_{\Delta w} \cdot \Delta w_{it} + \beta_{\Delta b} \cdot \Delta b_{it} + \beta_{\Delta I} \cdot \Delta I_{it} + \Delta u_{it}, \qquad (5)$$

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where w denotes wealth, and b denotes the number of rounds that have elapsed since the last occurrence of bad weather. The use of multiple rounds of data allows for a more precise estimate of coefficients on w and b. This in turn allows a more accurate estimate of the impact of providing insurance. Given the multiple rounds of observations it is important to difference the dummy variable that indicates the presence of insurance (Wooldridge 2002). Also although w and b are included as covariates the coefficients on these estimates are also of interest. In controlling for these covariates in the regression analysis we are able to both better explore the impact of insurance on fertilizer purchases, as well as the impact of changes in wealth and weather. In our fullest specification, we include both b and b^2 to proxy for the belief in the law of small numbers. It may be that b^2 is a superior proxy if π (an individuals subjective perception of ρ) falls at a faster rate when b increases from 7 to 8 than it does when b increases from 1 to 2.

Nearest neighbor matching is also used to estimate the impact of providing insurance. This estimation method provides consistent estimates of the impact of insurance, but does not provide any information on additional relationships of interest, such as the relationship between fertilizer purchases and weather and fertilizer purchases and wealth. There are a number of matching methods that can be used. We present results for nearest neighbor matching using the `nnmatch` estimator in Stata (Abadie et al. 2004). Matching can also be conducted using estimates of the propensity score with `pscore` in Stata (Becker and Ichino 2002), however this requires correction of the standard errors (given the two stage estimation procedure) and bootstrapping has been shown inappropriate for this context (Abadie and Imbens 2008). An additional advantage of using `nnmatch` is that it allows for exact matching on specific variables if required, something we make use of in the analysis.

However, there are two additional assumptions that must be met to consistently estimate the impact of insurance on behaviour. First, there must be sufficient overlap in the covariate distributions, such that like individuals in each state can be compared (Imbens 2004). Second, it must be the case that there is a common time effect across the two groups (Blundell and Costa-Dias 2002). This requires that there is nothing in the initial characteristics or progression of sessions that could cause the outcome variable of interest to evolve differently.

Imbens (2004) notes that when there are cases of no-overlap that arise as a result of outliers in the control observations (as is the case in round 3, only the control observations had experienced good weather in the previous round), it can give rise to artificially precise estimates. When assessing result for round 3, we should be aware that the estimates of the coefficient on insurance may appear more significant than they should. In round 4, there is an outlier in the treatment observations as only some observations with insurance experienced bad weather in round 3. In this case inclusion of the outliers can result in biased estimates (Imbens 2004). In the analysis of round 4 results we omit observations from the session in which bad weather occurred in round 3. In the fixed effects estimation all observations are used. The multiple observations for each individual allows an estimate of the behavioural response to good and bad weather both with and without insurance. With this more accurate estimate on the impact of weather on behaviour, the estimate of the impact of insurance also becomes more precise.

An additional difference in insurance and no-insurance sessions is the initial level of fertilizer purchases. Fertilizer purchases were much higher in rounds 1 and 2 of the sessions in which insurance was offered in rounds 3 and 4. We hypothesize that this is as a result of differences in *b* going into round 1. The difference in initial fertilizer purchases could have two possible effects. It could indicate a preference for fertilizer purchases among those who received insurance, causing higher levels of fertilizer purchases observed among the insured to arise from this difference in initial preferences between groups. However, this would be controlled for by differencing as this nets out any time constant unobservable characteristics such as a preference for fertilizer.

More importantly, the difference in initial fertilizer purchases could also result in a violation of the second key assumption, the assumption of common time effects across each group. Individuals purchasing higher levels of fertilizer initially were less likely to keep increasing the number of bags of fertilizer purchased even if their exposure to risk reduced, their wealth increased, or their perception of the net returns to fertilizer purchases improved. Fertilizer purchases were limited to a maximum of two bags per round in the experimental session. These individuals were already at a corner solution.[3] This, in combination with the fact that wealth increased in each round (likely to cause fertilizer purchases to increase for the sample as a whole), may confound any effect insurance may have in encouraging farmers to purchase more fertilizer. This is the opposite effect to that observed in Eissa and Liebman (1996) in which the control group contained a much high proportion of labour market participation than the treatment group, causing economic growth to attribute a larger market participation impact to the treatment (Blundell and Costa-Dias). Matching on initial fertilizer purchases, and including initial levels of fertilizer purchases in the regression analysis allows us to control for this effect. Matching has been shown to provide good estimates of the average treatment effect when, as in this case, data on the initial values of the outcome of interest can be used as part of the matching criteria (Heckman et al. 1997).

4 Results

4.1 Main results

The empirical testing strategy rests on comparing the difference in fertilizer purchases in early and later rounds of the game protocol between individuals that were offered insurance in later rounds and individuals that were not. We estimate the determinants of changes in fertilizer purchases across rounds and determine whether the provision of insurance had any impact on changing the amount of fertilizer bought.

Table 4 presents the unconditional estimations of the difference in fertilizer purchases for those with and without insurance. The table compares rounds 1 and 3, 2 and 3, 1 and 4 and 2 and 4. These unconditional results are mixed. The first two

[3]This is of course also true for those purchasing no bags of fertilizer, but in reality only 5% of individuals purchased no bags of fertilizer.

Table 4 Basic difference-in-difference

Difference in bags of fertilizer purchased in rounds...	(1) 1 and 3	(2) 2 and 3	(3) 1 and 4	(4) 2 and 4
Insurance	0.154*	0.157**	−0.152*	−0.149**
	(0.0826)	(0.0733)	(0.0843)[a]	(0.0641)
Constant	−0.0746	−0.157**	0.231***	0.149***
	(0.0692)	(0.0643)	(0.0580)	(0.0535)
Observations	248	248	248	248
Adjusted R^2	0.009	0.013	0.009	0.016

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
[a] Robust standard errors in parentheses

Table 5 Matching estimates of impact of insurance

Difference in bags of fertilizer purchased in rounds...	(1) 1 and 3	(2) 2 and 3	(3) 1 and 4	(4) 2 and 4
Nearest neighbor matching	0.273**	−0.061	−0.059	−0.027
	(0.113)	(0.074)	(0.077)	(0.061)

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

estimates are positive and significant. The second two are negative and significant. From these results it is difficult to interpret what the impact of insurance on fertilizer purchases really is. We also note that the R-squared of these regressions are very low, suggesting that the provision of insurance explains very little of the variation in changes in fertilizer purchases.

As the previous section highlighted, differences in initial fertilizer purchases, previous bad weather draws, and changes in wealth and weather across rounds also need to be controlled for. It is perhaps worth noting here that, in this experiment, changes in wealth do not depend solely on weather draws. Changes in wealth arise as a result of both subjects' choices and weather draws. Additionally, given the return to fertilizer varied across sessions, identical choices and weather draws may yield different changes in wealth in different sessions.

In Table 5 we present estimates from a nearest neighbor matching estimation to control for some of these differences. Observations were matched on previous fertilizer purchases, level of wealth, change in wealth and experience of the weather. Exact matching was performed on the amount of fertilizer previously purchased. In the latter two columns outliers in the treated pool (those for whom bad weather had occurred in round 3) were omitted. Overall the estimates are similarly mixed, however the only significant estimate of impact is positive. This perhaps suggests some positive effect of insurance, but overall, conclusive results on the impact of insurance remain elusive.

Table 6 presents difference-in-difference estimates estimated with and without fixed effects. The OLS results cluster standard errors at the subject level. The depen-

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Table 6 Difference-in-difference regression estimates[a]

	(1) OLS	(2) Fixed effects	(3) OLS	(4) Fixed effects
Δ insurance	0.121*	0.290***	0.0831	0.301***
	(0.0673)[b,c]	(0.0842)	(0.0697)	(0.0862)
Δ wealth	0.0696***	0.0213	0.0804***	0.0132
	(0.0173)	(0.0223)	(0.0182)	(0.0228)
Δb	−0.0158	0.000341	0.0608	0.0908
	(0.0433)	(0.0487)	(0.0466)	(0.0866)
Δb^2			−0.0156***	−0.0152
			(0.00500)	(0.01110)
Dummy for	−0.607***	−1.495***	−0.583***	−1.477***
max fertilizer	(0.0465)	(0.0763)	(0.0466)	(0.0778)
Constant	0.343***	0.945***	0.345***	0.969***
	(0.0475)	(0.0664)	(0.0469)	(0.0671)
Observations	744	744	744	744
Number of id		248		248
Adjusted R^2	0.309	0.541	0.321	0.547
F-test of joint significance of b, b^2[d]			4.88	0.95
			(0.0079)	(0.3897)

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$
[a] Round dummies were included but are not shown
[b] Standard errors in parentheses
[c] In columns (1) and (3) standard errors are corrected for clustering at the subject level
[d] P-values in parentheses

dent variable is the change in fertilizer purchases from round to round. The independent variables include change in wealth w and changes in the perceived probability of bad weather brought about by changes in the history of weather realizations, b. In the first two columns of results, b is included linearly, in the last two columns of results b^2 is included as well to allow for the fact that any change in expectations resulting from an increase of $b = 1$ to $b = 2$ may be smaller than the change in expectations resulting from an increase of $b = 7$ to $b = 8$.

The estimates suggest that in each case, insurance has a positive impact on fertilizer purchases, although the effect is not significant in column (3). The results also indicate that fertilizer purchases are driven by changes in wealth, and that there is some impact of changes in perceptions, as measured by b^2. In column (3) and (4) we see that the longer an individual has gone without seeing a bad weather draw, the less likely are they to invest in fertilizer. This is consistent with the evolution of subjective expectations as the law of small numbers would predict. There is little difference in the coefficients on the other variables of interest or the R^2 when using b and b^2, but given the slightly better performance of models in which b^2 is included, we continue with this choice of functional form for the future regression results.

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4.2 Further assessment of the impact of insurance

The fixed effects results suggest that insurance has a significant and sizable impact on fertilizer purchases. Using the most favorable results from column (4), we see that insurance made the purchase of an additional bag of fertilizer 0.291 more likely. Taking the median expected return to fertilizer of 75%, this would imply that insurance provision would increase the average return realised by farmers by 22%. This is in addition to any welfare benefits that may result from improved consumption smoothing as a result of insurance provision.

We explore further whether provision of insurance had a differential impact on behaviour when it was offered free, or for different types of people. In particular we examine whether insurance had a larger effect for those who had more wealth, those who better understood the contract, those who were more risk averse, or those who faced a relatively more risky investment prospect. We also determined whether farmers who were more favorable to fertilizer purchases in their farming decisions (measured by whether or not they had bought fertilizer in the 5 years prior to the survey) were more likely to increase fertilizer purchases in response to insurance provision in the game protocol. Data collected in the household survey was used to provide a measure of understanding of the contract, and of risk aversion.[4] Information from the game protocol was used to measure the coefficient of variation (C.V.) of return to fertilizer. In each case we split the sample in half according to measures of understanding, risk aversion CV of return and fertilizer preference, and compared the impact of insurance in each sub-sample. Results using a fixed effects specification (that used in column (4) of Table 6) are presented in Table 7.

In the first column we assess whether insurance had a different impact on behaviour when it was paid for as opposed to when it was offered free. Column (1) indicates that insurance has a marginally larger impact on fertilizer purchases when individuals paid for it; however, the difference in coefficients is not statistically significantly different.

In columns (2) to (6) we assess whether other characteristics of the individuals or sessions altered the impact of insurance on purchases of fertilizer. We might consider that insurance would have a larger effect for those with lower levels of wealth given the cost implied by using all one's money in the game (no fertilizer could be purchased in the following round), and perhaps also if we assume decreasing marginal utility of wealth. We find that insurance does seem to have a much larger effect for poorer individuals. The difference is large enough to be weakly significant (P-value of F-test is 0.1448).

Understanding of the insurance contract was measured by assessing participant's understanding of a similar contract described in a survey conducted after the game protocol. A weather insurance contract was described and questions on the contract asked. Subjects with a higher and lower understanding of the contract were partitioned equally with an indicator dummy.[5] Interacting this measure of understanding

[4] A measure of risk aversion can also be derived from choices made in the game protocol, and choices in the game protocol were correlated with the measure collected in the household survey.

[5] This meant that subjects scoring 5 or more out of a possible 6 were recorded as having a high understanding and those who scored 4 or lower were recorded as having a low understanding.

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Table 7 Heterogenous effects of insurance on Δ choice (fixed effects specification)[a]

	(1)	(2)	(3)	(4)	(5)	(6)
ΔI^* pay	0.323***					
	(0.0974)					
ΔI^* free	0.273***					
	(0.0864)					
ΔI^* high wealth		0.275***				
		(0.0854)				
ΔI^* low wealth		0.403***				
		(0.112)				
ΔI^* high understand			0.316***			
			(0.0881)			
ΔI^* low understand			0.244**			
			(0.121)			
Δ^* risk averse				0.293***		
				(0.0816)		
Δ * risk neutral				0.283***		
				(0.107)		
ΔI^* high CV					0.261***	
					(0.0902)	
ΔI^* low CV					0.345***	
					(0.103)	
ΔI^* has bought fertilizer						0.298***
						(0.0821)

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Table 7 (*Continued*)

	(1)	(2)	(3)	(4)	(5)	(6)
ΔI^* has not bought fertilizer						0.277^{***}
						(0.0994)
Δ wealth	0.0124		0.0130	0.0172	0.00886	0.0171
	(0.0231)		(0.0229)	(0.0225)	(0.0248)	(0.0225)
Δb	0.0911	0.113^{*}	0.0910	0.0881	0.0952	0.0883
	(0.0866)	(0.0632)	(0.0867)	(0.0868)	(0.0876)	(0.0868)
Δb^2	−0.0150	−0.0160	−0.0151	−0.0152	−0.0150	−0.0152
	(0.0111)	(0.0107)	(0.0111)	(0.0111)	(0.0111)	(0.0111)
Dummy for max fertilizer	-1.473^{***}	-1.486^{***}	-1.478^{***}	-1.470^{***}	-1.483^{***}	-1.470^{***}
	(0.0782)	(0.0780)	(0.0779)	(0.0766)	(0.0792)	(0.0767)
Constant	0.967^{***}	0.986^{***}	0.969^{***}	0.960^{***}	0.975^{***}	0.960^{***}
	(0.0672)	(0.0632)	(0.0672)	(0.0645)	(0.0694)	(0.0646)
Observations	744	744	744	744	744	744
Number of id	248	248	248	248	248	248
Adjusted R^2	0.542	0.543	0.542	0.542	0.542	0.542
F-test of joint significance	0.52[c]	2.14	0.49	0.01	0.93	0.06
	(0.4723)[d]	(0.1448)	(0.4863)	(0.9117)	(0.3363)	(0.7994)

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

[a] Round dummies were included but are not shown

[b] Standard errors in parentheses

[c] F-test of joint significance of main pair of coefficients: i.e. column (1) ΔI^* pay and ΔI^* free; column (2) ΔI^* high wealth and ΔI^* low wealth; and so on

[d] P-values in parentheses

with the provision of insurance, suggests that those more able to understand the contract were more likely to increase fertilizer purchases, but the difference in the value of the coefficients is not statistically significantly different.

Data on risk preferences were collected by offering a Binswanger style series of lotteries to the subjects in the post-survey and asking them to select the lottery they would prefer to play. Respondents were paid according to their choice and the lottery outcome. Subjects that were more or less risk averse were equally partitioned. Insurance was found to have a larger and more significant effect for those who are more risk averse, as the theoretical model would predict.[6]

The impact of insurance was also assessed differentially for those who faced fertilizer returns with higher risk measured as the coefficient of variation of the return (C.V.). The results suggest that insurance was more effective in encouraging greater investment when the risk of the return to investment was high. However, neither of these differences are large enough to be statistically significantly different given our sample size.

Finally the fertilizer supply response was compared for those who had reported using fertilizer in the 5 years prior to survey and those who had not. This was done because, despite the explicit parametrization of the return to fertilizer in the game protocol, individuals entered the session with a different perception of the benefit to using fertilizer, and this perception is somewhat reflected in their fertilizer use decision.Indeed, we find that insurance had a stronger effect for those who had used fertilizer in the previous 5 years, those who most likely viewed the benefits to fertilizer as higher, but the difference is very small and not statistically significantly different from zero.

Overall this disaggregation suggests that insurance has more impact when individuals purchase it with their own money, and for risk averse individuals when it is better understood, the risk of investment is high, and who were perhaps more predisposed to purchase fertilizer. However, with the exception of wealth, in each case the magnitude of the difference is not large and is not statistically significantly different from zero given our sample size.

4.3 Robustness checks

A highly significant variable in the difference-in-difference estimations presented in Tables 6 and 7 is the dummy indicating farmers who could not increase their fertilizer purchases further because they already purchased two bags in the previous round. This dummy was included to control for corner solutions. A Tobit model cannot be used given the difference-in-difference identification strategy causes the constrained households to appear in the middle of the distribution. A fixed effects estimation procedure also makes using a Tobit difficult. In this section we explore the robustness of our results to alternative means with which to handle the preponderance of corner solutions in the data.

[6] This meant that subjects with a constant partial risk aversion coefficient less than 0.47 were recorded as risk neutral and those with a partial risk aversion coefficient equal to or higher than this were recorded as risk averse.

First, we run a Heckman selection model in which the selection equation selects farmer who were not constrained in their choice (we assume that farmers that we observe choosing two bags of fertilizer in successive rounds are constrained in their choice) and for whom (5) is observed. Given the positive relationship between wealth and fertilizer purchases, a farmer was much more likely to find himself constrained if he was rich enough to buy two bags of fertilizer in the first round of the game protocol. We thus include "wealth in the first round of the game" to identify the selection equation.

The first two columns of Table 8 present the fixed effects and Heckman difference-in-difference results. The Heckman results are qualitatively identical, but insurance is no longer significant whilst b^2 is much more significant.

Second, we run a Tobit model. To run a Tobit model we must no longer consider changes in fertilizer purchases as the dependent variable, but rather consider the level of fertilizer purchases in each round. A fixed effects regression on levels should yield similar results to the difference-in-difference regression without fixed effects, and indeed we find this to be the case in column (3). However, given it is not possible to run a fixed effects Tobit model, we run a random effects model on levels including individual characteristics (particularly those that are statistically different across IFG and MIFG at the individual level, recall Table 4) instead of fixed effects. These results are presented in columns (4) and (5). The results across both the linear and Tobit specifications are quite similar. Wealth stays positive and significant, but insurance and b^2 become insignificant (although the sign on the insurance coefficient is positive). The results on wealth thus appear to be quite robust to a random effects specification, but not the results on insurance and perceptions.

5 Conclusion

In this paper we have assessed evidence in support of the hypothesis that insurance provision induces farmers to take greater, yet profitable, risks. Although a number of recent experimental studies have been conducted in which weather-index based insurance has been randomly allocated, thereby allowing an empirical test of this hypothesis (Giné and Yang 2007; Giné et al. 2008), insufficient take up of insurance has not allowed for an assessment of its impact (Cole et al. 2009). In this setting small scale framed field experiments may afford the means by which to explore such an impact of insurance.

We conducted and analyzed results from a framed field experiment in rural Ethiopia in which farmers were asked to make a simple decision: whether or not to purchase fertilizer and if so, how many bags. Some evidence was found that insurance has a positive impact on fertilizer purchases. It is perhaps not surprising that stronger results were not present on average, in a short game protocol.

Purchases were also found to depend on wealth and, in accordance with the law of small numbers, the past history of weather realizations in the game suggesting changes in perceptions of the costs and benefits to fertilizer purchases was also driving changes in behaviour.

Table 8 Robustness checks[a]

	Δf, OLS	Δf, Heckman	f, FE[b]	f, RE[c]	f, Tobit RE
ΔI	0.301***	0.00751			
	(0.0862)	(0.230)			
I			−0.0491	−0.0474	0.138
			(0.0607)	(0.0552)	(0.211)
Δ wealth	0.0132	0.225***			
	(0.0228)	(0.0357)			
wealth			0.0918***	0.0303***	0.121***
			(0.0139)	(0.00566)	(0.0248)
Δb	0.0908	0.158			
	(0.0866)	(0.0992)			
b			0.0874***	0.154***	−0.0220
			(0.0324)	(0.0454)	(0.143)
Δb^2	−0.0152	−0.0337**			
	(0.0111)	(0.0155)			
b^2			−0.0215***	−0.0145***	0.0112
			(0.00419)	(0.00470)	(0.0178)
Dummy for max fertilizer	−1.477***		−0.305***	0.196***	
	(0.0778)		(0.0330)	(0.0274)	
Has bought fertilizer				0.0652	0.529**
				(0.0533)	(0.230)
Understanding of insurance				−0.0217*	−0.0909*
				(0.0112)	(0.0514)
Age				−0.00338	−0.0107
				(0.00245)	(0.00872)

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Table 8 (*Continued*)

	Δf, OLS	Δf, Heckman	f, FE[b]	f, RE[c]	f, Tobit RE
Gender				−0.0698	−0.287
				(0.0888)	(0.354)
Binswanger risk preference				−0.00336	0.0432
				(0.0175)	(0.105)
Area of land owned				−0.0782	−0.295
				(0.0571)	(0.265)
Initial endowment				−0.00929	−0.0104
				(0.01000)	(0.0475)
ρ				0.305***	1.077**
				(0.0976)	(0.449)
Return to fertilizer				0.109	0.461
				(0.0933)	(0.390)
Crop lost last rain failure				0.0686	0.344
				(0.112)	(0.661)
Constant	0.969***	0.619***	0.491***	0	1.384
	(0.0671)	(0.176)	(0.116)	(0)	(1.215)
Observations	744	744	992	624	624
Number of id	248		248	208	208
Adjusted R^2	0.543		0.287		

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

[a] Round dummies were included but are not shown

[b] FE denotes fixed effects

[c] RE denotes random effects

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