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An Experiment on the Impact of Weather Shocks and Insurance on Risky Investment

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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 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 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 of fertilizer purchases.

Keywords: insurance, input response, field experiment

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1. INTRODUCTION

Many investment options available to people in the developing world have returns characterized 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 the farmers.

A rich theoretical literature considers how uncertainty affects investment decisions of poor people. 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). That 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. Such 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 that 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 United States; for example, Horowitz and Lichtenberg 1993; Ramaswami 1993; Smith and Goodwin 1996). However, those insurance contracts differ significantly from the one considered in this paper in that they insure crop yields, which depend both on production investments and weather, and not returns to a given production investment. Such traditional contracts are subject to considerable moral hazard that affects 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 the hypothesis in question (Gine et al. 2008; Gine and Yang 2007). However, there has not been sufficient take-up, either in the number of people accessing insurance or the level of 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) that 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.

Although small-scale field experiments (for example, 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 or on decision making in the laboratory. Recent work has explored willingness to partake in risk-sharing arrangements (Bone, Hey, and Suckling 2004; Charness and Genicot 2009), willingness to pay for insurance against low-probability catastrophic events (see, for example, Laury, McInnes, and Swarthout 2009), and behavior in experimental insurance markets (Camerer and Kunreuther 1989). The work that is closest to assessing the impact of insurance on investment behavior in a small-scale experiment is Carter (2008). He

[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.

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 behavioral 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 behavior, changes in an individual's perception of the degree of risk to which he or she is exposed can also result in behavioral adaptation. In the face of imperfect information about the stochastic process determining output, individuals form beliefs about expected return and risk. Such beliefs are updated as a result of realizations of the stochastic process. Whereas some posit Bayesian updating of beliefs (Viscusi 1985; Smith and Johnson 1988; McCluskey and Rausser 2001), a considerable and growing body of evidence suggests that individuals use heuristic tools in forming and updating beliefs (Tversky and Kahneman 1971, 1974; Kahneman and Tversky 1972, 1973; Grether 1980; Mullainathan and Thaler 2000; Vissing-Jorgensen 2003; Charness and Levin 2005; Rabin and Vayanos 2009). The use of such 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. Whereas the importance of wealth and liquidity in undertaking investments in production is well documented (Dercon and Christiaensen 2007), the role of previous shocks in affecting perceptions has been harder to identify. Surveys do not usually collect information on beliefs, so the identified relationship between previous shocks and future behavior has been as a result of the changes in wealth it brings. Dercon and Christiaensen (2007) show this for the case of fertilizer purchases under weather risk (the case considered here).

Wealth affects not only liquidity to make investments but also an individual's aversion to risk. An individual's aversion to risk tends to fall as his or her wealth level rises (Arrow 1971). Additionally, in the presence of missing markets an individual's ability to insure consumption from one time round to the next increases with wealth, both as a result of greater asset holdings with which to self-insure (Lim and Townsend 1998; Fafchamps, Udry, and Czukas 1998) and as a result of better networks with which to share risk with other individuals (de Weerdt 2001). In intertemporal models, it is the curvature of the value function that determines a household's preference for risk, rather than the curvature of an individual's utility function. The more a household can disassociate consumption from income earned in one round through intertemporal transfer of resources, the flatter the value function becomes with respect to current income (Deaton 1991). Thus Eswaran and Kotwal (1990) show that for a given degree of risk aversion, underinvestment in risky production activities will be greater for households that are less able to insure consumption from uncertain returns. This relationship is borne out empirically by Morduch (1991), Dercon (1996), and Hill (2009).

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 has 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 percent of cultivated area (Seyoum Tafesse, 2009). A number of reasons 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, Burton, and Ozanne 2004; Dercon and Hill 2009), and limited or untimely availability of fertilizer (Byerlee et al. 2007). Analysis suggests that an additional reason for low fertilizer use despite seasonal credit is that without insurance against the risk of harvest failure the seasonal credit provided does not ease the credit/insurance constraint poor households face in adopting fertilizer. Households that were more susceptible to the risk of low consumption outcomes (as a result of low levels of wealth and a high probability of low rainfall levels) were less likely to apply fertilizer, even when seasonal fertilizer loans were present (Dercon and Christiaensen 2007). A further indication that risk may be a factor in fertilizer adoption is the finding that rainfall variability affects adoption of fertilizer and improved seed (World Bank 2006). Risk has been shown to affect technology adoption in general in Ethiopia: farmers who declared themselves as risk averse were found to be less likely to adopt new technology, suggesting that people perceive new technologies as risky to start with (Knight, Weir, and Woldehanna 2003).

In the framed field experiment, farmers were asked to make a simple decision: whether 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. By examining the impact of weather-index insurance in this way, a first assessment of the potential supply response of weather-index insurance can be garnered.

Purchases were also found to depend on the realization of the weather in the previous round. We explore the mechanisms that give rise to this relationship and find that it may be the result of both changes in wealth weather brings about and the impact of this round's weather on the subjective probability of good weather next round. The probability of good weather was constant throughout the game protocol and communicated to all farmers. However, theoretical and empirical work has shown that a tendency to believe in the law of small numbers (people exaggerate "the likelihood that a short sequence of independently and identically distributed signals resembles the long-run rate at which these signals are generated" [Rabin 2002, 775]) encourages an individual to think that early draws of one signal increase the odds of subsequent draws of the other signals.

In the next section we set out a model to formalize the intuition behind the hypothesis that providing insurance will increase investment in crop production. In Section 3 the experimental game protocols are detailed and the survey site and implementation strategy are described. Section 4 discusses the empirical strategy, and Section 5 presents the empirical results. Section 6 concludes.

2. CONCEPTUAL FRAMEWORK

A Two-Period Model of Investment in Fertilizer, with and without Insurance

We develop a two-period choice problem in which a farmer chooses between investing in fertilizer and holding cash in the first period.[2] There are net returns to purchasing fertilizer (the return it yields is higher than its cost), but the return is stochastic, depending on the weather. In the second period, weather uncertainty is resolved, and the farmer receives the income from the investments he or she made and consumes his or her income.

Specifically, the farmer solves the following constrained optimization problem:

$$\max_{f_1} \quad EU(c) \quad \text{s.t.} \tag{1}$$

$$y_2 = (y_b + \theta g(f_1)) \tag{2}$$

$$y_1 \geq pf_1 \tag{3}$$

$$c = y_1 - pf_1 + y_2 \tag{4}$$

$$f_1, c \geq 0, \tag{5}$$

where f_1 is the level of fertilizer purchased (at a per unit cost of p) in the first period, c is the consumption of the farmer, and y_i denotes the income of the household per period ($i = 1,2$). The household starts with a given level of income in the first period (y_1), whereas second-period income (y_2) is made up of two parts: a base income, y_b, that does not depend on weather realizations, and $\theta g(f_1)$, which is the weather-dependent return to fertilizer investments (θ represents the weather, and $g(.)$ is the production function that is increasing in f_1).

This is a standard decision problem faced by many rural households: how much of current savings should be invested in a risky but high-return good, and how much should be kept in cash. In this decision problem, as is often the case, the farmer cannot borrow to finance investment in the high-return good. Investment must be made from cash on hand. Utility is increasing and strictly concave, reflecting risk aversion. The first-order conditions provide the optimal level of fertilizer that the farmer will choose to purchase.

In the experimental game protocol, the farmer also faces the same decision problem (as is further detailed in the description of the experimental design in the next section). In the game protocol, two simplifying assumptions are imposed, and we make them here also. First, there are only three levels of fertilizer that a farmer can apply. He or she can choose to apply no fertilizer, one bag, or two bags. In reality fertilizer purchases are likely to be more continuous than this (although package sizes may result in some discontinuity of application). Second, we assume that weather is either good or bad, and that this binary outcome has a known probability (or at least an announced probability—we return to this subsequently) associated with it. Let us denote $\theta = 1$ as representing good weather and $\theta = 0$ as representing bad weather. The probability of good weather is ρ, and thus the probability of bad weather is $1 - \rho$.

We are less interested in identifying the optimal level of fertilizer purchased than in determining how a farmer's optimal choice will change with the introduction of an insurance contract. We take a similar line of reasoning to Cai et al. (2009) in assessing the farmer's fertilizer decision and the likely impact of insurance provision. Let us first assume that y_1 is sufficiently high that it does not constrain a

[2] As standard in models when discussing theoretical concepts, we maintain the term *period.* When discussing empirical issues (that is, the game protocol or the empirical analysis/results), we maintain the term *round.*

farmer's choice and we are not at a corner solution. As in Cai et al., and for simplicity, we consider the choice between $f_1 = 0$ and $f_1 = 1$. The same reasoning can be employed to consider the choice between $f_1 = 0$ and $f_1 = 2$ or the choice between $f_1 = 1$ and $f_1 = 2$.

First, consider the case of no insurance. If the farmer chooses not to buy fertilizer ($f_1 = 0$), the expected utility is

$$EU(c)|_{f_1=0,I=0} = u(y_1 + y_b), \tag{6}$$

where I is an indicator variable that takes the value of 1 if there is insurance and 0 if not. If the farmer chooses to buy one bag ($f_1 = 1$), expected utility would be given as

$$EU(c)|_{f_1=1,I=0} = \rho u(y_1 - p + y_b + g(1)) + (1-\rho)u(y_1 - p + y_b). \tag{7}$$

A farmer's choice of f_1 will be made to maximize expected utility. Thus a farmer will choose $f_1 = 1$ over $f_1 = 0$ if

$$\rho u(y_1 - p + y_b + g(1)) + (1-\rho)u(y_1 - p_1 + y_b) > u(y_1 + y_b) \tag{8}$$

and the converse were the inequality reversed.

Suppose now that farmers are mandated to buy insurance.[3] The insurance pays out T in the event that bad weather strikes, and it costs m. We assume that the insurance is priced at its actuarially fair price, such that $m = (1-\rho)T$. This insurance changes the decision problem: expected utility under $f_1 = 0$ is now

$$EU(c)|_{f_1=0,I=1} = \rho u(y_1 - m + y_b) + (1-\rho)u(y_1 - m + y_b + T) \tag{9}$$

and expected utility under $f_1 = 1$ is now

$$EU(c)_{f_1=1,I=1} = \rho u(y_1 - m - p + y_b + g(1)) + (1-\rho)u(y_1 - m - p + y_b + T). \tag{10}$$

Farmers will now choose $f_1 = 1$ if

$$\rho u(y_1 - m - p + y_b + g(1)) + (1-\rho)u(y_1 - m - p + y_b + T) >$$
$$\rho u(y_1 - m + y_b) + (1-\rho)u(y_1 - m + y_b + T). \tag{11}$$

We are interested in determining the conditions under which farmers would change the level of fertilizer they purchase (up or down) as a result of insurance. Let us assume that individual utility can be characterized by a quadratic utility function as in Gine et al. (2008), such that $EU(c) = \bar{c} - R\sigma_c^2$, where $\bar{c}$ is the mean of c, σ_c^2 is the variance of c, and R is a measure of an individual's preference for risk. This utility function is chosen for its analytical properties, but it also has the desirable property of decreasing absolute risk aversion. Using this assumption, we can characterize household expected utility as

[3] Note that this is a point of departure from the Cai et al. reasoning, in that they assume that a household is choosing both the level of risky investment and the level of insurance coverage. In many cases these are jointly determined, although taxation and public insurance provision would be one example where that is not the case. In the game protocol, the level of insurance coverage was not a choice the subject made as this gave greater power to tests of the impact of insurance provision. This is the rationale for this assumption.

$$EU(c)|_{f_1=0,I=0} = y_1 + y_b \tag{12}$$

$$EU(c)|_{f_1=1,I=0} = y_1 + y_b + \rho g(1) - p - R\sigma^2 \tag{13}$$

$$\begin{aligned} EU(c)|_{f_1=0,I=1} &= y_1 + y_b - m + (1-\rho)T - R\sigma_T^2 \\ &= y_1 + y_b - R\sigma_T^2 \end{aligned} \tag{14}$$

$$\begin{aligned} EU(c)|_{f_1=1,I=1} &= y_1 + y_b - m - p + \rho g(1) + (1-\rho)T - R\sigma_I^2 \\ &= y_1 + y_b + \rho g(1) - p - R\sigma_I^2, \end{aligned} \tag{15}$$

where σ^2 denotes the variance of income without insurance ($I = 0$) and is $\sigma^2 = \rho(1-\rho)g(1)^2$. The variance of the insurance payout (σ_T^2) is $\sigma_T^2 = \rho(1-\rho)T^2$. The insurance payout reduces the variance of income such that the variance of income under insurance ($I = 1$), σ_I^2, is

$$\sigma_I^2 = \rho(1-\rho)(g(1)^2 + T^2 - 2g(1)T).$$

From this we can see that farmers will switch from $f_1 = 0$ to $f_1 = 1$ under insurance provision if

$$\rho g(1) - p < R\sigma^2 \tag{16}$$

and

$$\rho g(1) - p > R(\sigma_I^2 - \sigma_T^2). \tag{17}$$

By construction, insurance payouts are negatively correlated with consumption risk and $\sigma^2 > \sigma_I^2 - \sigma_T^2$. Specifically, $\sigma_I^2 - \sigma_T^2 = \rho(1-\rho)(g(1)^2 - 2g(1)T)$. If we assume that $\rho(1-\rho)(g(1)^2 - 2g(1)T)$ is positive (meaning that $T < g(1)/2$), equations 16 and 17 hold true for a range of positive values of R. Namely,

$$\frac{\rho g(1)-p}{\sigma_I^2-\sigma_T^2} > R > \frac{\rho g(1)-p}{\sigma^2}. \tag{18}$$

Farmers with a risk preference parameter in this range will choose to increase the level of fertilizer that they apply when they purchase insurance. Some farmers will also choose not to switch. A farmer that chooses $f_1 = 0$ both with and without insurance has R given by

$$R > \frac{\rho g(1)-p}{\sigma_I^2-\sigma_T^2} > \frac{\rho g(1)-p}{\sigma^2}, \tag{19}$$

and a farmer that chooses $f_1 = 1$ both with and without insurance has R given by

$$\frac{\rho g(1)-p}{\sigma_I^2-\sigma_T^2} > \frac{\rho g(1)-p}{\sigma^2} > R. \tag{20}$$

For all ranges of R, then, f_1 increases or stays the same when insurance is provided. The number of farmers that purchase fertilizer under the presence of insurance is equal to or larger than the number of farmers that purchase fertilizer without insurance. However, we note that if a household is risk loving (meaning $R < 0$) and $\sigma_T^2 > \sigma_I^2$, then a household may switch from $f_1 = 1$ to $f_1 = 0$.

Corner Solutions and the Possibility of Future Play

Thus far we have assumed that farmers are not constrained in making their decision. However, it is possible that farmers may not have enough money to purchase fertilizer, and as a result the level of fertilizer applied will be given by $f_1 = y_1/p$. When insurance is provided, the need to pay for insurance causes this constraint to change to $f_1 = (y_1 - m)/p$. This is something we account for in the analysis. The possibility that the household's fertilizer choice may be constrained causes initial wealth to have some relevance for the choice of fertilizer an individual applies.

We have presented a two-period model to characterize the household's decision problem, but in reality this decision problem is repeated many times as farming households face this decision year after year. This was also the case in the game protocol played by farmers, as farmers engaged in multiple rounds of decision making. In the second period, farming households have to satisfy consumption needs, and what is left will be the amount available to invest in fertilizer in the subsequent year. To fully capture this, a dynamic household decision problem should be specified. Here we note that the impact of developing a fuller model is that households may invest cautiously in fertilizer even at low (but nonbinding) levels of wealth (Kurosaki and Fafchamps 2002).

Next, we discuss expectation formation and the implications thereof for our empirical analysis.

Expectations

The probability that good weather occurs, ρ, is an important determinant of the level of fertilizer a farmer chooses to apply. We have assumed that ρ is common knowledge to all farmers and that it stays constant across time. In reality farmers will have different beliefs about the size of ρ. Those beliefs will be based on a farmer's knowledge and may change over time with the experience of rainfall patterns. The beliefs may be formed on the basis of Bayesian updating, but heuristic principles (such as overweighting particularly salient events) will likely also be used by the farmer as he or she forms expectations.

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), and Rabin and Vayanos (2009). The law of small numbers dictates that people 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 people believe that draws that are not locally representative (in that they do not represent the long-run rate) are quite unlikely.

This has particular relevance for the decision context we are considering. 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 or she consider the possibility that he or she 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, as the previous subsection suggests), 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, $\pi g(1)$. Repeated rounds of 0 can be thought to increase π and thus increase the subjective expected return to fertilizer, $\pi g(1)$.

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 five to eight. To proxy for the likely impact of the law of small numbers on subjective expectations formation, we note 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 or she 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 (or transformations thereof) a fairly intuitive and simple proxy to capture the subject's evolution of beliefs given a relatively "long" history of draws (that is, five to eight rounds).

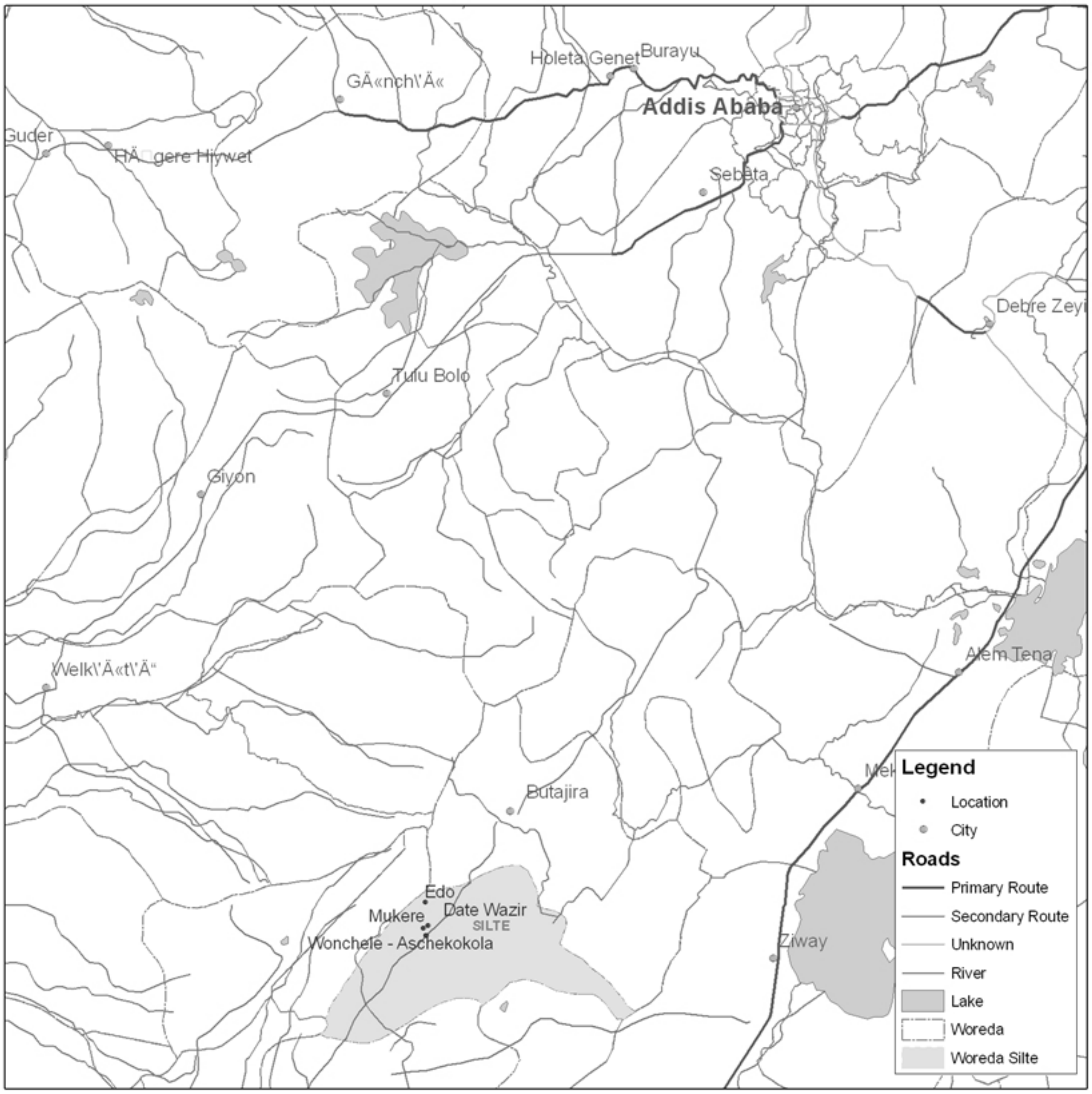
3. THE EXPERIMENTS

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. For example, Dercon et al. (2005) show that just under half of rural households in Ethiopia reported to have been affected by drought in a five-year round from 1999 to 2004. The consumption levels of those reporting a serious drought were found to be 16 percent lower than those of the families not affected, and the impact of drought was found to have long-term welfare consequences: those who had suffered the most in the 1984–85 famine were still experiencing lower growth rates in consumption in the 1990s compared with those who had not faced serious problems in the famine.

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 halfway between Butajira and Hosannah. There are around 2,000 households living in Danicho Mukhere, in a relatively dispersed fashion. The kebele comprises eight 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), but 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 that a variety of agroclimatic and market-access conditions were covered. The villages selected were as follows: one village on the main road (Wonchele-Ashekokola), two villages in the lowland area with slightly varying accessibility (Date Wazir and Mukhere), and one village in the highlands (Edo). Each of the four selected villages is indicated in Figure 1. 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.

Figure 1. Map of Silte woreda containing treatment villages



Source: Hill and Viceisza (2010).

In the following subsections we describe the design and implementation of the framed field experiment that was conducted.

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 (later we discuss the external validity of these games further). So we developed a framed game protocol in which farmers had to make fertilizer purchase decisions. 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. We refer to this treated environment as the *modified* IFG (MIFG). Further details of each protocol are discussed below.

The Investment in Fertilizer Game Protocol

A given round t of the IFG consisted of the following steps:

1. The farmer had an endowment y_t.
2. The farmer had to decide, prior to weather risk being resolved, how many bags of fertilizer f_t to purchase. He or she could purchase zero, one, or two bags of fertilizer at unit price p. All fertilizer purchased was automatically applied as input to the production process.
3. The weather risk was resolved. With probability ρ, the weather was good ($\theta_t = 1$), and with probability $1 - \rho$ the weather was bad ($\theta_t = 0$).
4. The farmer received additional income that was determined by (1) a minimum income from production y_b, (2) the returns to fertilizer as affected by the weather $\theta_t g(f_t)$, and (3) a fixed consumption fee k that had to be paid regardless of the weather. In the game protocol, $g(f_t)$ was taken to have the linear form $a + rf_t$, where r represents the return to fertilizer (in turn dependent on the weather once multiplied by θ_t) and $a, r \geq 0$. Furthermore, consumption was a fee rather than a choice. This is because our main aim is to study fertilizer decisions in the presence of insurance or not. Explicitly introducing consumption as an additional choice variable within the experiment would have complicated the task at hand without contributing to the research question of interest. Nonetheless, we chose to model consumption c as a (residual) choice variable in the model to reflect the fact that the subject could walk away with earnings at the end of the experiment session that could be used for consumption "outside of the lab." So even though consumption was not a choice that affected earnings within the experiment, there may exist a hidden tension between investing in fertilizer within the game protocol and holding cash that can be used for other purposes after the game protocol. It is this "consumption" that the model is trying to capture. The farmer's income under no insurance at the beginning of round $t + 1$, y_{t+1}, was thus determined as posited in the model:

$$y_{t+1} = (y_t - pf_t - k) + y_b + (a + rf_t)\theta_t. \tag{21}$$

Procedurally, the preceding steps were implemented as follows:

1. The farmer's endowment was contained in a white envelope (allocation of the endowment is discussed in the implementation subsection). The farmer's wealth evolved according to his or her choices and weather shocks. All earnings were kept in the white envelope, thus enabling the farmer to keep track of his or her wealth throughout the game protocol.
2. The farmer revealed his or her preference for fertilizer by placing the amount of money that corresponded to the value of the number of bags of fertilizer, pf_t, in a 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 experimenter returned the yellow envelope to the farmer, and the farmer confirmed the number of fertilizer vouchers that were in the yellow envelope.
3. The probability of good or 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. We chose to let distinct farmers draw the weather each round, as opposed to the experimenter, to foster additional transparency and credibility into the design of the experiment. This was also likely to help subjects understand the underlying stochastic process better.

4. The farmer would go to the assistant experimenter individually to receive payment for his or her additional earnings according to his or her choice and the weather shock. The assistant experimenter was behind dividers in order to maintain subject privacy and mitigate peer effects that may arise from observing peers' additional earnings (we return to this subsequently).

As mentioned previously, the IFG and the MIFG both consisted of four periods and all earnings were kept in the white envelope. Subjects were informed that whatever was in the white envelope at the end of the experiment session was theirs to keep. Although 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 in some MIFG sessions. Thus we expect our difference-in-difference analysis to control for this effect. Our empirical analysis is discussed in further detail later.

The Modified Investment in Fertilizer Game Protocol

The MIFG was similar to the IFG, with the exception that the last two periods of the game protocol were played in the presence of *mandated* insurance. During the last two periods of the game protocol, the farmer either had to purchase insurance at unit cost $m > 0$ ("out-of-pocket") or was provided with a grant equal to m ("granted") to purchase insurance at the same price. In either case, the farmer could only purchase one unit of insurance. Insurance was actuarially fair and paid T in times of bad weather.

Our choice of mandated insurance is primarily for experimental design purposes. One of the advantages of conducting a framed field experiment is that it is possible to control aspects of the decision problem more difficult to control in reality. Letting farmers choose whether to buy insurance (as one would do in reality) would have resulted in some farmers not buying insurance and would have decreased the power of tests to assess its impact. So we imposed a random insurance shock that enabled us to characterize differences between farmers' decisions with and without insurance. Despite this "mandate," farmers were clearly informed by the experimenter that they would be purchasing insurance. This was the case regardless of whether the insurance was out-of-pocket or granted. The benefits of the insurance contract were also made very clear—that is, that insurance paid out if the weather failed. This was important to ensure a powerful test of the behavioral impact of insurance on fertilizer purchases (upward or downward). The price of insurance was also varied to see if this would affect behavior.

Procedurally, the last two periods of the MIFG differed from those in the IFG as follows. When revealing his or her preference for fertilizer, the 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. The farmer was paid according to his or her choice and the weather shock in the presence of insurance. As in the IFG, the farmer individually went to the assistant experimenter to receive payment for his or her additional earnings in private. The farmer's income under insurance $y_{I,t+1}$ was thus determined as

$$y_{I,t+1} = (y_t - pf_t - k - m + b) + y_b + (a + rf_t - b)\theta_t. \tag{22}$$

We expect a comparison across the IFG and the MIFG to provide a test of our main hypothesis since the mandated insurance shock represents a decrease in risk in the income distribution, which as the model predicts, should increase fertilizer choices for given levels of risk attitudes. We can use equations 21 and 22 to reiterate this decrease in risk as a result of actuarially fair insurance. Holding the number of fertilizer bags fixed, we can establish that the difference between the expected values of income with and without insurance are equal to $-\rho m + (1 - \rho)(T - m)$, which is zero if insurance is actuarially fair. This establishes that the mean income is the same in the two treatments. The variance of income is lower in the presence of insurance than not, given that insurance reduces the spread between incomes in the low- and high-payoff states. These two conditions establish that insurance induces a mean preserving contraction (that is, decrease in risk) in the income distribution.

We use our difference-in-difference design to compare fertilizer choices across the IFG and the MIFG for given rounds. This enables us to test the behavioral impact of insurance on fertilizer choices controlling for any learning, order, fatigue, and wealth effects. Nonetheless, we note that it may have been interesting to vary the order in which subjects participated in the insurance periods. For example, we could have assigned a subset of subjects to first make decisions in the presence of insurance and then without. Alternatively, we could also have had a subset of subjects always make decisions in the presence of insurance. We chose not to implement such interesting variations to our design mainly due to the restriction on the number of sessions we could run. Also, it was hypothesized that subjects would find the progression from no insurance to insurance more logical than the other way around. Regardless, these might be interesting extensions to test the impact of an *increase* in risk (such as that which results from moving from insurance to no insurance) on behavior.

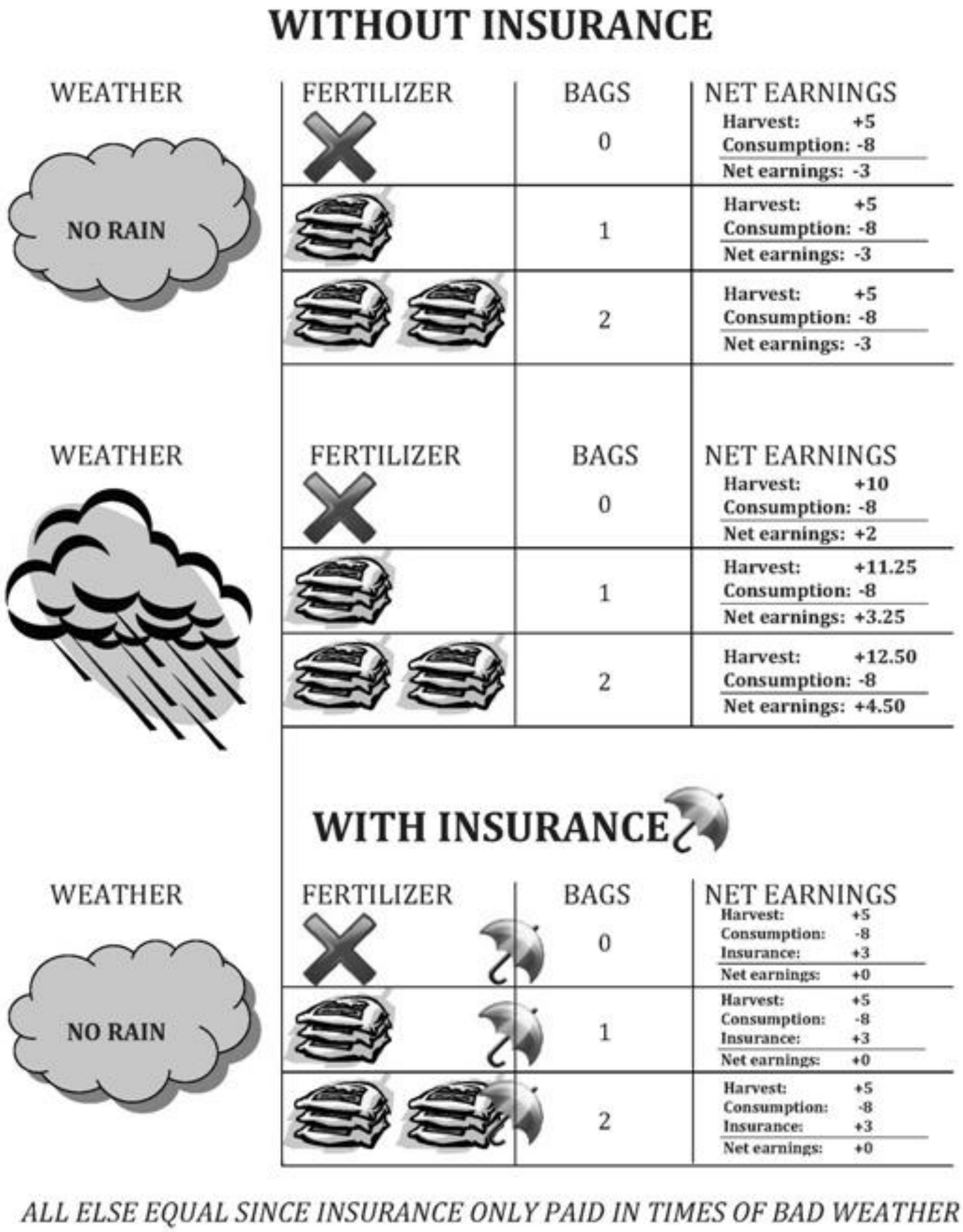
Implementation

We conducted 12 sessions during the course of seven days. Of the 12 total sessions, six sessions were IFG and six were MIFG. Furthermore, six sessions offered 25 percent return on fertilizer and six sessions offered 100 percent return (this was held constant within sessions). The probability of bad weather $1-\rho$ 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 led to very high realizations of bad weather, thus constraining individuals for several periods of decision making. Therefore, we exclude this session from our analysis.

The game protocols were parameterized as follows. The consumption fee k was always set at 8 birr (the “birr” is Ethiopia’s national currency). The initial endowment y_t at the beginning of the game protocol varied randomly from 2 birr to 16 birr. The additional income from production a and the minimum income from production y_b were both set at 5 birr. The price of fertilizer p was 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 equal to 3 birr.

Each experiment session consisted of registration, instruction, practice, decision making, and final payment in private. Instructions were done orally, and selected parts of the graphic in Figure 2 were displayed on the board (depending on the protocol) to support such instruction. A complete set of subject instructions is available upon request.

Figure 2. Graphical display of IFG and MIFG protocols



Source: Hill and Viceisza (2010).

To maintain a high degree of experimenter control, particularly over the explanation that was provided to subjects, three measures were taken as per the norm in laboratory-like experimental sessions conducted in developed countries. First, one of the authors served as the experimenter and the other author served as the assistant experimenter. Second, the same experimenter and assistant experimenter conducted all sessions. Finally, 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 of the decision-making environment before actually making choices.

All phases of the experiment session other than the registration phase were done twice since each session comprised an IFG or MIFG preceded by a protocol to elicit the willingness to pay (WTP) for insurance. Although the data elicited in the WTP protocol are not relevant for this study, the protocol served three purposes for our main question. First, it was a good way for subjects to familiarize themselves with the concept of insurance, in particular, when insurance would pay out. Second, by accumulating earnings in the WTP protocol, subjects got a sense of entitlement over their earnings. Subjects used their final earnings from the WTP protocol to make fertilizer purchases in the IFG and MIFG. Third, it provided a long history of weather draws that is used in identifying the role the formation of expectations may play in determining fertilizer purchases. Our difference-in-difference comparison enables us to control for wealth or order effects, or both, arising from this design; although switching the order of the IFG/MIFG and the WTP protocols for a random subset of sessions would have enabled an explicit test of any such effects. On average the complete session lasted 150 minutes and paid 27 birr. This compares to one and a half days of casual farm labor wage in this area.

The experiments were conducted in the library of the local school located at the center of Danicho Mukhere kebele. It was a large room with tables and chairs that were spaced out. Additionally subjects were separated by dividers to provide more privacy to individuals when they were making decisions. These dividers were motivated as "houses" in which one could make private decisions without involving one's neighbor. A picture of one of our sessions is shown in Figure 3.

Figure 3. Typical experiment session

Source: Hill and Viceisza (2010).

Other Design Issues and 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 (meaning 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. Those factors include the farmer's subjective belief that the next round's weather will be bad, the liquidity constraints a farmer faces, social effects such as peer effects and trust in insurance, and a farmer's understanding of the insurance product. We tackle each of these in our experimental design as discussed next.

First, consider expectation formation. Subjects were informed of the stochastic process underlying the weather. In any given session, a subject was informed that the probability of bad weather in a given round was $1 - \rho$. As discussed in the expectations section, however, previous weather shocks might alter subjects' expectations of the probability of bad weather in the next round. Although we wanted to account for such expectation formation in the empirical analysis, we chose not to explicitly elicit expectations "internal" to the game protocol. Our main reasoning was that this additional step would have considerably added to the length of the game protocol. So we chose to proxy for this expectation formation by modeling subjects as if they believe in the law of small numbers (Rabin 2002). Although expectations about weather shocks in the day-to-day environment should not matter (and are controlled for by our empirical specification), the household survey collected subjects' perceptions of bad weather based on previous years' observations. This was mainly to document any variation in perceptions that exists across our subject pool. These findings are discussed later.

Second, 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 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).[4] 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.

Third, consider social effects such as the influence of one's peers or social networks on fertilizer choices. Our game protocols mitigated peer effects by separating farmers during the decision-making phase of the experiment. The dividers discussed in the previous section were used for this purpose. Subjects were also asked not to communicate with each other. 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 (for example, 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, although we recognize that peer effects may be an interesting avenue for future work. Farmers' individual earnings were not made public, and the traditional insurance groups (iddirs) through which subjects were sampled (the next subsection discusses the sample design) played no role in sharing individual earnings. So for the purposes of the game protocol, these groups were merely a sampling tool.

Finally, consider trust toward and understanding of the insurance product. Since insurance was mandated and introduced by the game protocol, 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

[4] At an anecdotal level, some subjects that reached bankruptcy asked the experimenter whether they could borrow from their "neighbor" in the experiment.

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. This mainly occurred during the WTP part of the experiment session. 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.

Sample Selection

Each of the four selected villages from Danicho Mukhere kebele has a large iddir containing all the households in the village as members, and many smaller iddirs that each contain 20 to 40 members. Given that some of the other research questions considered as part of the broader research project were considering the provision of insurance through these traditional insurance groups, and given that each household in the kebele is an active member of one of the groups, it was decided to sample through the iddirs. Each large iddir from the four selected villages was automatically selected. To select the smaller iddirs we listed all the iddirs in the four villages. From that list of iddirs, 20 were randomly sampled (five from each village). Leaders of those iddirs were contacted and asked to come and answer some questions on their iddir (the iddir survey) and to list all the members of the iddir.

Twelve people were randomly sampled from the iddir membership lists. We stratified by leader/nonleader to ensure that at least two leaders from each iddir participated. Additionally, we randomly selected 10 people from each village (from the lists for that village) to participate as members of the large iddir. Two leaders of the large iddir were also selected to participate.

Although our target number of households was 240 (10 from each iddir), in total 288 people were sampled. 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 could not undertake the survey. Of the 280 listed, 261 participated in the experimental sessions and 241 of those people also completed a household questionnaire, 94 percent of whom completed the survey subsequent to participation in the game protocol.

Table 1 presents some descriptive statistics on the people who participated in the experiment and survey. The majority of participants (84 percent) were male and were engaged in farming as their main activity (91 percent). The majority of these farmers had very little education (the mean level of education was only 2.3 years).

Weather shocks are not unknown to these farmers. As Table 1 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 percent of his or her crop when the rain fails (compared with 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.

Table 1. Descriptive statistics

	Statistic	All farmers	Insurance sessions	No insurance sessions	t-test of difference[a]
		Socioeconomic characteristics			
Gender (1 = male)	Proportion (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 labor 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

Source: Hill and Viceisza (2010).
Notes: [a] The continuity-corrected Pearson $\chi^2(1)$ statistic is reported for tests of equality between medians.
* $p < 0.1$. ** $p < 0.05$. *** $p < 0.01$.

In the presence of quite considerable rainfall risk, Table 1 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 percent of farmers experienced losses in productive assets or income, or both, and 64 percent reduced consumption in addition to experiencing losses in productive assets or income, or both. 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 labor-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 the farmers: 50 percent had purchased fertilizer in the season prior to the experiment, and 63 percent had purchased fertilizer in the five years prior to the survey. In comparison, only 22 percent had purchased seeds in the season prior to participation and only 9 percent had hired labor and 15 percent, oxen.

Next we discuss the empirical strategy.

4. 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 random. The allocation of good and bad weather was also randomly assigned as live weather draws were made by participants 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 behavior 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,

$$\Delta f_{it} = \beta_0 + \beta_{\Delta I} \cdot \Delta I_{it} + \Delta u_{it}, \tag{23}$$

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 subsequently, 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 1 presents summary statistics disaggregated by whether insurance was or was not 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 that individuals with similar characteristics were in each session.

Table 2 shows characteristics of the sessions. As the weather was drawn randomly live during the session, each session varied in the amount and timing of bad weather. Given that 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 2, 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.

In sessions in which insurance was provided, bad weather draws were less likely. There was a very large 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 large 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.

Table 2. Session characteristics

	Round	All sessions	Insurance sessions	No insurance sessions	t-test of difference
Proportion of bad weather draws		0.22	0.21	0.23	-1.66*
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)	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**
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**

Source: Hill and Viceisza (2010).
Note: * $p < 0.1$. ** $p < 0.05$. *** $p < 0.01$.

In the analysis, these differences in wealth and weather 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:

$$\Delta f_{it} = \beta_0 + \beta_{\Delta w} \cdot \Delta w_{it} + \beta_{\Delta b} \cdot \Delta b_{it} + \beta_{\Delta I} \cdot \Delta I_{it} + \Delta u_{it}, \tag{24}$$

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 better explore both the impact of insurance on fertilizer purchases and the impact of changes in wealth and weather. We alternately 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 individual's subjective perception of ρ) falls at a faster rate when b increases from seven to eight than it does when b increases from one to two.

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 it does not provide any information on additional relationships of interest, such as the relationship between fertilizer purchases and weather and fertilizer purchases and wealth. A number of matching methods exist 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, two additional assumptions must be met to consistently estimate the impact of insurance on behavior. 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 nothing exists in the initial characteristics or progression of sessions that could cause the outcome variable of interest to evolve differently.

Imbens (2004) notes that when cases of no overlap 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 results 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 behavioral response to good and bad weather both with and without insurance. With this more accurate estimate on the impact of weather on behavior, 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. 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 important, 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.[5] 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 higher proportion of labor market participation than the treatment group, causing economic growth to attribute a larger market participation impact to the treatment (Blundell and Costa-Dias 2002). 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).

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

5. RESULTS

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 who were offered insurance in later rounds and individuals who 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 3 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 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 values 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 highlights, differences in initial fertilizer purchases and changes in wealth and weather across sessions and 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 participants' choices and weather draws. Additionally, given that the return to fertilizer varied across sessions, identical choices and weather draws may yield different changes in wealth in different sessions.

Table 3. Basic difference-in-difference

	(1)	**(2)**	**(3)**	**(4)**
Difference in bags of fertilizer purchased in rounds…	1 and 3	2 and 3	1 and 4	2 and 4
Insurance	0.154*	0.157**	-0.152*	-0.149**
	(0.0826)	(0.0733)	(0.0843)	(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

Source: Hill and Viceisza (2010).
Note: Robust standard errors in parentheses.
* $p < 0.1$. ** $p < 0.05$. *** $p < 0.01$.

In Table 4 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 5 presents difference-in-difference estimates estimated with and without fixed effects. The dependent 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 to allow for the fact that any change in expectations resulting from an increase of $b = 1$ to $b = 2$ is likely to 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.

Table 4. Matching estimates of impact of insurance

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

Source: Hill and Viceisza (2010).
Note: * $p < 0.1$. ** $p < 0.05$. *** $p < 0.01$.

Table 5. Difference-in-difference regression estimates

	(1)	(2)	(3)	(4)
	Ordinary least squares	**Fixed effects**	**Ordinary least squares**	**Fixed effects**
Δ insurance	0.121*	0.290***	0.118*	0.291***
	(0.0673)	(0.0842)	(0.0632)	(0.0845)
Δ wealth	0.0696***	0.0213	0.0876***	0.0289*
	(0.0173)	(0.0223)	(0.0154)	(0.0169)
Δb	-0.0158	0.000341		
	(0.0433)	(0.0487)		
Δb^2			-0.00992*	-0.00356
			(0.00516)	(0.00642)
Dummy for max. fert.	-0.607***	-1.495***	-0.599***	-1.494***
	(0.0465)	(0.0763)	(0.0459)	(0.0783)
Constant	0.343***	0.945***	0.351***	0.950***
	(0.0475)	(0.0664)	(0.0470)	(0.0661)
Observations	744	744	744	744
Number of individuals		248		248
Adjusted R^2	0.309	0.541	0.314	0.542

Source: Hill and Viceisza (2010).

Note: Standard errors in parentheses. Round dummies were included but are not shown.

* $p < 0.1$. ** $p < 0.05$. *** $p < 0.01$.

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 columns 3 and 4 we see that the longer an individual has gone without seeing a bad weather draw, the less likely he or she is 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 or b^2, but given the slightly better performance of models in which b^2 is used, we continue with this choice of functional form for the future regression results.

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 29 percent more likely. Taking the median expected return to fertilizer of 75 percent, this would imply that insurance provision would increase the average return realized by farmers by 21.825 percent. This is in addition to any welfare benefits that may result from insurance provision.

We explore further whether provision of insurance had a differential impact on behavior when it was offered free and when it was offered for different types of people. In particular we examine whether insurance had a larger effect for those who better understood the contract, for those who were more risk averse, or for those who faced a relatively more risky investment prospect. We also determine whether farmers who were more favorable to fertilizer purchases in their farming decisions (measured by whether they had bought fertilizer in the five 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 were used to provide a measure of understanding of the contract and of risk aversion.[6] Information from the game protocol was used to measure the coefficient of variation (CV) 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 subsample. Results using a fixed-effects specification (that used in column 4 of Table 5) are presented in Table 6.

In the first column we assess whether insurance had a different impact on behavior 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. In columns 2 to 5 we assess whether other characteristics of the individuals or sessions altered the impact of insurance on purchases of fertilizer.

Understanding of the insurance contract was measured by assessing participants' 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. Participants with a higher and lower understanding of the contract were partitioned equally with an indicator dummy.[7] Interacting this measure of understanding with the provision of insurance suggests that those more able to understand the contract were more likely to increase fertilizer purchases.

Data on risk preferences were collected by offering a Binswanger-style series of lotteries to the participants in the postsurvey and asking them to select the lottery they would prefer to play. Respondents were paid according to their choice and the lottery outcome. Participants who 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.[8]

The impact of insurance was also assessed differentially for those who faced fertilizer returns with higher risk measured as the CV of the return. The results suggest that insurance was more effective in encouraging greater investment when the risk of the return to investment was high.

Finally the fertilizer supply response was compared for those who had reported using fertilizer in the five years prior to the 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 that perception is somewhat reflected in their fertilizer use decision. The much higher use of fertilizer observed in the highland villages is most likely because of the greater benefit to using it for the soil-crop combination in the highlands compared with the midlands. Indeed, we find that insurance had a stronger effect for those who had used fertilizer in the previous five years, those who most likely viewed the benefits to fertilizer as higher. This suggests that

[6] 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.

[7] This meant that participants 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.

[8] This meant that participants 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 that were recorded as risk averse.

the way in which the experiment was framed was important in determining the behavioral effects observed.

Table 6. Heterogenous effects of insurance on Δ choice (fixed-effects specification)

	(1)	(2)	(3)	(4)	(5)
ΔI* pay	0.312***				
	(0.0957)				
ΔI* free	0.264***				
	(0.0853)				
ΔI* high understand		0.306***			
		(0.0866)			
ΔI* low understand		0.234*			
		(0.120)			
ΔI* risk averse			0.285***		
			(0.0804)		
ΔI* risk neutral			0.274**		
			(0.106)		
ΔI* high CV				0.328***	
				(0.1000)	
ΔI* low CV				0.257***	
				(0.0892)	
ΔI* has bought fertilizer					0.289***
					(0.0807)
ΔI* has not bought fertilizer					0.270***
					(0.0986)
Δ wealth	0.0281	0.0287*	0.0322*	0.0258	0.0322*
	(0.0172)	(0.0170)	(0.0165)	(0.0183)	(0.0166)
Δb^2	-0.00340	-0.00353	-0.00392	-0.00297	-0.00391
	(0.00647)	(0.00643)	(0.00645)	(0.00665)	(0.00646)
Dummy for max. fertilizer	-1.489***	-1.494***	-1.486***	-1.499***	-1.486***
	(0.0787)	(0.0784)	(0.0769)	(0.0799)	(0.0770)
Constant	0.948***	0.950***	0.942***	0.955***	0.942***
	(0.0663)	(0.0662)	(0.0637)	(0.0676)	(0.0638)
Observations	744	744	744	744	744
Number of individuals	248	248	248	248	248
Adjusted R^2	0.541	0.541	0.541	0.541	0.541

Source: Hill and Viceisza (2010).
Note: Robust standard errors in parentheses. Round dummies included but not shown. CV = coefficient of variation.
* $p < 0.1$. ** $p < 0.05$. *** $p < 0.01$.

Overall this disaggregation suggests that insurance has more impact on fertilizer purchases for those who purchase insurance with their own money, for risk-averse individuals, for those who better understand the contract, for those for whom the risk of investment is high, and for those who are perhaps more predisposed to purchase fertilizer. However, in each case the magnitude of the difference is not large.

Robustness Checks

A highly significant variable in the difference-in-difference estimations presented in tables 5 and 6 is the dummy indicating farmers who could not increase their fertilizer purchases further because they had already purchased two bags in the previous round. This dummy was included to control for corner solutions. A Tobit model cannot be used given that 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.

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). Given the positive relationship between wealth and fertilizer purchases, a farmer was much more likely to find himself or herself constrained if he or she 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 7 present the ordinary least squares (OLS) and Heckman difference-in-difference results. The Heckman results are qualitatively identical, but insurance is no longer significant whereas 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 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. The results on wealth thus appear to be quite robust to a random-effects specification, but not the results on insurance and perceptions.

Table 7. Robustness checks

	Δf, OLS	Δf, Heckman	f, FE	f, RE	f, Tobit RE
ΔI	0.118*	0.0559			
	(0.0632)	(0.226)			
I			0.0252	0.0434	-0.157
			(0.0535)	(0.0513)	(0.170)
Δ wealth	0.0876***	0.247***			
	(0.0154)	(0.0334)			
Wealth			0.0997***	0.0328***	0.145***
			(0.0135)	(0.00537)	(0.0210)

Table 7. Continued

	Δf, OLS	Δf, Heckman	f, FE	f, RE	f, Tobit RE
Δb^2	-0.00992*	-0.0157			
	(0.00516)	(0.0106)			
b^2			-0.0142***	0.00226	0.00551
			(0.00373)	(0.00200)	(0.00709)
Dummy for max. fertilizer	-0.599***		-0.322***	0.193***	
	(0.0459)		(0.0328)	(0.0256)	
Has bought fertilizer				0.131***	0.596***
				(0.0480)	(0.216)
Understanding of insurance				-0.0178*	-0.0415
				(0.0100)	(0.0471)
Age				-0.00320	-0.00966
				(0.00217)	(0.00811)
Gender				-0.0393	-0.249
				(0.0709)	(0.319)
Binswanger risk preference				0.0124	0.0998
				(0.0174)	(0.0982)
Area of land owned				-0.0982*	-0.256
				(0.0501)	(0.249)
Initial endowment				-0.00910	-0.0586
				(0.00934)	(0.0440)
ρ				0.283***	1.072***
				(0.0972)	(0.384)
Return to fertilizer				0.117	0.856**
				(0.0804)	(0.373)
Constant	0.351***	0.615***	0.579***	1.290***	0.663
	(0.0470)	(0.164)	(0.114)	(0.251)	(1.052)
Observations	744	744	992	876	876
Number of id			248	219	219
Adjusted R^2	0.314		0.280		

Source: Hill and Viceisza (2010).
Note: Robust standard errors in parentheses. Round dummies included but not shown.
OLS = ordinary least squares; FE = fixed effects; RE = random effects.
* $p < 0.1$. ** $p < 0.05$. *** $p < 0.01$.

6. CONCLUSION

In this paper, we 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 was randomly allocated, thereby allowing an empirical test of this hypothesis (Gine, Townsend, and Vickery 2008; Gine and Yang 2007), 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 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. Disaggregation of the impact of insurance suggests that farmers who were more risk averse or who understood the contract better were more likely to increase fertilizer purchases in the presence of insurance. Purchases were also found to depend on wealth and, in accordance with the law of small numbers, the past history of weather realizations, suggesting changes in perceptions of the costs and benefits of fertilizer purchases were also driving changes in behavior.

REFERENCES

Abadie, A., D. Drukker, J.L. Herr, and G.W. Imbens. 2004. Implementing matching estimators for average treatment effects in Stata. *Stata Journal* 4 (3): 290–311.

Abadie, A., and G.W. Imbens. 2008. On the failure of the bootstrap for matching estimators. *Econometrica* 76 (6): 1537–1557.

Arrow, K.J. 1971. *Essays in the theory of risk bearing.* Amsterdam: North-Holland.

Asfaw, A., and A. Admassie. 2004. The role of education on the adoption of chemical fertiliser under different socioeconomic environments in Ethiopia. *Agricultural Economics* 30 (3): 215–228.

Barrett, C.B. 1996. On price risk and the inverse farm size-productivity relationship. *Journal of Development Economics* 51: 193–215.

Becker, S.O., and A. Ichino. 2002. Estimation of average treatment effects based on propensity scores. *Stata Journal* 2 (4): 358–377.

Blundell, R., and M. Costa-Dias. 2002. *Alternative approaches to evaluation in empirical microeconomics.* Cenmap Working Paper cwp10/02. London, UK: Institute for Fiscal Studies.

Bone, J., J. Hey, and J. Suckling. 2004. A simple risk-sharing experiment. *Journal of Risk and Uncertainty* 28 (1): 23–38.

Byerlee, D., D. Spielman, D. Alemu, and M. Gautam. 2007. *Policies to promote cereal intensification in Ethiopia: A review of evidence and experience.* Discussion Paper 707. Washington, D.C.: International Food Policy Research Institute.

Cai, H., Y. Chen, H. Fang, and L.-A. Zhou. 2009. Microinsurance, trust, and economic development: Evidence from a randomized natural field experiment Working paper, Cambridge, MA: National Bureau of Economic Research.

Camerer, C., and H. Kunreuther. 1989. Experimental markets for insurance. *Journal of Risk and Uncertainty* 2 (3): 265–299.

Carter, M. 2008. Inducing innovation: Risk instruments for solving the conundrum of rural financeWorking Paper, Maddison, WI: Basis CRSP.

Charness, G., and G. Genicot. 2009. Informal risk sharing in an infinite-horizon experiment. *Economic Journal* 119 (537): 796–825.

Charness, G., and D. Levin. 2005. When optimal choices feel wrong: A laboratory study of Bayesian updating, complexity, and affect. *American Economic Review* 95 (4): 1300–1309.

Cole, S.A., X. Gine, J. Tobacman, P.B. Topalova, R.M. Townsend, and J.I. Vickery. 2009. *Barriers to household risk management: Evidence from India.* Finance Working Paper 09-116. Cambridge, Mass., U.S.A.: Harvard Business School.

Dadi, L., M. Burton, and A. Ozanne. 2004. Duration analysis of technological adoption in Ethiopian agriculture. *Journal of Agricultural Economics* 55 (3): 613–631.

de Weerdt, J., ed. 2001. *Risk sharing and endogenous group formation: Insurance against poverty.* Oxford, UK, Oxford University Press.

Deaton, A. 1991. Saving and liquidity constraints. *Econometrica* 59 (5): 1221–1248.

Dercon, S. 1996. Risk, crop choice, and savings: Evidence from Tanzania. *Economic Development and Cultural Change* 44 (3): 385–514.

Dercon, S., J. Hoddinott and T. Woldehanna. 2005. Consumption and shocks in 15 Ethiopian Villages, 1999-2004. Journal of African Economies, vol. 14, pp. 559-585.

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

Dercon, S., and R.V. Hill. 2009: Growth from agriculture in Ethiopia: Identifying key constraints. Paper prepared for the Department for International Development–funded study Understanding the Constraints to Continued Rapid Growth in Ethiopia: The Role of Agriculture.

Eissa, N., and J. Liebman. 1996. Labor supply response to the earned income tax credit. *Quarterly Journal of Economics* 111 (2): 605–637.

Eswaran, M., and A. Kotwal. 1990. Implications of credit constraints for risk behaviour in less developed economies. *Oxford Economic Papers* 42 (2): 473–482.

Fafchamps, M. 1992. Cash crop production, food price volatility, and rural market integration in the Third World. *American Journal of Agricultural Economics* 74 (1): 90–99.

Fafchamps, M., C. Udry, and K. Czukas. 1998. Drought and saving in West Africa: Are livestock a buffer stock? *Journal of Development Economics* 55 (2): 273–305.

Finkelshtain, I., and J.A. Chalfant. 1991. Marketed surplus under risk: Do peasants agree with Sandmo? *American Journal of Agricultural Economics*, 73: 557-567.

Gine, X., R. Townsend, and J. Vickery. 2008. Patterns of rainfall insurance participation in rural India. *World Bank Economic Review* 22 (3): 539–566.

Gine, X., and D. Yang 2007. *Insurance, credit, and technology adoption: Field experimental evidence from Malawi*. World Bank Policy Research Working Paper 4425.Washington, DC:World Bank.

Grether, D.M. 1980. Bayes rule as a phenomenon: The representative heuristic. *Quarterly Journal of Economics* 95 (3): 537–557.

Harrison, G.W., and J.A. List. 2004. Field experiments. *Journal of Economic Literature* 42 (4): 1009–1055.

Heckman, J., H. Ichimura, and P. Todd. 1997. Matching as an econometric evaluation estimator. *Review of Economic Studies*65 (2): 605–654.

Heckman, J., and R. Robb. 1985. Alternative methods for evaluating the impact of interventions. *Journal of Econometrics*, 30(1-2): 39-67.

Hill, R.V. 2009. Using stated preferences and beliefs to identify the impact of risk on poor households. *Journal of Development Studies,*forthcoming.

Horowitz, J.K., and E. Lichtenberg. 1993. Insurance, moral hazard, and chemical use in agriculture. *American Journal of Agricultural Economics* 75 (November 1993): 926–935.

Imbens, G.W. 2004. Nonparametric estimation of average treatment effects under exogeneity: A review. *Review of Economics and Statistics* 86 (1): 4–29.

Kahneman, D., and A. Tversky. 1972. Subjective probability: A judgment of representativeness. *Cognitive Psychology* 3 (3): 430–454.

________. 1973. On the psychology of prediction. *Psychological Review* 80: 237–251.

Knight, J., S. Weir, and T. Woldehanna. 2003. The role of education in facilitating risk-taking and innovation in agriculture. *Journal of Development Studies* 39 (6): 1-22.

Kurosaki, T., and M. Fafchamps. 2002. Insurance market efficiency and crop choices in Pakistan. *Journal of Development Economics* 67 (2): 419–453.

Laury, S.K., M.M. McInnes, and T. Swarthout. 2009. Insurance decisions for low-probability losses. *Journal of Risk and Uncertainty*,39 (1): 17-44.

Lim, Y., and R.M. Townsend. 1998. General equilibrium models of financial systems: Theory and measurement in village economies. *Review of Economic Dynamics* 1 (1): 59–118.

McCluskey, J.J., and G.C. Rausser. 2001. Estimation of perceived risk and its effect on property values. *Land Economics* 77 (1): 42–56.

Morduch, J. 1991. Risk and welfare in developing countries. Ph.D. thesis, Harvard University, Cambridge, Mass., U.S.A.

Mullainathan, S., and R.H. Thaler. 2000. *Behavioral economics.* Working Paper 7948. Cambridge, Mass., U.S.A.: National Bureau of Economic Research.

Munshi, K. 2004. Social learning in a heterogeneous population: Technology diffusion in the Indian green revolution. *Journal of Development Economics* 73 (1): 185–213.

Rabin, M. 2002. Inference by believers in the law of small numbers. *Quarterly Journal of Economics* 117 (3): 775–816.

Rabin, M., and D. Vayanos. 2010. The gamblers and hot-hand fallacies: Theory and applications. *Review of Economic Studies*,77: 730-778.

Ramaswami, B. 1993. Supply response to agricultural insurance: Risk reduction and moral hazard effects. *American Journal of Agricultural Economics* 75 (November 1993): 914–925.

Rapoport, A., and D.V. Budescu. 1997. Randomization in individual choice behavior. *Psychological Review* 104 (3): 603–617.

Sandmo, A. 1971. On the theory of the competitive firm under price uncertainty. *American Economic Review* 61 (1): 65–73.

Seyoum Tafesse, A. 2009. Decomposition of growth in cereal production in Ethiopia. Background paper prepared for the Department for International Development–funded study Understanding the Constraints to Continued Rapid Growth in Ethiopia: The Role of Agriculture.

Smith, K., and F.R. Johnson. 1988. How do risk perceptions respond to information? The case of radon. *Review of Economics and Statistics* 70 (1): 1–8.

Smith, V.H., and B.K. Goodwin. 1996. Crop insurance, moral hazard, and agricultural chemical use. *American Journal of Agricultural Economics* May (1996): 428–438.

Spielman, D. 2009. Encouraging economic growth in Ethiopia: Perspectives on agricultural input markets, agricultural extension and advisory services, and agricultural education and training. Briefing note prepared for the Department for International Development–funded study Understanding the Constraints to Continued Rapid Growth in Ethiopia: The Role of Agriculture.

Tversky, A., and D. Kahneman. 1971. Belief in the law of small numbers. *Psychological Bulletin* 76 (2): 105–110.

________. 1974. Judgement under uncertainty: Heuristics and biases. *Science* 185 (2): 1124–1131.

Viscusi, W.K. 1985. Are individuals Bayesian decision makers? *American Economic Association Papers and Proceedings* 75 (2): 381–385.

Vissing-Jorgensen, A. 2003. Perspectives on behavioral finance: Does “irrationality” disappear with wealth? Evidence from expectations and actions. Kellogg School of Management, Northwestern University, June 2, 2003, Evanston, Ill., U.S.A.

Wooldridge, J.M. 2002. *Econometric analysis of cross section and panel data.* Cambridge, Mass., U.S.A.: MIT Press.

World Bank. 2006. *Ethiopia: Policies for pro poor agricultural growth.* Report of the World Bank.

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