Insurance, Credit, and Technology Adoption: Field Experimental Evidence from Malawi*

Xavier Giné
Development Economics Research Group, World Bank
and Bureau for Research and Economic Analysis of Development (BREAD)

Dean Yang
Ford School of Public Policy and Department of Economics, University of Michigan;
Bureau for Research and Economic Analysis of Development (BREAD);
and National Bureau of Economic Research (NBER)

March 2008

Abstract

Adoption of new agricultural technologies may be discouraged by their inherent riskiness. We implemented a randomized field experiment to ask whether provision of insurance against a major source of production risk induces farmers to take out loans to invest in a new crop variety. The study sample was composed of roughly 800 maize and groundnut farmers in Malawi, where by far the dominant source of production risk is the level of rainfall. We randomly selected half of the farmers to be offered credit to purchase high-yielding hybrid maize and groundnut seeds for planting in the November 2006 crop season. The other half of farmers were offered a similar credit package, but were also required to purchase (at actuarially fair rates) a weather insurance policy that partially or fully forgave the loan in the event of poor rainfall. Surprisingly, take up was lower by 13 percentage points among farmers offered insurance with the loan. Take-up was 33.0% for farmers who were offered the uninsured loan. There is suggestive evidence that reduced take-up of the insured loan was due to farmers already having some limited liability in case of default: insured loan take-up was positively correlated with farmer education, income, and wealth, which may proxy for the individual's default costs. By contrast, take-up of the uninsured loan was uncorrelated with these farmer characteristics.

Keywords: risk-sharing, insurance, credit, microfinance, technology adoption

* Gine: xgine@worldbank.org. Yang: deanyang@umich.edu. We gratefully acknowledge financial support from CRMG (World Bank) and in particular the support of Erin Bryla, Shadreck Mapfumo and Frank Masankha. We also thank Ephraim Chirwa and the Wadonda team for their efforts in collecting the data. We received valuable feedback and suggestions from Chris Ahlin, Steve Boucher, Adriana Lleras-Muney, Eldar Shafir, and participants in several seminars. Paola de Baldomero Zazo, Jessica Goldberg and Cheryl Raleigh provided superb research assistance.

1. Introduction

The adoption of new technology plays a fundamental role in the development process. In the 1950s and 1960s, the so-called Green Revolution transformed agricultural production in developing countries by introducing high-yield crop varieties and other modern cultivation practices. While the modernization of production brought about significant increases in agricultural productivity and growth, the impact of the Green Revolution has been uneven. There is enormous variation, within regions and between regions, in the extent to which households have benefited from the availability of these new technologies.[1]

Among the often cited reasons why technology has failed to diffuse, aversion to risk, credit constraints and limited access to information are leading candidates (Feder, Just and Zilberman, 1985).[2] Undoubtedly, production risk is a major source of income fluctuations for rural households involved in agricultural activities, especially in developing countries. Because high yield varieties are more profitable but also riskier, households unwilling to bear consumption fluctuations may decide not to adopt. In addition, in policy circles the lack of access to credit has traditionally been considered a major obstacle to technology adoption and development.[3]

With complete and frictionless financial markets, fluctuations would not be a source of concern as households would be able to protect consumption, and credit would flow to activities with the highest marginal return. But in developing countries, insurance and credit markets are typically incomplete or altogether absent. In this environment, the separation of consumption and production decisions may not obtain (Benjamin, 1992),

[1] See Griliches (1957) on adoption of hybrid corn in the United States, Evenson (1974) on diffusion of agricultural technologies internationally, and Goldman (1993) on technology adoption across regions in Kenya.

[2] See Evenson and Westphal (1995), Rogers (1995) and Munshi (forthcoming) for a more recent review. See also the introduction in Conley and Udry (2005) for references, as well as Besley and Case (1994). Recent work on technology adoption and social learning includes Foster and Rosenzweig (1995), Munshi (2004), Conley and Udry (2005), and Duflo, Kremer, and Robinson (2006).

[3] The following quote from 1973 by Robert McNamara when he was the World Bank president exemplifies this view: "The miracle of the Green Revolution may have arrived, but for the most part, the poor farmer has not been able to participate in it. He simply cannot afford to pay for the irrigation, the pesticide, the fertilizer… For the small holder operating with virtually no capital, access to capital is crucial".

and thus, the relative importance of credit constraints and risk aversion may be confounded (Chaudhuri and Osborne, 2002).

This last point is illustrated by the well-known positive correlation between wealth and adoption of new technology.[4] Some have argued that this correlation provides evidence for credit constraints, because wealthier farmers have better access to credit and thus face lower financial constraints to adopt. However, even if we ignore that unobserved heterogeneity (correlated with wealth) may be ultimately responsible for the observed correlation, under plausible assumptions wealthier households will also be more tolerant of risk. Therefore, it is not clear whether the correlation is driven by credit constraints and thus imperfections in the credit market, or by risk aversion and therefore lack of insurance instruments to hedge risk. Disentangling the two explanations is crucial because they call for very different government interventions.

This paper describes the findings of a randomized field experiment we implemented testing whether bundling insurance with credit increased farmers' willingness to adopt a new technology. The specific context of the study was the adoption of high-yield hybrid varieties of maize and groundnut among small landholders in Malawi. Nearly all Malawian households (97% in 2004-2005) are engaged in maize production, but only 58% use hybrid maize varieties (World Bank 2006). Smale and Jayne (2003) note that hybrid maize adoption in Malawi has lagged behind adoption in Kenya, Zambia, and Zimbabwe.

Existing studies document that hybrid seed use in Malawi is correlated with wealth and other indicators of household socioeconomic status. Data from the country's nationally-representative Integrated Household Survey conducted in 2004-2005 documents higher adoption of hybrid maize among households in the highest quintile of land ownership (66%) than in the lowest quintile (53%) (World Bank 2006). Among maize farmers in southern Malawi, Chirwa (2005) finds that close to 60% do not use hybrid maize varieties, and that adoption rises in income, education, and plot size. Simtowe and Zeller (2006) find higher maize adoption among households with access to credit. Due to the potential correlation between access to credit and ability (or willingness) to cope with risk, it is unclear in these studies whether credit constraints or

[4] See Feder, Just, and Zilberman (1985), Just and Zilberman (1983), Besley and Case (1993).

absence of insurance markets (or both) are the key constraints hindering hybrid seed adoption in Malawi.

To test the importance of risk in hindering hybrid seed adoption, we randomized whether farmers' loans to purchase hybrid seeds were insured against rainfall risk, by far the dominant source of production risk in Malawi. The study sample was composed of roughly 800 maize and groundnut farmers in 32 localities in central Malawi. We randomly selected 16 localities where farmers were offered credit to purchase high-yielding hybrid maize and groundnut seeds for planting in the November 2006 crop season. In the remaining 16 localities, farmers were offered a similar credit package, but were also required to purchase (at actuarially fair rates) a weather insurance policy that partially or fully forgave the loan in the event of poor rainfall.

If borrowers are risk averse while the lender is not, a standard debt contract (credit only) will in general not be optimal because it requires that the borrower bear all the risk when he or she is the least prepared to bear it. But in the presence of informational asymmetries (requiring verification costs) or under bounded rationality, the simplicity of the debt contract may indeed be close to being optimal (see Dowd, 1992 for a review).

In any event, the requirement in a debt contract that repayment be non-contingent may be responsible for a lower demand for credit as prospective borrowers fear the loss in utility associated to having to repay even when production fails. In other words, risk averse borrowers may prefer planting a traditional variety that does not require credit, to adopting the hybrid variety that is riskier.[5] In this situation, the provision of insurance should in principle *raise* adoption among risk-averse farmers.

Our experimental results are at odds with this prediction. Take-up was 33.0% among farmers who were offered the basic loan without insurance. Take up was lower, at only 17.6%, among farmers whose loans were insured against poor rainfall. A potential explanation is that farmers already are implicitly insured by the limited liability inherent in the loan contract, so that bundling a loan with formal insurance (for which an insurance premium is charged) is effectively an increase in the interest rate on the loan.

[5] Dercon and Christiaensen (2007) provide evidence that consumption risk discourages fertilizer use by Ethiopian farmers. See also Binswanger and Sillers (1983) and Boucher et al. (2006).

We offer suggestive evidence in support of this hypothesis: among farmers offered the insured loan, take-up is positively associated with a farmer's education, income, and wealth. These variables may proxy for the farmer's default costs (the extent to which a farmers' assets can be seized by the lender in case of default, or the value of the future relationship with the lender), and if so should be correlated with the benefit a farmer can expect from insurance. By contrast, for farmers offered the uninsured loan, these characteristics are not associated with take-up.

The remainder of this paper is organized as follows. In Section 2 we describe the experimental design and the survey data**.** We describe the main empirical results on the impact of the insurance on take-up in Section 3, and then in Section 4 explore the determinants of take-up separately in the treatment and control groups. Section 5 discusses additional explanations for lower take-up in the insured group. Section 6 concludes. The Appendix provides further details on the variables used in the empirical analysis.

2. A Simple Model of Technology Adoption

Why were farmers less likely to take up the loan for the hybrid or improved seeds when it was bundled with insurance? To fix ideas, we present a simple model of a risk-averse household that is deciding whether or not to take up the package. The benchmark model predicts that the value that farmers attach to the *explicit* insurance bundled with the loan is negatively related to the *implicit* insurance in the loan contract provided by the limited liability constraint. Indeed, when the maximum that lenders can seize is the value of production, the loan contract provides insurance to borrowers because repayment is already contingent: in case of production failure, borrowers repay less. Under certain conditions, risk-averse agents could prefer not to adopt the hybrid seeds if the loan was bundled with insurance at an actuarially fair price, but they would adopt them if a standard (uninsured) loan contract was offered. If, on the other hand, farmers could always repay the bank, the loan would no longer provide implicit insurance because the limited liability constraint would never bind. In this case, a risk-averse farmer should be unambiguously better off when the loan is bundled with insurance.

To formalize the argument, imagine a farmer that can grow a crop using either traditional or hybrid seeds. Output from traditional seeds is Y_T. Hybrid seeds have higher average yields but are riskier: Y_H with probability p and Y_L with probability 1-p. In addition, the seeds are costly, so assuming no liquid wealth, the farmer needs to borrow from a bank to be able to purchase them. Assume that the bank offers a standard debt contract (uninsured loan) at interest rate r and that the cost of the hybrid seeds is C. In case of a default, the lender can seize up to the full value of farm output (Y_H or Y_L), but only seizes other assets with probability ϕ. We therefore assume that farmers pledge illiquid assets W as collateral and that if seized, their value is enough to cover the repayment of the loan. The probability ϕ can be seen as the perceived likelihood that assets will be seized by the bank, so that any value of $\phi < 1$ represents imperfect enforcement of loan contracts. In practice, this probability is influenced by recovery costs and the reputation that the lender has built by chasing after defaulters.

If the farmer plants the traditional seeds, the utility of the farmer is $U_T = u(Y_T + W)$, where the subscript T denotes usage of traditional seeds.

In contrast, if the farmer decides to adopt the hybrid seeds, then consumption in the high state is $c_H = Y_H - R + W$, where $R = (1+r)C$ is the amount to be repaid to the bank. If the low state is realized, consumption will depend on whether realized output is high enough to cover the amount owed to the bank. When it is not, that is, when $Y_L < R$, then consumption is given by $c_L = Y_L - R + W$ if the bank seizes part of the collateral to recover the repayment. Otherwise, consumption will be $c_L = W$ since the borrower's liability is limited to realized output. The expected utility of adopting the hybrid seeds is

$$U_U = pu(Y_H - R + W) + (1-p)[\phi u(y_L - R + W) + (1-\phi)u(W)] \text{ if } Y_L < R \quad , \qquad (1)$$

where subscript U denotes uninsured loan. If, on the other hand, low output suffices to repay the bank, then

$$U_U = pu(Y_H - R + W) + (1-p)u(y_L - R + W), \text{ if } Y_L \geq R. \qquad (2)$$

Suppose now that banks offer a bundle of credit with rainfall insurance (insured loan). Rainfall can take on two values, low rain l and high rain h, with a probability of high rain of q. Let ρ be the correlation between rainfall and income.[8] Using the definition of correlation, and letting $\varepsilon = \rho\sqrt{p(1-p)q(1-q)}$, we can write the joint probabilities of income and rainfall as $\Pr(Y_H, h) = pq + \varepsilon$, $\Pr(Y_H, l) = p(1-q) - \varepsilon$, $\Pr(Y_L, h) = (1-p)q - \varepsilon$ and $\Pr(Y_L, l) = (1-p)(1-q) + \varepsilon$.

If rainfall is low, the insurance pays out the principal and interest, which now includes the cost of the hybrid seeds C and the insurance premium π. Thus, $R^I = (1+r)(C+\pi)$ where the premium, if priced fairly, solves $(1+r)\pi = (1-q)R^I$ which simplifies to $\pi = \frac{1-q}{q}C$. Combining both expressions, we can write the amount to be repaid under the insured loan as a function of the uninsured loan amount to be repaid, yielding $R^I = \frac{R}{q}$.

For simplicity, we now set the probabilities to $p=q=1/2$. In this case, expected utility of adopting the hybrid seeds with an insured loan if income in the low state cannot cover the bank repayment ($Y_L < 2R$) can be written as

$$\begin{aligned} U_I = {} & \frac{(1+\rho)}{4}u(Y_H - 2R + W) + \frac{(1-\rho)}{4}u(Y_H + W) + \\ & \frac{(1-\rho)}{4}[\phi u(Y_L - 2R + W) + (1-\phi)u(W)] + \frac{(1+\rho)}{4}u(Y_L + W) \end{aligned} \tag{3}$$

In the case where income in the low state can cover bank repayment,

$$\begin{aligned} U_I = {} & \frac{(1+\rho)}{4}u(Y_H - 2R + W) + \frac{(1-\rho)}{4}u(Y_H + W) + \\ & \frac{(1-\rho)}{4}u(Y_L - 2R + W) + \frac{(1+\rho)}{4}u(Y_L + W) \end{aligned} \tag{4}$$

Notice that without basis risk, that is, when $\rho=1$, no repayment is due when Y_L is realized. In addition, if collateral was never seized, that is, if $\phi = 0$, then when $Y_L < R$ the uninsured loan would be strictly preferred to the insured loan. More formally,

$$U_U = \frac{1}{2}u(Y_H - R + W) + \frac{1}{2}u(W) > \frac{1}{2}u(Y_H - 2R + W) + \frac{1}{2}u(W) = U_I.$$

---

[8] Technically, ρ is the maximum feasible correlation coefficient given p and q. Because income are rainfall are assumed binary variables, unless $p=q$ (as we later assume), the two variables cannot be perfectly correlated.

When limited liability binds, consumption in the low state is the same under each type of loan, yet consumption in the high state is lower under the insured loan because the repayment is higher since the premium is included.

We now specialize the utility function to be CRRA. Thus,

$$u(c) = \frac{c^{1-\sigma}}{1-\sigma}, 0 < \sigma < 1 .$$

Our objective is to find the coefficient of relative risk aversion σ_{TU} as a function of output in the low state Y_L that leaves a farmer indifferent between adopting the hybrid seeds (and therefore borrowing) without insurance and using the traditional seeds. If the farmer's coefficient of risk aversion satisfies $\sigma \leq \sigma_{TU}$, the farmer will adopt the hybrid seeds, otherwise, he or she will prefer to use the traditional ones. The coefficient σ_{TU} satisfies $U_T(\sigma_{TU}) = U_U(\sigma_{TU})$, which unfortunately does not have a closed form solution.

The analogous cutoff coefficient σ_{TI} for the insured loan satisfies

$$U_T(\sigma_{TI}) = U_I(\sigma_{TI}) .$$

Figure 1 plots the cutoff coefficient of relative risk aversion σ_{TU} and σ_{TI} as a function of income in the low state Y_L assuming that $\phi = 0$ and $\rho > 0$. For a given Y_L, if $\sigma < \sigma_{TU}$ ($\sigma > \sigma_{TU}$), the farmer would prefer (not) to adopt the hybrid seeds if offered the uninsured loan. Analogously, if $\sigma < \sigma_{TI}$ ($\sigma > \sigma_{TI}$), the farmer would prefer (not) to adopt the hybrid seeds if offered the insured loan.

Notice that when $Y_L < R$, the cutoff $\sigma_{TU}(Y_L)$ is constant (does not depend on Y_L) because the limited liability clause is binding. In this case, the farmer consumes W regardless of Y_L which is seized by the bank, so his or her consumption does not depend on Y_L. If, more generally, the bank can seize assets W with probability $\phi > 0$, then consumption in the low state does depend on Y_L, because $c_L = Y_L - R + W$. In this case, the cutoff coefficient of relative risk aversion $\sigma_{TU}(Y_L)$ will be increasing in Y_L with a slope proportional to $\phi > 0$. Notice also that $\sigma_{TI}(Y_L)$ is increasing in Y_L through equation (3) even if $\phi = 0$. The intuition is that in the low state, consumption if the insurance pays out is given by $c_L = Y_L + W$, which clearly depends positively on Y_L.

We are now interested in determining under what conditions farmers will prefer the insured loan to the uninsured one. In other words, when will $\sigma_{TI} > \sigma_{TU}$? Figure 1 shows clearly that there is a threshold level $\hat{Y}_L < R$ such that if $Y_L < \hat{Y}_L$, then $\sigma_{TI} < \sigma_{TU}$, and $\sigma_{TI} \geq \sigma_{TU}$ if $Y_L \geq \hat{Y}_L$. Therefore, if income in the low state is low enough, the uninsured loan contract is already providing enough implicit insurance and thus some farmers would adopt the hybrid seeds if offered the uninsured loan but would prefer to grow the traditional seeds if offered the insured loan since explicit insurance is too expensive relative to its value.

It is important to realize that Figure 1 is drawn for fixed $(Y_H, Y_T, r, C, p, q, \phi, \rho)$. Figure 2 shows the importance of basis risk by changing the correlation coefficient between rainfall and output to $\rho < 0$. The rest of variables and parameters are same as those in Figure 1. In this case, because basis risk is so large and insurance such a poor product, there is no level of Y_L under which the insured loan is preferred to the uninsured loan.

In sum, Figures 1 and 2 show that there are situations in which more farmers would adopt the hybrid seeds with an uninsured loan than with an insured one. Thus, our findings suggest that either limited liability or basis risk were key factors in limiting the value of the insurance policy.

3. Experimental Design and Survey Data

The experiment was carried out as part of the Malawi Technology Adoption and Risk Initiative (MTARI), a cooperative effort among several partners: the National Smallholder Farmers Association of Malawi (NASFAM), Opportunity International Bank of Malawi (OIBM), the Malawi Rural Finance Corporation (MRFC), the Insurance Association of Malawi (IAM), and the Commodity Risk Management Group (CRMG) of the World Bank. NASFAM is an NGO that provides technical assistance and marketing services to nearly 100,000 farmers in Malawi. It is by far the largest farmer association in the country. The farmers in the study were current NASFAM members. NASFAM field officers disseminated the information on the insured and uninsured loans to farmers, and handled the logistics of supplying farmers with the hybrid seeds purchased on credit. OIBM and MRFC are microfinance lenders and provided the credit for purchase of the hybrid seeds. OIBM is a member of the global Opportunity International network of microfinance institutions, while MRFC is a government-owned corporation. IAM designed and underwrote the actual insurance policies with technical assistance from the World Bank.

The microfinance institutions offered the loans for the hybrid seeds as group liability contracts for clubs of 10-20 farmers. Take-up of the loan was an individual decision, however, and only the subset of farmers who took up the loan were jointly liable for each others' loans. NASFAM contacted clubs in June and July 2006 and offered them the opportunity to be included in the study. Our study sample consists of 159 clubs from four different regions of central Malawi: Lilongwe North, Mchinji, Kasungu, and Nkhotakota. Figure 3 shows the study locations. In these clubs there were 787 farmers who agreed to be part of the study and were available to be surveyed in the following September.

To minimize concerns about fairness if farmers discovered that other farmers in the study were being treated differently, the treatments were randomized at the level of 32 localities. Each locality has roughly 5 clubs from neighboring villages. Localities were randomized into two equal sized groups: 16 "uninsured" (control) localities and 16 insured (treatment) localities. Figure 4 plots the location of control (in red) and treatment (in black) farmers. The 394 farmers from "uninsured" localities were simply offered a loan (standard debt contract) for the hybrid seeds, while the 393 farmers from "insured" localities were not only offered the loan for the hybrid seeds (identical to the "uninsured" one) but they also received a rainfall insurance policy with an approximately actuarially-fair premium. In this insured loan group, farmers were required to take the insurance if they wanted the loan package.

Farmers were given the option to purchase an improved groundnut only or improved groundnut and a hybrid maize seed and fertilizer package.[9] In order to obtain either package, a deposit of 12.5 percent of the package amount was required in advance. The uninsured groundnut loan package provided enough seed (32 kg.) of an improved variety (ICGV-SM 90704) for planting on one acre of land, with a total of MK 4,692.00 to be repaid at harvest time 10 months later (roughly US$33.51).[10] Of this total repayment, MK 3,680 was the cost of seed and MK 1,012.00 was interest.[11] Farmers offered the insured groundnut package were in addition charged for the insurance premium, which ranged from MK 297.98 in Nkhotahota to MK 529.77 in Lilongwe (about 6 to 10 percent of the uninsured principal) so that the total repayment due at harvest time was between MK 5,130.07 and MK 5,367.45 (roughly US$36.23-US$38.34). In field trials, the improved groundnut variety performed better than traditional varieties along several dimensions. It had higher yields, was less susceptible to drought, had a shorter maturation period, exhibited greater disease resistance, and had higher oil content.

Corresponding costs for the hybrid maize package (which provided inputs sufficient for ½ acre of land) were as follows: MK 3,900 for seeds and fertilizer for a total uninsured package of MK 4,972.50 (US$35.52) and an insurance premium that ranged from MK647.16 to MK 1,082.29, depending on the reference weather station. Like the improved groundnut seed, hybrid maize is bred to be disease resistant and high-yielding. In pre-release trials in mid-altitude areas of Malawi, DK 8051 had higher yield than all comparison varieties. It outperformed the trial mean by 12.7 percent, and outperformed MH18, another hybrid variety used by farmers in our sample, by 32.7 percent. The DK8051 is also resistant to common diseases including GLS, leaf blight, and other conditions (Wessels 2001).[13]

[9] The option of a maize seed and fertilizer only was not given because maize is typically for consumption, and thus NASFAM and the lenders wanted to ensure repayment of the loan using the proceeds from the sale of groundnut, a cash crop.
[10] In October 2006, roughly 140 Malawi kwacha (MK) were convertible to US$1.
[11] The annual interest rate for loans in this study was 33%, but because the loan was over a 10-month period, the rate charged was 27.5% (33% x 10 / 12).
[13] Although the improved seeds appear less risky in field trials, farmers may not necessarily know this, or may require a period of learning about appropriate farming techniques before being able to realize such improvements. So in the short run the improved seeds may still be more risky.

Output on farms planted with hybrid varieties of seeds is still sensitive to rainfall (Mwale et al 2006, Nigam et al 2006), which potentially makes weather insurance worthwhile for the hybrid seeds. The insurance policy bundled with the loan pays out a proportion (or the totality) of the principal and interest depending on the level of rainfall. In other words, the insured loan is in essence a *contingent* loan whose repayment amount depends on the realization of rainfall at the nearest weather station. The coverage for both maize and groundnut policies is for the rainy season, which is the prime cropping season, running from September to March. The contract divides the cropping season into three phases (sowing, podding/flowering and harvest) and pays out if rainfall levels fall below particular threshold or "trigger" values during each phase. As Figure 5 shows for a given phase, an upper and lower threshold is specified for each of the three phases. If accumulated rainfall exceeds the upper threshold, the policy pays zero for that phase. Otherwise, the policy pays a fixed amount for each millimeter of rainfall below the threshold, until the lower threshold is reached. If rainfall falls below the lower threshold, the policy pays a fixed, higher payout. The total payout for the cropping season is then simply the sum of payouts across the three phases. The maximum payout corresponds to the total loan amount plus the premium and the interest payment.

The timing of the phases, thresholds and other parameters of the model were determined using crop models specific to improved groundnut and hybrid maize as well as interactions with individual farmers. During the baseline survey, when farmers were asked what affects groundnut production the most, close to 70 percent said rainfall, and less than 20 percent said pests, the next reason in importance. The upper threshold corresponds to the crop's water requirement or the average accumulated rainfall at the rainfall gauge (whichever is lowest), while the second trigger is intended to capture the water requirement necessary to avoid complete harvest failure. Translated into financial market terminology, the relationship between rainfall and payoffs resembles a "put spread" option for each phase. The insurance policy's premium payment was calculated based on projected payouts using historical rainfall data, plus a 17.5% government-mandated surtax.

The weather insurance policy offered was customized to each of the four project regions. Payouts were based on the rainfall readings at the weather station closest to the individual in question (there was a separate station for Lilongwe North, Kasungu, Nkhotakota, and Mchinji). The insurance premium charged in each region was calculated as the expected value of the insurance payout (plus the surtax). Therefore the premium was lower in places where the likelihood of a bad rainfall shock is lower.

All farmers in the study were administered a household socioeconomic survey in September 2006. The survey covered income, education, assets, income-generating activities (including detailed information on crop production and crop choice), measures of risk aversion, and knowledge about financial products such as credit and insurance.

After the completion of the survey, an orientation meeting was held in each of the 32 localities in October 2006 where NASFAM field officers explained the loan product being offered (insured or uninsured) to the study farmers. Farmers then had two weeks to decide whether to take up the loan, which required a deposit of 12.5% of the loan amount at the local NASFAM field office. Seeds and fertilizer were then delivered to pre-specified collection points near the club meeting place, and planting occurred with the beginning of the rains in November.

Summary statistics from the baseline survey are presented in Table 1, and variable definitions are provided in the Appendix.

4. Empirical results

In what follows, the "treatment group" refers to farmers who were offered the insured loan, and the "control group" refers to farmers offered the uninsured loan. Randomization of treatment should ensure that treatment and control groups have similar baseline characteristics on average. To check this, Table 2 presents means of several key farmer and household characteristics for the treatment and control groups, as well as the p-value of the F-test that the difference in means is statistically significantly different from zero.

For nearly all the variables presented (gender of the respondent, female headship of the respondent's household, self-reported risk aversion, respondent's age, land ownership, an index of housing quality constructed from indicators for various household amenities, and net income), the difference in means is not statistically different from zero.

The sole exception is that years of education among treatment group respondents is 0.84 years lower than in the control group, and this difference is statistically significant at the 10% level. As farmer years of education is a key variable (and will later be shown to be positively correlated with take-up), this is unfortunate. However, we will provide evidence later that lower education in the treatment group can only go a very small way towards explaining their lower take-up rates. We also take comfort in the fact that we cannot reject the hypothesis that all the variables are jointly insignificant in predicting treatment status (the F-test yields a p-value of 0.31).

Because the treatment is assigned randomly at the locality level, the impact of the treatment on take-up of the hybrid seed loan can be estimated via the following regression equation:

(1) $$Y_{ij} = \alpha + \beta I_j + \delta X_{ij} + \phi_j + \varepsilon_{ij},$$

where Y_{ij} = adoption decision for individual i in locality j (1 if adopting and 0 otherwise), I_j is insurance status (1 if the loan is insured and 0 otherwise), X_{ij} are individual-level baseline control variables, and ϕ_j are fixed effects for four study regions. ε_{ij} is a mean-zero error term. Treatment assignment at the locality level creates spatial correlation among farmers within the same locality, so we report standard errors that are clustered at the locality level (Moulton 1986). There is a concern that significance tests based on clustered standard errors may overreject the null when the number of clusters is "small" (Bertrand, Duflo and Mullainathan 2004; Cameron, Gelbach, and Miller 2007).[14] Therefore, we also report p-values derived from a bootstrapping procedure that Cameron, Gelbach, and Miller (2007) have demonstrated has good size properties with small numbers of clusters (as few as 5).[15]

---

[14] To be sure, it is not clear that 32 should be considered a "small" number of clusters. In Cameron, Gelbach, and Miller (2007), clustered standard errors perform quite well for the 30-cluster case, and Bertrand, Duflo and Mullainathan (2004) find in their CPS application that clustered standard errors do not lead to overrejection of the null hypothesis for as few as 20 clusters (see their Table 8).

[15] The bootstrap procedure resamples residuals using so-called Rademacher weights (equal probabilities for 1 or -1) to obtain a new sampling of residuals from a restricted regression that imposes the null hypothesis in each of 999 replications. In each pseudo-sample, the Wald test statistic from OLS estimation with clustered standard errors is calculated for the statistical significance of the coefficient on "Treatment"

The coefficient β on the insurance dummy variable is the impact of being offered the insured loan on adoption, and answers the question "How much does insurance raise demand for the hybrid seed loan?" Due to the randomization of treatment, controls for baseline variables should not strictly be necessary, and in practice have little effect on the estimated treatment effect β, but they do help absorb residual variation and reduce standard errors. In addition, it is useful to include a control for farmer education because, as discussed above, the locality-level randomization failed to eliminate statistically significant (at the 10% level) differences between the education levels of treatment and control respondents.

Table 3 presents estimates of regression equation (1) in specifications with various combinations of baseline control variables. Column 1 presents the simplest possible specification, where the only right hand side variable is the indicator for treatment. The treatment effect (-0.154) is negative and large in magnitude, although the coefficient is not statistically significantly different from zero at conventional levels (the p-value implied by clustered standard errors is 0.155, and the bootstrapped p-value is 0.198).

Additional control variables for baseline characteristics in subsequent columns add explanatory power to the regression (as reflected in rising R-squared) and so help reduce the standard error on the treatment coefficient while having minimal effects on the coefficient point estimate. Column 2 adds fixed effects for the four study regions, which reduces the magnitude of the point estimate slightly (to -0.141). The coefficient is now statistically significant at the 10% level with clustered p-values, and is marginally significant (p-value 0.116) with bootstrapping.

In column 3, a variety of other control variables are additionally included in the regression (gender of the respondent, female headship of the respondent's household, household income, respondent's education, respondent's age, acres of land ownership, an index of housing quality and net income). The coefficient declines slightly to -0.132 as a result, and with both types of p-values the coefficient is only marginally significant (clustered and bootstrapped p-values are 0.107 and 0.140, respectively).

---

being different from the null. The location of the original Wald test statistic in the distribution of bootstrapped Wald test statistics provides the bootstrapped p-value.

Column 4 allows for more flexible functional forms for the continuous baseline control variables (respondent's education, household income, respondent's age, land ownership) by including dummy variables for each quintile of these variables. The coefficient estimate is now -0.128 and it has become slightly more precise. With clustered standard errors the p-value is 0.082, and with bootstrapping it is 0.120.

Finally, because treatment farmers are less educated on average than control farmers, it is important to understand whether the control for respondent's years of education makes a substantial difference in the estimated coefficient. In column 5, the dummy variables for education are dropped from the regression. As it turns out, dropping these controls has very little effect: the coefficient and significance levels are very similar to those in the previous column where the education dummy variables are included.

Given the marginal or close-to-marginal significance levels, Table 3's results are at best suggestive evidence that bundling insurance with the hybrid seed loan led to lower take-up (by roughly 13 percentage points) compared to the uninsured loan. Having said that, it is also of interest to test whether we can reject null hypotheses representing modest positive increases in take-up, such as $\beta = 0.05$ or $\beta = 0.10$ (increases of 5 and 10 percentage points, respectively).

Table 4 presents clustered and bootstrapped p-values from F-tests of the statistical significance of the coefficient on Treatment vis-à-vis the null hypotheses $\beta = 0.05$ and $\beta = 0.10$. Across columns of Table 4, the coefficient on Treatment that is tested is from the corresponding regression of Table 3.

The null of 0.05 is rejected across all regressions at conventional levels. As expected, bootstrapped p-values are higher than clustered ones, but even for bootstrapped p-values the 0.05 null is rejected at significance levels of either 10% (regressions 1-3) or 5% (regressions 4 and 5). The 0.10 null is of course rejected even more strongly, achieving the 5% significance level in all regressions for bootstrapped p-values (and achieving the 1% level for clustered standard errors in 4 out of 5 regressions).

In sum, we can reject at conventional significance levels the hypothesis that bundling weather insurance with the hybrid seed loan led to an increase in take-up of 5 percentage points or more (which, compared to the 33% take-up rate in the control group, would have been an effect of only modest magnitude).

These results are consistent with the theoretical model of Section 2, which predicts that if output in the low state (Y_L) is low enough, fewer farmers will take up the loan package if it is insured than if it is not insured. This is possible because for low enough Y_L, limited liability binds and farmers' consumption cannot fall below W. The loan contract provides enough *implicit* insurance and thus farmers have little interest in *explicit* weather insurance – and in fact will exhibit lower demand for a loan bundled with insurance for which a premium must be paid.

If farmers indeed placed zero value on the insurance, then the lower demand for insured loan take-up could simply reflect the fact that the insured loan had an effectively higher interest rate (due to the insurance premium charged). Compared with the annual interest for the uninsured loan (27.5%), effective interest rates on the insured loan for a farmer who did not value the insurance were substantially higher (but varied according to location because of differing probabilities of the rainfall events). Such a farmer taking out an insured groundnut loan faced an effective interest rate ranging from 37.8% to 44.4%, depending on the area. This represents an increase in the effective interest rate due to the insurance premium of from 37.5% at the low end to 61.3% at the high end. Comparing this to the 39.4% decline in take up associated with the insured loan (13 percentage points off the base of 33.0%), this would imply an interest rate elasticity of credit demand ranging from 0.64 to 1.05.[16]

5. Determinants of take-up of insured and uninsured loans

The theoretical model presented in Section 2 also makes testable predictions regarding the characteristics of farmers that should predict take-up for farmers offered the insured and uninsured loans. In Figure 1, starting from low levels of low-state income (Y_L), increases in Y_L initially have no relationship with adoption of the uninsured loan because the risk-aversion coefficient cutoff is flat until $Y_L = R$ (for $Y_L < R$, the bank confiscates income up to the loan repayment amount R and so there is no variation in income in the low state). However, for the *insured* loan, an increase in low-state income

[16] These elasticities are not out of line with the one existing randomized study we are aware of on the interest rate elasticity of credit demand. Karlan and Zinman (forthcoming) find that interest rate increases exhibit an interest rate elasticity of greater than 1 in urban South Africa.

should lead to higher take-up. In Figure 1, the risk-aversion coefficient cutoff line (the dotted line) slopes upward: as Y_L rises, the risk-aversion cutoff for adoption rises, and so more individuals in the population choose to adopt.

A sensible empirical test would be to regress the take-up indicator on a measure of Y_L, separately for the treatment (insured loan) and control (uninsured loan) groups. Because no measure of Y_L is available, instead we examine independent variables related to the farmer's education, income, and wealth. This requires an assumption that farmers with higher education, income, or wealth also have higher income in the low state, perhaps because they are more likely to follow risk-reducing farming practices (they may be more likely to have made irrigation investments, may have better knowledge about avoiding low output realizations, etc.).

Table 5 presents coefficient estimates from such regressions, separately for farmers in the two different treatment conditions. Columns 1 to 6 are regressions for the treatment (insured loan) group, and columns 7 to 12 are for the control (uninsured loan) group. All regressions in the table include region fixed effects plus a constant.

The regressions for the treatment group indicate a positive relationship between take-up on the one hand, and farmer education, income, and wealth on the other. In columns 1 to 4, the take-up indicator is regressed separately on (respectively) the respondent's years of schooling, net income, house quality, and acres of land owned. In each regression the coefficient is positive, and the coefficient on years of schooling is statistically significantly different from zero at the 5% level. The coefficients on net income and house quality are marginally significant. In column 6, all four of these variables are included on the right-hand side, and an F-test of the joint significance of the coefficients on these four independent variables rejects the null that they are jointly statistically insignificant with a p-value of 0.03.

By contrast, there is no indication that farmer education, income, and wealth is related with loan take-up in the control group. In the corresponding regressions for the control group in columns 7-10, none of the four variables of interest are even marginally statistically significantly different from zero, and the F-test of the joint significance of the coefficients on these four variables does not reject the null that they are jointly statistically insignificant (the p-value is 0.98).

If farmer education, income, and wealth are plausible proxies for low state income (Y_L), and if farmers in the study can plausibly be thought to be in the region of Figure 1 where low-state income is low enough (below the repayment amount R), these results are consistent with the model's predictions: loan take-up will be uncorrelated with Y_L when farmers are offered the uninsured loan, and positively correlated when farmers are offered the insured loan.

The patterns in Table 5 might also arise if farmers with higher education, income, and wealth also had higher values of ϕ (the probability that assets are seized upon default). Then such farmers could place higher value on the insurance because their seizable assets would be protected in the low state.

Another result of interest in Table 5 is that take up of the uninsured loan is negatively associated with farmers' self-reported risk aversion. In columns 11 and 12, the coefficient on risk tolerance (-0.015) is negative and statistically significantly different from zero at the 1% level. A one-point increase in self-reported risk aversion (on a scale of 0-10) leads to a 1.5 percentage point decrease in the likelihood of taking up the uninsured loan. By contrast, the relationship between self-reported risk aversion and take-up is much weaker for farmers offered the insured loan: while the coefficient on risk aversion is negative in columns 5 and 6, it is smaller in magnitude (-0.008) and is not statistically significantly different from zero.

These results on risk aversion are also consistent with the theoretical model, as long as income in the low state is low enough: in the lower range of Y_L in Figure 1, the risk aversion cutoff for uninsured loan adoption (the solid line) is flat, while the corresponding cutoff for insured loan adoption (dotted line) is upward sloped. Imagine a continuum of individuals uniformly distributed along the lower range of Y_L, and who are also uniformly distributed across the range of risk aversion coefficients σ on the vertical axis. Then in a regression of take-up on σ, the coefficient on σ will be higher for those offered the uninsured loan than those offered the insured loan.

To see this, imagine one could take a group of people whose values of σ were just below the uninsured loan cutoff (below the horizontal solid line in Figure 1), and make their values of σ slightly above that same line. Then all of these individuals would switch from adoption to non-adoption. If one carried out the same thought experiment but for individuals offered the insured loan, a substantially smaller fraction of the individuals would switch from adoption to non-adoption: the relevant risk-aversion cutoff line is now the dotted line, and so only those individuals near the intersection of the solid and dotted line would switch from adoption to non-adoption due to the upward perturbation of their σ.

6. Other potential explanations for take-up differences

It is useful at this point to address other potential explanations for the difference in take-up across the treatment and control groups.

Differences in mean education levels across treatment and control groups

Given that education is positively correlated with take-up of the insured loan, a valid concern is that some part of the observed difference in take-up between the treatment and control groups may be due to the fact that the treatment group had 0.841 fewer years of education on average than the control group (see Table 2). The coefficient on education in column 6 of Table 5 indicates that this difference in average years of education should account for roughly 0.0093 (0.93 percentage points) of the take-up difference between the two groups—a measurable amount, but not nearly enough to explain the full take-up difference of roughly 13 percentage points.

Complexity of the insurance feature

Moving beyond phenomena that are considered in the theoretical economic model of Section 2, it is possible that the insurance component was too complex for relatively uneducated farmers to understand, thus hindering take-up of the insured loan. Most farmers were being offered an insurance product for the first time, and may not have understood the concept or the complicated payout schedule (which depended on the level as well as timing of rainfall).

As indicated by the positive and significant coefficient on years of schooling in columns 1 and 6 of Table 5, take-up of the insured loan is positively associated with farmer education levels. By contrast, take-up of the uninsured loan is not correlated with farmer education levels. A possible explanation is that the uninsured loan was simple enough to understand for even the least-educated farmers – since no complicated insurance payout structure had to be explained – but that farmers had difficulty understanding the insured loan so adoption was limited to the better-educated farmers.

This complexity interpretation is consistent with evidence from other contexts (primarily in the developed world) that the complexity of social programs inhibits use by target populations. Bertrand, Mullainathan, and Shafir (forthcoming) argue that the complexity of the forms required for food stamp participants in the U.S. may be an important factor inhibiting program participation. In a field experiment, Duflo, Gale, Liebman, Orszag, and Saez (2005) find much higher response to matching incentives for IRA contributions than is found in the U.S. tax code's Savers Credit program. They attribute the higher response in their experiment to the fact that the Savers Credit program is quite complicated to decipher. Liebman and Zeckhauser (2004) show that individuals in the U.S. have a poor understanding of their income tax schedule. If complexity issues arise even in the relatively well-educated U.S. population, they may loom even larger for poorly-educated Malawian farmers.

One might think of complexity as the extent to which a given farmer fails to understand the insurance contract bundled with credit. While complexity can be modeled in many ways, one approach would be to posit that it affects the perceived basis risk or correlation between income and rainfall ρ. Say that the perceived correlation between rainfall and income is $\tilde{\rho} = \rho(1-\varphi) - \varphi$, where the parameter φ varies from 0 to 1 and measures the degree of complexity. When $\varphi = 0$ there is no complexity so that the farmer's perception of basis risk coincides with the actual basis risk $\tilde{\rho} = \rho$, but when $\varphi = 1$ there is maximum complexity and the perceived basis risk is also maximum $\tilde{\rho} = -1$, regardless of the actual correlation ρ. Thus, the higher the complexity, the higher the basis risk perceived by the farmer and as a result, the less desirable the insured loan will appear to be. As the difference between Figures 1 and 2 indicates, increasing basis risk by moving from $\rho > 0$ to $\rho < 0$ leads to lower adoption of the insured loan compared to the uninsured loan.

Other potential factors

It is also possible that being offered the insured loan may have primed farmers to weigh risk considerations more highly in their adoption decision. In many settings psychologists have found that "priming" by highly local and temporary influences can have large effects on decision making. For example, Bornstein (1989) and Zajonc (1968) find that mere exposure can increase affinity for certain things, even if the exposure is subliminal. Bettman and Sujan (1987) found that subjects were more receptive to advertisements emphasizing a camera's creative potential when they were primed with words related to "creativity."

In the experiment, farmers could have been encouraged to worry more about the riskiness of the hybrid seed investment when the insured loan was explained to them, reducing their adoption rates. When farmers were offered the uninsured loan, there was no discussion of weather risk, and farmers were simply given information on the loan terms. By contrast, the offer of the insured loan by its nature required a discussion of the risk of crop loss due to weather, as a motivation for the insurance. The increased salience of weather risk may have made farmers in insured loan treatment weigh risk more heavily in their decision to take up the loan (in comparison to farmers offered the uninsured loan). This increased perception of risk could have more than offset the risk-reduction effect of insurance, and could help explain lower adoption of the insured loan.

An additional possible explanation is that farmers could have perceived the default costs as different across the two products. When offered the uninsured loan, farmers may have thought that with some positive probability NASFAM would not actually impose substantial penalties if they defaulted on the loan. When the insured loan was offered to farmers, by contrast, there could have been greater emphasis on the fact that the lender was going to impose penalties for nonpayment (even if the loan were to be forgiven in the event of poor rainfall). Farmers could therefore have perceived higher costs for default in the credit plus insurance product, leading that product to have lower take-up.

7. Conclusion

A large body of theory and empirical work in development economics argues that technology adoption (and income-maximizing production choices more generally) may be hindered when returns are risky and insurance or other financial markets are imperfect. This paper reports the results of an experimental study that tested whether reducing risk fosters technology adoption. Nearly 800 maize and groundnut farmers in Malawi (where by far the dominant source of production risk is the level of rainfall) were offered credit to purchase high-yielding hybrid maize and groundnut seeds in advance of the planting season. Farmers were randomized into two groups that differed in whether the loan was insured against poor rainfall. Take-up was 33.0% for farmers who were offered the uninsured loan. Take up was lower, by 13 percentage points, among farmers offered insurance with the loan.

A potential explanation is that farmers already are implicitly insured by the limited liability inherent in the loan contract, so that bundling a loan with formal insurance (for which an insurance premium is charged) is effectively an increase in the interest rate on the loan. We offer suggestive evidence in support of this hypothesis: among farmers offered the insured loan, take-up is positively associated with a farmer's education, income, and wealth. These variables may proxy for the farmer's default costs (the extent to which farmers' income and wealth can be seized by the lender in case of default, or the value of the future relationship with the lender), and if so should be correlated with the benefit a farmer can expect from insurance. By contrast, for farmers offered the uninsured loan, these characteristics are not associated with take-up.

These results help underscore the difficulties inherent in designing effective approaches to reducing the consequences of environmental risks for farmers so as to encourage adoption of income-raising technologies. A number of other factors may have also contributed to lower take-up of the insured loan. For example, reduced take-up of the insured loan may have also been due to the high cognitive cost of evaluating the insurance. This hypothesis is consistent with the finding that insured loan take-up was positively correlated with farmer education levels (while take-up of the uninsured loan was uncorrelated with farmer education). If this is the case, marketing efforts devoted to reducing the complexity of the insurance from the farmer perspective can help ease the acceptance of insured loans. We view investigation of such behavioral factors as an important avenue for future research.

<u>Appendix: Variable definitions</u>

Data are from the Malawi Technology Adoption and Risk Initiative (MTARI) farm household survey in September-October 2006. All variables refer to respondent or respondent's household.

Take-up equal to 1 if respondent signed up for hybrid seed loan, 0 otherwise. *Treatment* equal to 1 if respondent offered insured loan, 0 if offered uninsured loan.

House quality is the first principal component of several binary asset variables. Variables are defined for housing construction materials, water source, and electricity source. In general, variables are defined such that "1" represents a higher standard of living than "0." The binary asset variables used in this analysis are for brick housing construction, non-earthen floors, metal roofs, and running water (including water piped into the residence and water from a public tap). Additionally, we use two variables that are exceptions to the rule of "1" representing a higher standard of living. The first of these is for well water, as opposed to either running water or unimproved water sources. The second is for gas lighting, as opposed to either electricity or solar power, or firewood, candles, or no lighting.

Net income is computed as the sum of farm profits and non farm income, and is reported in Malawi kwachas (MK). Farm profits are the monetary value of crops produced less the monetary cost of farming inputs. Farming inputs include irrigation, fertilizer, chemical insecticides, manure or animal penning, hired equipment such as tractors, and hired manual labor and oxen labor. Information on farm revenue and expenditure was collected for each plot; total farm profits are computed as the sum of profits over all plots farmed by an individual. Non farm income includes wages from agricultural labor (on other peoples' farms); wages from non-agricultural labor; wages or in-kind wages from public works programs; remittances; benefits from government programs; pension income; and other sources of income. Information on these sources of income was collected for each respondent, and added to farm profits to compute total net income.

Land owned is in acres.

Risk aversion is self-reported on 0-10 scale: higher indicates greater aversion to risk in trying new crop varieties.

Binary variables were generated to allow flexible functional form estimates of the impact of *education*, *net income* and *land ownership* and are computed as follows. For education, the first quintile includes those with 0 to 2 years of schooling; the second quintile includes those with 3 or 4 years of schooling; the third quintile includes those with 5, 6, or 7 years of schooling; the fourth quintile includes those with 8 years of schooling; and the fifth quintile includes those with 9 to 15 years of schooling. For income, the quintile breakdown is as follows: the first quintile includes those with net incomes of between -215,343 MK and 550 MK; the second quintile includes those with net incomes between 600 MK and 5,380 MK; the third quintile includes those with incomes between 5,400 MK and 13,000 MK; the fourth quintile includes those with incomes between 13,218 MK and 27,300 MK; and the fifth quintile includes those with incomes between 27,500 MK and 3,712,300 MK. Finally, five dummy variables for land ownership represent holdings of 0 to 3 acres; 3.25 to 4 acres; 4.25 to 6 acres; 6.25 to 10 acres; and 10.25 to 108 acres, respectively. Indicator variables for age are binary variables for the following age categories: under age 25, 25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55-59, 60-60, and 65 and over.

References

Benjamin, Dwayne. 1992. "Household Composition, Labor Markets, and Labor Demand: Testing for Separation in Agricultural Household Models" *Econometrica*, Vol. 60, No. 2, pp. 287-322.

Bertrand, M., E. Duflo and S. Mullainathan, 2004. "How Much Should We Trust Differences-in-Differences Estimates?" *Quarterly Journal of Economics*, Vol. 119, pp. 249-275.

Bertrand, Marianne, Sendhil Mullainathan, and Eldar Shafir, "Behavioral Economics and Marketing in Aid of Decision-Making among the Poor," *Journal of Public Policy and Marketing*, forthcoming.

Besley, Timothy and Anne Case (1993). "Modeling Technology Adoption in Developing Countries." *American Economic Association Paper and Proceedings*, Vol. 83(2), May, pp. 396-402.

Besley, Timothy and Anne Case (1994). "Diffusion as a Learning Process: Evidence from HYV Cotton," Princeton University Working Paper.

Bettman, J. R., & Sujan, M., "Effects of framing on evaluation of comparable and non-comparable alternatives by expert and novice consumers," *Journal of Consumer Research*, 14, 1987, p. 141-154.

Binswanger, Hans P. and Donald A. Sillers, 1983. "Risk Aversion and Credit Constraints in Farmers' Decision-Making: A Reinterpretation" *Journal of Development Studies* 20, 5-21.

Bornstein, R.F., "Exposure and effect: Overview and meta-analysis of research, 1968-1987," *Psychological Bulletin*, 106, 1989, p. 265-289.

Boucher, Stephen, Michael R. Carter, Catherine Guirkinger. 2006. "Risk Rationing and wealth Effects in Credit Markets" Working Paper No 05-010, Department of Agricultural and. Resource Economics, UC-Berkeley.

Chaudhuri, Shubham and Theresa Osborne, 2002. “Financial Market Imperfections and Technical Change in a Poor Agrarian Economy” Working Paper, European University Institute, Florence, Italy.

Cameron, A Colin, Jonah. B. Gelbach,and Doug Miller, 2007. “Bootstrap-Based Improvements for Inference with Clustered Errors,” NBER Technical Working Paper No. 344, September.

Conley, Timothy and Christopher Udry, “Learning About a New Technology: Pineapple in Ghana,” mimeo, Yale University, July 2005.

Dercon, Stefan and Luc Christiaensen, “Consumption risk, technology adoption and poverty traps: evidence from Ethiopia,” World Bank Policy Research Working Paper 4257, June 2007.

Dowd, Kevin, 1992. “Optimal Financial Contracts” *Oxford Economic Papers* 44, pp. 672-693.

Duflo, E., Gale, W., Liebman, J., Orszag, P., and Saez, E., “Saving incentives for low- and middle-income families: evidence from a field experiment with H&R Block,” NBER Working Paper No. 11680, October 2005.

Duflo, Esther, Michael Kremer and Jonathan Robinson, “Understanding Technology Adoption: Fertilizer in Western Kenya: Evidence from Field Experiments,” mimeo, MIT, Harvard University, and Princeton University, April 2006.

Evenson, Robert (1974). “International Diffusion of Agrarian Technology.” *Journal of Economic History*, Vol. 34(1), March, pp. 51-73.

Evenson, R. and L. Westphal (1995). “Technological Change and Technology Strategy.” *Handbook of Development Economics*. J. Behrman and T. N. Srinivasan. Amsterdam, North-Holland. 3A: 2209-2300.

Feder, Gershon & Just, Richard E & Zilberman, David, 1985. "Adoption of Agricultural Innovations in Developing Countries: A Survey," *Economic Development and Cultural Change*, University of Chicago Press, vol. 33(2), pp. 255-98.

Foster, A. and M. Rosenzweig (1995) “Learning by Doing and Learning from Others: Human Capital and Technical Change in Agriculture” *Journal of Political Economy*, Vol. 103(6), p 1176-1209.

Goldman, Abe (1993). “Agricultural Innovation in Three Areas of Kenya: Neo-Boserupian Theories and Regional Characterization.” *Economic Geography*, Vol. 69(1), January, pp. 44-71.

Griliches, Zvi (1957). "Hybrid Corn: An Exploration in the Economics of Technological Change." *Econometrica*, Vol. 25(4), October, pp. 501-522.

Just, Richard E. and David Zilberman (1983). "Stochastic Structure, Farm Size and Technology Adoption in Developing Agriculture." *Oxford Economic Papers*, Vol. 35(2), July, pp. 307-328.

Karlan, Dean S., and Jonathan Zinman, "Credit Elasticities in Less-Developed Economies: Implications for Microfinance," *American Economic Review*, forthcoming.

Liebman, J.B. & Zeckhauser, R.J., "Schmeduling," working paper, Harvard University, 2004.

Moulton, Brent, "Random Group Effects and the Precision of Regression Estimates," *Journal of Econometrics*, 32, 3, August 1986, p. 385-397.

Munshi, Kaivan, "Technology Diffusion," in Kaushik Basu, ed., *Oxford Companion to Economics in India*. New Delhi: Oxford University Press, forthcoming.

Munshi, Kaivan, "Social Learning in a Heterogeneous Population: Technology Diffusion in the Indian Green Revolution," *Journal of Development Economics,* 73 (1), 2004, pp. 185-215.

Mwale, C.D., S.C. Nambuzi, A.E. Kauwa, D.Kamalongo I.Ligowe, V.H. Kabambe and W.Mhango, "On-farm evaluation of drought and low-nitrogen tolerant varieties using the mother-baby scheme in 2005/06 season," working paper, Bunda College of Agriculture, University of Malawi, 2006.

Nigam, S. N., R. Aruna, D. Y. Giri, G. V Ranga Rao, and A. G. S. Reddy, *Obtaining Sustainable Higher Groundnut Yields: Principles and Practices of Cultivation*. Andhra Pradesh, India: International Crop Research Institute for the Semi-Arid Tropics, 2006.

Rogers, Everett M., *The Diffusion of Innovations*, 4th Edition. New York: Simon & Schuster, 1995.

Simtowe, Frankin, "Can risk-aversion explain part of the non-adoption puzzle for hybrid maize? Empirical evidence from Malawi," *Journal of Applied Sciences*, 6, 7, 2006, p. 1490-1498.

Simtowe, Franklin and Manfred Zeller, "The impact of access to credit on the adoption of hybrid maize in Malawi: an empirical test of an agricultural household model under credit market failure," Munich Personal RePec Archive (MPRA) Paper No. 45, September 2006.

Smale, Melinda, Paul W. Heisey, and Howard D. Leathers, "Maize of the Ancestors and Modern Varieties: The Microeconomics of High-Yielding Variety Adoption in Malawi," *Economic Development and Cultural Change*, 43, 2, January 1995, p. 351-368.

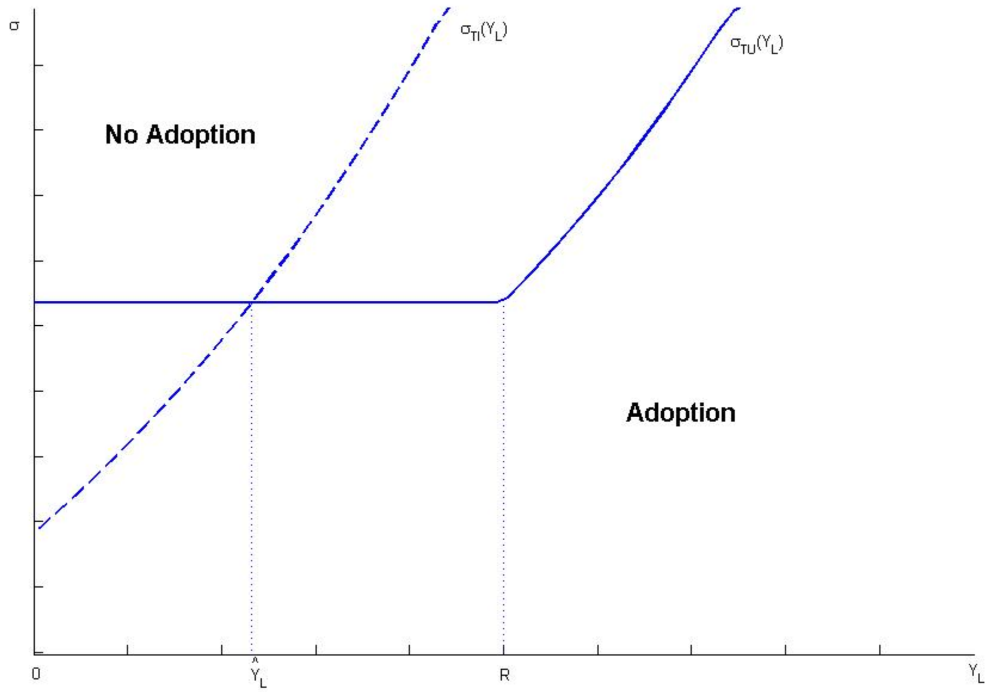
Smale, Melinda and Thom Jayne, "Maize in Eastern and Southern Africa: 'Seeds' of Success in Retrospect," International Food Policy Research Institute, EPTD Discussion Paper No. 97, January 2003.

Wessels, W. (2001) "Proposal to Release DK8051 and DK8031 and DK8041", Monsanto South Africa.

World Bank, "Malawi Poverty and Vulnerability Assessment 2006: Investing in Our Future," draft, June 2006.

Zajonc, R.B., "Attitudinal effects of mere exposure," *Journal of Personality and Social Psychology Monographs,* 9, 2, 1968, p. 1-27.

<u>Figure 1</u>. Cutoff coefficients of relative risk aversion when $\phi = 0$ and $\rho > 0$



<u>Figure 2</u>. Cutoff coefficients of relative risk aversion when $\phi = 0$ and $\rho < 0$

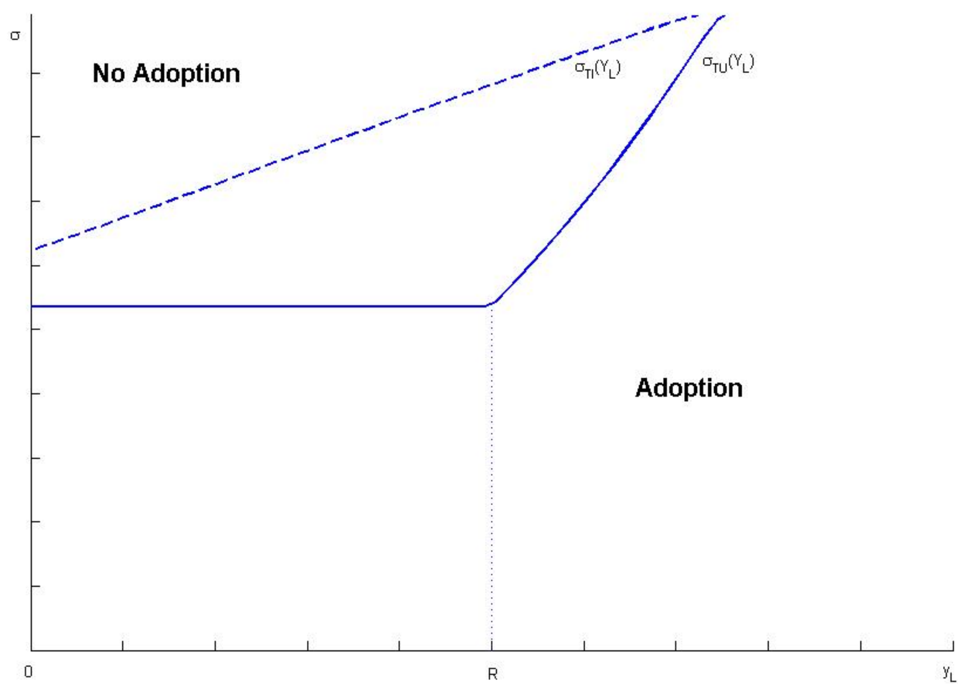


Figure 3. Malawi study areas

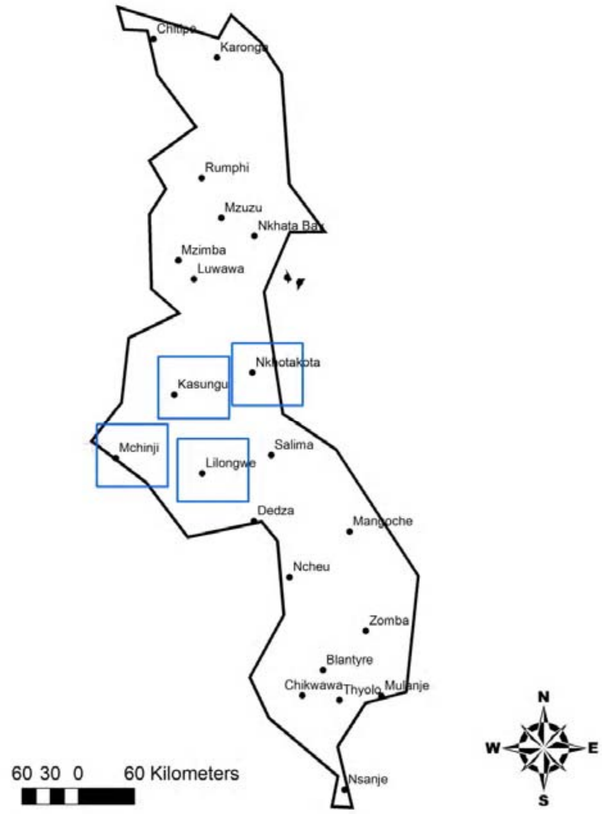
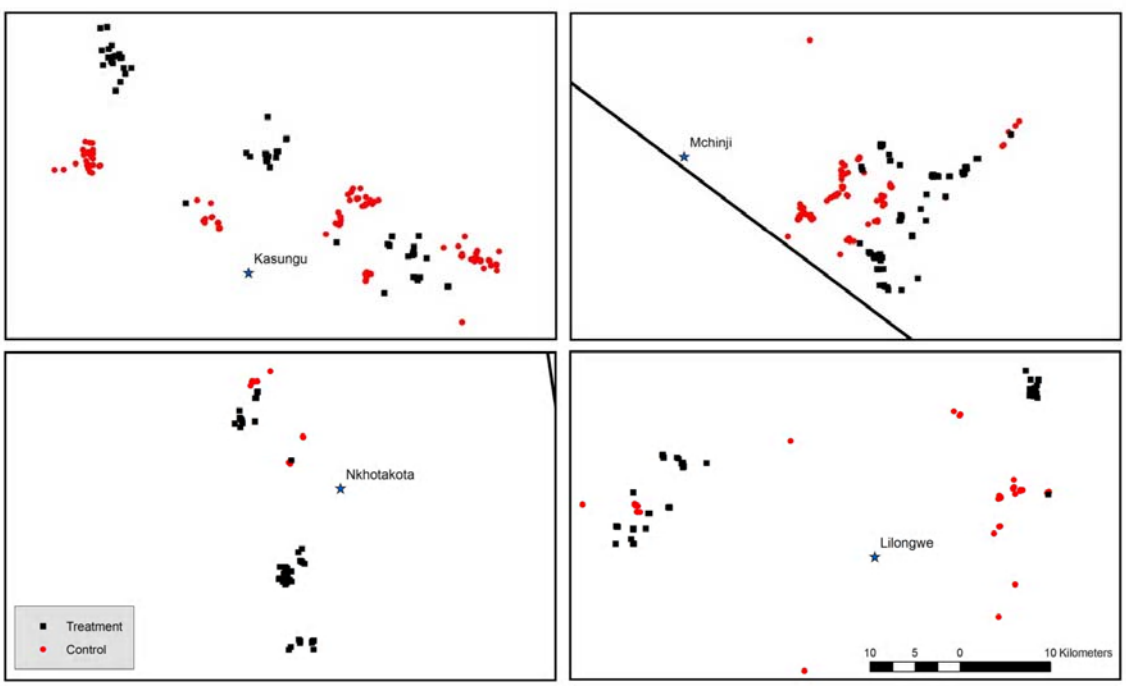


Figure 4. Farmer locations in central Malawi study areas



<u>Figure 5</u>. Insurance policy

The rainfall insurance policy divides the cropping season into three phases. The graph below shows how rainfall during the phase translates into the insurance payout for one phase.

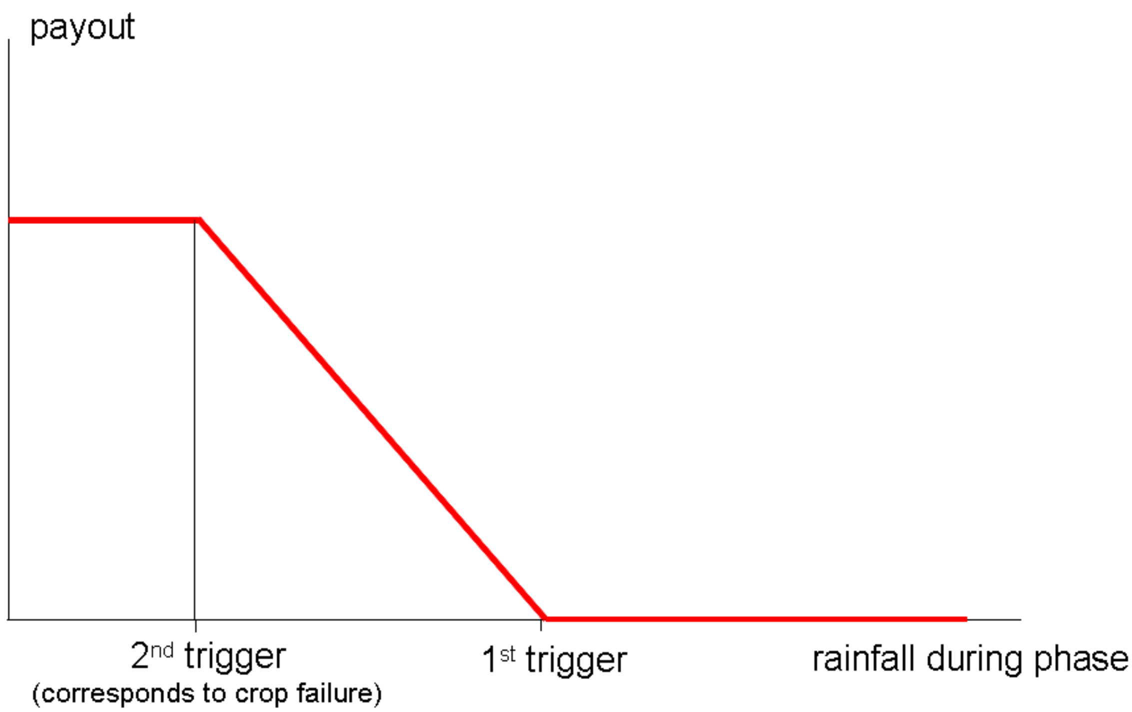


Table 1: Summary statistics

September - October 2006

Variable	Mean	Std. Dev.	Min.	10th pct.	Median	90th pct.	Max.	Num. Obs.
Take-up (indicator)	0.25	0.43	0	0	0	1	1	787
Treatment (indicator)	0.50	0.50	0	0	0	1	1	787
Female (indicator)	0.44	0.50	0	0	0	1	1	787
Household is female headed (indicator)	0.12	0.33	0	0	0	1	1	787
Years of schooling	5.34	3.50	0	0	5	10	12	787
Risk aversion (self-reported)	2.59	3.29	0	0	0	10	10	787
Age	40.64	12.50	13	26	39	58	86	787
Land owned (acres)	7.10	8.32	0	2	5	13	108	787
House quality	-0.03	1.27	-0.91	-0.85	-0.73	2.59	3.10	787
Net income (MK 100,000)	0.26	1.50	-2.15	-0.01	0.09	0.45	37.12	787

Notes -- Data are from the Malawi Technology Adoption and Risk Initiative (MTARI) farm household survey in September - October 2006. All variables refer to respondent or respondent's household. See Appendix for variable definitions.

<u>Table 2</u>: Differences in means, treatment vs. control group

September - October 2006

<u>Variable</u>	<u>Treatment mean</u>	<u>Control mean</u>	<u>Difference</u>	<u>p-value</u>
Female (indicator)	0.443	0.445	-0.002	0.975
Household is female headed (indicator)	0.125	0.119	0.006	0.852
Years of schooling	4.919	5.760	-0.841*	0.062
Risk aversion (self-reported)	2.632	2.564	0.068	0.779
Age	40.936	40.357	0.579	0.759
Land owned	6.440	7.759	-1.319	0.117
House quality	-0.144	0.087	-0.231	0.228
Net income (MK 100,000)	0.202	0.316	-0.114	0.364

* significant at 10%; ** significant at 5%; *** significant at 1%

<u>Notes</u> -- Table presents means of key variables for treatment group (farmers offered insured loan) and control group (farmers offered uninsured loan) in September - October 2006, prior to treatment. P-value is for F-test of difference in means across treatment and control groups, and accounts for clustering at level of 32 localities. See Appendix for variable definitions.

<u>Table 3</u>: Impact of insurance on take-up of loan for hybrid seeds
(Ordinary least-squares estimates)

Dependent variable: Respondent took up loan for November 2006 planting season

	(1)	(2)	(3)	(4)	(5)
Treatment indicator	-0.154	-0.141	-0.132	-0.128	-0.134
	[0.109]	[0.082]*	[0.082]	[0.074]*	[0.076]*
Clustered s.e. p-value:	*0.155*	*0.085*	*0.107*	*0.082*	*0.077*
Bootstrapped p-value:	*0.198*	*0.116*	*0.140*	*0.120*	*0.110*
Female (indicator)			-0.027	-0.036	-0.039
			[0.031]	[0.034]	[0.035]
Household is female headed (indicator)			0.038	0.054	0.049
			[0.053]	[0.053]	[0.051]
Years of schooling			0.010		
			[0.005]*		
Age			0.002		
			[0.001]		
Land owned			0.001		
			[0.002]		
House quality			0.016	0.015	0.016
			[0.018]	[0.018]	[0.017]
Net income (MK 100,000)			0.009		
			[0.014]		
Region fixed effects		Y	Y	Y	Y
Indicators for 5-year age categories				Y	Y
Land quintile indicators				Y	Y
Income quintile indicators				Y	Y
Education quintile indicators				Y	
Mean dependent variable	0.253	0.253	0.253	0.253	0.253
Observations	787	787	787	787	787
R-squared	0.03	0.13	0.15	0.17	0.17

* significant at 10%; ** significant at 5%; *** significant at 1%

Notes -- Standard errors clustered by 32 localities in square brackets. Dependent variable equal to 1 if respondent took up loan for November 2006 planting season, and 0 otherwise. Treatment indicator is 1 if loan is insured (respondent is in treatment group), 0 otherwise (respondent is in control group). Region fixed effects are for four study regions (Lilongwe North, Kasungu, Mchinji, and Nkhotakota). See Appendix for variable definitions and quantile indicators. Bootstrapped p-values for Treatment indicator obtained via wild bootstrap with Rademacher weights and imposing null hypothesis, as in Cameron, Gelbach, and Miller (2007).

<u>Table 4</u>: Testing against alternative null hypotheses

P-values from test of significance of "Treatment" coefficient vs. alternative null hypotheses

	Regression (coefficient estimates in Table 3)				
	(1)	(2)	(3)	(4)	(5)
Null = 0.05					
Clustered s.e. p-value:	*0.060*	*0.020*	*0.026*	*0.016*	*0.015*
Bootstrapped p-value:	*0.068*	*0.056*	*0.066*	*0.048*	*0.048*
Null = 0.10					
Clustered s.e. p-value:	*0.019*	*0.003*	*0.005*	*0.002*	*0.002*
Bootstrapped p-value:	*0.044*	*0.016*	*0.024*	*0.014*	*0.016*

<u>Notes</u> -- Table reports p-values from test of significance of Treatment indicator against alternative null hypotheses, for clustered standard errors vs. bootstrapping. Original regression coefficients reported in Table 3 for columns 1-5 respectively. Bootstrapped p-values for Treatment indicator obtained via wild bootstrap with Rademacher weights and imposing null hypothesis, as in Cameron, Gelbach, and Miller (2007).

<u>Table 5</u>: Determinants of take-up in treatment and control groups
(Ordinary least-squares estimates)

<u>Dependent variable</u>: Respondent took up loan for November 2006 planting season

	Treatment group (insured loan)						Control group (uninsured loan)					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Years of schooling	0.014**					0.011*	-0.001					-0.002
	[0.005]					[0.005]	[0.008]					[0.009]
Net income (MK 100,000)		0.098				0.075		0.004				0.003
		[0.059]				[0.053]		[0.010]				[0.010]
House quality			0.041			0.027			0.011			0.011
			[0.027]			[0.030]			[0.022]			[0.022]
Land owned				0.001		0.001				0.001		0.001
				[0.003]		[0.003]				[0.002]		[0.002]
Risk aversion (self-reported)					-0.008	-0.008					-0.015***	-0.015***
					[0.006]	[0.006]					[0.004]	[0.004]
Region fixed effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Mean dependent variable	0.176	0.176	0.176	0.176	0.176	1.176	0.330	0.330	0.330	0.330	0.330	0.330
Observations	393	393	393	393	393	393	394	394	394	394	394	394
R-squared	0.074	0.078	0.073	0.058	0.061	0.101	0.274	0.274	0.274	0.274	0.286	0.287
					F-stat.: joint signif. of first 4 independent variables	3.446					*F-stat.: joint signif. of first 4 independent variables*	0.113
					P-value	0.03					*P-value*	0.98

* significant at 10%; ** significant at 5%; *** significant at 1%
<u>Notes</u> -- Standard errors clustered by localities in square brackets. Dependent variable equal to 1 if respondent took up loan for November 2006 planting season, and 0 otherwise. Omitted region indicator is for Kasungu. See Appendix for variable definitions.