# 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)

**Abstract**

Does production risk suppress the demand for credit? 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 adopt a new crop technology. 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

---

## 1. Introduction

A great deal of attention is paid to imperfections in credit markets as barriers to growth in rural areas of developing countries. Most prominently, the literature has emphasized limitations in the supply of credit due to asymmetric information and imperfect enforcement. The problems that arise can often be characterized by a borrower's inability to commit to fulfilling a debt contract. Debtors cannot credibly reveal their borrowing type truthfully (adverse selection), promise to exert effort so that their production enterprise does not fail (ex-ante moral hazard), report their production output honestly (ex-post moral hazard), or promise to repay the loan even when output was sufficient (opportunistic default).[1]

A second type of credit market imperfection is due to the absence of or limitations in insurance markets. Uninsured borrowers may be deterred from taking on loans by the risk of high default costs (e.g., confiscation of assets) in states of the world where income is low and they are unable to repay the loan. Binswanger and Sillers (1983) and Boucher, Carter, and Guirkinger (2008) have emphasized so-called "risk rationing," or risk-motivated voluntary withdrawal from the credit market.[2]

This paper focuses on the second of these two categories of credit market imperfections. We conducted a randomized field experiment to determine whether bundling insurance with a loan (intended to finance adoption of a new crop technology) increased demand for the loan. The specific context of the study was the adoption of high-yield hybrid varieties of maize and groundnut among smallholder farmers in Malawi.

To test the importance of risk in hindering take-up of loans for hybrid seed adoption, we randomized whether farmers' loans 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-

---

[1] For comprehensive reviews of this literature, see Dowd (1992), Ghosh, Mookherjee and Ray (2000), and Conning and Udry (2005).

[2] Relatedly, Dercon and Christiaensen (2007) argue that consumption risk discourages fertilizer use by Ethiopian farmers.

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 (Dowd 1992).

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. 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. 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 income in the low state (a measure of default costs, if crop output can be seized by 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.

In addition to shedding light on the interactions between credit and insurance markets, this paper also contributes to our understanding of technology adoption in rural areas of developing countries. 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.[8] 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.

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).[9] 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.[10]

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

---

[8] 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.

[9] 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).

[10] 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".

This last point is illustrated by the well-known positive correlation between wealth and adoption of new technology.[11] 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 absence of insurance markets (or both) are the key constraints hindering hybrid seed adoption in Malawi (and elsewhere). Disentangling the two explanations is crucial because they call for very different government interventions.

Our findings are also related to existing research documenting relatively limited demand for weather insurance in developing countries. Our theoretical model where borrowers' limited liability limits the value of formal weather insurance is reminiscent of Rosenzweig and Wolpin (1993), who show in simulations that the gain from weather insurance for Indian farmers is minimal due the existence of informal insurance mechanisms that create a consumption floor. Giné, Townsend, and Vickery (2008) find relatively low take-up (4.6%) of a standalone rainfall insurance policy among farmers in rural Andhra Pradesh, India in 2004. Using door-to-door marketing visits, Cole et al. (2008) find substantially higher take-up (27%) in 2006 among the same sample of farmers in Andhra Pradesh and a take-up of 23% of another standalone rainfall insurance policy in rural Gujarat, India. They also find that variations in marketing can have substantial impact on the take-up. Both Giné, Townsend, and Vickery (2008) and Cole et al. (2008) find, as we do in this paper, that take-up is correlated with farmers' wealth. Their story is one of credit constraints: since the insurance policy must be purchased at the onset of the season, coinciding with the purchase of the other agricultural inputs (labor for land preparation, seeds, fertilizer, etc.) there are competing uses for the cash

---

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

and only the better-off can afford the policy. In the Malawi field experiment we examine in the current paper, there is also a deposit that needs to be paid upfront, but the fact that wealth and income matter for the insured loan but not for the uninsured loan suggest that something other than credit constraints may be at play.

The remainder of this paper is organized as follows. In Section 2 we present a simple model that is consistent with the lower take-up in the insured group. In Section 3 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 4, and then in Section 5 explore the determinants of take-up separately in the treatment and control groups. Section 6 discusses additional explanations for lower take-up in the insured group. Section 7 concludes. The Appendix provides further details on the variables used in the empirical analysis.

## 2. A Simple Model

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 $1\text{-}p$ and $Y_T < pY_H + (1-p)Y_L$. 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 $C$. Borrowers pledge illiquid assets $W$ as collateral, and we assume that $W > (1+r)C = R$, that is, the value of the collateral is enough to cover the repayment of the loan $R$. 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 $\phi$. The probability $\phi$ 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 again $R = (1+r)C$ 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

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

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

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

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 $\rho$ be the correlation between rainfall and income.[12] 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 $\pi$. Thus, $R^I = (1+r)(C+\pi)$ where the premium, if priced fairly, solves $(1+r)\pi = (1-q)R^I$ which simplifies to $\pi = \dfrac{1-q}{q}C$. 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 $R^I = \dfrac{R}{q}$.

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

$$U_I = \frac{(1+\rho)}{4}u(Y_H - 2R + W) + \frac{(1-\rho)}{4}u(Y_H + W) +$$
$$\frac{(1-\rho)}{4}[\phi u(Y_L - 2R + W) + (1-\phi)u(W)] + \frac{(1+\rho)}{4}u(Y_L + W)$$

(3)

where the first term on the right hand side is the joint probability of $Y_H$ and $h$ times the utility in that state, and the rest of the terms are the joint probabilities of $Y_H$ and $l$, $Y_L$ and $h$ and $Y_L$ and $l$, multiplied by the utility in the respective states of nature.

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

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

(4)

where the probability of collateral foreclosure $\phi$ does not appear because the borrower always has enough output to repay the bank.

---

[12] Technically, $\rho$ 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.

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

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

When limited liability binds, if output in the low state is zero or, more generally, low enough, then consumption in the low state is similar under each type of loan, but consumption in the high state is far lower when the insured loan is taken because the amount to be repaid includes the premium.

In order to understand when an insured loan will be preferred to a standard one (uninsured), 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 $\sigma_{TU}$ 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 $\sigma_{TU}$ satisfies $U_T(\sigma_{TU}) = U_U(\sigma_{TU})$, which unfortunately does not have a closed form solution.

The analogous cutoff coefficient $\sigma_{TI}$ for the insured loan satisfies $U_T(\sigma_{TI}) = U_I(\sigma_{TI})$.

Figure 1 plots the cutoff coefficient of relative risk aversion $\sigma_{TU}$ and $\sigma_{TI}$ 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 farmer consumes $W$ regardless of $Y_L$ which is seized by the bank due to limited liability and so the cutoff $\sigma_{TU}(Y_L)$ is constant because

it 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 $c_L = Y_L - R + W$ with probability $\phi$. (With probability $1 - \phi$, consumption in the low state is $c_L = W$). When $\phi > 0$, 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 $\phi = 0$. When the insured loan is taken, consumption in the low state if the insurance pays out is given by $c_L = Y_L + W$, which clearly depends positively on $Y_L$. The intuition here is that the higher the level of $Y_L$, the higher the farmer's default cost (the more the farmer "stands to lose" upon default via confiscation of his or her output), and so the more valuable is an insured loan.

We are now interested in determining under what conditions a farmer will prefer the insured loan to the uninsured one. In other words, when will $\sigma_{TI} > \sigma_{TU}$? Figure 1 shows 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. 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.

In sum, Figure 1 shows that there are situations in which more farmers would adopt the hybrid seeds with an uninsured loan than with an insured one. Limited liability turns out to be a key factor in limiting the value of the insurance policy.

## 3. Experimental Design and Survey Data

The experiment was carried out as a collaborative 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, but the subset of farmers who took up the loan were told that they were jointly liable for each others' loans. In practice, however, joint liability schemes in Malawi are seldom enforced. When a default occurs, lenders may at best seize the defaulter's movable assets, such as furniture or a TV set, but even this happens only rarely.[13] 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 2 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 3 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-

---

[13] In focus groups with farmers, few suggested having heard stories about someone they did not know having lost his assets after defaulting on a loan, but they all knew defaulters first-hand and none had their assets seized.

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.[14] 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).[15] Of this total repayment, MK 3,680 was the cost of seed and MK 1,012.00 was interest.[16] 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

---

[14] 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.

[15] In October 2006, roughly 140 Malawi kwacha (MK) were convertible to US$1.

[16] 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).

percent. The DK8051 is also resistant to common diseases including GLS, leaf blight, and other conditions (Wessels 2001).[17]

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 4 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.

---

[17] 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.

The weather insurance policy was customized to each of the four project regions. Payouts were based on the rainfall readings at the closest weather station to the individual in question (there was a separate station for Lilongwe North, Kasungu, Nkhotakota, and Mchinji). The insurance policy was priced at the actuarially fair premium,[18] plus a 17.5% government-mandated surtax.[19] Therefore the premium was lower in places where the likelihood of a bad rainfall shock is lower.[20]

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

---

[18] To be clear, computing the actuarially fair premium on the insurance policy is straightforward, because payouts depend solely on the occurrence of well-defined meteorological events. Historical data from the same weather stations that are used to determine payouts provide the probability distribution of the weather events. The actuarially fair premium is then simply the expected payout of the policy given the historical distribution of the weather events.

[19] The policy was designed by the Insurance Association of Malawi with the technical assistance from the World Bank. Because the World Bank was also involved in the design of the stand-alone weather insurance policies in India, they share a very similar design. The introduction of weather insurance in India is studied in Giné, Townsend and Vickery (2008) and Cole, Topalova and Tobacman (2008).

[20] If borrowers did not value insurance, then one should expect take-up of the insured loan to be higher in areas with lower premiums. If, on the contrary, borrowers valued insurance, then the demand for insurance would be correlated with the occurrence of the insured event, and therefore higher demand would be associated with higher premiums, in which case the correlation would be zero. We tested whether take-up was higher in areas with lower premiums and found that while point estimates are in the expected direction (higher take-up with lower premiums), the limited amount of variation in premiums leads to large standard errors so that we cannot reject the null that premiums are unrelated with take-up (results available from authors on request).

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:

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

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 $\phi_j$ are fixed effects for four study regions. $\varepsilon_{ij}$ 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 2008).[21] 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).[22]

The coefficient $\beta$ 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 $\beta$, 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

---

[21] To be sure, it is not clear that 32 should be considered a "small" number of clusters. In Cameron, Gelbach, and Miller (2008), 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).

[22] 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" 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.

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).

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.[23]

## 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, since $\phi = 0$). However, for the *insured* loan, an increase in low-state income 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

---

[23] 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.

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.

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. The relationship between self-reported risk aversion and take-up is also negative for farmers offered the insured loan, although the coefficient is smaller in magnitude (-0.008) and is not statistically significantly different from zero. These results are consistent with the theoretical model: individuals with higher risk aversion (for given $Y_L$) are more likely to be located above the risk aversion cutoff line in Figure 1 and to decide not to take up the loan.

**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.

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.

It is also possible that farmers may have been uncertain about the risk characteristics of the hybrid seeds, and took the fact that they were offered insurance as a signal from NASFAM that the seeds were riskier than they would have thought otherwise. Lower take-up of the credit plus insurance product would then be a rational response.

Basis risk may also have been a problem: the insurance policy may simply have been designed in such a way that it was not attractive to farmers because it insured weather events that had little to do with actual output on the farm. This may have been the case if the weather stations are too far away (so that rainfall at the weather station is poorly correlated with rainfall on the farmer's field), or if the insured meteorological events are poorly chosen (e.g., rainfall is insured in months that are not important for output). If basis risk is large enough, then the insurance policy will be unattractive to farmers and our finding that take-up of the package is lower with insurance (for which the premium is charged) would not be surprising.

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 induces greater demand for loans to finance 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 value of harvest proceeds that could be seized by 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.

The focus here has been on the *farmer*'s demand for insurance, not the *lender*'s. When one takes into account the lender's perspective, a much clearer picture emerges. For the lender, weather insurance is likely to be an attractive way to mitigate default risk and thus, it can become an effective risk management tool with the potential of increasing access to credit in agriculture at lower prices.

## Appendix: Variable definitions

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.

Besley, Timothy and Anne Case (1993). "Modeling Technology Adoption in Developing Countries." *American Economic Association Paper and Proceedings*, Vol. 83, No. 2, May, pp. 396-402.

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

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

Boucher, Stephen, Michael R. Carter, Catherine Guirkinger (2008). "Risk Rationing and wealth Effects in Credit Markets." *American Journal of Agricultural Economics,* Vol. 90, No. 2, May, pp. 409-423.

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 (2008).  "Bootstrap-Based Improvements for Inference with Clustered Errors," *Review of Economics and Statistics*, Vol. 90, No. 3, August, pp. 414-427.

Cole, Shawn, Xavier Giné, Jeremy Tobacman, Robert Townsend, Petia Topalova and James Vickery 2008, "Barriers to Household Risk Management" working paper, Harvard Business School, World Bank, Oxford University, MIT, NY Fed and IMF.

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

Conning, Jonathan and Christopher Udry (2005). "Rural Financial Markets in Developing Countries," in R. E. Everson, P. Pingali, and T.P. Schultz (eds.), *The Handbook of Agricultural Economics, Vol. 3: Farmers, Farm Production, and Farm Markets*, Elsevier Science.

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, Esther, Michael Kremer and Jonathan Robinson, "Understanding Technology Adoption: Fertilizer in Western Kenya: Evidence from Field Experiments," mimeo, MIT and Harvard 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.

Giné, Xavier, Robert Townsend, and James Vickery (2008), "Patterns of Rainfall Insurance Participation in Rural India," *World Bank Economic Review*, forthcoming.

Ghosh, P., D. Mookherjee, and D. Ray (2000). "Credit Rationing in Developing Countries: An Overview of the Theory," in D. Mookherjee and D. Ray, eds., *Readings in the Theory of Economic Development*, Malden, MA: Blackwell, pp. 283-301.

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.

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.

Rosenzweig, Mark and Kenneth Wolpin, "Credit Market Constraints, Consumption Smoothing, and the Accumulation of Durable Production Assets in Low-Income Countries: Investments in Bullocks in India," *Journal of Political Economy*, Vol. 101, No. 2, 1993, pp. 223-244.

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.

**Figure 1**. Cutoff coefficients of relative risk aversion when $\phi = 0$ and $\rho > 0$
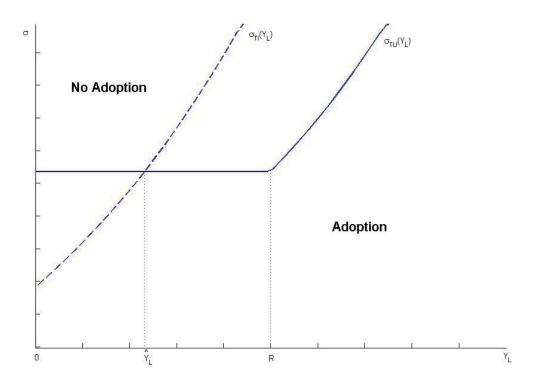
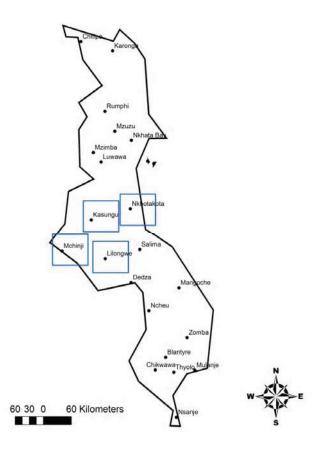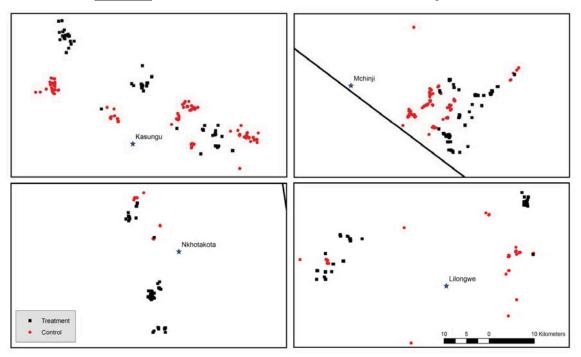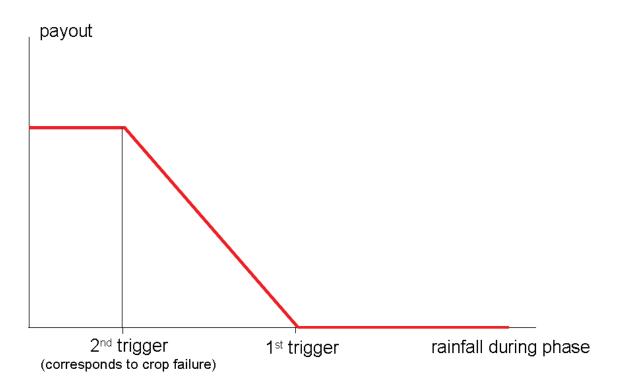**Figure 2**. Malawi study areas



**Figure 3**. Farmer locations in central Malawi study areas

**Figure 4. 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.

**Table 2: Differences in means, treatment vs. control group**

September - October 2006

| Variable | Treatment mean | Control mean | Difference | p-value |
|---|---|---|---|---|
| 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%

Notes -- 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.

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

<u>Dependent variable</u>: 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%

<u>Notes</u> -- 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 (2008).

**Table 4: 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 |

Notes -- 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 (2008).

**Table 5: Determinants of take-up in treatment and control groups**
(Ordinary least-squares estimates)

Dependent variable: 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%

Notes -- 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.