THE ECONOMICS OF INTERLINKING CREDIT AND INSURANCE

PART 1: THE DEMAND SIDE

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Despite their compelling logic, index insurance contracts that transfer risk from smallholder farmers and pastoralists have met with sometimes indifferent demand and low uptake by the intended beneficiary populations. While discouraging, the ever-mounting evidence that risk plays an important role in the creation and perpetuation of rural poverty demands further efforts to solve this problem.

Conventional economic theory suggests that individuals are averse to fluctuations in their levels of consumption and that therefore they will be willing to tradeoff some consumption on average in return for lower variation in consumption. While this standard perspective is unassailable on its own grounds, it overlooks the mass of evidence that indicates that risk is costly for reasons that run much deeper than sporadic fluctuations in families’ levels of consumption. It also unnecessarily offers the farmer what is essentially a zero sum proposition: Does the farmer want to spend a fraction of a given income level on insurance, implying a reduction in spending on other goods and services?

Arguably, demand for insurance will be stronger and sustainable when it offers the farmer a non-zero sum choice. Income insurance can become a non-zero sum proposition if it simultaneously underwrites an increase in expected income even as it reduces risk exposure. This positive sum game can happen if income insurance crowds in the adoption of new, higher returning technologies, either by improving the supply of credit to purchase these technologies or by increasing farmers’ willingness to bear the risk to borrow and otherwise adopt these technologies. Similarly, by preserving productive assets for future periods, asset
insurance also offers higher incomes over time and makes insurance a positive sum game. In environments like the arid areas of East Africa, which are characterized by asset-based poverty traps, the positive sum nature of asset insurance can be especially strong (see Barrett and Chantarat 2010).

This paper looks more closely at the first mechanism, exploring whether, when and how index insurance can enhance the functioning of agricultural credit markets and enhance farmers’ expected income even as it reduces the variance of income. Section 1 below reviews the ways in which risk in the presence of asymmetric information undercuts agricultural credit markets from both the demand and supply sides. Drawing on the market interlinkage model of Braverman and Stiglitz (1982), Section 2 explores index insurance as a mechanism that modifies the liability or default clause that farmers face in choosing their production technology. While the existence of basis risk under index contracts adds complexity to the analysis, we show that the more favorable implicit default clause that exists under index insurance creates a type of positive moral hazard as it crowds in greater risk taking and moves producers towards a socially optimal choice of technology. Section 3 then uses numerical methods to further explore the impact of this kind of interlinkage on the likely demand for insurance. While it is clear that index insurance will not work in all environments, we show how the existence of interlinked credit and insurance will increase the effective demand for insurance, bringing with it both growth and poverty reduction benefits. Finally, Section 4 concludes the paper with some thoughts on contract design and implementation issues.
Section 1  Risk and Agricultural Credit Markets

Uninsured risk can directly distort economic decisions on the use and accumulation of assets. In addition, risk can undercut the development of rural financial intermediation and credit institutions, creating a second round of indirect effects of risk on innovation. This section explores how risk and information costs knot up the development of rural credit markets from both the demand and supply sides.

Going back at least to the seminal contribution of Stiglitz and Weiss (1986), the credit market has been one venue in which the impact of asymmetric information has been extensively studied. A key insight from this literature is that asymmetric information can result in quantity rationing in loan markets, meaning that some individuals are unable to secure desired loans at the market rate of interest. In conventional, price-rationed markets, such excess demand would provoke an increase in price (the interest rate) until supply and demand were equated. Stiglitz and Weiss show that lenders may find it profit maximizing to keep the price of their product low even in the face of excess demand. The economic impact is that some farms and businesses will face credit constraints and unable to adopt profitable, income improving technologies.
The figure above, taken from material prepared for the recent World Development Report on agriculture, illustrates the ubiquity of constrained access to capital in 3 recent surveys of agricultural producers in Latin America. The constrained constitute some 40% of all producers. Constrained producers on average use only 50% to 75% of the purchased inputs of unconstrained producers and enjoy net incomes (returns to land and family labor) that are between 60% and 90% of the level of unconstrained farm households. As mentioned in the introduction to this paper, a recent econometric analysis of the data from Peru estimates that total agricultural output would be 25% in the region studied higher if all these credit constraints were eliminated (Boucher and Guirkinger, 2006).

Financial constraints are not only costly; they tend to be biased against lower wealth households. Figure 2 shows that the constrained farm households have wealth levels that average 50% or less of the wealth levels of unconstrained

households. This pattern not only means that benefits from agricultural growth is less equally distributed then they might be, it also means that smallholders are less able to compete for access to land through either rental or purchase markets.

The root of the problem here is that especially formal lenders will tend to offer only a limited menu of contracts, restricted to those that have heavy collateral requirements. In the first instance, this truncation of the contract menu may result in wealth-biased quantity rationing as just discussed. Second, the truncation of the contractual menu results in what recent theoretical work calls risk rationing, meaning that individuals turn down available contracts for which they qualify because they are unwilling to bear the risk of collateral loss (Boucher, Carter and Guirking 2008). In the Nicaraguan and Honduran studies illustrated in Figure 2, 20% and 40% of credit constrained borrowers are risk rationed. In the case of Peru, where panel data is available, the fraction of constrained borrowers who were risk rationed rose from 20% to 50% between 1998 and 2003 (with the overall fraction of constrained households dropping form 56% to 43%). In all three countries, risk rationed producers behave almost identically to quantity rationed

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1 Note that for a given default risk, a lender should be willing to tradeoff between the interest rate on a loan and the collateral required. In the presence of asymmetric information, lenders will prefer relatively low interest rate contracts with high collateral requirements as the collateral serves to reduce moral hazard and the probability of default.

2 Eliciting information on credit constraints is difficult (see Boucher et al., forthcoming). In the course of carrying out the research on the prevalence of quantity rationing, we discovered a not insignificant number of small farmers who report having access to a loan contract, but who choose not to accept the loan contract for fear of losing the collateral assets required by the contract. Typically such farmers reported an unwillingness to risk land loss that would threaten their future livelihood and that of their children who would also depend on that land.
households, using fewer inputs and pursuing less remunerative income generating strategies.

Risk rationing thus illustrates the way in which uninsured risk spills over from the demand side and hampers the development of effective financial intermediation. Risk can also thwart the development of credit markets from the supply side. From a lender’s perspective, agricultural loans are problematic because an important component of the risk faced by farmers is correlated, meaning that if one farmer is having trouble repaying a loan because of drought or other climatic reasons, it is highly likely that other farmers will be facing the same problem. A loan portfolio with too many agricultural loans will thus be unstable in the face of correlated risk. A sufficiently large financial institution can potentially diversify a loan portfolio against correlated agricultural risk. Such risk is more problematic for many microfinance lenders that are smaller scale and locally based institutions. This observation is especially true for microfinance lenders that utilize borrower groups whose members are jointly liable for each others’ loan repayment. Uninsured, correlated risk would thus seem to explain the limited impact of the microfinance revolution on small-scale agriculture.

In addition to its direct effect on lender willingness to carry a portfolio of agricultural loans, uninsured correlated risk also has an indirect, political economy effect on rural financial markets. In the wake of the 1998 El Nino climate shock, Binswanger and Rosenzweig (1987) make a similar argument, noting that financial intermediaries which both drew deposits from and made loans to agricultural households would have severe stability in drought and other years of covariate shocks.
indebted farmers in Peru pressed the government for relief, arguing that their inability to repay was obviously not their fault. The resulting Rescate Financiera (Financial Rescue) mandated lenders to forgive agricultural loans.

Not surprisingly, lenders were unhappy with this rescue plan and reacted to it by furthering restricting the amount of their loan portfolio that they would place in agricultural projects. In a recent study, Tarazona and Trivelli (2005) interviewed all institutional agricultural lenders in Peru’s north coast department of Piura. All lenders reported severe portfolio restrictions on agricultural lending because fears of both climatic and political risk. The largest regional financial institution indicated that they put no more than 3% of their loan portfolio in agriculture. To put this figure in perspective, Piura has an agriculturally dependent economy, with close to 50% of its regional GDP coming from agriculture.

In summary, the particular features of the agricultural economy—information costs and correlated risk—militate against the development of deep and effective financial markets. This failure of institutional innovation and development is especially costly for smallholder farmers who are likely most averse to risk and least able to exploit outside financial options. It is little wonder that technological change has been hard to sustain in rainfed areas of Africa where smallholders predominate. In this context, it may seem that direct public provision of credit may be the best solution. Unfortunately, the prior dismal record of public agricultural banks suggest otherwise. What then is the best way to untie the

\footnote{There are, however, several interesting examples of redesigned public agricultural development banks that show substantial promise (see Trivelli, 2007 and World Bank, 2007).}
Gordian knot that holds down the development of rural and especially agricultural financial markets?

Section 2  Inducing Positive Moral Hazard with Interlinked Credit and Insurance

In their seminal analysis of market interlinkage, Braverman and Stiglitz (1982) explored how a contractual principal (e.g., a landlord/lender) could use interlinked credit and land rental contracts to indirectly control decisions by an agent (renter/borrower) that are otherwise beyond the direct control of the principal because of agency costs. In particular they show how bundling land and credit contracts allows the landlord to manipulate the renter’s choice of labor effort (which would otherwise be beyond the landlord’s control) as well as the renter’s choice of technology.

The figure below, taken from Braverman and Stiglitz, illustrates the key insight from their analysis. The horizontal axes of the graphs displays the (stochastic) income produced by the renter that is influenced by the renter’s choice of technology and effort. The vertical axes display the borrower-renter’s level of utility as a function of those income outcomes under loan default clauses. The middle graph illustrates an unlimited liability loan contract in which low income realizations result in severe losses for the borrower-renter (e.g., loss of collateral assets or other non-economic pain). Braverman and Stiglitz show how this unlimited liability default clause induces the borrower-renter to supply more effort to the production process than would otherwise, allow the lender-landlord to indirectly control an action that she or he normally could not.
The far right graph, which illustrates a limited liability contract, offers debt forgiveness to the borrower when the production process fails. In their analysis, Braverman and Stiglitz show that this kind of default clause will induce the borrower-renter to choose more productive, but riskier technologies than they otherwise would. As we will show in the next section, index insurance contracts offer a similar liability structure and can have similar effects on farmers’ choice of technology.

2.1 A Model of Credit, Insurance and Technology Choice

In this model farmers maximize their utility by making two decisions, one is purchase of insurance and the other is technology adoption. We assume for the moment that farmers have access to capital that is sufficient to fund the purchase of the input bundles associated with any of the available technologies. To keep matters simple, we will assume that all capital is accessed through a fully collateralized loan contract such that the farmer fully liable for repayment of the amount borrowed.
Using this model, we will show three things. First, we will show that farmers will be partially risk rationed in the absence of insurance. That is, farmers will choose technologies that are safer, cheaper and lower returning than the best available technology, even though they have access to the loans needed to buy even the most expensive technology.

Second, we will show that when actuarially unfair (marked-up) index insurance contracts are made available, only those farmers who face relatively high (low) covariant (idiosyncratic) risk will purchase the insurance.

Third and finally, we will show that the impact of insurance on farming well-being can be broken up into two, separate parts. The first part is a pure insurance effect and can be recovered by not allowing the farmer to adjust technology after the purchase of insurance. While seemingly artificial, this would correspond to a reality in which farmers are credit constrained and unable to borrow the funds needed to enhance their choice of production technology.

The second part of the value of insurance comes from the fact that it partially de-risk-rations farmers as they move to higher yielding, but riskier technologies. We show that this second impact not only enhances the value of insurance to farmers, but expands the range of conditions under which farmers would find it desirable to buy insurance.

We turn now to introduce the elements of the model: production function and stochastic component, insurance condition and utility function.
Production and Stochastic Structure

To keep matters relatively simple, we follow Braverman and Stiglitz (1982) and express net agricultural income as a function of stochastic environmental factors, $\theta$, and the technology chosen by the farmer, $\Omega \equiv [\theta_1, \theta_n]$. Expected net farm income is increasing in $\Omega$. The cost of the technology is $g(\Omega)$, and these costs must be paid up-front. Specifically we assume that net farm income is generated as follows:

$$y = \theta f(\Omega), \quad f'(\Omega) > 0 \quad (1)$$

Equation (1) implies that high level of technology raises average output but also increases variance of output. The cost of technology is embedded in function $f$.

Different from Braverman and Stiglitz’s model, $\theta$ does not only include environmental factors $r_c$, the weather index, but also idiosyncratic factors $r_i$:

$$\theta = r_c + r_i \quad (2)$$

We further assume that $r_c$ and $r_i$ follow symmetric three-point distributions and are independent of each other. The density functions of $r_c$ and $r_i$ are

$$r_c = \begin{cases} 0 & p \\ 1 & 1 - 2p \\ 2 & p \end{cases} \quad \text{and,} \quad r_i = \begin{cases} -1 & \pi \\ 0 & 1 - 2\pi \\ 1 & \pi \end{cases} \quad (3)$$

$\pi, p \in [0, \frac{1}{2}]$

$r_c$ is distributed among 0, 1, and 2 with probability of $p$, $1 - 2p$ and $p$ respectively, and $r_i$ is distributed among -1, 0 and 1 with probability of $\pi$, $1 - 2\pi$ and $\pi$.
respectively. Therefore, $r_e$ has mean equal to 1 and variance $\sigma_{r_e}^2$ equal to $2p$, while $r_i$ has mean equal to 0 and variance $\sigma_{r_i}^2$ equal to $2\pi$.

Using relation (2) and (3), the mean and variance of $\theta$ can be calculated as

$$E(\theta) = 1$$
$$\text{Var}(\theta) = \sigma_{\theta}^2 = 2(p + \pi) \quad \text{(4)}$$

Because there is no limit to the farmer’s liability to pay $c(\Omega)$, the payoff function to the farmer will appear as one of the first two panels in the Braverman and Stiglitz suite of graphs above.

*Index Insurance Contracts*

The index insurance contract only covers output fluctuations that result from variations in the covariant component, $r_e$. We assume that $r_e$ is costlessly observed by everyone, and to keep discursively simple, we will refer to the measure of $r_e$ as a weather index. Indemnity payments are paid to insured farmers when the weather index $r_e$ falls below a threshold of pre-determined $\bar{r}_e$. Given the above distribution of $r_e$, $\bar{r}_e$ is assumed between 0 and 1. And the amount of indemnity $z$ is a function of the difference between the threshold and weather index as:

$$z = (\bar{r}_e - r_e)f(\bar{\Omega}), \quad \bar{r}_e \in (0, 1) \quad \text{(6)}$$

where $f(\bar{\Omega})$ is function $f$ evaluated at a constant $\bar{\Omega}$.

We assume that the premium for this insurance contract, $\bar{p}$, is equal to the actuarial fair premium (expected indemnity payment) plus a management cost $\beta$: 12
\[ \bar{p} = E(z \{ r_s \leq \bar{r} \}) + \beta = f(\Omega)\bar{r}_s p + \beta, \quad \beta > 0, \quad f(\Omega) > 0 \quad (7) \]

Ignoring the idiosyncratic shock \( r_s \), the payoff function for an insured farmer would be identical to graph (c) above in the Braverman and Stiglitz diagram. That is, index insurance would operate exactly like a default clause in a loan contract with the kink point happening at \( \bar{r}_s f(\Omega) \). However, the existence of idiosyncratic risk implies that even the insured farmer will experience income fluctuations below this point. After specifying a utility function, we will examine the interplay between these different stochastic elements, technology choice and the demand for insurance.

**Utility function**

A quadratic utility function is adopted:

\[ U(c) = c - \varphi c^2, \quad \varphi \in (0, \frac{1}{2c}) \quad (8) \]

where \( c \) is net income and \( \varphi \) is a parameter positively correlated with absolute risk aversion coefficient. Net income \( c \) is equal to income minus possible insurance premium \( \bar{p} \) and plus possible insurance indemnity \( z \). Thus

\[ c = qy - \bar{p} I \{ I = 1 \} + z I \{ I = 1 \} 1 \{ r_s \leq \bar{r} \} \quad (9) \]

where \( y \) is output, \( q \) is price of output and normalized to 1. Variable \( I \) is binary equal to 1 if farmer buy insurance and equal to 0 if not buy. The indicator function \( 1 \{ r_s \leq \bar{r} \} \) denotes the condition for indemnity payment. If insurance is not purchased, net income is just equal to output. If insurance is purchased but indemnity condition is not held, net income is equal to output minus insurance.
premium. If insurance is purchase and indemnity condition is held, net income is equal to output minus premium plus indemnity. Therefore, utility can be written as:

\[ U = U(f(\Omega), I, p, \pi, \beta, \theta, r_c, \varphi, \bar{r}, f(\Omega)) \]  

(10)

2.2 Demand for Insurance

The farmer choose \( \Omega \) and \( I \) to maximize his expected utility, taking into account the production function and insurance contracts described above:

\[
V \equiv \max_{\Omega, I} E[U(c)] \\
\text{subject to :} \\
c = f(\Omega) - \bar{p}1\{I = 1\} + z1\{I = 1\}1\{r_c \leq \bar{r}\} \\
g(\Omega) \leq B
\]

(11)

Assuming that the credit constraint does not bind, we first solve for \( \Omega \). The first order condition of the maximization problem for \( \Omega \) gives the optimal \( \Omega' \) satisfying

\[
f(\Omega') = \frac{1}{2\varphi} + (f(\bar{\Omega}) \bar{r}, p + \beta)1\{I = 1\} \\
2(p + \pi) + 1
\]

(12)

Equation (12) indicates that, first, the optimal level of technology choice with insurance purchase is higher than that without insurance purchase; second, as the total risk \(2(p + \pi)\) increases, optimal level of technology decreases.

Now set constant term \( f(\bar{\Omega}) \) equal to low level technology which is \( f(\Omega') \) conditional on without insurance purchase,

\[
f(\bar{\Omega}) = f(\Omega'|I = 0) = \frac{1}{2\varphi} \\
2(p + \pi) + 1
\]
This specification is to prevent \( f(\Omega) \) from being so high that the insurance indemnity introduce more risk to income rather than reduce risk.

Because the decision to purchase insurance is discrete, the farmer compares optimized utility when insurance is purchased \((I=1)\), with utility when insurance is not purchased. Formally, insurance is purchased if

\[
\Delta V = V_1 - V_0, \tag{13}
\]

where \( V_1 \) is the value function with \( I=1 \) (i.e., \( V_1 = V(f(\Omega) = f(\Omega^* | I = 1), I = 1) \)) and \( V_0 \) is the value function with \( I=0 \) (i.e., \( V_0 = V(f(\Omega) = f(\Omega^* | I = 0), I = 0) \)). Let \( \bar{V} \) be expected utility when insurance is purchased, but input choice does not adjust:

\[
\bar{V} = V(f(\Omega) = f(\Omega^* | I = 0), I = 1)
\]

Note that \( V~ \) can be seen as the value function in the case when the borrowing constraint just equals \( g(\Omega^*(I = 0)) \) such that the credit constraint just binds at the non insurance equilibrium.

Adding and subtracting \( \bar{V} \) to expression (13),

\[
\Delta V = [V_1 - \bar{V}] - [V_0 - \bar{V}] = \Delta V_1 - \Delta V_0,
\]

allows us to decompose the factors that influence the demand for insurance into two components, the first related to the pure insurance value, and the second related to limited liability effect that reduces risk rationing.
The farmer would choose to buy insurance if \( \Delta V \), the sum of \( \Delta V_i \) and \( \Delta V_o \), is greater than zero. We can show that \( \Delta V_i \) is always positive, since

\[
\Delta V_i = \frac{\varphi(f(\Omega, \bar{r}, p + \beta)^2}{2(p + \pi) + 1}
\]

meaning that with purchase of insurance farmer will always choose high level technology. The sign of \( \Delta V_o \) is not as straightforward as \( \Delta V_i \). But we can derive that at the lower bound of \( p \), \( \Delta V_o \) is less than zero,

\[
\Delta V_o \bigg|_{p=0} = -\frac{2\pi}{2\pi + 1} \beta - \varphi \beta^2 < 0
\]

while at the upper bound of \( p \), \( \Delta V_o \) is greater than zero conditional on \( \beta \) less than a certain level determined by \( \pi \),

\[
\Delta V_o \bigg|_{h=2} = \frac{\bar{r}_c - \frac{1}{4} \bar{r}_c^2}{4 \varphi(2 + 2\pi)^2} - \frac{1 + 2\pi}{2 + 2\pi} \beta - \varphi \beta^2 > 0
\]

when \( \beta < \sqrt{\frac{\bar{r}_c - \frac{1}{4} \bar{r}_c^2 + (1 + 2\pi)^2 - (1 + 2\pi)}{2\varphi(2 + 2\pi)}} \)

Since \( \Delta V_o \) is a continuous function of \( p \), there exists a solution \( p^* \), such that at \( p = p^* \Delta V_o \) is equal to zero, meaning farmer is indifference between buying and not buying insurance when he adopts low level technology and is exposed to total risk of \( 2(p^* + \pi) \). Farmers who has total risk greater than \( 2(p^* + \pi) \) tend to buy insurance and those whose total risk are less than \( 2(p^* + \pi) \) tend to not buy.
Because $\Delta V_i$ is strictly positive, if there exist a $p^{**}$ such that at $p = p^{**}$ $\Delta V$ is equal to zero, $p^{**}$ must be smaller than $p^*$. This indicates that farmers with total risk in the interval of $2(p^{**} + \pi)$ and $2(p^* + \pi)$ will switch from the choice of not buying insurance when the bundle of insurance and high technology is not available, to the choice of buying insurance when the bundle is available.

Section 3    Numerical Analysis of Insurance Demand

To get a better understanding of how this model works, we undertake some numerical simulations (parameters for the simulation are in the appendix below).

The diagram below explores the demand for insurance over the space defined by the parameter $\pi$ that determines the magnitude of idiosyncratic risk and the parameter $p$ that determines the magnitude of covariant risk. For the case of an exponential CARA utility function, the solid blue line maps the locus of points for which a farmer $\Delta V_0 = 0$, i.e. risk structures that make the farmer indifferent towards buying insurance when there is only the pure value of the insurance and no elastic credit supply effect to allow expansion in the farmer’s economic possibilities. Below that locus there would be demand for insurance $\Delta V_0 > 0$, and above it there would be no demand.

The solid red line displays the locus of parameter values where $\Delta V = 0$.

Above that line, there is no demand for insurance, below there is demand. The area in between the red and blue curves shows the additional demand for insurance that is crowded in when insurance either the credit constraint does not bind or
insurance is coupled with a credit expansion effect. It should be note that this crowding in effect not only increases the fraction of the space where there is positive credit demand, it also increases the value of insurance to those who would have purchased it for its pure insurance value.

![Demand for insurance](image)

**Section 4  Conclusion**

While preliminary, the analysis here takes some first steps to showing how efforts to interlink credit and insurance are likely to meet with greater and stronger demand. As we build on this work, we need also to consider how index insurance can influence the lending decisions of agricultural lenders.
References


