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# Where and how index insurance can boost the adoption of improved agricultural technologies

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ABSTRACT

Remote sensing and other advances have led to an outpouring of programs that offer index insurance to small scale farmers with the expectation that this insurance will enable adoption of improved technologies and boost living standards. Despite these expectations, the evidence to date on the uptake and impacts of insurance is mixed. This paper steps back and considers theoretically where index insurance might be most effective, and whether it should be offered as a standalone contract, or explicitly interlinked with credit contracts. Emerging from this analysis is a set of nuanced recommendations based on the structure of risk and the property rights (collateral) environment.



## 1. Introduction

Decades of research have identified risk as a primary impediment to the adoption of improved agricultural technologies that can, on average, substantially boost the incomes of poor, small-farm households (for a survey of early work, see Feder et al., 1985).[1] Risk directly discourages technology adoption by making farmers unwilling to invest their own savings, which they otherwise need to buffer consumption against potential income shortfalls. Risk may also discourage low wealth households from investing funds borrowed from others, when available, for fear of the default consequences, a phenomenon that Boucher et al. (2008) dub risk rationing. Indirectly, risk that is correlated across farmers, such as weather risk, poses a portfolio problem for microfinance and other potential lenders, raising further the cost of credit to the small farm sector, further discouraging technology adoption.

While insurance mechanisms would seem to be a natural response to this problem of risk-inhibited technology adoption, an earlier generation of efforts to employ individual indemnity-based agricultural insurance collapsed under the weight of asymmetric information and transaction costs (Barnett et al., 2008; Hazell, 1992).[2] Recent technological innovations in remote sensing, as well as the rediscovery of old ideas like area yield insurance (see Halcrow, 1949), have reignited efforts to use insurance to crowd-in technology adoption, but this time relying on "index insurance" that makes payments based on an easy-to-measure index, which cannot be influenced by the individual, but which is correlated with (but not identical to) individual outcomes.[3] At best, index insurance can only protect individuals against covariant risk, meaning shocks, like droughts, that are correlated across individuals.

With the outpouring of new index insurance schemes (see Carter et al., 2014; International Fund for Agricultural Development World Food Program, 2010; Miranda et al., 2012 for listings of new programs),

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[1] This is no more evident than in the sub-Saharan Africa where irrigation is scarce, risk is high and the use of improved seeds and fertilizers stands at a tiny fraction of the levels in other areas of the developing world (Bank, 2007).

[2] Conventional insurance relies on loss verification to control moral hazard. Unfortunately, for a small, remote farmer, a single loss verification will consume multiple years of premium payments, rendering this kind of insurance economically infeasible. Similarly, individual-specific loss rating is non-economic for small-scale, exposing conventional insurance schemes to adverse selection.

[3] Index insurance indemnifies insured farmers based on an external index such as directly measured average yields in a region or average yields as predicted by rainfall, remotely sensed measures of plant growth such as evapotranspiraiton. Because these area measures are beyond the influence of any individual producer, index insurance is largely immune to the moral hazard and adverse selection problems that sank earlier efforts to use conventional insurance for small-scale agriculture. Carter (2012) discusses technical design issues and options, while Miranda et al. (2012) and Carter et al. (2014) review experience with index insurance to date.

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reliable impact evaluations are beginning to appear. While several show strongly positive impacts of index insurance on small farm investment and technology adoption (e.g., Elabed and Carter, 2014; Karlan et al., 2014; Mobarak and Rosenzweig, 2013) find that index insurance significantly boosts investment in high returning technologies in the 25 to 35% range), the study by Giné and Yang (2009) finds contrary results, with an index insurance contract significantly reducing investment in a new agricultural opportunity.

The goal of this paper is to step back from both the policy excitement and the mixed impact evaluation results and theoretically consider where and how index insurance can be expected to be effective as an instrument to boost small farm technology adoption. To do this, we put forward a model of a risk averse household that is exposed to both idiosyncratic and covariant risk. The household chooses between a low-input, low risk and low yielding technology versus a high input, high risk and high yielding technology. We examine the technology choice of the household in three, perfectly competitive financial environments: one in which credit alone is available; one in which credit and separate standalone index insurance contracts are available; and, one in which an "interlinked" credit and index insurance contract is available.[4] Within each contractual environment, we consider the impact of property rights regimes, ranging from those in which land is not mortgageable and loans are under collateralized, to those in which land is mortgageable and loans fully collateralized.

Finally, because individual household choices generate externalities (via their impact on lender portfolio risk and hence of loan pricing), we assemble a financial market equilibrium model of technology choice. For a typical distribution of initial wealth and risk aversion, we consider the equilibrium impact of index insurance on technology adoption across a variety of agro-ecological environments distinguished by the aggregate level of risk as well as by the degree to which that risk is covariant or idiosyncratic.

Table 1 reports the main dimensions of the analysis, as well as summarizing the key implications of our model under our "base case" assumption of an agro-ecology that that is relatively favorable for index insurance. This base case scenario assumes that agricultural production risk is high, and that a large fraction of that risk is covariant risk that can be effectively covered by an index insurance contract. As can be seen in Table 1, absent insurance, uptake of the new profitable technology is modest, especially when loans are fully collateralized such that the farmer bears the risk of default. Standalone insurance roughly doubles technology uptake in the case of fully collateralized loans, but has no impact when lenders bear default risk when loans are under-collateralized. Indeed, requiring standalone insurance for the under-collateralized case would likely reduce uptake of loans and the improved technology. However, when index insurance is explicitly interlinked in the low collateral case, it pushes technology uptake to almost 100% as competitive lenders lower the cost of capital to farmers. While these are striking results, we show that they are not general and where and how index insurance works very much depends on the underlying severity and structure of risk.

The remainder of this paper is organized as follows. Section 2 puts forward the basic farm household technology choice model and introduces index insurance contracts. Section 3 considers credit supply by a perfectly competitive banking sector under alternative property rights and collateral regimes. Section 4 then considers the impact of insurance on technology adoption under these different regimes. While Sections 2–4 operate under base case assumptions that are favorable to the effective functioning of index insurance, Section 5 then examines the impact of index insurance on technology uptake in different agro-ecological environments characterized by different intensities of risk and variation in the extent to which risk is covariant. Drawing all our results together, Section 6 concludes with recommendations on where and how to introduce index insurance as a tool to accelerate the adoption of improved agricultural technologies.

**Table 1**
Percentage of farmers adopting improved technology under different scenarios.

| Property rights regime | No insurance | Standalone insurance | Interlinked insurance |
|---|---|---|---|
| Under-collateralized | 20–40% | No impact | 70–100% |
| Fully collateralized | 0–20% | 20–40% | 20–40% |

Assumes a high risk environment where the coefficient of variation of production exceeds 35% and at least 40% of total risk is insurable, covariant risk.

## 2. Risk and insurance options for the small farm household

This section models the technology choices and the financial contracts potentially available to households in a stylized small farm sector. Central to our model is the assumption that farm households face two sources of risk: an idiosyncratic risk, and a correlated or covariant risk that simultaneously affects all farms in the sector. Later section use these elements to explore the impact of index insurance and interlinked credit and insurance on technology uptake.

### 2.1. Risk and self-insurance through technology choice

Small farm households are assumed to have access to two technologies, a traditional technology with low, but stable returns, and a higher yielding, but riskier technology. The latter requires substantial use of purchased inputs. Both technologies are subject to idiosyncratic ($\theta_s$) and covariant shocks ($\theta_c$). We assume a multiplicative risk structure and write the output of low-yielding technology as:

$$y_T = \theta g_T \tag{1}$$

where $\theta = (\theta_c + \theta_s)$ with support $[0, \overline{\theta}]$, probability distribution function denoted $f^N(\theta)$, cumulative distribution function denoted $F^N(\theta)$ and $E(\theta) = 1$. The superscript $N$ denotes the absence of insurance. We assume that this traditional technology does not require any purchased inputs so that the returns to household-owned factors from the low yielding technology is $\rho_T = y_T$.

The output of the improved, high-yielding technology is:

$$y_H = \theta g_H(K), \tag{2}$$

where $K$ is the amount of purchased inputs required. We assume that these inputs are financed by borrowing from a rural credit market that offers loans of size $K$ at contractual interest rate $r$ and a collateral requirement $\chi$.[5] Net returns to the household under this loan contract are as follows:

$$\rho_H = \begin{cases} y_H - (1+r)K = \theta g_H(K) - (1+r)K, \text{ if } \theta > \tilde{\theta} \\ -\chi, \text{ otherwise} \end{cases} \tag{3}$$

where $\tilde{\theta} = \frac{(1+r)K - \chi}{g_H(K)}$ is the level of the shock such that the value of the collateral plus the output produced just equals the value required for full loan repayment. This specification follows (Stiglitz and Weiss, 1981) and assumes that the household retains no income (or pledged collateral assets) until the loan is fully repaid. To make the technology choice problem meaningful, we assume that the higher-yielding technology offers higher expected returns to the farm household: $E[\rho_H] > E[\rho_T]$.

At the end of the production period, consumable household wealth $c_j$ is equal to $\rho_j + W + B, j = T, H$. Consumable household wealth is the sum of rurns to production ($\rho_j$) plus the household's inherited wealth ($W$) and its risk-free income from non-farm activities ($B$). The lowest consumable

[4] As detailed below, an interlinked contract is one in which the lender has first claim on any insurance payments up to the level of outstanding loan liability.

[5] Self-finance exposes the farmer to unlimited liability and is equivalent to a fully collateralized loan contract if the savings rate is equal to the loan rate.