The Impact of Interlinked Insurance and Credit Contracts on Financial Market Deepening and Small Farm Productivity

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Summary

- Twin puzzles
  - Ample evidence that uninsured risk depresses small holder productivity and the development of rural financial markets
  - Yet, to date it has proven hard to sustain formal agricultural insurance despite apparent need (Gine/Yang; Sarris et al.)
- Explore prospects for resolving these twin puzzles with formal theory of the behavior of smallholder household and a competitive sector of rural lenders
- Demonstrate that
  - Neither credit nor insurance markets likely to fully develop in isolation
  - However, "interlinking" these markets and contracts is more likely to succeed
  - How interlinkage works depends on collateral environment
  - Insurance subsidies may be smart
  - Account theoretically for some surprising empirical results

Outline

- Small farm household model
  - Technology choices & self-insurance
  - Credit contracts & collateral environments
  - Index insurance as 'mean preserving squeeze'
- Competitive lender model
  - Iso-expected profit contract locus (partial equilibrium)
  - Interlinkage pivots contract locus
  - Portfolio composition & supply price of risky ag credit
- Partial Equilibrium Analysis of Technology Choice (exogenous cost of capital to agriculture)
  - No insurance baseline
  - Independent & interlinked index insurance
- Numerical Simulation of Equilibrium Credit Market
  - Agents differentiated by wealth & risk aversion
  - Credit market equilibrium concept
  - Technology choice with & without index insurance
  - Are insurance subsidies 'smart'?

Household Model

Technology & self-insurance

- 'Safe,' low yielding technology:

$$y_\ell = \theta g_\ell ; \rho_\ell = y_\ell$$

  where $\theta = (\theta_c + \theta_s)$ with support $[0, \bar{\bar{\theta}}]$, pdf $f(\theta)$, cdf $F(\theta)$ and $E(\theta) = 1$.

- Capital-using, high returning technology:

$$y_h = \theta g_h(K),$$

  where K is the amount of purchased inputs and we assume that $g_h > g_\ell$.

Household Model

Technology & self-insurance

- To buy K need loan contract, denoted $\ell < K, r, \chi >$ and returns to household are:

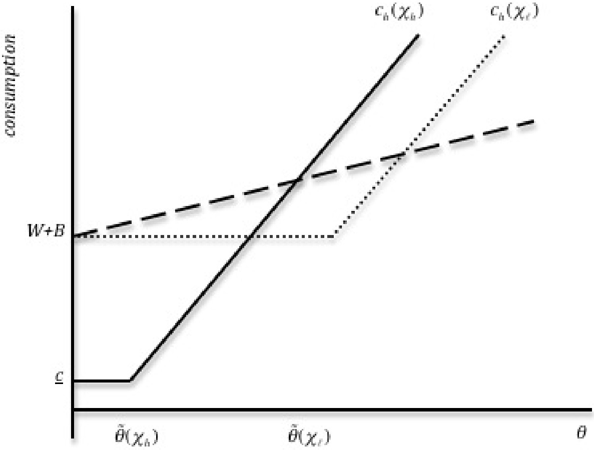
$$\rho_h = \begin{cases} \theta g_h(K) - (1+r)K, \; if \; \theta > \tilde{\theta} \\ -\chi, \; otherwise \end{cases},$$

  where $\tilde{\theta} = \frac{(1+r)K-\chi}{g_h(K)}$ just permits full loan repayment

- Consider case where high technology profitable for all: $E[\rho_h] > E[\rho_\ell] > 0$
- Implies that no one will be price-rationed out of credit market as always have a profitable project
- Consumption: $c_t = B + \rho_t + W, t = h, \ell$, and lowest possible consumption under high technology is $\underline{c} = B + W - \chi$.

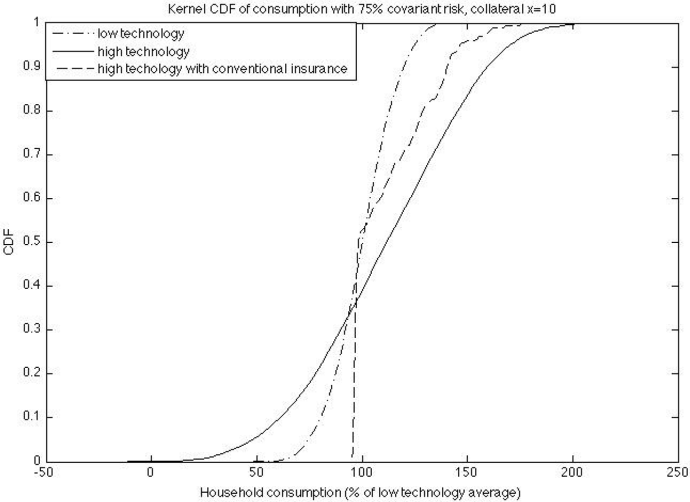
Household Model

Collateral & Returns



Low Technology as Self Insurance

Basis risk & actuarially unfair



Index insurance contract, $I_t < \hat{\theta}_c, z_t, \beta >$, pays off when covariant shock (θ_c) is less than $\hat{\theta}_c$ the strike point; has actuarially fair premium z_t (normalized by g_t); and a markup β. Payoff to insured producers given by:

$$y_t^I = \begin{cases} (\theta_c + \theta_s)g_t + (\hat{\theta}_c - \theta_c)g_t - z_t g_t - \beta = (\hat{\theta}_c + \theta_s - z_t)g_t - \beta, \; if \; \theta \\ (\theta_c + \theta_s)g_t - z_t g_t - \beta, = (\theta_c + \theta_s - z_t)g_t - \beta \; otherwise \end{cases}$$

By defintion of actuarial fairness: $z_t g_t = g_t E[1(\hat{\theta}_c > \theta_c)(\hat{\theta}_c - \theta_c)]$.

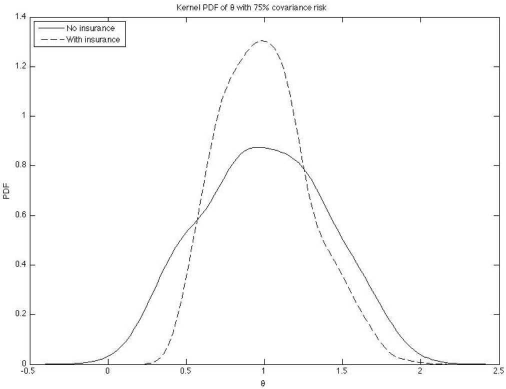
- Under insurance, gross farm income is determined by transformed random variable:

$$\theta^I = \theta + s(\theta) \text{ where } s(\theta) = 1(\hat{\theta}_c > \theta_c)(\hat{\theta}_c - \theta_c) - z_t$$

where $E[\theta^I] = E[\theta] = 1$ and pdf [cdf], f^I $[F^I]$ is a mean preserving squeeze of f:

Mean Preserving Squeeze

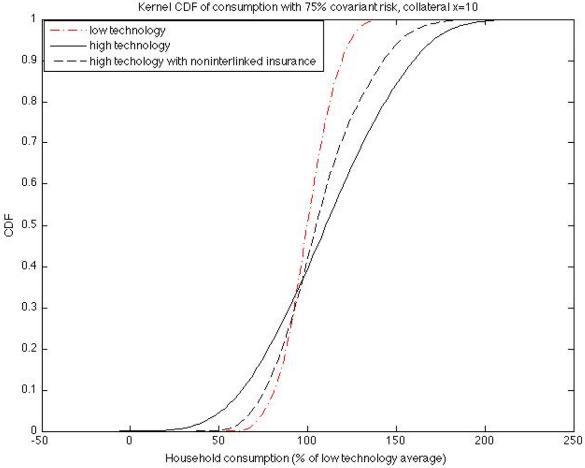
Key integral properties



$$\int_0^{\bar{\bar{\theta}}} [F(\theta) - F^I(\theta)]d\theta = 0; \int_0^y [F(\theta) - F^I(\theta)]d\theta > 0 \, \forall y < \bar{\bar{\theta}}$$

Intuition on Index Insurance

Can it stochastically dominate self-insurance?



Competitive Credit Market Model

- Three interest rates matter in the model:
  - $\bar{\pi}$ is the exogeous (risk-free) opportunity cost of capital
  - $\bar{\pi^a}$ is the portfolio risk adjusted interested rate that a lender must earn on its agricultural loan portfolio
  - r is the nominal interest charged to an individual borrower
- $r(\chi|\bar{\pi}^a) \geq \bar{\pi}^a(n_a) \geq \bar{\pi}$
- Let's look at each of these in turn

Competitive Credit Market Model

Iso-expected profit contract locus

- Under standard loan contract $\ell(K, r, \chi)$, lender profits are:

$$\pi = \begin{cases} rK, \ \textit{if}\ \theta > \tilde{\theta} \\ \chi + \theta g_h(K) - K, \ \textit{otherwise} \end{cases}.$$

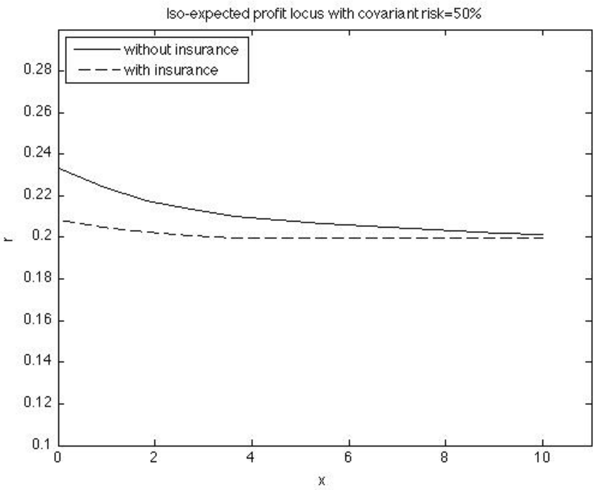
- Under this specification, lender profits are concave in the random variable θ and expected lender earnings are:

$$E(\pi) = [1 - F(\tilde{\theta})]rK + \int_0^{\tilde{\theta}} (\chi + \theta g_h(K) - K) f(\theta) d\theta$$

- Iso-expected profit locus defined by the interest rate-collateral combinations that just yield expected returns equal to $\bar{\pi}^a$.
  - $\frac{\partial r}{\partial \chi} = \frac{-F(\tilde{\theta})}{1-F(\tilde{\theta}))K} < 0$

Competive Credit Market Model

Iso-expected profit locus & interlinkage



- A credit contract is *interlinked* with insurance when the bank has first claim on insurance proceeds and thus treats its returns as driven by the insured probability functions f^I and F^I
- The insured iso-expected profit will lie below uninsured locus for all undercollateralized contracts (see figure again)

Competitive Credit Market Model

Portfolio composition and supply price of risky credit

- Assume lender has funds for n loans of size K that can divided between agricultural loans (n_a) and non-agricultural loans (n_b) that pay $\bar{\pi}$ for certain
- Lender's gross rate of return on the portfolio of n loans will be given by:

$$G = \frac{\sum_{i=1}^{n_A} \pi(\theta_i)/K + n_b\bar{\pi}}{n}.$$

- Because of reserve requirements and political economy risk, lender faces a penalty function, $P(G)$, that reduces net lender portfolio returns when G falls below a critical threshold level $\tilde{\pi}$.
- Net portfolio returns (N) are given by:

$$N = \begin{cases} G \; if \; G > \tilde{\pi} \\ G - P(G) \; otherwise, \; with \; P', P'' \leq 0 \end{cases}$$

Competitive Credit Market Model

Market Supply of Agricultural Credit

- To supply n_a agricultural loans, the lender must fulfill a standard, zero profit participation constraint:

$$E(N) \geq \bar{\pi}$$

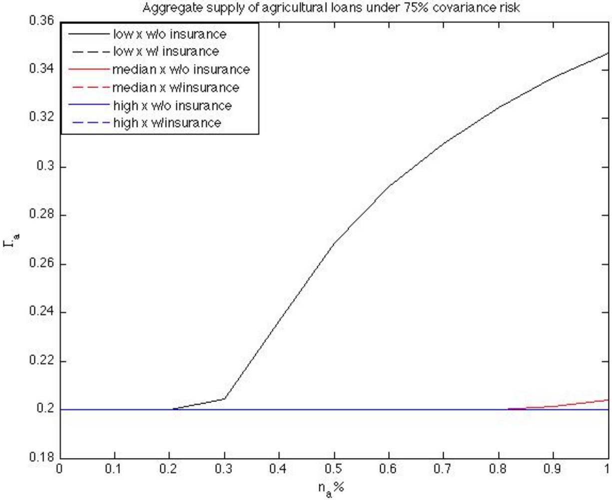
- Letting $\bar{\pi}^a$ denote $E(\pi_i)$, and F_G (f_G) denote the cdf (pdf) of G, this condition can be rewriten as:

$$\bar{\pi} + \frac{n_a}{n}(\bar{\pi}_a - \bar{\pi}) - \int_0^{\tilde{\pi}} P(G) f_G(G) dG \geq \bar{\pi}$$

- This condition implicitly defines the market supply function, $\bar{\pi}^a(n_a)$
- By elminating covariant risk, index insurance (which is a mean preserving squeeze of f_G) flattens this supply relationship

Competitive Lender Model

Portfolio composition and supply price of risky credit



Techology Uptake Absent Formal Insurance

- Expected utility under low technology (self-insurance via income smoothing):

$$V_\ell = \int_0^{\bar{\bar{\theta}}} u(\theta g_\ell + W + B) f(\theta) d\theta$$

- Expected utility under high technology (some implicit insurance if limited liability):

$$V_h = F(\tilde{\theta}) u(\underline{c}) + \int_{\tilde{\theta}}^{\bar{\bar{\theta}}} u(\theta g_h - (1+r)K + W + B) f(\theta) d\theta$$

Technology Uptake Absent Formal Insurance

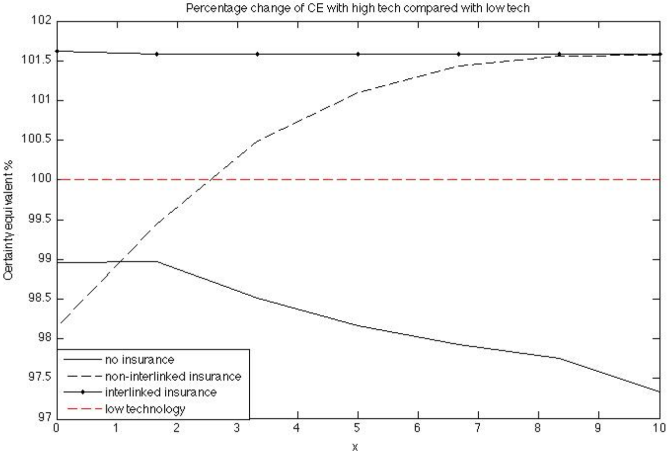
- Farmers' decision on technology:

$$\Delta_{h\ell} = V_h - V_\ell = \left[F(\tilde{\theta})u(\underline{c}) - \int_0^{\tilde{\theta}} u(\theta g_\ell + W + B) f(\theta) d\theta \right] +$$

$$\left[\int_{\tilde{\theta}}^{\bar{\bar{\theta}}} [u(\theta g_h - (1+r)K + W + B) - u(\theta g_\ell + W + B)] f(\theta) d\theta \right]$$

- First term is negative, second term is non-negative
- Under high collateral, $\underline{c}$ is low and risk averse may choose low technology(risk rationing)
- Under low collateral, lending is risky, r is high and risk averse may also choose low technology

Technology Uptake under Alternative Insurance Schemes
Highly risk averse farmers (CRRA=3) & $n_a = N$



Technology Uptake under Index Insurance

- High tech with non-interlinked index insurance

$$V_h^I = U(\underline{c})F^I(\tilde{\theta}) + \int_{\tilde{\theta}}^{\bar{\bar{\theta}}} U[\theta g_h - (1+r)K + W + B] f^I(\theta) d\theta$$

- Decision on technology:

$$\Delta_{h\ell}^I = V_h^I - V_\ell = (V_h^I - V_h) + (V_h - V_\ell) = \Delta_{hh}^I + \Delta_{h\ell}$$

- The change in expected consumption under limited liability loan contract (actuarially fair contract is not 'fair'):

$$E(c_h^I) - E(c_h) = g_h \int_0^{\tilde{\theta}} [F^I(\theta) - F(\theta)] d\theta \leq 0$$

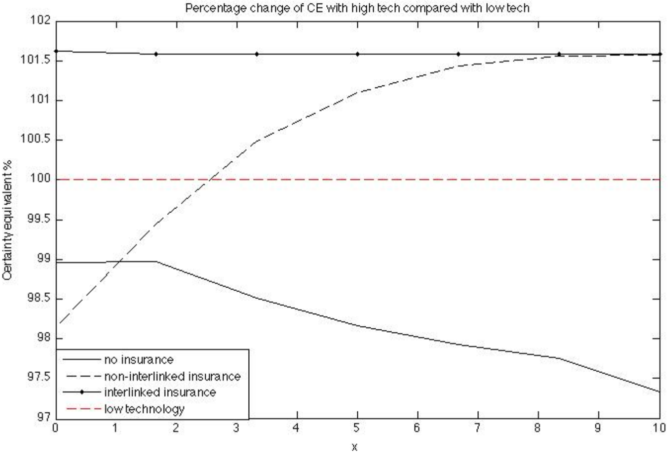
Technology Uptake under Index Insurance

$$\Delta_{hh}^{I} = U'(\underline{c})g_h \int_{0}^{\tilde{\theta}} [F^I(\theta) - F(\theta)]d\theta + \int_{\tilde{\theta}}^{\bar{\bar{\theta}}} [\int_{0}^{\theta} (F^I(y) - F(y))dy]U'' g_h^2 d\theta$$

- The first term ≤ 0 (expected consumption); the second term ≥ 0 (consumption flunctuation)
- for the risk averse,
  - high collateral $\chi = (1 + r)K$, $\tilde{\theta} = 0$: $\Delta_h^{h'} > 0$
  - low collateral $\chi = 0$, $\tilde{\theta} > 0$: Δ_{hh}^{I} is more likely to be negative
  - Δ_{hh}^{I} increases in χ

Technology Uptake under Alternative Insurance Schemes

Highly risk averse farmers (CRRA=3) & $n_a = N$



Technology Uptake under Interlinked Index Insurance

- High tech with interlinked index insurance

$$V_h^{II} = U(\underline{c})F^I(\tilde{\theta}^I) + \int_{\tilde{\theta}^I}^{\bar{\bar{\theta}}} U[\theta g_h - (1 + r^I)K + W + B]f^I(\theta)d\theta$$

with endogenous $r^I = r^I(\chi,\, n_a,\, f^I(\theta))$.

- Decision on technology:

$$\Delta_{h\ell}^{II} = V_h^{II} - V_\ell = \Delta_{hh}^{II} + \Delta_{hh}^{I} + \Delta_{h\ell}$$

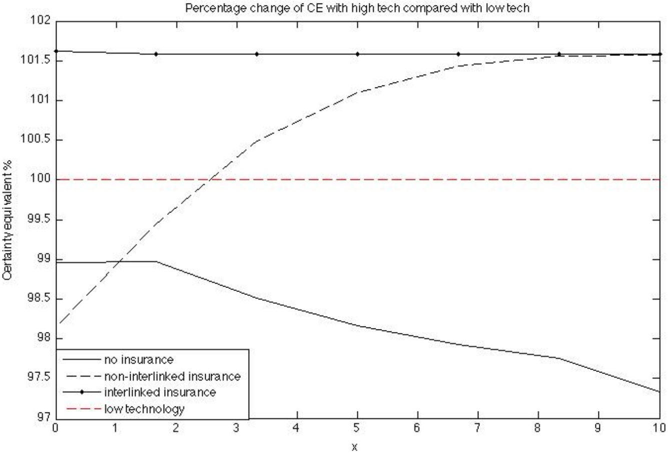
Technology Uptake under Interlinked Index Insurance

$$\Delta^{II}_{hh} = V^{II}_h - V^I_h = \int_{\tilde{\theta}}^{\bar{\bar{\theta}}} (U[\theta g_h - (1+r^I)K + W] - U[\theta g_h - (1+r)K + W + B]) f^I(\theta) d\theta + \int_{\tilde{\theta}^I}^{\tilde{\theta}} (U[\theta g_h - (1+r^I)K + W + B] - U(\underline{c}))\, f^I(\theta) d\theta$$

- $\Delta^{II}_{hh} \geq 0$, decreasing in χ
- High collateral $\chi = (1+r)K$, $r^I = r$, and $\tilde{\theta}^I = \tilde{\theta}$: $\Rightarrow \Delta^{II}_{hh} = 0$
- Low collateral$\chi < (1+r)K$, $r^I < r$, and $\tilde{\theta}^I < \tilde{\theta}$: $\Rightarrow \Delta^{II}_{hh} > 0$

Technology Uptake under Alternative Insurance Schemes

Highly risk averse farmers (CRRA=3) & $n_a = N$



Credit Market Equilibrium for Stylized Economy

- Economy defined as a distribution of agents over risk aversion-wealth space, $h(\psi, W)$ and a collateral rule
- Write the aggregate supply of agricultural loans, n_a^s, as a function of the price r:

$$n_a^s = n_a^s(r \mid \chi, f(\theta), f^I(\theta), P)$$

- Aggregate demand of agricultural loans, n_a^d, is a function of r:

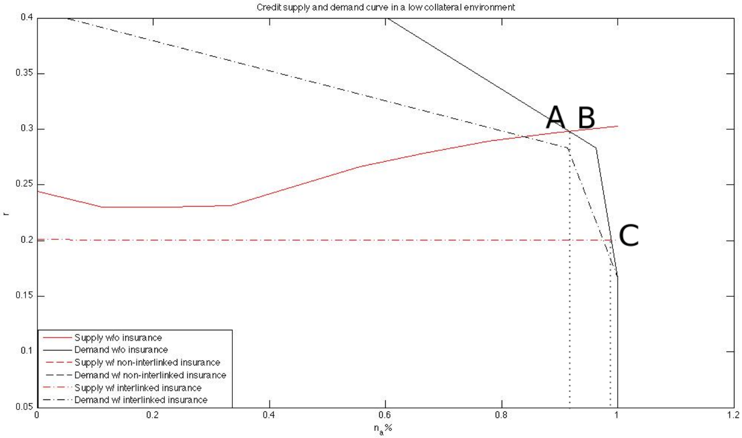
$$n_a^d = n_a^d(r \mid \chi, f(\theta), f^I(\theta), h(\psi, W))$$

- Taking $\bar{\pi}$ and χ as given, market equilibrium defined by the value of r such that:

$$n_a^s = n_a^d = n_a$$

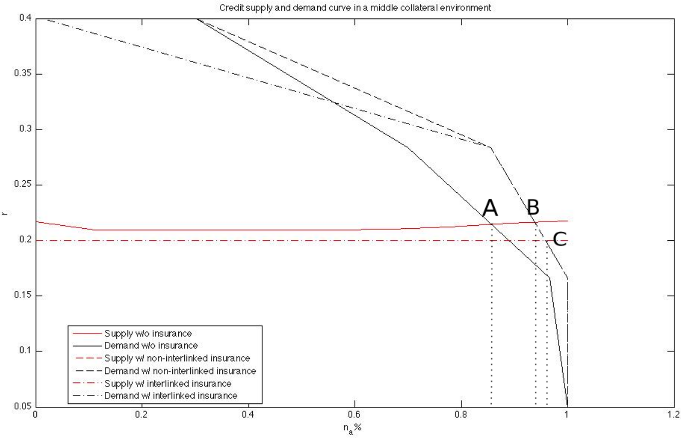
Equilibrium Uptake of High Technology

Low Collateral Case



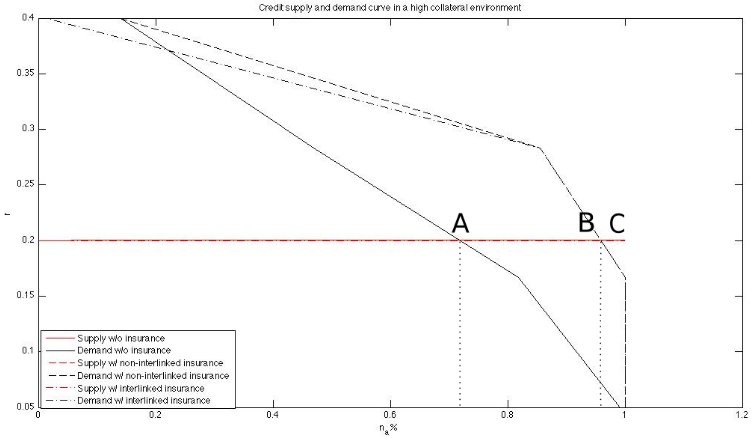
Equilibrium Uptake of High Technology

Intermediate Collateral Case



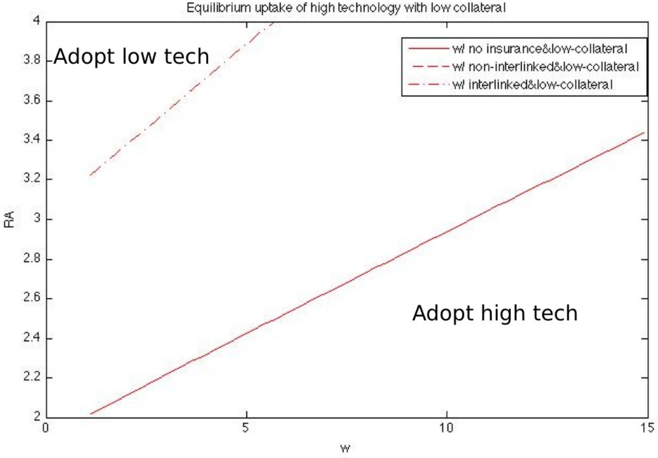
Equilibrium Uptake of High Technology

High Collateral Case



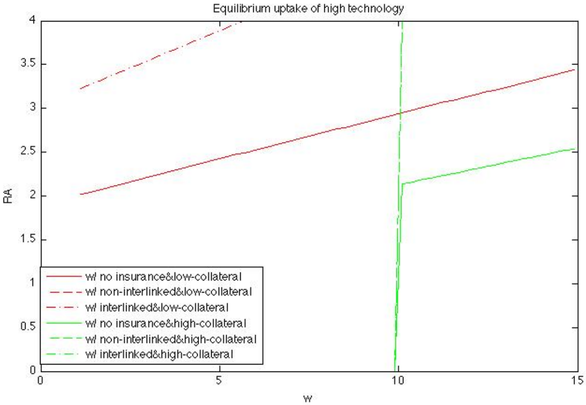
Technolgy Adoption Heterogeneity

Low Collateral Case



Technolgy Adoption Heterogeneity

High Collateral Case



Uptake, Loadings & Smart Subsidies

- High basis risk and loading costs undermine the performance of interlinked contracts.
- Is there a role for 'smart subsidies?
  - Calculate the tax rate that would have to be charged so that incremental tax collections on new production cover load ing costs
  - Under 'reasonable assumptions,' a 16% tax rate will cover a 30% loading cost

Summary of Impact on Technology Uptake

	Low collateral environment	*High collateral environment*
Self-insurance only	Low uptake (credit expensive; induces risk rationing)	Very low uptake (risk rationing)
Insurance as separate contract	No demand for Insurance & Technology Adoption Does Not Improve	Increases uptake by reducing farmers' risks (Demand Effect; Supply Limits)
Interlinked insurance & credit	Increases uptake by lowering interest rates (Supply Effect)	Relaxes supply constraints

Conclusions & Challenges for Program Design

- Linkage with opportunity for improved technology opens the door to stochastically dominate actuarially unfair self-insurance
- Neither the credit market nor the insurance market can fully develop in isolation
- Subtle interplay with collateral requirements and implicit insurance of credit contracts
- Implications for determining insured party
  - retail insurance to farmer versus sell as insurance to lenders
  - key question: how to simulate competitive market and shift of benefits to small farm households? State contigent loan contracts as in Ahmed=McIntosh-Sarris project is one way