Index Insurance: Financial Innovations for Agricultural Risk Management and Development

Sommarat Chantarat
Arndt-Corden Department of Economics
Australian National University

PSEKP Seminar Series, Gadjah Mada University
30 January 2012
Outline of my talk

- Motivations
- Development and implement index insurance program
- Satellite based livestock insurance in Kenya
- Prospects for Indonesia: Interesting research questions
Insurance and Development

- Economic costs of uninsured (weather and natural disaster) risk, especially with threshold-based poverty traps

- Insurance → protect rural livelihoods and escape poverty
  - Provide safety net to prevent collapse of vulnerable populations
  - Encourage investment and asset accumulation by the poor
  - Induce financial deepening by crowding in credit market and social insurance

- Insurance → pre-finance effective emergency response and recovery
  - Timely response enhances resilience to shocks and reduce costs of humanitarian responses/social protection programs
**Insurance and Agricultural Risk Management**

### Two types of formal agricultural insurance

**Conventional crop insurance**
Compensate actual loss, multi-peril or named coverage
- High costs of verifying losses
- Moral hazard and adverse selection
- Existing programs are very costly and largely subsidized

**Index insurance**
Compensate specific loss based on objectively measured index NOT actual loss
- Low costs – no farm-level loss verification
- Low incentive problems – insured cannot influence payout probability
- Challenges in minimizing basis risk

**Motivations**
- High frequency/ Low loss/ Idiosyncratic
  Self and informal insurance effective
- Low frequency/ Extreme loss/ Covariate
  Need to transfer to formal risk market

**L**
Agricultural Livelihood/Income/Asset Loss

**Index Insurance**
- Kenya Experience
- Prospects for Indonesia

No successful crop insurance in the world, not likely work in rural areas

Promise as a market viable instruments, more suitable for rural areas in DCs
Developing Index Insurance Program

1. Identify loss to be insured ($L_{lt}$)
   - Identify uninsured loss by testing simple consumption risk sharing hypothesis (e.g., Townsend 1994), $L_{lt}$ is uninsured if $H_0: c = 0$ is rejected
     \[
     \Delta C_{lt} = a_0 + a_l + a_t + bX_{lt} + cL_{lt} + \varepsilon_{lt}
     \]

2. Select objectively measured index ($\theta_{lt}$)
   - Highly correlated with loss, available reliably in near-real time, non-manipulable by insured parties, high spatial distribution, at least 20 years historical profiles

3. Quantify insurable loss from index ($\hat{L}(\theta_{lt})$)
   - $\theta_{lt}$ needs to explain most of the loss variations:
     \[
     L_{lt} = L(\theta_{lt}) + \varepsilon_{lt} \rightarrow \hat{L}(\theta_{lt})
     \]
   - Use micro data of $L_{lt}$ to minimize basis risk

4. Identify optimal contract structure
   - Payoff based on $\hat{L}(\theta_{lt})$: $\Pi_{lt}(\hat{L}(\theta_{lt})| L^*) = \max(\hat{L}(\theta_{lt}) - L^*, 0) \times \text{sum insured}$
   - Stand-alone contract, group-based contract, interlinked insurance-loan
Developing Index Insurance Program

5. Actuarial pricing
   • Actuarial fair premium: burn rate and/or Monte Carlo simulation based on \( f(\theta_{lt}) \)
   \[
   p_t(\hat{L}(\theta_{lt})|L^*) = E(\Pi_{lt}(\hat{L}(\theta_{lt})|L^*)) = \int \Pi_{lt}(\hat{L}(\theta_{lt})|L^*) df(\theta_{lt})
   \]

6. Ex-ante contract evaluation
   • Simulated welfare and behavior response impacts using dynamic model/data
   • Field experiments to elicit willingness to pay among targeted clients

7. Develop education and extension tools for pilot sale
   • Simplified products, financial educational tools, targeted learning network

8. Identify cost effective delivery mechanisms
   • Delivery through mobile technology, local financial institutions, network groups

9. Long-term micro-level impact assessment
   • Randomized survey and experiments to elicit demand, impacts on welfare, induced behavior responses from control and treatment groups
Satellite vegetation based livestock insurance in Kenya

(1) **Identify loss to be insured:**
Catastrophic livestock losses from drought as key uninsured risk in this area

- Observed household welfare co-move with livestock losses

![Seasonal Livestock Loss (%)](chart1.png)

![Average Household Consumption ($/day)](chart2.png)

Correspondence should be addressed to Sommarat.Chantarat@anu.edu.au
Motivations  Index Insurance  Kenya Experience  Prospects for Indonesia

Satellite vegetation based livestock insurance in Kenya

(2) Selecting index: NASA MODIS Normalized difference vegetation index (NDVI) as index

- Indication of availability of vegetation over rangeland
- Spatiotemporal rich (1×1 km²)
- Available in near-real time every 15 day (1982-present)

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(3) **Quantify insurable loss from index:** construct predicted livestock loss from the empirical model: $M_{lt} = M(ZNDVI_{lt}) + \varepsilon_{lt}$
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\[ M_{lt} = M(ZNDVI_{lt}) + \epsilon_{lt} \]
Satellite vegetation based livestock insurance in Kenya

(3) **Quantify insurable loss from index:** construct predicted livestock loss from the empirical model: $M_{lt} = M(ZNDVI_{lt}) + \varepsilon_{lt}$

**Regime switching model** for zone-specific, seasonal mortality prediction:

$$M_{lt} = \begin{cases} M_1(X(ndvi_{lt})) + \varepsilon_{1lt} & \text{if } Czndvi_{poslt} \geq \gamma \\
M_2(X(ndvi_{lt})) + \varepsilon_{2lt} & \text{if } Czndvi_{poslt} < \gamma \end{cases} \quad \Rightarrow \quad \hat{M}(ZNDVI_{lt})$$
Satellite vegetation based livestock insurance in Kenya

(3) **Quantify insurable loss from index:** construct predicted livestock loss from the empirical model: 
\[ M_{lt} = M(ZNDVI_{lt}) + \varepsilon_{lt} \]

Predictive Performance of predicted livestock loss, \( \hat{M}(ZNDVI_{lt}) \)

- Out-of-sample prediction errors within +/-10% (especially in the bad year)
- Predict historical droughts well
Satellite vegetation based livestock insurance in Kenya

(4) Identify optimal contract structure

- **Insurable loss:** Area average livestock loss indicated by $\hat{M}(ZNDVI_{lt})$
- **Seasonal indemnity payment:**

$$\Pi_{lt}(\hat{M}(\theta_{lt})| M^*, TLU, P_{TLU}) = \max(\hat{M}(ZNDVI_{lt}) - M^*, 0) \times TLU \times P_{TLU}$$

- **Coverage:** Division level, annual contract (covers two seasonal payouts)

(5) Actuarial fair premium:

<table>
<thead>
<tr>
<th>Strike ($M^*$)</th>
<th>10%</th>
<th>30%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fair premium rate</td>
<td>6.8%</td>
<td>3.2%</td>
</tr>
<tr>
<td>$\Pr(\hat{M}(NDVI) &gt; M^*)$</td>
<td>34.5%</td>
<td>19.8%</td>
</tr>
</tbody>
</table>

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(6) **Ex-ante contract evaluation:** simulations of stochastic dynamic model based on observed household dynamic data

**Pastoral production function:**

\[
f(H_{it}, X_{it}) = \begin{cases} f_{L}(H_{it}, X_{it}) + b_{it} & \text{if } H_{it} \leq H^* \\ f_{H}(H_{it}, X_{it}) & \text{if } H_{it} > H^* \end{cases}
\]

**Herd dynamics with stochastic environment:**

\[
H_{it+1} = (1 + g(NDVI_{it}, \varepsilon_{it}) - m(NDVI_{it}, \varepsilon_{it})) H_{it} + i_{it}
\]

**Household budget constraint:**

\[
c_{it} + i_{it} \leq f(H_{it}, X_{it}) + (W_{it} - W_{it+1}) + (\pi - \rho)h_{it}H_{it}
\]

**Household Intertemporal problem:**

\[
V(H_{it}) = \max_{c_{it},i_{it}} u(c_{it}) + \delta_{it}E(V(H_{t+1} | \Gamma_{i}(NDVI_{t}, \varepsilon_{it}, \pi_{t}))
\]

- In most case, insured herd SOSD uninsured herd: insurance reduces prob. of extreme loss
- Contract seems to be effective despite the existence of basis risk!
### Satellite vegetation based livestock insurance in Kenya

#### (6) Ex-ante contract evaluation: Willingness to pay experiments (210 hhs)

<table>
<thead>
<tr>
<th>Contract Coverage Model (Dependent Variable)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Premium rate</td>
<td>-0.146***</td>
<td>-0.140***</td>
<td>-0.143***</td>
<td>-0.135***</td>
<td>-0.453***</td>
<td>-0.452***</td>
<td>-0.454***</td>
</tr>
<tr>
<td>(0.036)</td>
<td>(0.033)</td>
<td>(0.039)</td>
<td>(0.036)</td>
<td>(0.045)</td>
<td>(0.0455)</td>
<td>(0.045)</td>
<td></td>
</tr>
<tr>
<td>Preference</td>
<td>-0.184</td>
<td>-0.177</td>
<td>-0.190</td>
<td>-0.166</td>
<td>-0.085</td>
<td>-0.106</td>
<td>-0.077</td>
</tr>
<tr>
<td>Discount rate</td>
<td>(0.153)</td>
<td>(0.157)</td>
<td>(0.139)</td>
<td>(0.149)</td>
<td>(0.225)</td>
<td>(0.224)</td>
<td>(0.231)</td>
</tr>
<tr>
<td>Risk aversion</td>
<td>-0.085</td>
<td>-0.083</td>
<td>-0.085</td>
<td>-0.085</td>
<td>0.303***</td>
<td>0.308***</td>
<td>0.308**</td>
</tr>
<tr>
<td>(0.123)</td>
<td>(0.112)</td>
<td>(0.120)</td>
<td>(0.120)</td>
<td>(0.120)</td>
<td>(0.159)</td>
<td>(0.159)</td>
<td>(0.159)</td>
</tr>
<tr>
<td>Risk aversion × Have bank account</td>
<td>1.247***</td>
<td>1.249***</td>
<td>1.234***</td>
<td>1.249***</td>
<td>0.0448</td>
<td>0.0442</td>
<td>0.0434</td>
</tr>
<tr>
<td>(0.180)</td>
<td>(0.234)</td>
<td>(0.234)</td>
<td>(0.234)</td>
<td>(0.234)</td>
<td>(0.0328)</td>
<td>(0.0328)</td>
<td>(0.0328)</td>
</tr>
<tr>
<td>Ambiguity aversion</td>
<td>-0.005</td>
<td>-0.037</td>
<td>-0.029</td>
<td>-0.034</td>
<td>-0.0340</td>
<td>-0.001</td>
<td>-0.001</td>
</tr>
<tr>
<td>(0.031)</td>
<td>(0.031)</td>
<td>(0.035)</td>
<td>(0.035)</td>
<td>(0.035)</td>
<td>(0.169)</td>
<td>(0.169)</td>
<td>(0.169)</td>
</tr>
<tr>
<td>Ambiguity aversion × Have bank account</td>
<td>0.0376</td>
<td>0.0375</td>
<td>0.0375</td>
<td>0.0375</td>
<td>0.0309</td>
<td>0.237</td>
<td>0.237</td>
</tr>
<tr>
<td>(0.034)</td>
<td>(0.034)</td>
<td>(0.034)</td>
<td>(0.034)</td>
<td>(0.034)</td>
<td>(0.0383)</td>
<td>(0.0383)</td>
<td>(0.0383)</td>
</tr>
</tbody>
</table>

#### Price Elasticity of Insurance Demand

**Herd size (TLU)**

- **95% CI**
  - **lpoly smooth density: herdtlu**

#### Premium Vs. Chosen Insurance Coverage

#### Demand determinants

- (+) familiarity with fn. product
- (+) with interacting financial experience with risk aversion
- (+) perceived loss profile
- (+) expected loss
- (+) wealth (wealth eff.)
- (-) perceived basis risk
- (+) credit constraint (buffer stock)

### Modest demand exists at 20%+fair

Less elastic among the rich
Satellite vegetation based livestock insurance in Kenya

(7) Develop education and extension tools: using experimental games with real incentives

- Replicate the pastoral livelihood in the community
- Teach how this insurance work and how it will affect herd dynamics
- The game also allows us to study hh’s behavior responses from insurance!

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(8) **Identify cost effective delivery mechanisms** to remote clients using mobile technology

- The contract has been commercialized in northern Kenya since 2010
- Contracts sold to among 10% of populations in the first year
- Local insurance company underwrites the contract with Swiss Re

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(9) Long-term micro-level impact assessment

- 4-year panel household survey, baseline (2009) with annual repeat
- **Challenges:** (i) cannot randomize eligibility for insurance
  (ii) low uptake reduces power of estimating avg. treatment effects
- **Hence quasi-experiment with encouragement design:** use IV approach with multiple instruments (to generate variation in insurance purchase)
- **We randomize 3 instruments:**
  1. Insurance education \((e_{it})\)
  2. Eligibility for cash transfer \((t_{it})\)
  3. Discount coupon at 0-60% \((d_{it})\)

<table>
<thead>
<tr>
<th></th>
<th>Cash transfer</th>
<th>No cash transfer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Educated</td>
<td>4 sites</td>
<td>4 sites</td>
</tr>
<tr>
<td>Not educated</td>
<td>4 sites</td>
<td>4 control sites</td>
</tr>
</tbody>
</table>

- **Survey instruments:** welfare, Induced behavior responses, formal/informal access to credit, social insurance, environmental impacts
- **Empirical estimations** of demand determinants and impacts of insurance:

  **First stage:**  
  \[ D_{it} = \gamma_0 + \gamma_1 e_{it} + \gamma_2 t_{it} + \gamma_3 d_{it} + \varepsilon_{it} \]

  **Second stage:**  
  \[ \Delta Y_{it} = \rho_0 + \rho_1 D_{it} + \rho_2' X_{it} + D_{it} X_{it}' \rho_3 + \delta_i + \varepsilon_{it} \]

Stay tuned!
References


Chantarat, S. et al. (2011) “Willingness to Pay for Index-based Livestock Insurance: Results from a Field Experiment.” Mimeo

IBLI official site: [http://livestockinsurance.wordpress.com](http://livestockinsurance.wordpress.com/)
Prospects for Index Insurance in Indonesia

- **Interesting research questions**
  - The optimal contract design as part of existing risk management system (complementarities with self-, informal-insurance, government programs)
  - Impact assessment on welfare, productive investments, existing risk management mechanisms
  - Designs of financial educational tools
  - Viability of flood index insurance (e.g., using satellite imagery?) as part of overall flood management system