The Performance of Index Based Livestock Insurance (IBLI): Ex Ante Assessment in the Presence of a Poverty Trap

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Seminar at George Washington University
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Motivation: Poverty Traps and Shocks

Strong prior evidence of poverty traps in the arid and semi-arid lands (ASAL) of east Africa

Standard humanitarian response to shocks/destitution: food aid

Pay attention to the risk and dynamics that cause destitution ... else beware a relief trap!
Insurance and Development

- Economic costs of uninsured risk, esp. w/poverty traps
- **Sustainable insurance can:**
  - Prevent downward slide of vulnerable populations
  - Stabilize expectations & crowd-in investment and accumulation by poor populations
  - Induce financial deepening by crowding-in credit supply and demand
- But can insurance be sustainably offered in the ASAL?
- Conventional (individual) insurance unlikely to work, especially in small scale agro-pastoral sector:
  - Transactions costs
  - Moral hazard/adverse selection
Index-based Livestock Insurance (IBLI)

- Compensates area-averaged drought-related livestock losses
  Indemnity paid based on predicted mortality index estimated based on satellite-based vegetation index (NDVI)

- Advantages
  - Low transaction costs
  - Low incentive problems (e.g., moral hazard)
  - Reduce covariate risk exposure

- Disadvantages: Basis risk
  Imperfect match of individual mortality losses and the predicted mortality index

- Given this tradeoff, the impact of index insurance becomes an empirical question ... but no real evidence to date
This Paper’s Contribution

- Simulation analysis of IBLI performance given a poverty trap
  - IBLI as asset insurance
    - Intertemporal impact assessment given underlying asset dynamics
  - Household-level analysis
    - Estimate household-level basis risk factors and risk preferences
  - Explore WTP and aggregate demand for IBLI

Key Findings

- Non-linear IBLI performance conditional on initial herd size
  - IBLI valuation highest among the vulnerable non-poor
  - Herd size impact dominates those of basis risk or risk preferences
- Highly price elastic demand
- Potential for targeted subsidies of IBLI as a productive safety net
The Study Area in Northern Kenya & Data

- Four pastoral locations in Marsabit, where IBLI pilot launches in 2010
- Two panel data sets available:
  1. USAID PARIMA project (~30 hh/location, quarterly 2000-2002)
  2. Household survey and experiment (42hh/location, pseudo quarterly 2007-2008)
Pastoral communities, livestock as main source of livelihood

Vulnerable to covariate livestock loss (e.g., drought in 2000)

<table>
<thead>
<tr>
<th>Variables/Location</th>
<th>Overall</th>
<th></th>
<th>Location-Specific</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>S.D.</td>
<td>Mean</td>
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<tr>
<td>Climate</td>
<td></td>
<td></td>
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<tr>
<td>Annual Rainfall (mm)</td>
<td>290</td>
<td>185</td>
<td>366</td>
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<tr>
<td>Livestock per household, composition and seasonal loss</td>
<td></td>
<td></td>
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<tr>
<td>Livestock in 2008 (TLU)</td>
<td>15</td>
<td>18</td>
<td>2</td>
</tr>
<tr>
<td>Camel (%)</td>
<td>6%</td>
<td>8%</td>
<td>0%</td>
</tr>
<tr>
<td>Cattle (%)</td>
<td>14%</td>
<td>22%</td>
<td>28%</td>
</tr>
<tr>
<td>Small stock (%)</td>
<td>80%</td>
<td>21%</td>
<td>72%</td>
</tr>
<tr>
<td>Migration (%)</td>
<td>71%</td>
<td>38%</td>
<td>6%</td>
</tr>
<tr>
<td>Seasonal livestock loss (%)</td>
<td>9%</td>
<td>15%</td>
<td>3%</td>
</tr>
<tr>
<td>Income per capita</td>
<td></td>
<td></td>
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<tr>
<td>Income/day/capita (KSh)</td>
<td>35</td>
<td>89</td>
<td>8</td>
</tr>
<tr>
<td>Livestock share (%)</td>
<td>59%</td>
<td>40%</td>
<td>18%</td>
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<tr>
<td>Poverty Incidence</td>
<td></td>
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<tr>
<td>Headcount (15/day)</td>
<td>90%</td>
<td></td>
<td>99%</td>
</tr>
<tr>
<td>Headcount (10 TLU)</td>
<td>49%</td>
<td></td>
<td>97%</td>
</tr>
<tr>
<td>Statistics from 2000-2002 data (with catastrophic drought in 2000)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Livestock in 2000 (TLU)</td>
<td>25</td>
<td>28</td>
<td>14</td>
</tr>
<tr>
<td>Seasonal livestock loss (%)</td>
<td>13%</td>
<td>21%</td>
<td>21%</td>
</tr>
</tbody>
</table>
Index-based Livestock Insurance

- Indemnity is made at the end of each season if NDVI-based predicted mortality rate is beyond strike $M^*$

$$
\pi_{lt}(M^*, M_{ndvi_{lt}}) = \text{Max}(\hat{M}(ndvi_{lt}) - M^*, 0)
$$

Table 2: Summary of IBLI Contracts (from Chantarat et al. 2009a)

<table>
<thead>
<tr>
<th>Location</th>
<th>Predicted Mortality Index (M) (%)</th>
<th>Fair Premium Rate (% Herd Value)</th>
<th>Contract Strike</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>S.D.</td>
<td>P(M&gt;10%)</td>
</tr>
<tr>
<td>Dirib Gombo</td>
<td>8%</td>
<td>8%</td>
<td>28%</td>
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<tr>
<td>Logologo</td>
<td>9%</td>
<td>8%</td>
<td>34%</td>
</tr>
<tr>
<td>Kargi</td>
<td>9%</td>
<td>9%</td>
<td>38%</td>
</tr>
<tr>
<td>North Horr</td>
<td>9%</td>
<td>11%</td>
<td>34%</td>
</tr>
</tbody>
</table>
Analytical Framework: Bifurcated Herd Dynamics

(1) Nonlinear herd accumulation with subsistence consumption $H^c$

$$\tilde{H}_{ilt}^{t+1} = \left\{1 + \tilde{b}_{ilt} \left(ndvi_{lt}, \xi, H_{ilt}\right) + \tilde{i}_{ilt} \left(ndvi_{lt}, \xi, H_{ilt}\right) \right. \\
- \left. \max \left\{\tilde{o}_{ilt} \left(ndvi_{lt}, \xi, H_{ilt}\right), \frac{H^c}{H_{ilt}}\right\} - \tilde{M}_{ilt} \left(ndvi_{lt}, \xi, H_{ilt}\right)\right\} \cdot H_{ilt}$$

(2) This leads to bifurcation in herd accumulation with threshold $H^*(H^c)$

$$\tilde{H}_{ilt}^{t+1} = \eta \left(ndvi_{lt}, \xi, H_{ilt}\right) \text{ where } E \eta'_{H_{ilt}} (\cdot) < 0 \text{ if } H_{ilt} < H^*(H^c) \text{ and } E \eta'_{H_{ilt}} (\cdot) > 0 \text{ if } H_{ilt} \geq H^*(H^c).$$

(3) Intertemporal utility defined over livestock wealth with CRRA

(4) Certainty equivalent herd growth wrt. herd dynamics $\{H_{ilt}\}_{t=1,...}$

$$U(\eta_{ilt} H_{ilt}, ..., \eta_{ilt} H_{ilt}) = U(\tilde{H}_{ilt+1}^t (H_{ilt}), \tilde{H}_{ilt+2}^t (H_{ilt}), ..., \tilde{H}_{iT}^t (H_{ilt}))$$
Analytical Framework: IBLI

(5) IBLI makes indemnity payments at the end of each season:

\[ \pi_{lt}\left(M^*, \hat{M}(ndvi_{lt})\right) = \max\left(\hat{M}(ndvi_{lt}) - M^*, 0\right) \]

(6) Premium to be paid at the beginning of the season (loading \( a > 0 \))

\[ \rho_{lt}^{a}\left(M^*, \hat{M}(ndvi_{lt})\right) = (1 + a)E\pi_{lt} = (1 + a)\int\max(\hat{M}(ndvi_{lt}) - M^*, 0)df(ndvi_{lt}) \]

(7) Fully insured herd with IBLI (with \( g \) as non-mortality growth rates)

\[ \tilde{H}_{ilt+1} = \left(1 + \tilde{g}_{ilt}(ndvi_{lt}, \epsilon_{ilt}, H_{ilt} | H^{c}) - \tilde{M}_{ilt}(ndvi_{lt}, \epsilon_{ilt}) + \pi_{lt} - \rho_{lt}^{a}\right) \cdot H_{ilt} \]

(8) Basis risk is estimated from PARIMA data as:

\[ \tilde{M}_{ilt}(ndvi_{lt}, \epsilon_{ilt}) = \mu_{il} + \beta_i\left(\hat{M}_{ilt}(ndvi_{lt}) - \hat{\mu}_i\right) + \epsilon_{ilt} \]

(9) IBLI performance in improving welfare dynamics:

\[ \Delta \eta_{il}^c = \eta_{il}^{cI} - \eta_{il}^{cNI} = \eta(\mu_i, \beta_i, \epsilon_{ilt}, H_{ilt}, R_i) \]
Empirical Estimation and Simulation

(1) Estimate seasonal non-mortality growth function:

\[
\tilde{H}_{ilt+1} = \left\{ 1 + \tilde{b}_{ilt} (\text{ndvi}_{ilt}, \varepsilon_{ilt}, H_{ilt}) + \tilde{i}_{ilt} (\text{ndvi}_{ilt}, \varepsilon_{ilt}, H_{ilt}) \right\} 
- \text{Max} \left\{ \tilde{o}_{ilt} (\text{ndvi}_{ilt}, \varepsilon_{ilt}, H_{ilt}), \frac{H^c}{H_{ilt}} \right\} - \tilde{M}_{ilt} (\text{ndvi}_{ilt}, \varepsilon_{ilt}) \cdot H_{ilt}
\]

- \( H^c = 0.5 \) TLU / household / season
- Pool 4 seasons of PARIMA (00-02), 2 seasons of (07-08) survey data
- Two functions, 1 each conditional on good- or bad- vegetation conditions
Empirical Estimation and Simulation

(1) Estimate seasonal non-mortality growth function:

- If combined with mortality  >>  bifurcated herd dynamics at 15 TLU
Empirical Estimation and Simulation

(2) Estimate household-specific basis risk factors: \(\{\beta_i, \epsilon_{ilt}, \mu_{il}, \beta^e_i, \epsilon_{ilt}\}\)

Individual loss: \(\tilde{M}_{ilt}(ndvi_{lt}, \epsilon_{ilt}) - \mu_{il} = \beta_i (\hat{M}_{ilt}(ndvi_{lt}) - \hat{\mu}_l) + \epsilon_{ilt}\)

Unpredicted loss: \(\epsilon_{ilt} = \beta^e \epsilon_{lt} + e_{ilt}\)

with \(E(\epsilon_{ilt}) = 0, Var(\epsilon_{ilt}) = \sigma_{eilt}^2 I, E(e_{ilt}) = 0, E(e_{ilt}e_{jlt}) = 0\) if \(i \neq j\), \(Var(e_{ilt}) = \sigma_{eilt}^2 I\).

- Random coefficient models with random effect on the slope
- Use 4 seasons panel of PARIMA (2000-02)
- Estimated household beta (mean=0.8, sd=0.5) Vs. unpredicted loss (0,0.12)
(3) Estimate best fit joint distributions of \( \{\beta_i, \epsilon_{ilt}, \mu_{il}, H_{ilt}, \beta_i^e, \epsilon_{ilt}\} \)

- \( \chi^2 \) goodness of fit criterion

(4) Simulate herd dynamics of 500 hhs/area, 54 historical seasons

- Based on the estimated growth functions and parameters
- Use 54 seasons of historical NDVI since 1981, retaining sequencing
Empirical Estimation and Simulation

(5) Simulate household’s CRRA based on wealth specific distributions

<table>
<thead>
<tr>
<th>Gamble Choice</th>
<th>High Payoff</th>
<th>Low Payoff</th>
<th>Expected Payoff</th>
<th>S.D. Payoff</th>
<th>CRRA Interval</th>
<th>Geometric mean CRRA</th>
<th>Risk aversion class</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>0</td>
<td>R&gt;0.99*</td>
<td>1.0</td>
<td>Extreme</td>
</tr>
<tr>
<td>2</td>
<td>130</td>
<td>80</td>
<td>105</td>
<td>25</td>
<td>0.55&lt;R&lt;0.99*</td>
<td>0.7</td>
<td>Severe</td>
</tr>
<tr>
<td>3</td>
<td>160</td>
<td>60</td>
<td>110</td>
<td>50</td>
<td>0.32&lt;R&lt;0.55</td>
<td>0.4</td>
<td>Intermediate</td>
</tr>
<tr>
<td>4</td>
<td>190</td>
<td>40</td>
<td>115</td>
<td>75</td>
<td>0.21&lt;R&lt;0.32</td>
<td>0.3</td>
<td>Moderate</td>
</tr>
<tr>
<td>5</td>
<td>220</td>
<td>20</td>
<td>120</td>
<td>100</td>
<td>0&lt;R&lt;0.21</td>
<td>0.1</td>
<td>Low/Neutral</td>
</tr>
<tr>
<td>6</td>
<td>240</td>
<td>0</td>
<td>120</td>
<td>120</td>
<td>R&lt;0</td>
<td>0.0</td>
<td>Neutral/risk seeking</td>
</tr>
</tbody>
</table>

(6) Consider 5 fair IBLI with strikes of 10%, 15%, 20%, 25%, 30%

(7) Simulate average performance

\[ \Delta \eta_{il}^e = \eta_{il}^e - \eta_{il}^{cNI} = \eta(\mu_i, \beta_i, \epsilon_{it}, H_{it}, R_i) \]

over 54 pseudo sets of 54-season herd dynamics
Effectiveness of IBLI in Managing Asset Risk

Varying patterns of IBLI performance emerge for different herd sizes

- **Minimal IBLI Performance for Very Small Herd**

- **IBLI Stabilizes Pathway toward Growth for Herd Around Critical Threshold**

- **IBLI Reduces Probability of Extreme Herd Loss for Very Large Herd**

- **IBLI Eliminates Probability of Falling into Destitution for Herd Around Critical Threshold**

- **IBLI Impedes Asset Accumulation for Herd Around Critical Threshold**

- Negligible benefits for the poorest (herd<<H*)

- Varying performance for vulnerable herd around H*: Highest gains if IBLI preserves herd dynamics from shock soon after initial purchase

Bifurcated herd

H*=15 TLU
Effectiveness of IBLI in Managing Asset Risk

IBLI performance conditional on contract specifications and household’s basis risk factors

Table 3: Change in Certainty Equivalent Growth Rate, by Household Parameter

<table>
<thead>
<tr>
<th>Beginning Herd</th>
<th>Strike 5</th>
<th>Strike 10</th>
<th>Strike 15</th>
<th>Strike 20</th>
<th>Strike 30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beta 0.5</td>
<td>0%</td>
<td>-8%</td>
<td>18%</td>
<td>9%</td>
<td>2%</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>4%</td>
<td>24%</td>
<td>29%</td>
<td>15%</td>
</tr>
<tr>
<td></td>
<td>1.5</td>
<td>11%</td>
<td>40%</td>
<td>37%</td>
<td>29%</td>
</tr>
<tr>
<td>Beta 0.5</td>
<td>0%</td>
<td>-1%</td>
<td>8%</td>
<td>8%</td>
<td>2%</td>
</tr>
<tr>
<td></td>
<td>1.0</td>
<td>7%</td>
<td>14%</td>
<td>18%</td>
<td>11%</td>
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<td></td>
<td>1.5</td>
<td>9%</td>
<td>23%</td>
<td>21%</td>
<td>17%</td>
</tr>
<tr>
<td>Beta 0.5</td>
<td>0%</td>
<td>-3%</td>
<td>-1%</td>
<td>0%</td>
<td>-1%</td>
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<tr>
<td></td>
<td>1.0</td>
<td>-1%</td>
<td>1%</td>
<td>2%</td>
<td>0%</td>
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<tr>
<td></td>
<td>1.5</td>
<td>0%</td>
<td>5%</td>
<td>3%</td>
<td>3%</td>
</tr>
</tbody>
</table>

- Non-linear impact based on initial herd size relative to the threshold
  - Minimal role for H<15 TLU, greatest performance for H=15-20 TLU
- IBLI performance increases with beta
- 10% contract provides best result, though the most expensive
Effectiveness of IBLI in Managing Asset Risk

IBLI performance, 2000 simulated households

--- Effective demand exists for fair IBLI at 10%, 20% strike levels

--- Minimal change in performance wrt risk preference

--- 10% contract provides best result

--- Variation in performance across households with different characteristics
Willingness to pay for IBLI
By herd size

\[ \text{Premium} = (1 + a) \times \text{Fair} \]

- WTP beyond fair rate is only attained at herd size beyond \( H^* = 15 \) TLU
- Most of the population has no effective demand for IBLI
Larger herd owners are clientele for commercially loaded IBLI

Highly price elastic demand >> significant pricing implications

Very price elastic demand and lower than commercial rates among the vulnerable group (10-30 TLU) >>> premium subsidies desirable???
Optimally targeted subsidized IBLI maximizes poverty reduction outcomes:
Free provision to 10-20 TLU & subsidized at actuarially fair rate for 20-50 TLU

- Lower and stabilize asset poverty about 10% lower than w/o IBLI
- Most cost effective: at $20 per capita cost per 1% reduction in poverty HC
  (in contrast to the $38 per capita for the need-based transfers scheme)

Potential for IBLI as productive safety net
Conclusions

- Initial herd size is the key determinant of IBLI performance in the presence of threshold-based poverty trap
  - Greater effect than basis risk or risk preference
  - IBLI works least well with the poorest
  - IBLI is most valuable for the vulnerable non-poor

- 10% strike contract outperforms others

- Highly price elastic aggregate demand and limited demand at the commercially viable rates
  - Especially significant among the vulnerable group

- Targeted IBLI subsidies may work as a productive safety net
IBLI appears a promising option for addressing risk-based poverty traps

For more information visit www.ilri.org/livestockinsurance

Thank you for your time, interest and comments!