Cornell University

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

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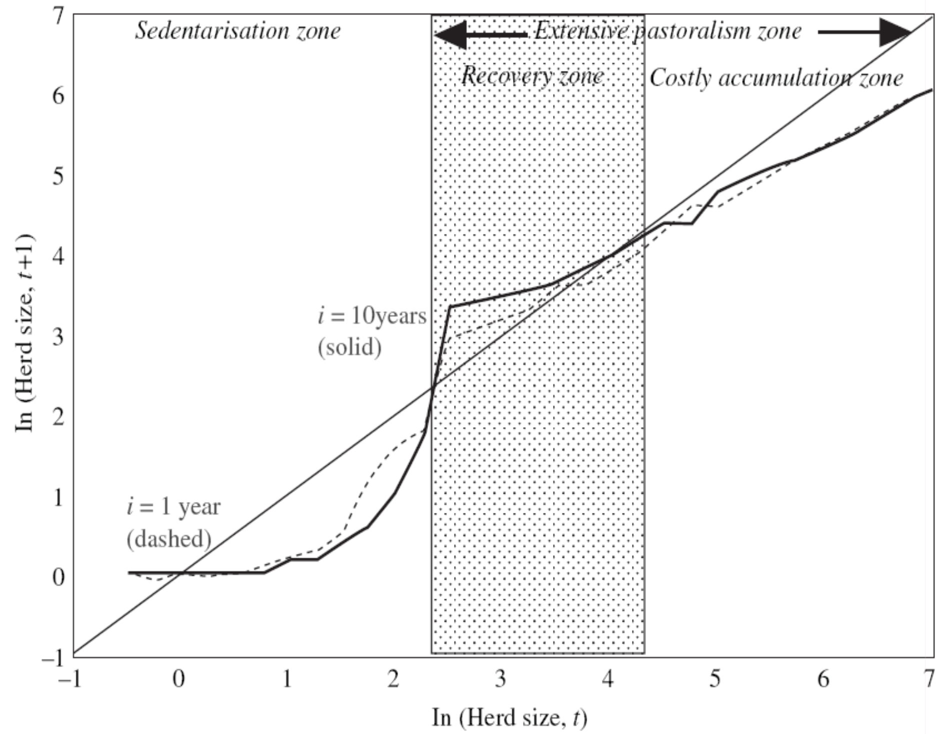
Motivation: Poverty Traps and Shocks

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.

But if transfers go only to the poor who are already in the poverty trap, the numbers of poor will grow. In the long-run, the inexorably poor worse off as the unnecessarily poor join their ranks and compete for



Nadaraya-Watson estimates using Epanechnikov kernel with bandwidth ($h = 1.5$)

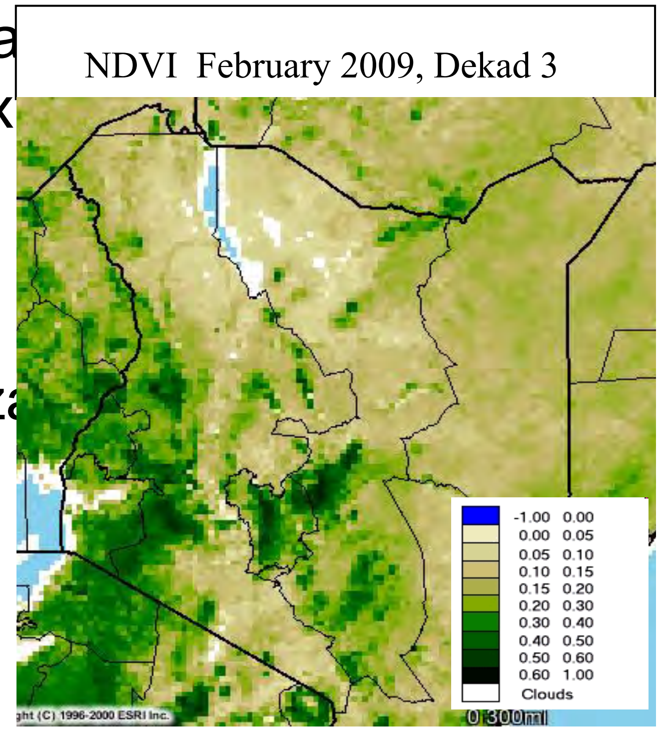
Insurance and Development

- 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 morta based on satellite-based vegetation index



- Advantages
  - Low transaction costs
  - Low incentive problems (e.g., moral haza
  - 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

Key Findings

  - Explore WTP and aggregate demand for IBLI

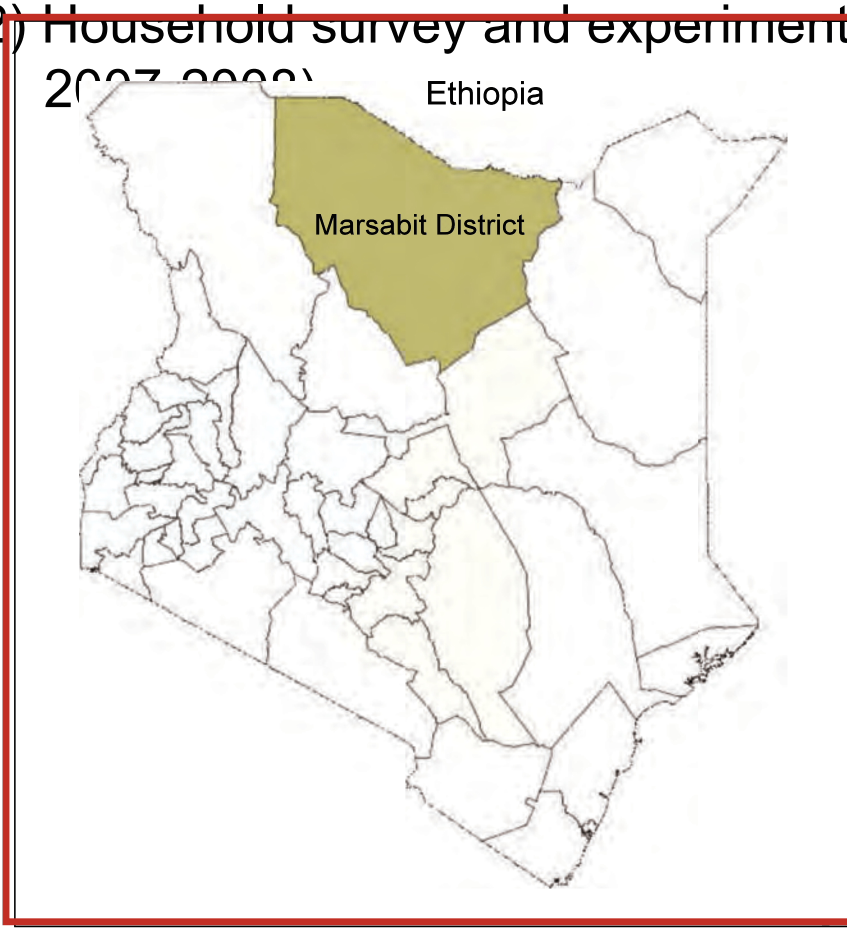
- Non-linear IBLI performance conditional on initial herd size
  - IBLI valuation highest among the vulnerable non-poor
  - Herd size impact dominates those of basis risk or risk preferences
- Highly price elastic demand

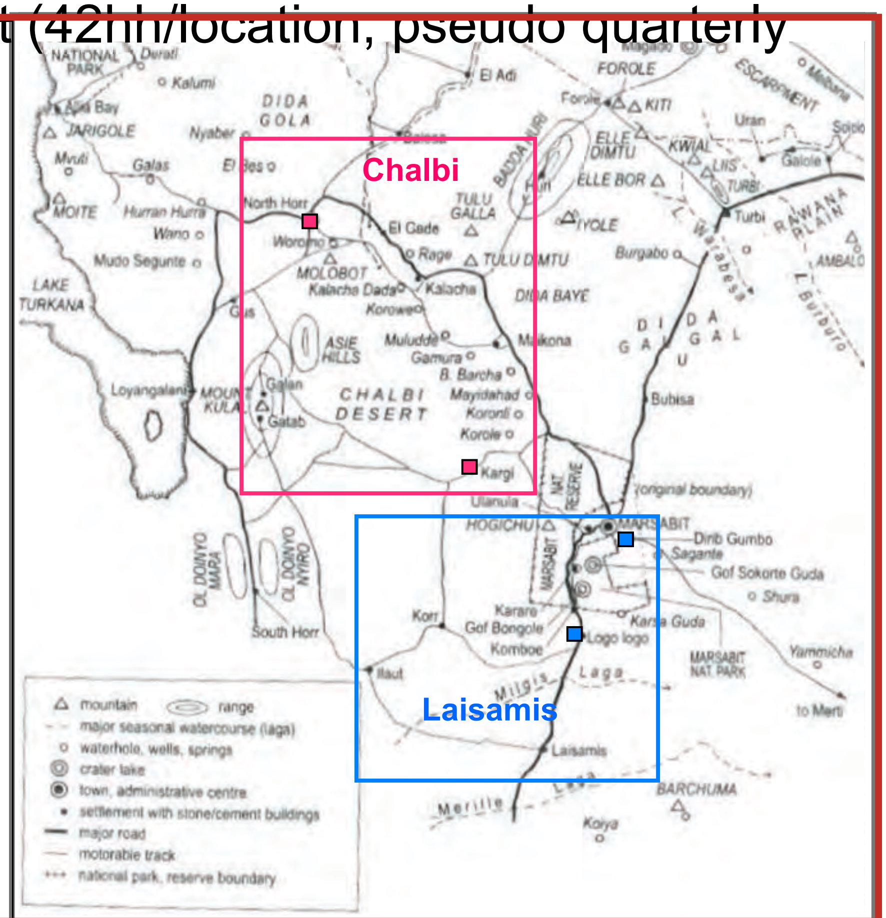
The Study Area in Northern Kenya & Data

- 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)





The Study Area in Northern Kenya & Data

- Pastoral communities, livestock as main source of livelihood
- Vulnerable to covariate livestock loss (e.g., drought in 2000)

Variables/Location	Overall		Location-Specific							
			Dirib Gombo		Logologo		Kargi		North Horr	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Climate										
Annual Rainfall (mm)	290	185	366	173	297	137	270	115	227	86
Livestock per household, composition and seasonal loss										
Livestock in 2008 (TLU)	15	18	2	4	16	22	17	10	25	19
Camel (%)	6%	8%	0%	4%	3%	9%	10%	5%	9%	8%
Cattle (%)	14%	22%	28%	34%	26%	18%	2%	3%	2%	3%
Small stock (%)	80%	21%	72%	34%	71%	19%	88%	6%	89%	9%
Migration (%)	71%	38%	6%	21%	87%	21%	88%	16%	88%	17%
Seasonal livestock loss (%)	9%	15%	3%	8%	15%	22%	5%	6%	11%	15%
Income per capita										
Income/day/capita (KSh)	35	89	8	18	32	31	18	28	78	163
Livestock share (%)	59%	40%	18%	31%	61%	35%	87%	24%	67%	34%
Poverty Incedence										
Headcount (1$/day)	90%		99%		85%		97%		79%	
Headcount (10 TLU)	49%		97%		52%		30%		18%	
Statistics from 2000-2002 data (with catastrophic drought in 2000)										
Livestock in 2000 (TLU)	25	28	14	10	19	16	40	45	26	16
Seasonal livestock loss (%)	13%	21%	21%	29%	15%	19%	11%	12%	7%	10%

Index-based Livestock Insurance

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

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

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

Location	Predicted Mortality Index (M) (%)				Fair Premium Rate (% Herd Value) Contract Strike				
	Mean	S.D.	P(M>10%)	P(M>20%)	10%	15%	20%	25%	30%
Dirib Gombo	8%	8%	28%	9%	2.5%	1.3%	0.6%	0.3%	0.1%
Logologo	9%	8%	34%	15%	3.4%	1.8%	0.7%	0.1%	0.1%
Kargi	9%	9%	38%	11%	3.3%	1.6%	0.9%	0.4%	0.2%
North Horr	9%	11%	34%	21%	4.3%	2.8%	1.5%	0.7%	0.3%

Analytical Framework: Bifurcated Herd Dynamics

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

$$\widetilde{H}_{ilt+1} = \begin{pmatrix} 1 + \widetilde{b}_{ilt}(ndvi_{lt}, \varepsilon_{ilt}, H_{ilt}) + \widetilde{i}_{ilt}(ndvi_{lt}, \varepsilon_{ilt}, H_{ilt}) \\ - Max\left\{ \widetilde{o}_{ilt}(ndvi_{lt}, \varepsilon_{ilt}, H_{ilt}), \dfrac{H^c}{H_{ilt}} \right\} - \widetilde{M}_{ilt}(ndvi_{lt}, \varepsilon_{ilt}) \end{pmatrix} \cdot H_{ilt}$$

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

$$\widetilde{H}_{ilt+1} = \eta\left(ndvi_{lt}, \varepsilon_{ilt}, H_{ilt}\right) \quad \text{where} \quad \begin{aligned} & E\eta'_{H_{ilt}}(\cdot) < 0 \ \text{ if } \ H_{ilt} < H^*(H^c) \\ & E\eta'_{H_{ilt}}(\cdot) > 0 \ \text{ if } \ H_{ilt} \geq H^*(H^c). \end{aligned}$$

(3) Intertemporal utility defined over livestock wealth with CRRA

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

$$U\left(\eta_{il}^I H_{ilt}, \ldots, \eta_{il}^I H_{ilt}\right) = U\left(\widetilde{H}_{ilt+1}^I(H_{ilt}), \widetilde{H}_{ilt+2}^I(H_{ilt}), \ldots, \widetilde{H}_{ilT}^I(H_{ilt})\right)$$

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)

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

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

$$\tilde{H}_{ilt+1}^I = \left(1 + \tilde{g}_{ilt}(ndvi_{lt}, \varepsilon_{ilt}, H_{ilt} \mid H^c) - \tilde{M}_{ilt}(ndvi_{lt}, \varepsilon_{ilt}) + \pi_{lt} - \rho_{lt}^a\right) H_{ilt}$$

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

$$\tilde{M}_{ilt}(ndvi_{lt}, \varepsilon_{ilt}) = \mu_{il} + \beta_i\left(\hat{M}_{lt}(ndvi_{lt}) - \hat{\mu}_l\right) + \varepsilon_{ilt}$$

(9) IBLI performance in improving welfare dynamics:

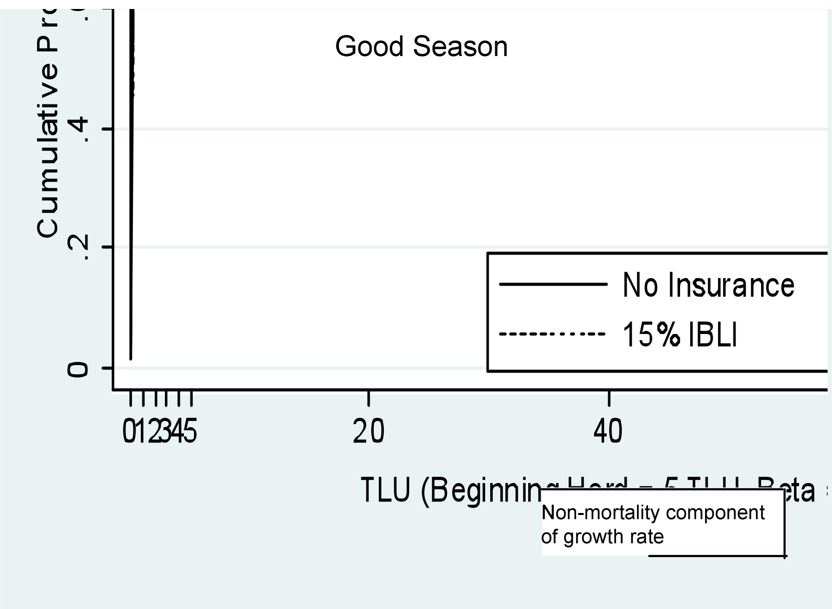
$$\Delta\eta_{il}^c = \eta_{il}^{cI} - \eta_{il}^{cNI} = \eta(\mu_i, \beta_i, \varepsilon_{ilt}, H_{ilt}, R_i)$$

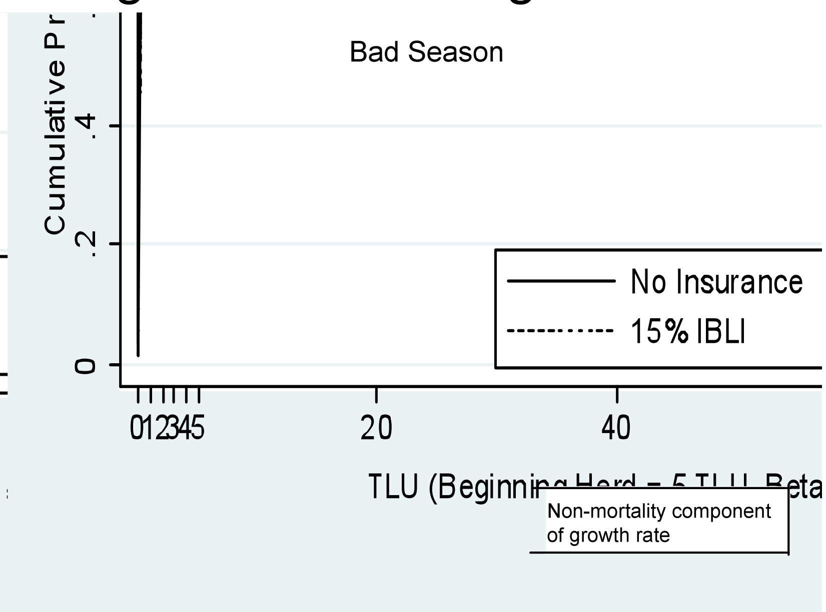
Empirical Estimation and Simulation

(1) Estimate seasonal non-mortality growth function:

$$\tilde{H}_{ilt+1} = \left(\begin{array}{l} 1 + \tilde{b}_{ilt}(ndvi_{lt}, \varepsilon_{ilt}, H_{ilt}) + \tilde{i}_{ilt}(ndvi_{lt}, \varepsilon_{ilt}, H_{ilt}) \\ - Max\left\{ \tilde{o}_{ilt}(ndvi_{lt}, \varepsilon_{ilt}, H_{ilt}), \dfrac{H^c}{H_{ilt}} \right\} - \tilde{M}_{ilt}(ndvi_{lt}, \varepsilon_{ilt}) \end{array} \right) \cdot H_{ilt}$$

- 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

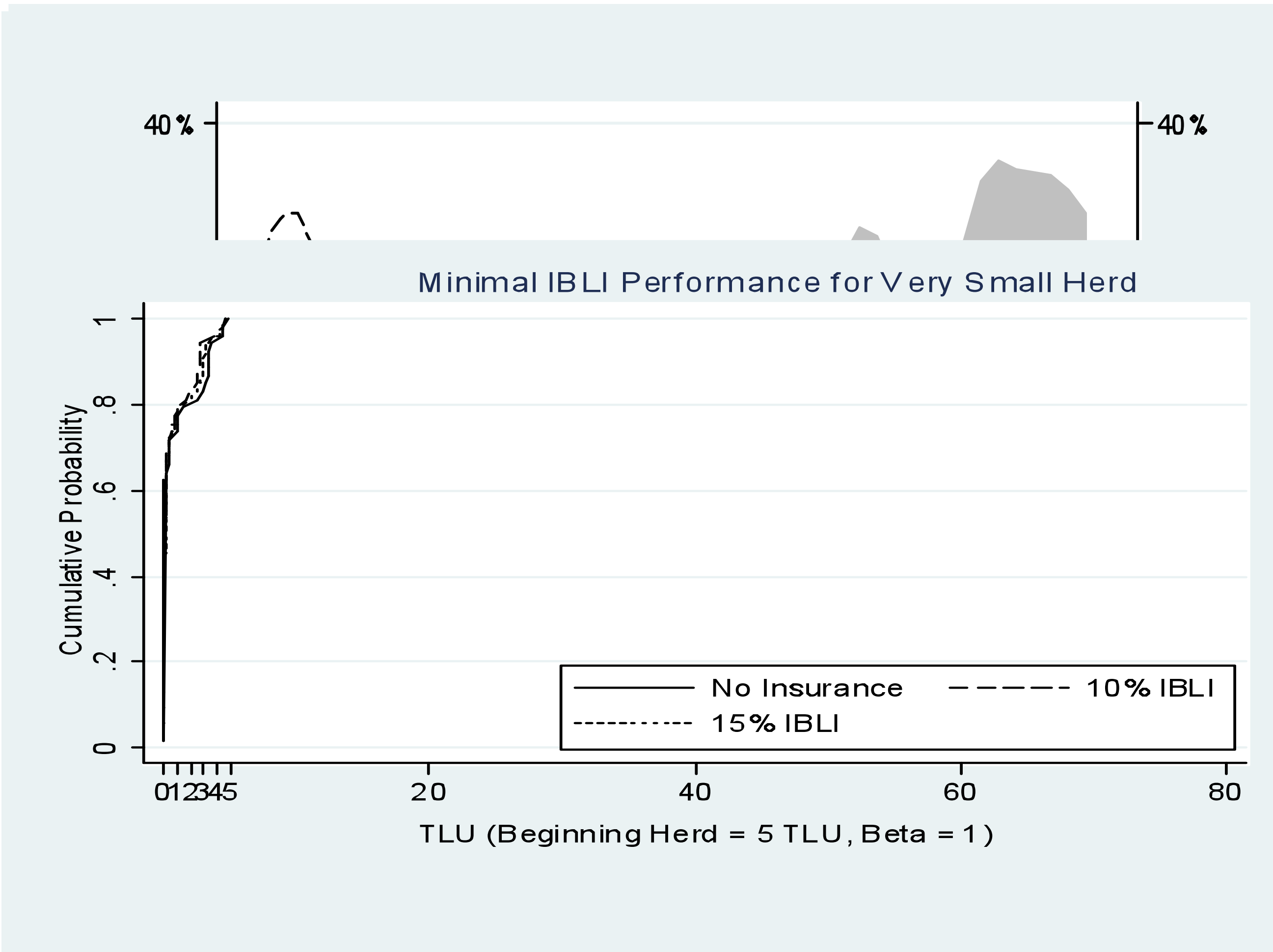




Empirical Estimation and Simulation

(1) Estimate seasonal non-mortality growth function:

- If combined with mortality >> bifurcated herd dynamics at 15 TLU



Empirical Estimation and Simulation

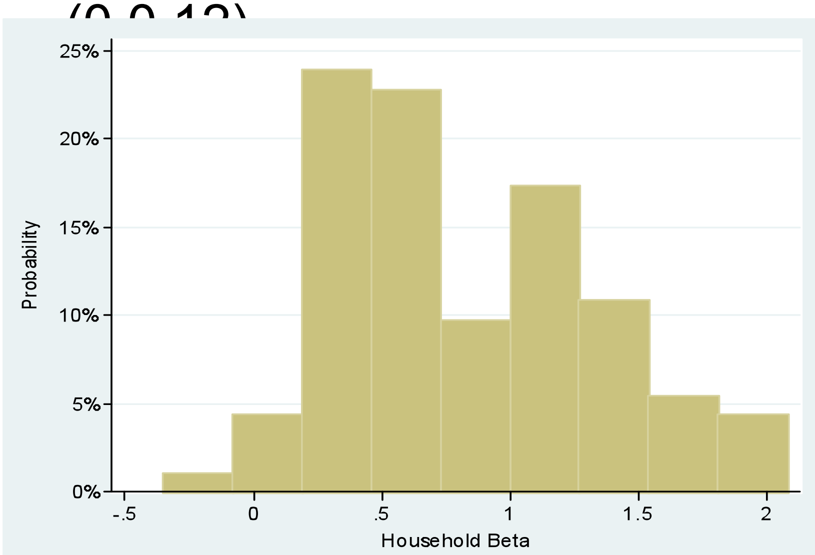
(2) Estimate household-specific basis risk factors: $\{\beta_i, \varepsilon_{ilt}, \mu_{il}, \beta_i^{\varepsilon}, e_{ilt}\}$

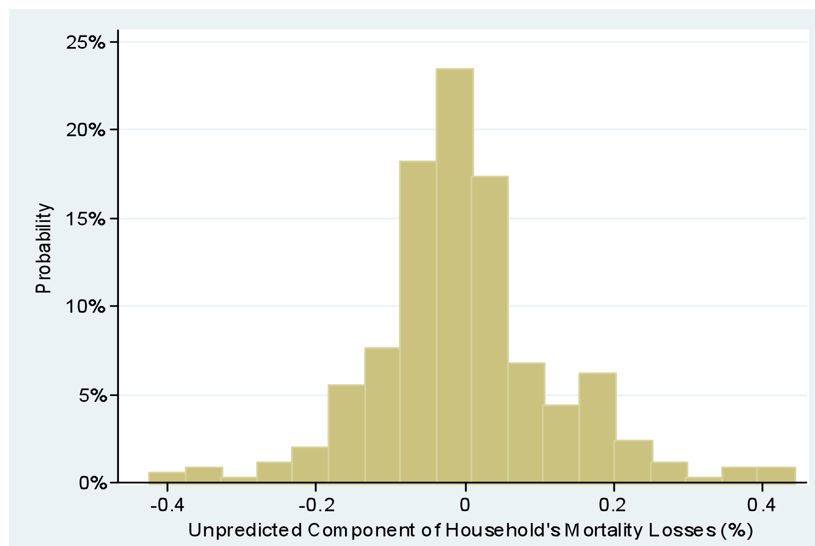
Individual loss: $\tilde{M}_{ilt}(ndvi_{lt}, \varepsilon_{ilt}) - \mu_{il} = \beta_i \left(\hat{M}_{lt}(ndvi_{lt}) - \hat{\mu}_l\right) + \varepsilon_{ilt}$

Unpredicted loss: $\varepsilon_{ilt} = \beta^{\varepsilon} \bar{\varepsilon}_{lt} + e_{ilt}$

with $E(\varepsilon_{ilt}) = 0$, $Var(\varepsilon_{ilt}) = \sigma_{\varepsilon il}^2 I$, $E(e_{ilt}) = 0$, $E(e_{ilt} e_{jlt}) = 0$ $if\ i \neq j$, $Var(e_{ilt}) = \sigma_{eil}^2 I$.

- 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)





Empirical Estimation and Simulation

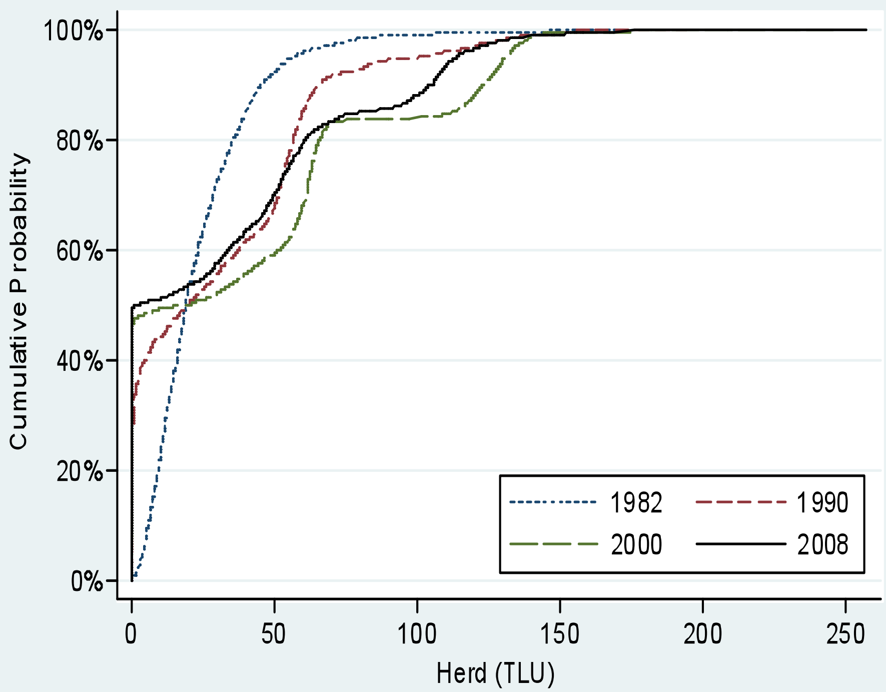
(3) Estimate best fit joint distributions of $\left\{\beta_i, \varepsilon_{ilt}, \mu_{il}, H_{ilt}, \beta_i^{\varepsilon}, e_{ilt}\right\}$

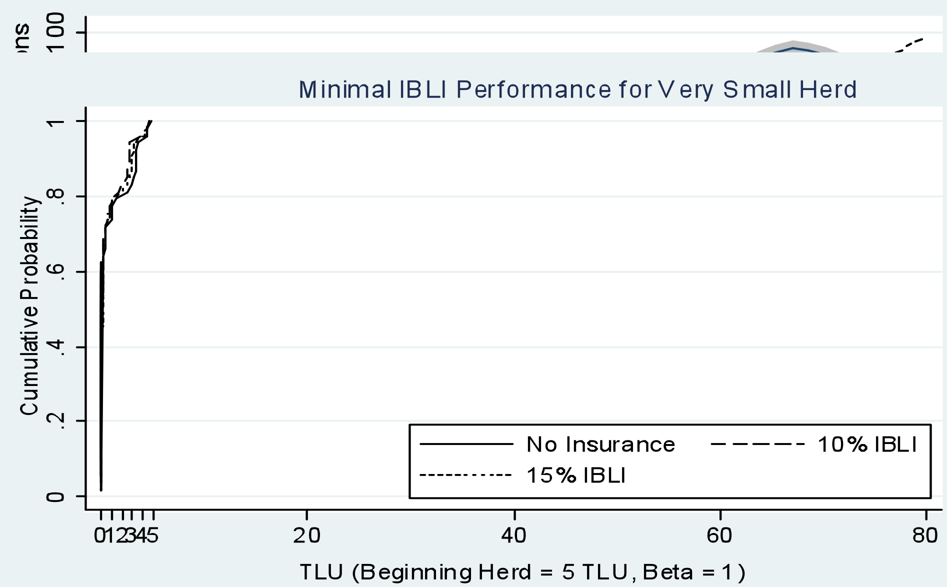
- χ^2 goodness of fit criterion

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

- Based on the estimated growth functions and parameters

Cumulative distribution of simulated herd	Bifurcated herd threshold at 15 TLU





Empirical Estimation and Simulation

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

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

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

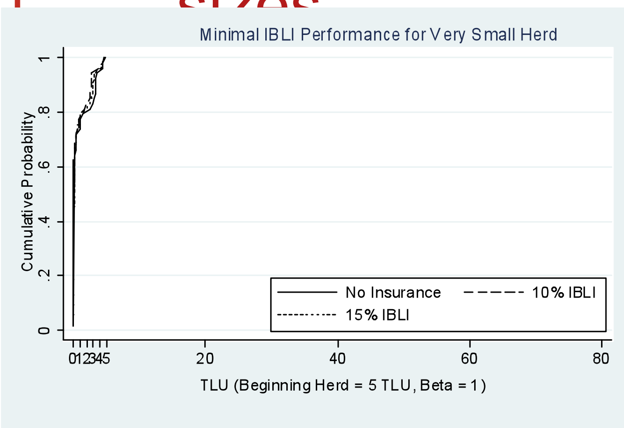
(7) Simulate average performance

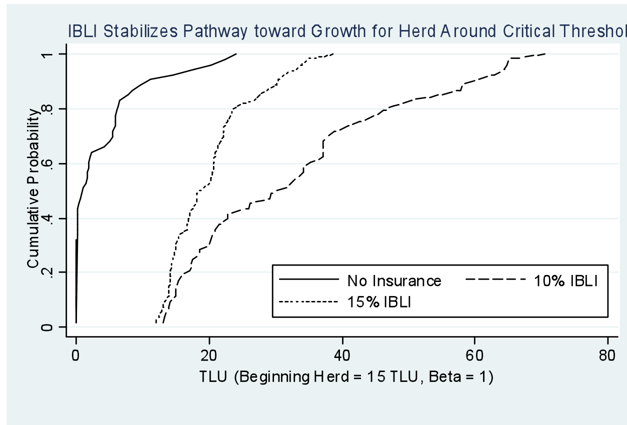
$$\Delta\eta_{il}^{c} = \eta_{il}^{cI} - \eta_{il}^{cNI} = \eta(u_i, \beta_i, \varepsilon_{ilt}, H_{ilt}, R_i)$$

over 54 pseudo sets of 54-season herd dynamics

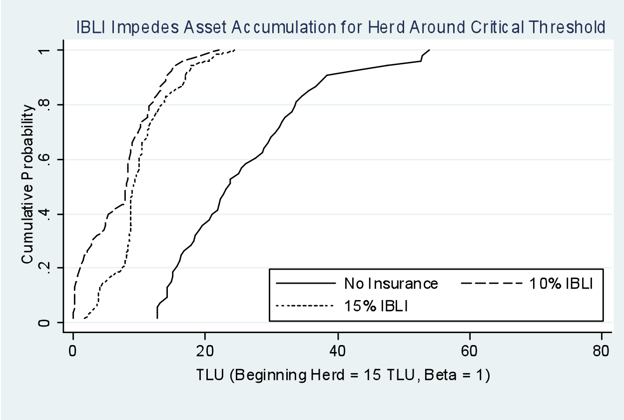
Effectiveness of IBLI in Managing Asset Risk

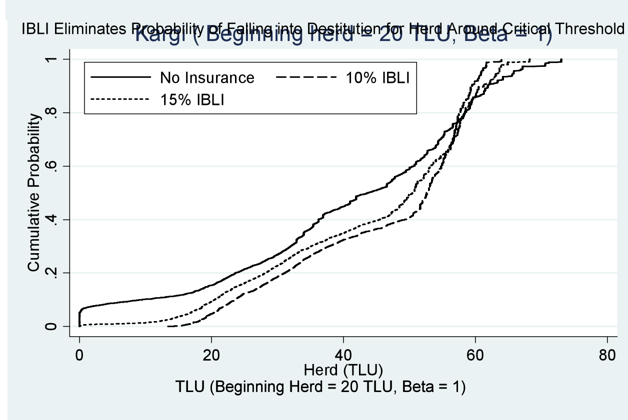
Varying patterns of IBLI performance emerge for different herd sizes

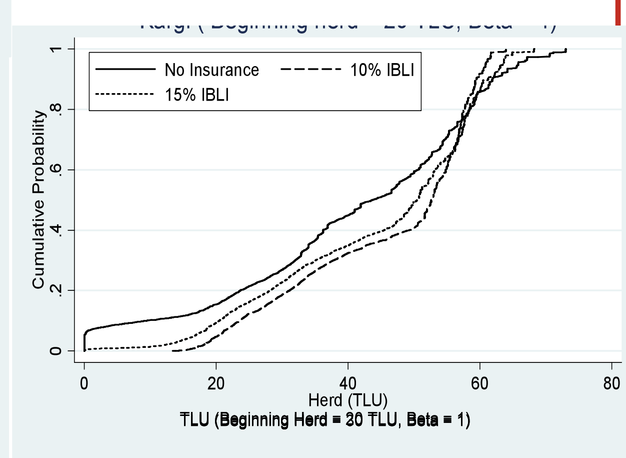




H*=15 TLU







- ➢ 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

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

Strike	10%			20%			30%		
Beta	0.5	1.0	1.5	0.5	1.0	1.5	0.5	1.0	1.5
Beginning Herd									
5	0%	0%	0%	0%	0%	0%	0%	0%	0%
10	-8%	4%	11%	-1%	7%	9%	-3%	-1%	0%
15	18%	24%	40%	8%	14%	23%	-1%	1%	5%
20	9%	29%	37%	8%	18%	21%	0%	2%	3%
30	2%	15%	29%	2%	11%	17%	-1%	0%	3%

- 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

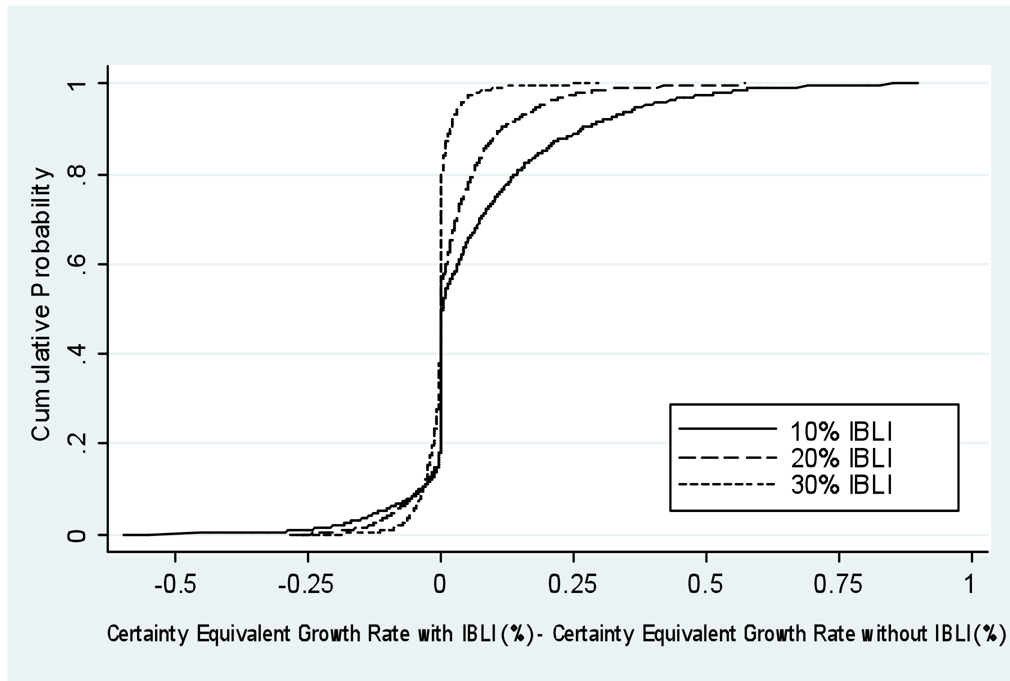
Without IBLI				With IBLI							
Stat.	Beta	Beginning Herd (TLU)	L-T Mean Herd (TLU)	Strike	Increase L-T Mean Herd (%)	Decrease SV(mean) (%)	Increase in CER Growth Rate (%)				
							CRRA				
							0.9	0.7	0.4	0.1	Simulated
Mean	0.8	16	33	10	17.4%	11.7%	6.4%	6.3%	6.0%	5.7%	6.1%
Median	0.7	14	31	20	6.7%	7.8%	2.7%	2.5%	2.3%	2.1%	2.5%
S.D.	0.5	28	30	30	0.2%	0.3%	-0.3%	-0.4%	-0.5%	-0.6%	-0.4%

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

-- Minimal change in performance wrt risk preference

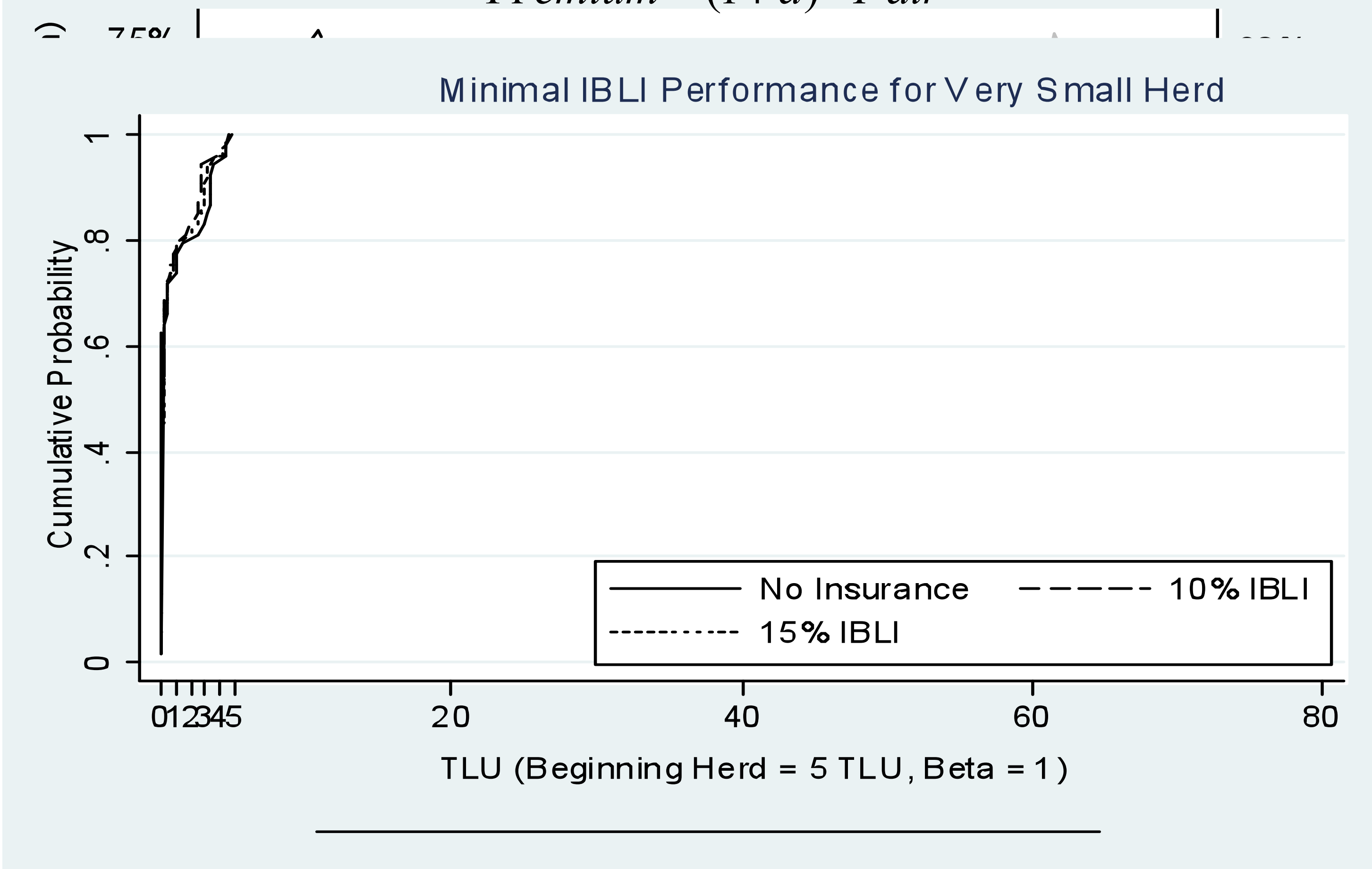
-- 10% contract provides best result

-- Variation in performance across households with different characteristics



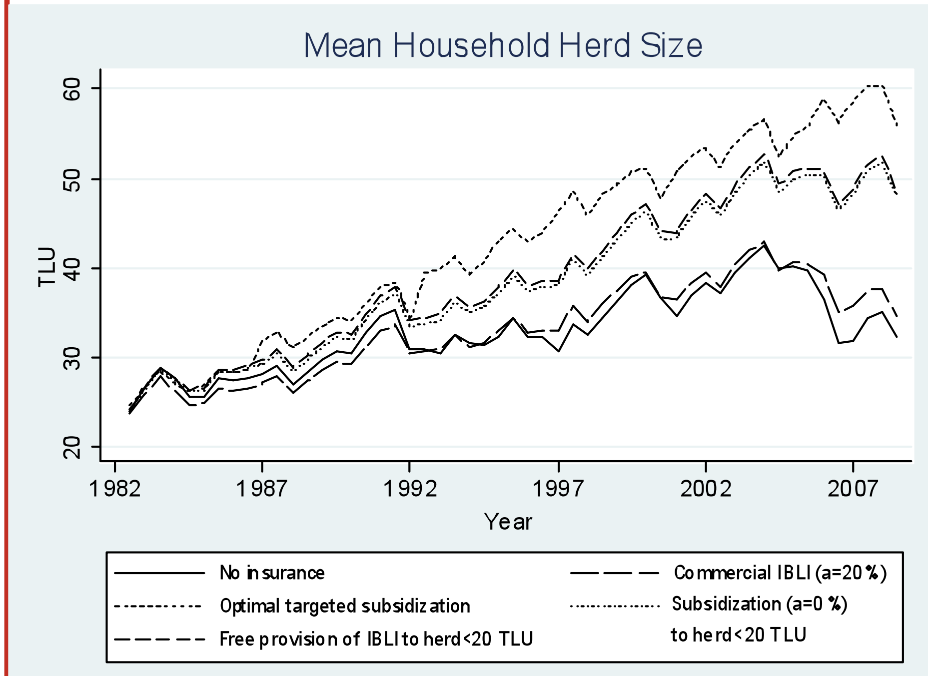
Willingness to pay for IBLI
By herd size

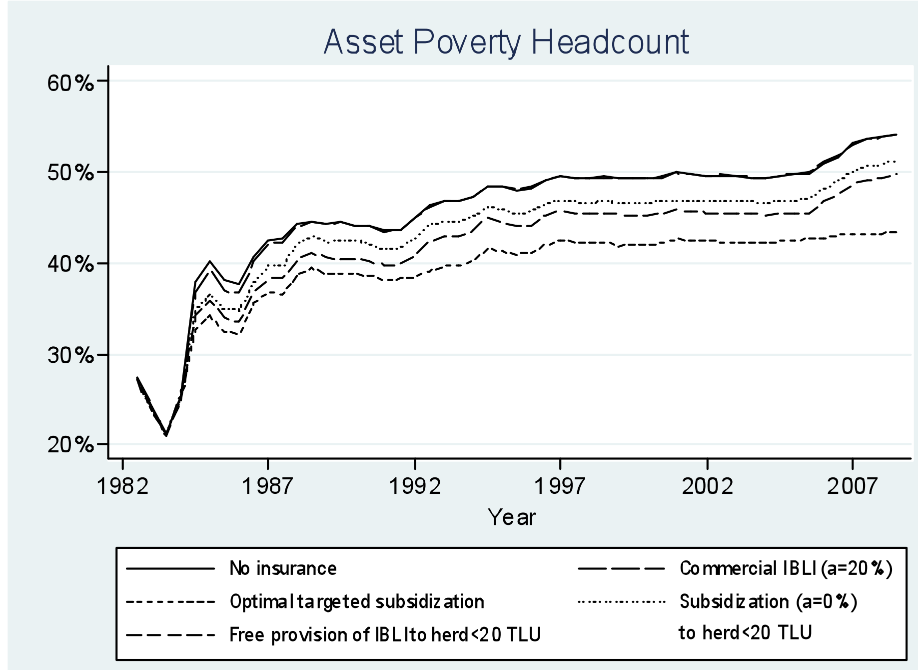
$$\Pr emium = (1 + a) * Fair$$



- WTP beyond fair rate is only attained at herd size beyond H*=15 TLU
- Most of the population has no effective demand for IBLI

Dynamic Outcome of Targeted IBLI Subsidies





- Optimally targeted subsidized IBLI maximizes poverty reduction outcomes:

  Free provision to 10-20 TLU & subsidized at actuarily 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!