Australian National University

Index Insurance: Financial Innovations for Agricultural Risk Management and Development

Sommarat Chantarat
Arndt-Corden Department of Economics
Australian National University

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Correspondence should be addressed to Sommarat.Chantarat@anu.edu.au

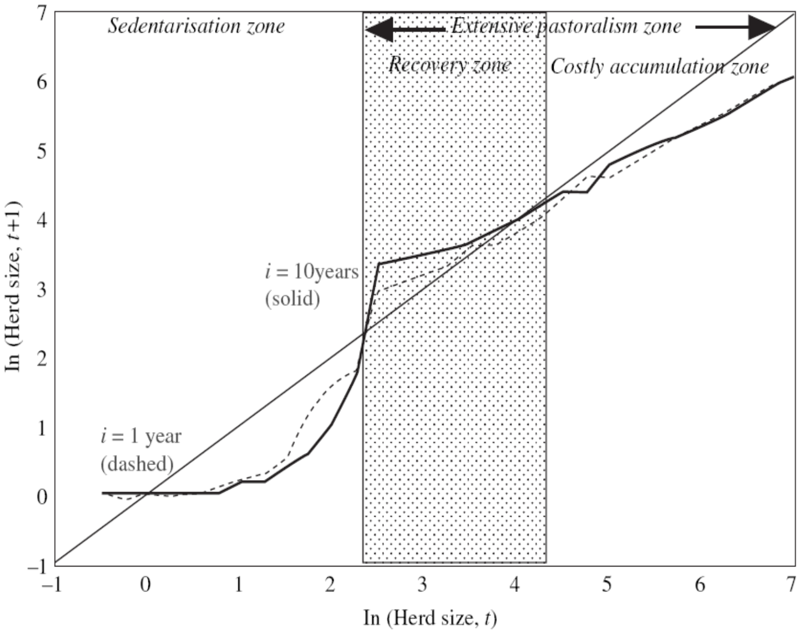
Outline of my talk

- **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 w/ threshold-based poverty traps**

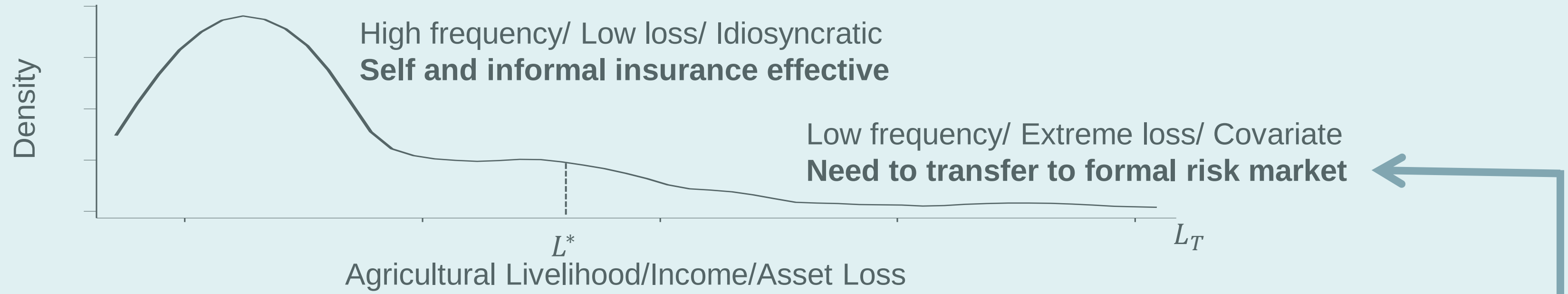
- **Insurance → protect rural livelihoods and escape poverty**
  - Provide safety net to prevent collapse of vulnerable populations
  - Encourage investment and asset accumulation by the poor
  - Induce financial deepening by crowding in credit market and social insurance



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

- **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

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

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

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

  $\Delta C_{lt} = a_0 + a_l + a_t + bX_{lt} + cL_{lt} + \varepsilon_{lt}$

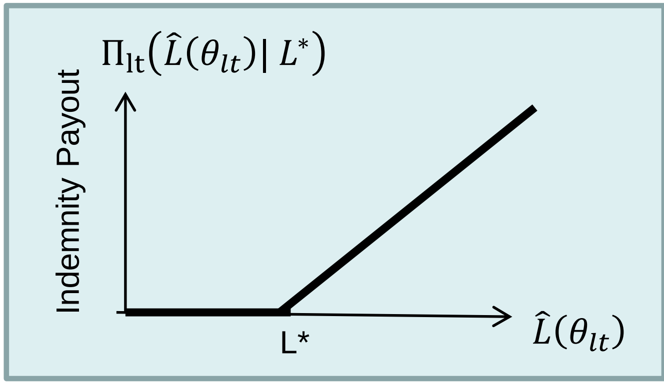
2. Select objectively measured index (θ_{lt})

- 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 ($\hat{L}(\theta_{lt})$)

- θ_{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 $\hat{L}(\theta_{lt})$: $\Pi_{lt}(\hat{L}(\theta_{lt})| L^*) = max(\hat{L}(\theta_{lt}) - L^*, 0) \times sum\ insured$
- 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 $f(\theta_{lt})$

$$p_l(\hat{L}(\theta_{lt})|\, L^*) = E\left(\Pi_{\mathrm{lt}}(\hat{L}(\theta_{lt})|\, L^*)\right) = \int \Pi_{\mathrm{lt}}(\hat{L}(\theta_{lt})|\, L^*)df(\theta_{lt})$$

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

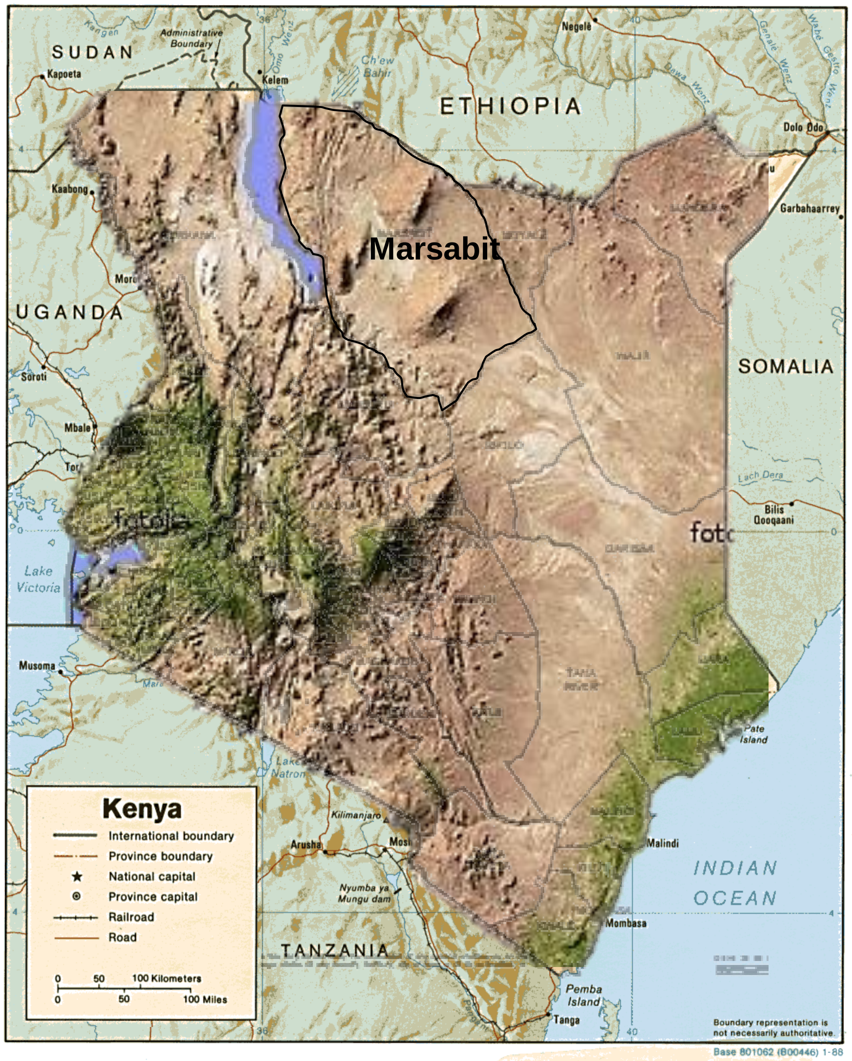
8. Identify cost effective delivery mechanisms

- 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

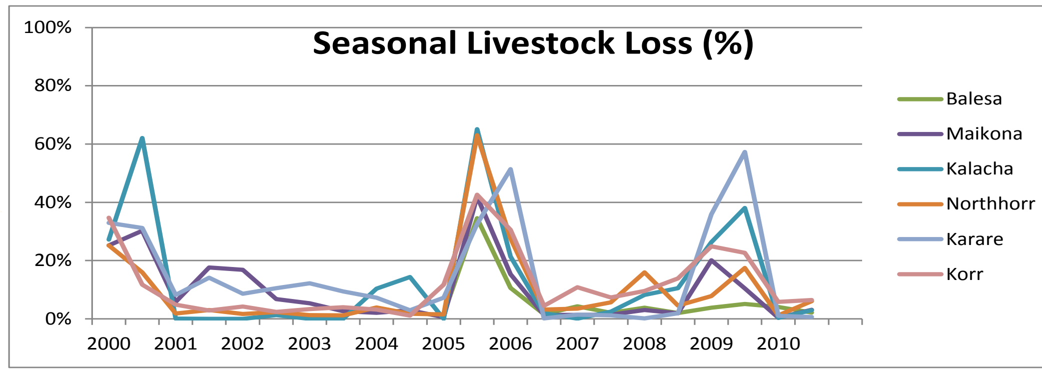
Satellite vegetation based livestock insurance in Kenya

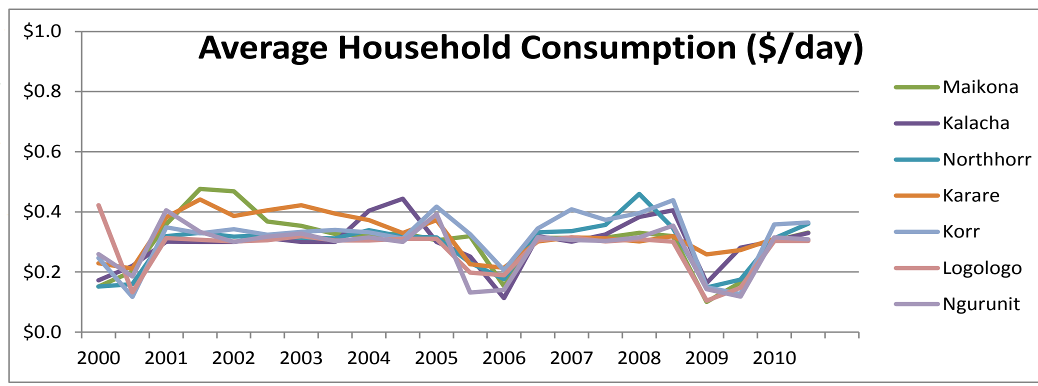


(1) Identify loss to be insured:

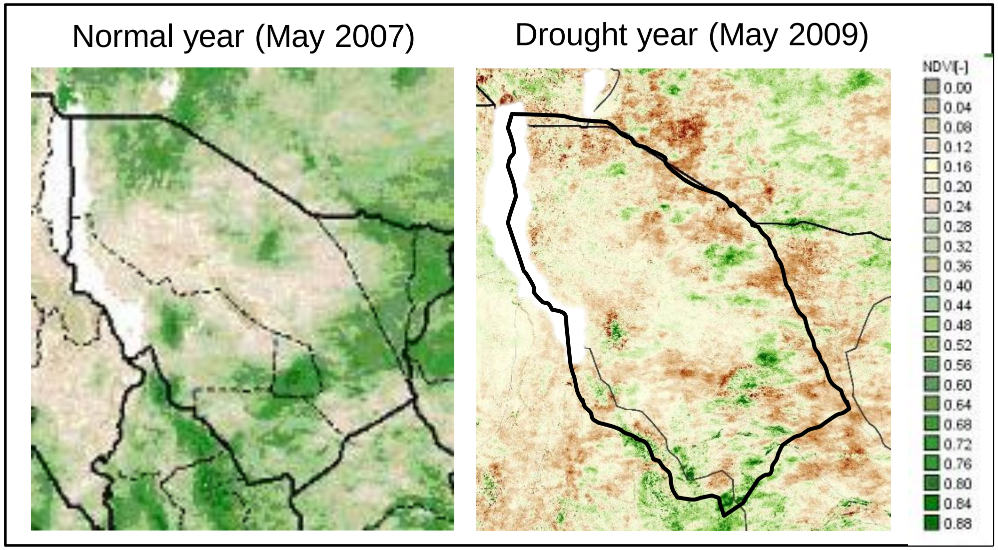
Catastrophic livestock losses from drought as key uninsured risk in this area

- Observed household welfare co-move with livestock losses



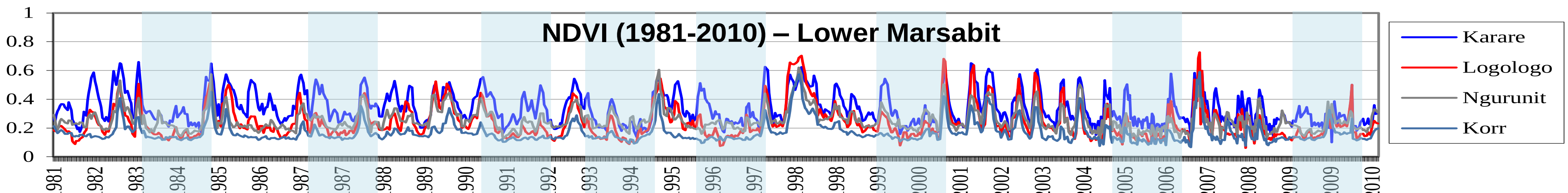


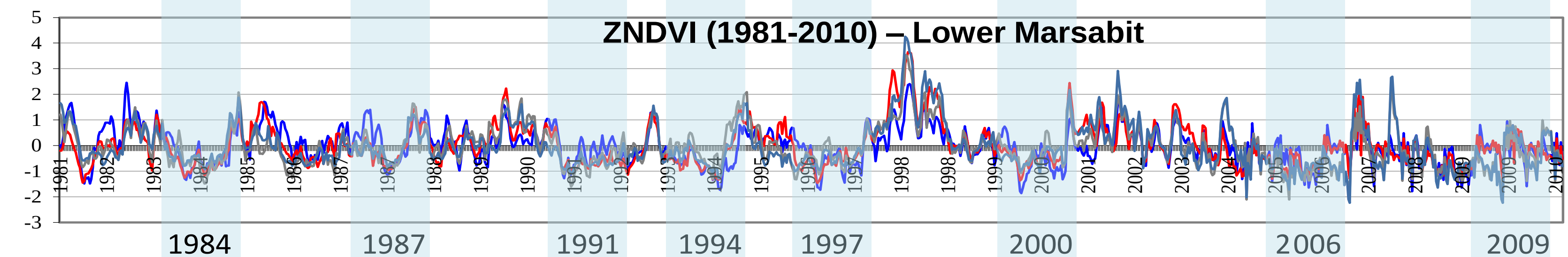
Satellite vegetation based livestock insurance in Kenya



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

- Indication of availability of vegetation over rangeland
- Spatiotemporal rich (1×1 km^2)
- Available in near-real time every 15 day (1982-present)



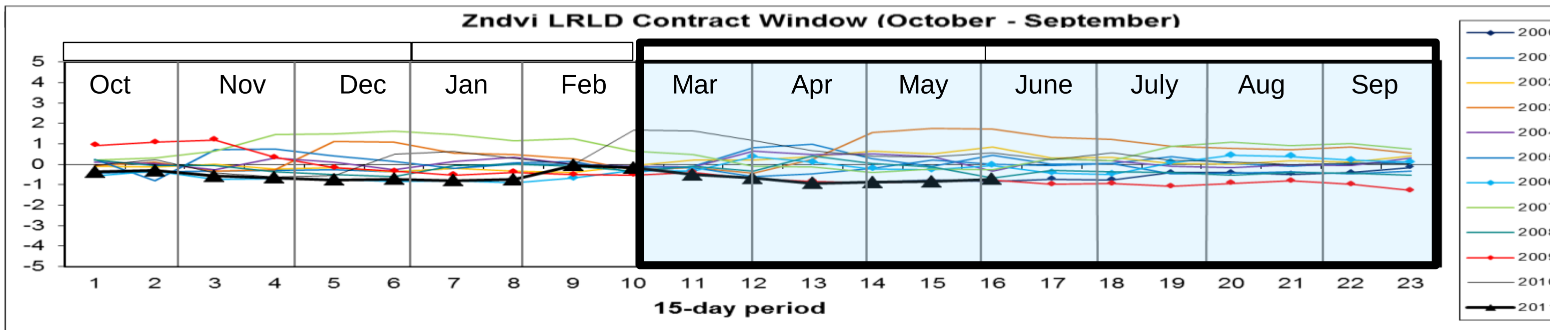


Historical Droughts ←

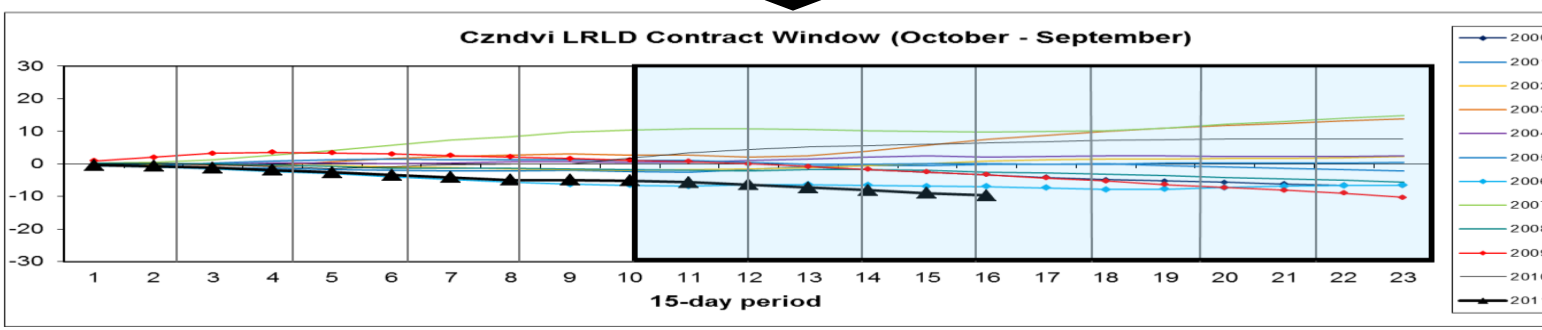
Satellite vegetation based livestock insurance in Kenya

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

$ZNDVI_{lt}$



$Cumulative\ ZNDVI_{lt}$



Satellite vegetation based livestock insurance in Kenya

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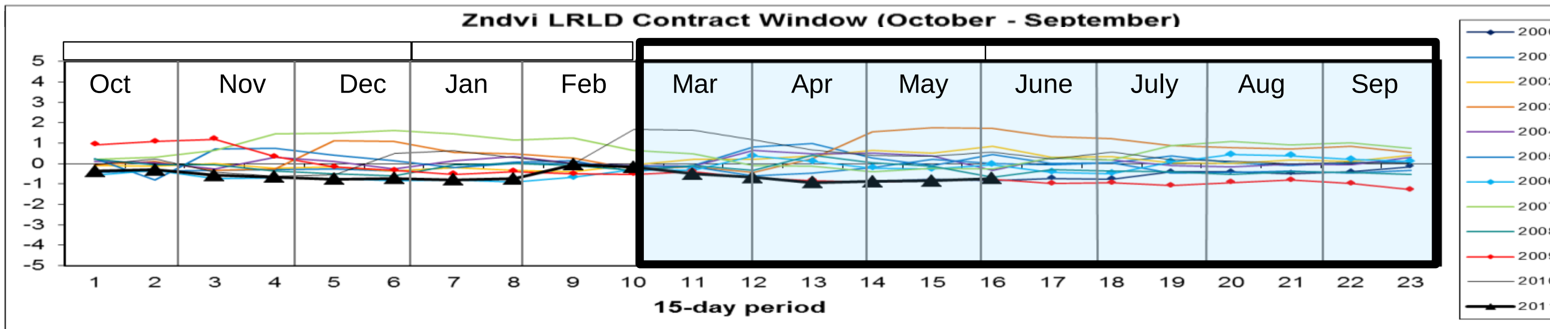
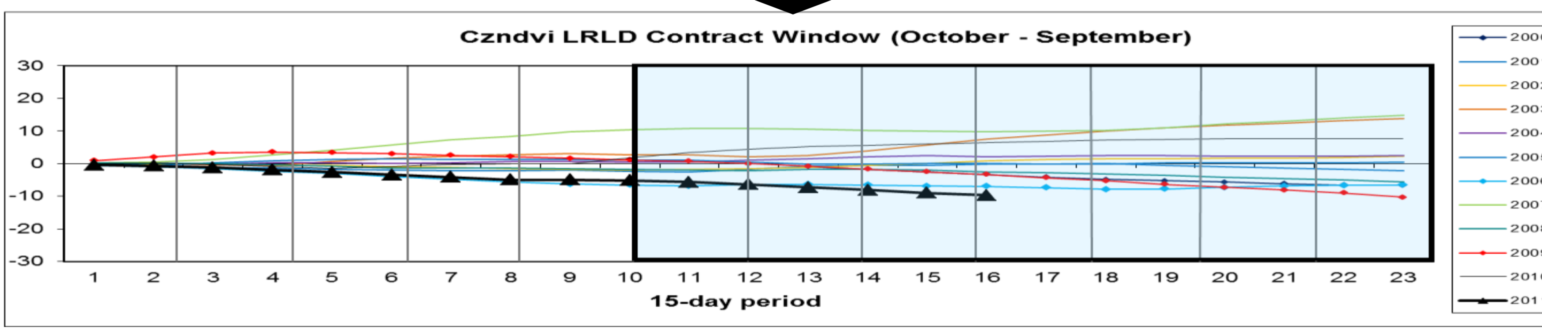


$Cumulative\ ZNDVI_{lt}$



$$Czndvi\_pre_s = \sum_{d \in T^s_{pre}} zndvi_{ds}$$

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$$Czndvi\_pos_s = \sum_{d \in T^s_{pos}} zndvi_{ds}$$

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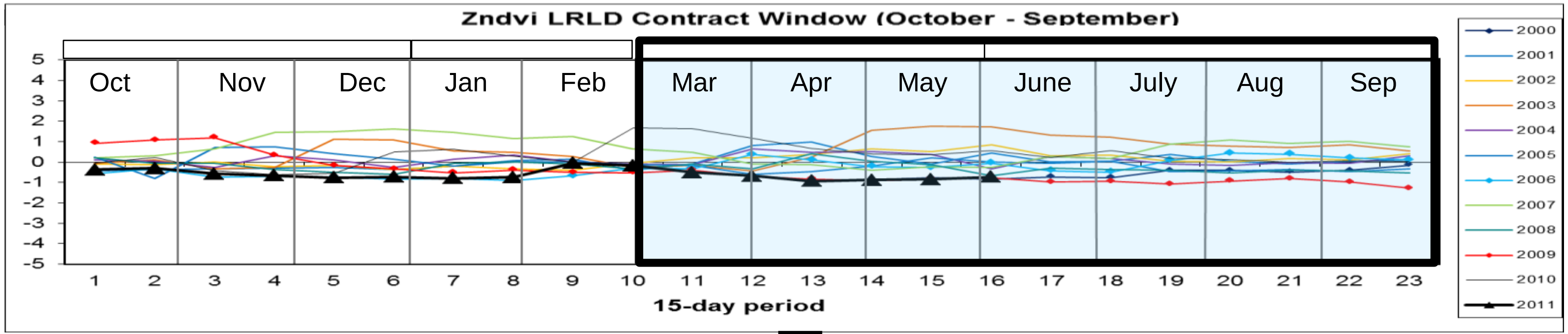
Construct $X(ndvi_{ls})$ variables from cum. ZNDVI process

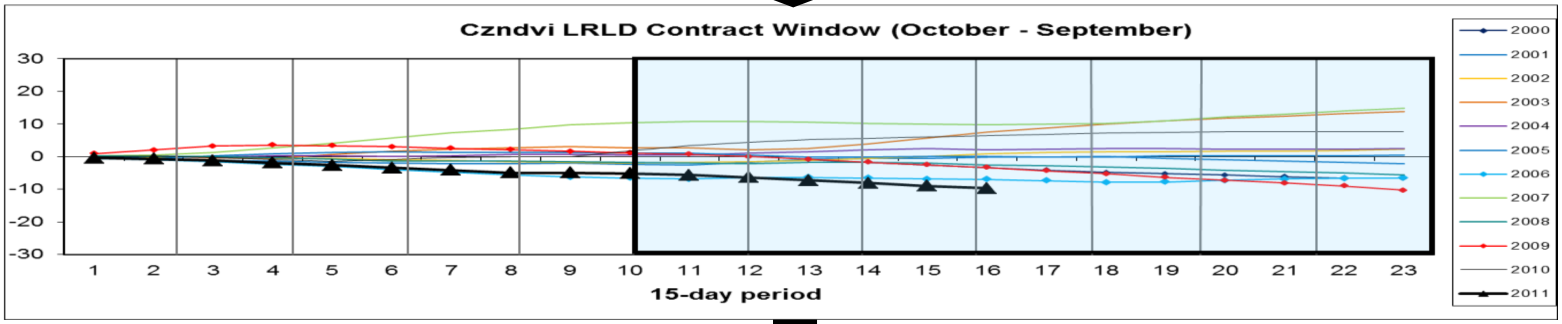
Satellite vegetation based livestock insurance in Kenya

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

$ZNDVI_{lt}$



$Cumulative$ $ZNDVI_{lt}$



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

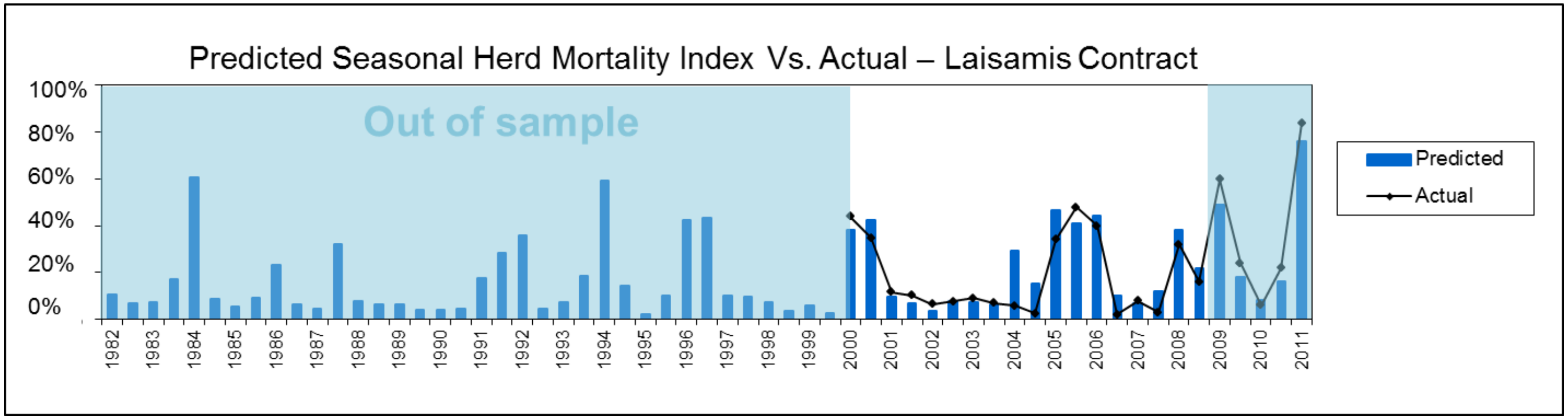
$$M_{lt} = \begin{cases} M_1(X(ndvi_{lt})) + \varepsilon_{1lt} & if\ Czndvi\_pos_{lt} \geq \gamma \quad (good\ climate\ regime) \\ M_2(X(ndvi_{lt})) + \varepsilon_{2lt} & if\ Czndvi\_pos_{lt} < \gamma \quad (bad\ climate\ regime) \end{cases} \Rightarrow \hat{M}(ZNDVI_{lt})$$

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, $\widehat{M}(ZNDVI_{lt})$

- Out-of-sample prediction errors within +-10% (especially in the bad year)
- Predict historical droughts well

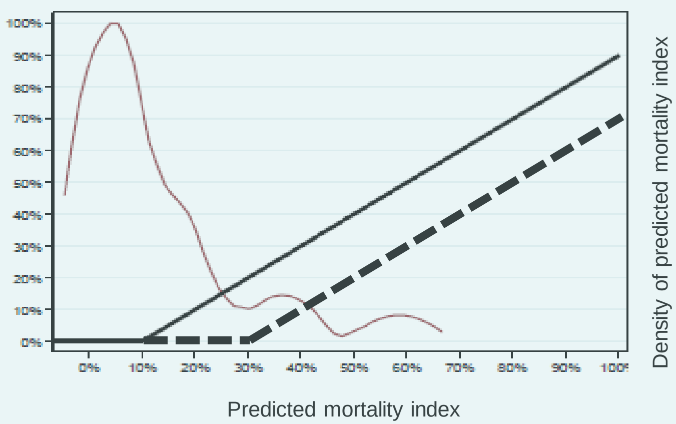


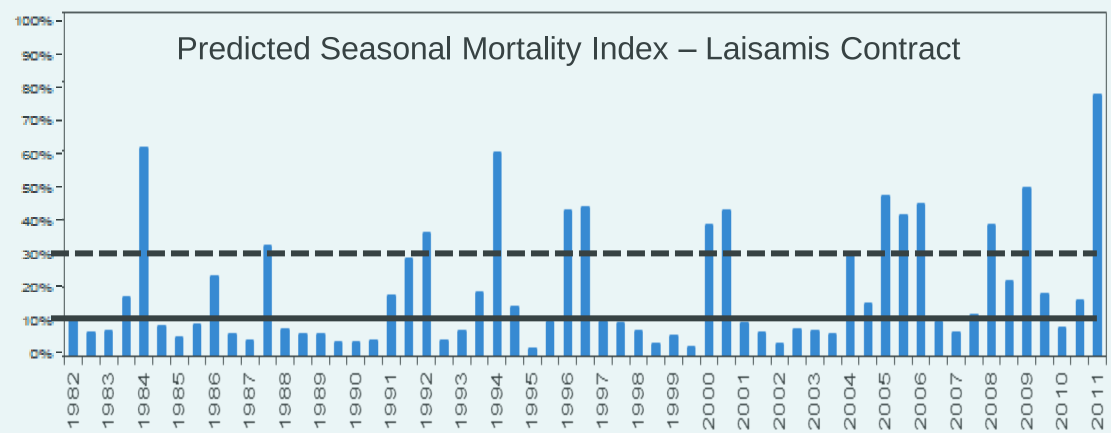
Satellite vegetation based livestock insurance in Kenya

(4) Identify optimal contract structure

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

$$\Pi_{\text{lt}}\left(\widehat{M}(\theta_{lt})\middle|\, M^*, TLU, P_{TLU}\right) = max\left(\widehat{M}(ZNDVI_{lt}) - M^*, 0\right) \times TLU \times P_{TLU}$$





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

(5) Actuarial fair premium:

(% of sum insured)

Strike (M^*)	10%	30%
Fair premium rate	6.8%	3.2%
Pr($\widehat{M_l}(NDVI) > M^*$)	34.5%	19.8%

Satellite vegetation based livestock insurance in Kenya

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

Pastoral production function:

$$f(H_{it}, X_{it}) = \begin{cases} f_L(H_{it}, X_{it}) + b_{it} & if \quad H_{it} \le H^* \\ f_H(H_{it}, X_{it}) & if \quad H_{it} > H^* \end{cases}$$

Herd dynamics with stochastic environment:

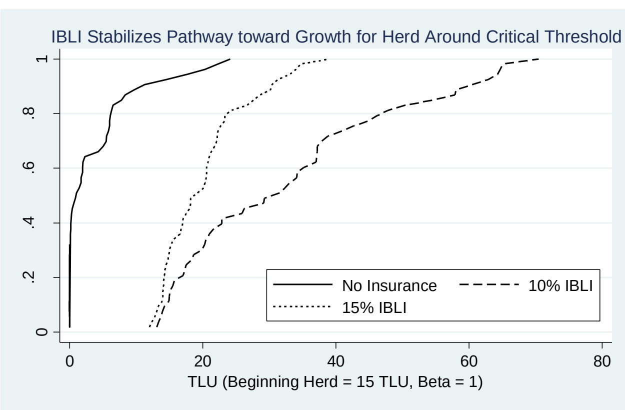
$$H_{it+1} = (1 + g(NDVI_t, \varepsilon_{it}) - m(NDVI_t, \varepsilon_{it}))\, H_{it} + i_{it}$$

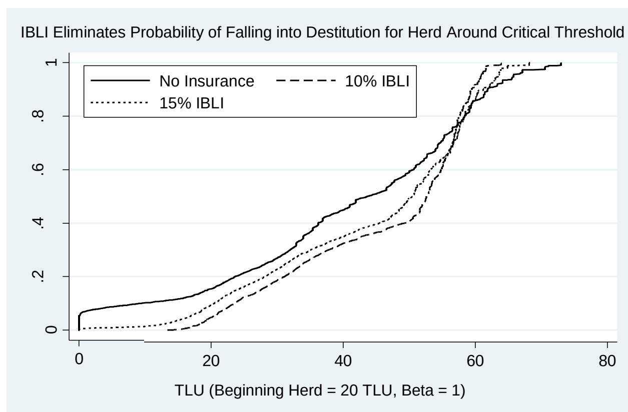
Household budget constraint:

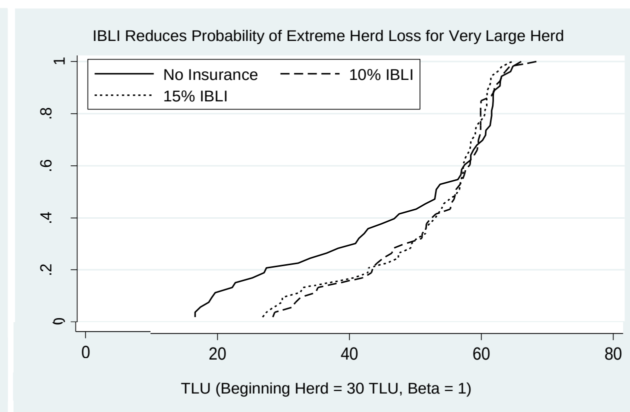
$$c_{it} + i_{it} \le f(H_{it}, X_{it}) + (W_{it} - W_{it+1}) + (\pi - \rho) h_{it} H_{it}$$

Household Intertemporal problem:

$$V(H_{it}) = \max_{c_{it}, h_{it}} u(c_{it}) + \delta_i E\left(V(H_{t+1}) | \Gamma_i(NDVI_t, \varepsilon_{it}, \pi_t)\right)$$







- 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

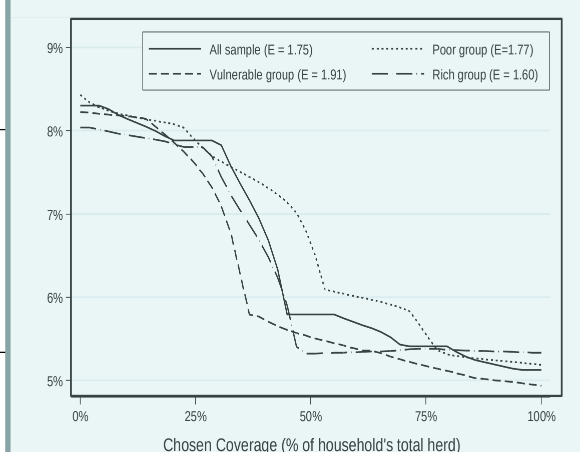
(6) Ex-ante contract evaluation: Willingness to pay experiments (210 hhs)

	1	2	3	4	5	6	7
Contract Coverage	100% Compulsory Coverage				Insured Chooses Coverage level		
Model (Dependent Variable)	Probit (Willing to purchase = 1)				Ordered Probit (0, 25%, 50%, 75%, 100%)		
Premium rate	-0.146***	-0.140***	-0.143***	-0.135***	-0.453***	-0.452***	-0.454***
	(0.036)	(0.033)	(0.039)	(0.036)	(0.046)	(0.0455)	(0.045)
Preference							
Discount rate	-0.184	-0.177	-0.190	-0.165	-0.085	-0.106	-0.077
	(0.158)	(0.157)	(0.139)	(0.149)	(0.225)	(0.224)	(0.231)
Risk aversion	-0.085	-0.083		-0.085	-0.303*		-0.308**
	(0.123)	(0.112)		(0.120)	(0.156)		(0.150)
Risk aversion × Have bank account		1.247***		1.249***	0.0448		0.042
		(0.180)		(0.234)	(0.0328)		(0.034)
Ambiguity aversion	-0.005		-0.037	-0.029		-0.0340	-0.001
	(0.031)		(0.031)	(0.035)		(0.169)	(0.137)
Ambiguity aversion × Have bank account			0.0376	0.0375		0.0309	0.237
			(0.034)	(0.034)		(0.0583)	(0.547)
Loss experience and perception							
Probability of m_it>200% mean_i	0.771***	0.728***	0.705**	0.687**	1.524**	1.440**	1.533**
	(0.284)	(0.282)	(0.281)	(0.274)	(0.617)	(0.606)	(0.598)
Experienced very bad long rain 2008	0.143**	0.135**	0.107	0.119*	0.208	0.164	0.207
(=1 if yes)	(0.067)	(0.065)	(0.069)	(0.071)	(0.199)	(0.207)	(0.212)
Expected livestock loss in 2009	0.708	0.679	0.690	0.629	1.568***	1.631***	1.559***
	(0.520)	(0.498)	(0.524)	(0.532)	(0.317)	(0.320)	(0.326)
Basis risk (% false negative when area	-0.497***	-0.475***	-0.488***	-0.459***	-0.179	-0.155	-0.174
Average loss trigger 10% strike)	(0.164)	(0.154)	(0.173)	(0.152)	(0.239)	(0.238)	(0.235)
Wealth and credit constraint							
Ln (total livestock)	-0.225***	-0.216***	-0.216***	-0.206***	-0.379***	-0.374***	-0.377***
	(0.017)	(0.018)	(0.016)	(0.015)	(0.119)	(0.124)	(0.122)
Ln (non-livestock productive assets)	0.038***	0.036***	0.036***	0.035***	0.0663***	0.0610***	0.068***
	(0.007)	(0.007)	(0.005)	(0.006)	(0.0168)	(0.0158)	(0.016)
Landholding	0.050*	0.048**	0.045*	0.044*	-0.0280	-0.0154	-0.026
	(0.026)	(0.024)	(0.027)	(0.025)	(0.0557)	(0.0654)	(0.060)
Credit constrained (=1 if yes)	0.225***	0.215***	0.175*	0.180*	0.268	0.182	0.262
	(0.083)	(0.078)	(0.094)	(0.094)	(0.214)	(0.220)	(0.211)
Financial experience and literacy							
Have bank account (=1 if yes)	0.337***	0.158	0.327***	0.155	0.0310	0.0729	-0.137
	(0.022)	(0.136)	(0.017)	(0.152)	(0.409)	(0.376)	(0.788)
Belong to active network (=1 if yes)	0.321***	0.300***	0.306***	0.289***	0.483**	0.452*	0.503**
	(0.037)	(0.030)	(0.047)	(0.038)	(0.234)	(0.241)	(0.256)
Head education (=1 if yes)	-0.033*	-0.032*	-0.040**	-0.037*	-0.0550*	-0.0380	-0.054*
	(0.019)	(0.017)	(0.019)	(0.019)	(0.0312)	(0.0316)	(0.031)

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)

Premium Vs. Chosen Coverage



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!

Satellite vegetation based livestock insurance in Kenya

(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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Satellite vegetation based livestock insurance in Kenya

(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})

	Cash transfer	No cash transfer
Educated	4 sites	4 sites
Not educated	4 sites	4 control sites

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

$$First\ stage: \quad D_{it} = \gamma_0 + \gamma_1 e_{it} + \gamma_2 t_{it} + \gamma_3 d_{it} + \varepsilon_{it}$$

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

Stay tuned!

References

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IBLI official site: 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