Pricing And Simulation Of Catastrophe Bonds For A Small And Less Developed Country: The Case Of Long And Short Rains In Kenya

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Problem Statement

- Many countries with a large agricultural base have volatility in capital flows and the current account that are largely dependent on the agricultural economies.
- When systemic risk such as famine-strength drought hits, the current account balance reserved for repaying sovereign debt can b e diverted to providing emergency food assistance.
- Markets aware of this covariate risk then discount the treasury bonds to increase yields to compensate investors for accepting the risk.
- This research seeks to examine whether it is optimal for a country to issue catastrophe bonds as part of its sovereign debt portfolio.

CAT bond and sovereign debt sustainability

- Sovereign debt of many LDCs are especially prone to natural disasters
  - Natural disasters triggered many sovereign debt defaults in the history
- The costs of sovereign defaults include:
  - Reputational costs
  - Trade exclusion costs
  - Costs to the domestic financial system, etc.
- Can CAT bond improve sovereign debt sustainability and also improve the social welfare?

CAT bond as a risk financing tool

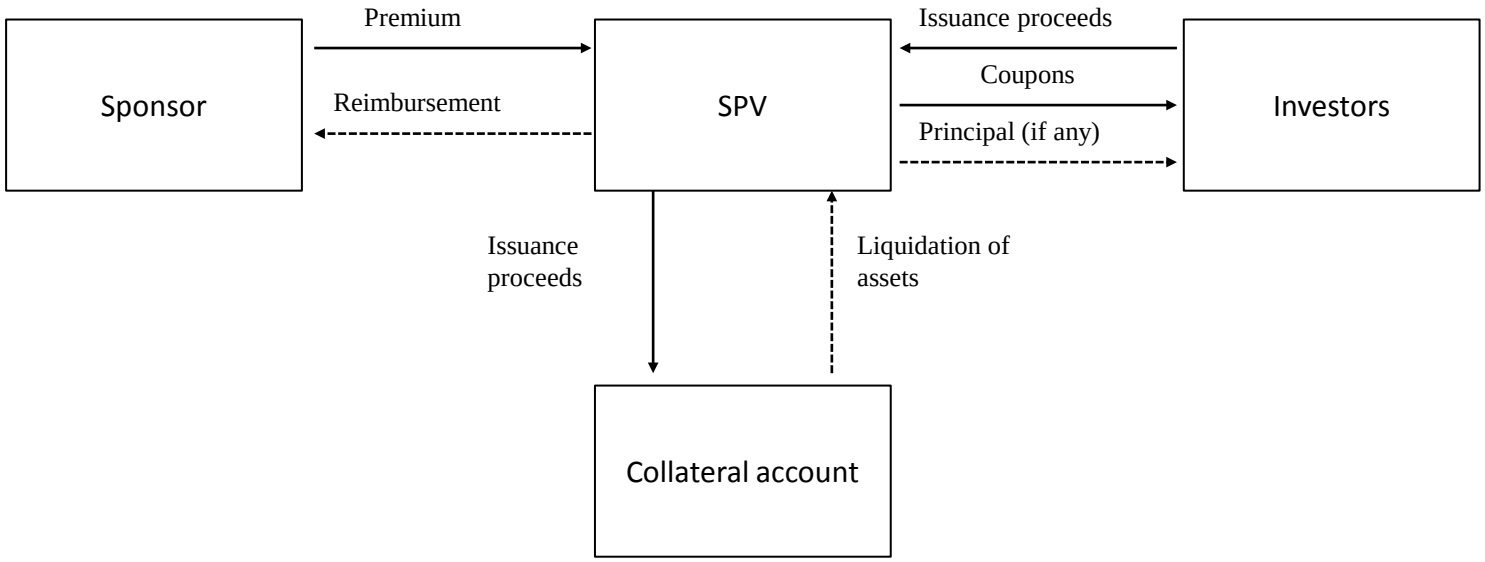
- Whether country level risk financing strategy is necessary for catastrophe risks?
  - The answer is yes.
- CAT bond as a risk financing tool could help overcome:
  - Adverse selection
  - Moral hazard
  - Basis risk
- Mexico has issued CAT bonds to cover it earthquake risks under the *MultiCat* program of the World Bank

Motivation

- We are interested in catastrophic drought risk in a small country that is largely agrarian like Kenya and Ethiopia
- We want to pick an appropriate pricing method for the drought risk from existing CAT bond pricing literatures
- A real world simulation of drought linked CAT bond will improve the know-how of potential CAT bond sponsors or issuers (e.g. government or national disaster trust)
- Ultimately, we want to improve LDCs' access to advanced risk financing strategies like CAT bond

What is a catastrophe bond?

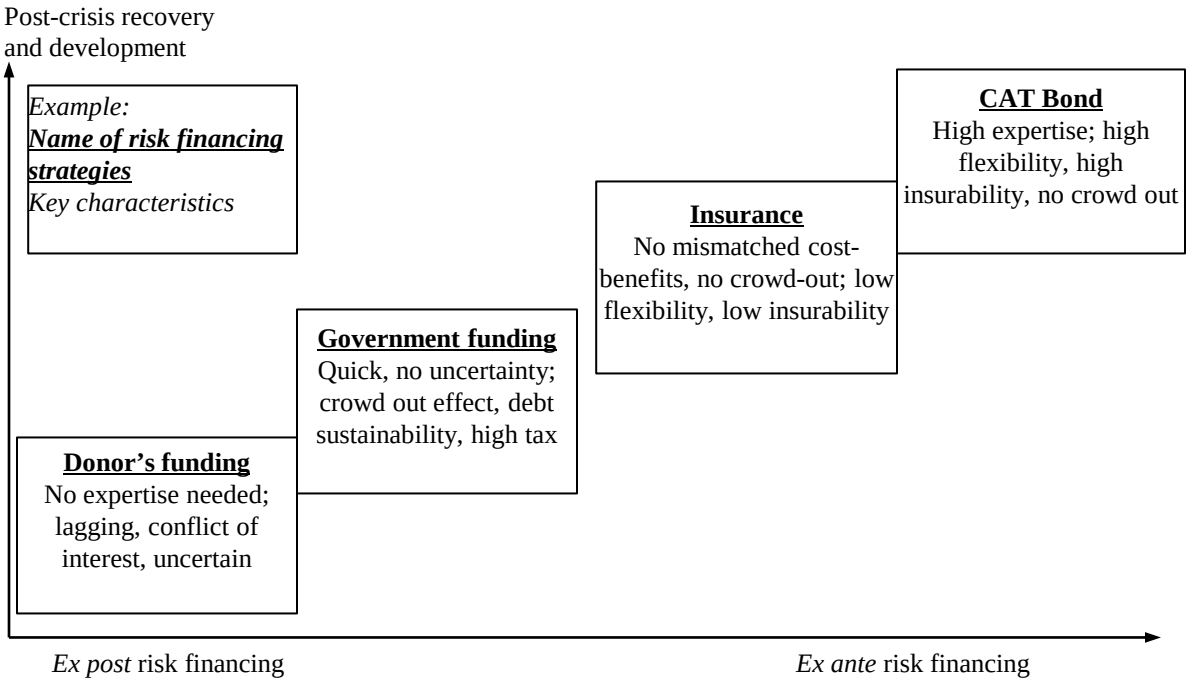
- Cash flow structure of a CAT bond



- Triggering mechanisms: indemnity loss, industry loss, modeled loss, and parametric.

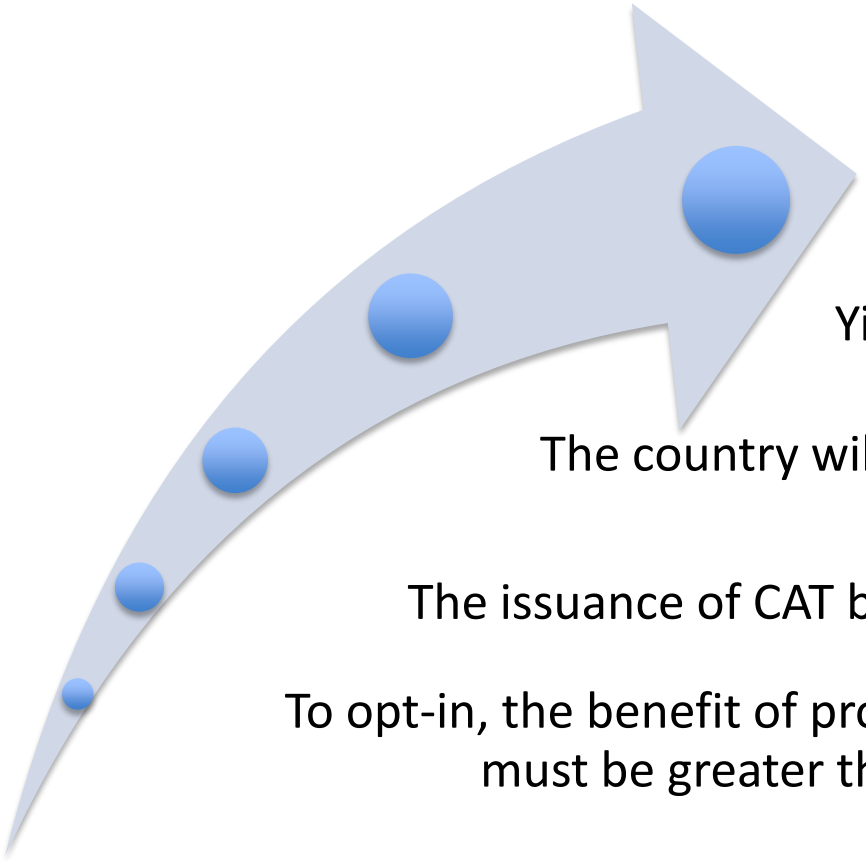
CAT bond as a development tool

- CAT bond could improve post-crisis development



CAT bond and sovereign debt sustainability

- Our findings from an inter-temporal wealth maximizing model



Social welfare will increase.

Yield of sovereign bond will be lower.

The country will have a less default incentive on its sovereign bond.

The issuance of CAT bond will crowd out sovereign bond.

To opt-in, the benefit of production & consumption smoothing must be greater than the cost premium for CAT bond.

Pricing of CAT bond

- Review existing pricing literatures
  - Arbitrage free models
  - Contingent claim models
- Discuss why the closed form solution of CAT bond pricing (Jarrow, 2010) is the appropriate one for our application
  - Computation ease to the issuers and investors in LDCs
  - Utilize historical inputs that is transparent and easily available
  - Robust to different term structures
- Review the proof of this closed form solution and re-innovate certain steps

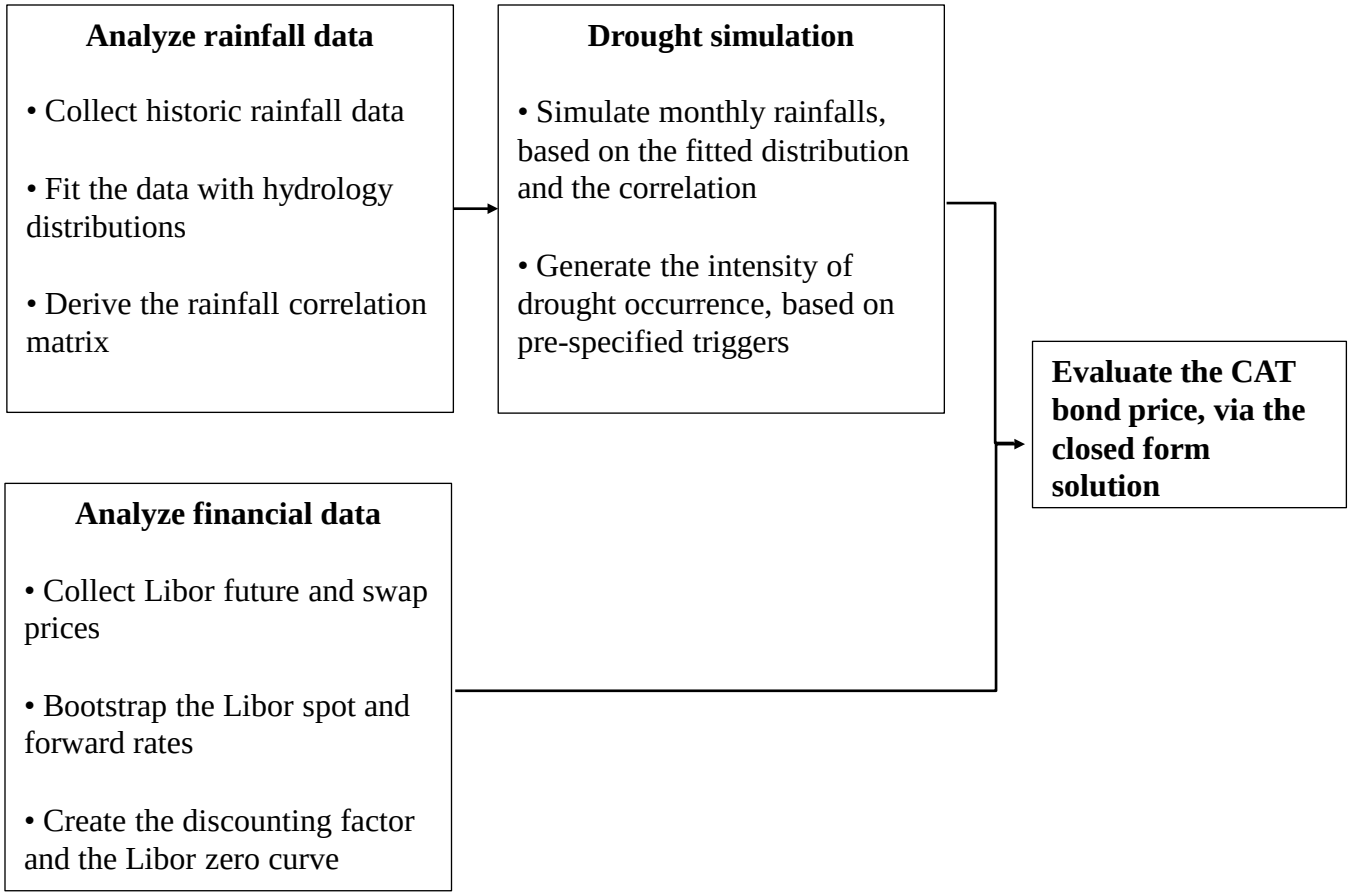
Closed form solution of CAT bond pricing

$$B_t = A(L_{t+k-\Delta} + \mathrm{c})\Delta \mathrm{p}(\mathrm{t}, \mathrm{t}+\mathrm{k}) e^{-\int_t^{t+k} \lambda_u du} + Ap(t, t+k) e^{-\int_t^{t+k} \lambda_u du} + \int_t^{t+k} E_t(Y_s)\lambda_s e^{-\int_t^s \lambda_u du} \mathrm{p}(\mathrm{t}, \mathrm{s})\, ds - \int_{t+k}^{T} [\mathrm{A} - E_t(Y_s)]\mathrm{p}(\mathrm{t}, \mathrm{s})\lambda_s e^{-\int_t^s \lambda_u du} ds + A(\theta + \mathrm{c})\Delta E_t \left(\sum_{s=2}^{T} \mathrm{p}(\mathrm{t}, \mathrm{s}) e^{-\int_t^s \lambda_u du} \right)$$

- First term is the discounted value of the next coupon payment with both the floating forward Libor rate and the fixed spread, weighted by the probability of no catastrophe event.
- Second term is the discounted price of a Libor floating rate note with face value A of CAT bond at time t+k, weighted by the probability of no event during t to t+k.
- Third term is the discounted recovery of principal, weighted by the probability of catastrophe event between time t and t+k.
- Fourth term is the expected losses after the next coupon, which is the difference between the principal and the recovered portion, weighted by the probability of catastrophe event between time t+k and T.
- The last term is the fixed payment after the next coupon, which contains both the shift term and the spread term, weighted by the probability of no catastrophe event.

Simulation of the CAT bond

- Simulation process of the drought CAT bond



Baseline model for long and short rains in Kenya

- Parameters of the baseline model

Parameter	Description	Value of the baseline model
t	Launch date of the CAT bond	March 04, 2014
T	Maturing date of the CAT bond	March 04, 2017
Δ	Frequency of coupon payment	Per quarter
L_t	Annualized Libor forward rate	Figure 5.2 upper line
l_t	Annualized Libor spot rate	Figure 5.2 lower line
θ	Shift between the forward & spot on $t + \Delta$	0.011%
c	Coupon spread over Libor	4% (annualized)
A	Face value of the CAT bond	$1000
$E(Y_\tau)$/A	Pre-specified recovery rate	50%
K_L	Drought trigger in long rain season	200 millimeters
K_S	Drought trigger in short rain season	50 millimeters

Results from the simulation

- CAT Bond Price with Respect to the Trigger Levels and Time after Launch

	230, 65	220, 60	210, 55	**200, 50**	190, 45	180, 40	170, 35
0 YEAR	702.2	746.6	790.1	838.5	892.4	937.2	976.0
0.5 YEAR	721.1	764.7	807.3	852.5	902.4	943.3	978.1
1 YEAR	767.0	805.9	842.2	881.0	922.3	955.2	982.9
1.5 YEAR	796.2	831.7	865.1	898.4	933.8	961.8	984.8
2.0 YEAR	859.8	885.6	908.6	932.0	955.9	974.1	989.0
2.5 YEAR	904.2	922.3	939.1	954.1	969.6	981.5	990.8
3 YEAR	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0

Results from the simulation

- CAT Bond Price at issue with Respect to the Trigger Levels and Recovery Rates

	230, 65	220, 60	210, 55	**200, 50**	190, 45	180, 40	170, 35
0%	331.5	415.1	497.1	588.4	690.2	774.8	848.1
10%	405.7	481.4	555.7	638.4	730.6	807.3	873.7
20%	479.8	547.7	614.3	688.4	771.1	839.8	899.2
30%	553.9	614.0	672.9	738.4	811.5	872.3	924.8
40%	628.1	680.3	731.5	788.5	852.0	904.7	950.4
50%	702.2	746.6	790.1	838.5	892.4	937.2	976.0
60%	776.3	812.9	848.7	888.5	932.9	969.7	1001.5
70%	850.5	879.2	907.3	938.6	973.3	1002.2	1027.1
80%	924.6	945.5	965.9	988.6	1013.8	1034.6	1052.7
90%	998.7	1011.8	1024.5	1038.6	1054.2	1067.1	1078.2
100%	1072.9	1078.1	1083.1	1088.7	1094.7	1099.6	1103.8

Results from the simulation

- CAT Bond Price at issue with Respect to the Trigger Levels and The Drift of Libor Zero Coupon Curves

	230, 65	220, 60	210, 55	**200, 50**	190, 45	180, 40	170, 35
- 20 BPS	701.4	745.9	789.5	838.0	892.1	937.0	975.9
+ 0 BPS	702.2	746.6	790.1	838.5	892.4	937.2	976.0
+ 20 BPS	703.0	747.3	790.7	839.0	892.8	937.4	976.0
+ 40 BPS	703.8	748.1	791.3	839.5	893.1	937.6	976.1
+ 60 BPS	704.7	748.8	791.9	839.9	893.4	937.8	976.2
+ 80 BPS	705.5	749.5	792.5	840.4	893.7	938.0	976.2
+ 100 BPS	706.3	750.2	793.1	840.9	894.1	938.2	976.3

Our contribution

- Clearly identify the development and risk financing challenges that LDCs are facing under the catastrophe risks
- Examine CAT bond's role as a development and risk financing tool from multiple perspectives
- Employ an inter-temporal wealth maximizing framework to show the relationship between CAT bond and sovereign bond
- Clearly show how to simulate the price of CAT bond out of real world historical data
- Investigate the viability and robustness of the closed form solution
- Target our research on previously overlooked risk – the drought risk in Africa

Thank you!