Peer-to-peer (P2P) insurance: opportunities and challenges in Africa

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Historic Background

Sharing Economy

Product Sharing

Service Sharing

Risk Sharing

Risk Sharing

- Main benefit resides that an individual can mitigate very large potential losses by risk sharing.
- Pre-exchange risk (potential loss) X_i for $i = 1, ..., n$
- Aggregate risk of the pool given by $S = \sum_{i=1}^{n} X_i$
- post-exchange risk $h_i(S)$ for some deterministic functions $h_i \geq 0$
- Risk sharing pool should satisfy:
    - Self sufficient:
    $$S = \sum_{i=1}^{n} X_i = \sum_{i=1}^{n} h_i(S)$$
    - Individual's post-agreement loss should be preferable to the original, for example
    $$Var(h_i(S)) \leq Var(X_i)$$

P2P insurance vs traditional insurance

Definition:

*Peer-to-peer (P2P) insurance is a **decentralized network** in which participants pool their resources together to compensate those who suffer losses.*

P2P insurance

- Distributed network
- Pay back
- Increased transparency
- Reduced adverse selection

Traditional insurance

- Centralized network
- No Pay back
- No transparent rate making
- Asymmetry of information

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Notations

We consider a P2P insurance composed of n participants

- Each faces a risk X_i (potential loss) valued in $[0, \infty)$ with dist. F_i
- $S = \sum_{i=1}^{n} X_i$: is the total loss of the pool
- v_i: measure the disutility of potential loss to participant i
- Largest value for loss X_i: $F_i^{-1}(1) = \inf\{x \in \mathrm{R} \mid F_i(x) = 1\}$

Definitions

Definition:

A risk-sharing rule is a collection $(h_1, ..., h_n)$ of functions: $\sum_{i=1}^{n} h_i(s) = s \;\forall\; s \geq 0$

$h_i(S)$ is the risk after allocation for i and $\mathrm{E[v_i(h_i(S))]}$ is the disutility for i

Definition:

$(h_1, ..., h_n)$ is actuarially fair if, participants do neither gain nor lose from risk sharing, i.e $\mathrm{E[h_i(S)] = E[X_i]}$

Definition:

An actuarially fair risk-sharing rule $(h_1, ..., h_n)$ is Pareto optimal if there does not exist a actuarially fair risk-sharing rule $\left(\tilde{h}_1, \ldots, \tilde{h}_n\right)$ such that $(E[v_1(\tilde{h}_1(S))], \ldots, E[v_n(\tilde{h}_n(S))]) \leq (E[v_1(h_1(S))], \ldots, E[v_n(h_n(S))])$

Problem

Theorem (Borch 1962)

An actuarially fair risk-sharing rule $(h_1, \ldots, h_n)$ is Pareto optimal for any given total risk S taking values in the domain A if and only if there exist a function $J : A \to \mathbb{R}_+$ and positive constants $\alpha_1, \ldots, \alpha_n$ such that $\alpha_i v_i'(h_i(s)) = J(s)$ for all $s \in A$ and for all $i = 1, \ldots, n$

Find a collection of risk sharing rules $(h_1, ..., h_n)$ such that the following conditions are satisfied:

- $h_i \geq 0 \ \forall \ i = 1, \ldots, n$;
- feasibility, i.e. $\sum_{i=1}^{n} h_i(s) = s$ for all $s \in A$;
- actuarial fairness, i.e. $E\left[h_i(S)\right] = E[X_i]$ for all i;
- Pareto optimality, i.e. there exist positive constants $\alpha_1, \ldots, \alpha_n$ and a function J such that $\alpha_i v_i'(h_i(s)) = J(s)$

Special cases

1. Uniform risk-sharing rule:

$$h_i(S) = \frac{S}{n}$$

It is the case of same disutility function and X_i are iid

2. Mean proportional risk-sharing rule

$$h_i(S) = \frac{E[X_i]}{E[S]} S$$

It is the case where $\frac{v_i'(s)}{v_i''(s)} = \sigma_i s + \tau_i$

3. Case of non linear risk-sharing rule for $n = 2$

$$h_1(S) = S - \sqrt{aS + \left(\frac{a}{2}\right)^2} + \frac{a}{2}$$

$$h_2(S) = \sqrt{aS + \left(\frac{a}{2}\right)^2} - \frac{a}{2}$$

where $v_i(s) = \frac{s^{1+\gamma_i}}{1+\gamma_i}$ with $\gamma_2 = 2\gamma_1$

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Participant i	1	2	3	4
λ_i	0.08	0.08	0.1	0.1
$f_{C_i}(1)$	0.1	0.15	0.1	0.15
$f_{C_i}(2)$	0.2	0.25	0.2	0.25
$f_{C_i}(3)$	0.4	0.3	0.3	0.3
$f_{C_i}(4)$	0.3	0.3	0.4	0.3

$X_i = \sum_{k=1}^{N_i} C_{ik}$ with $N_i \sim \text{Poisson}(\lambda_i)$, $\quad (i = 1, 2, 3, 4)$

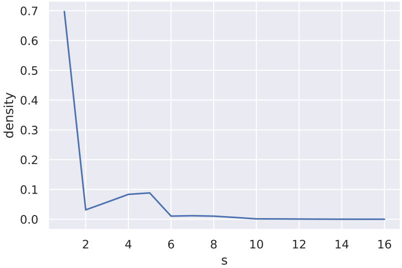
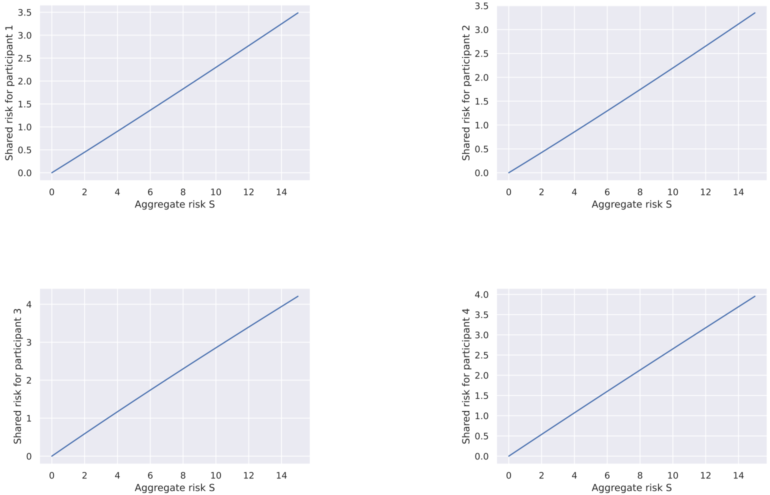
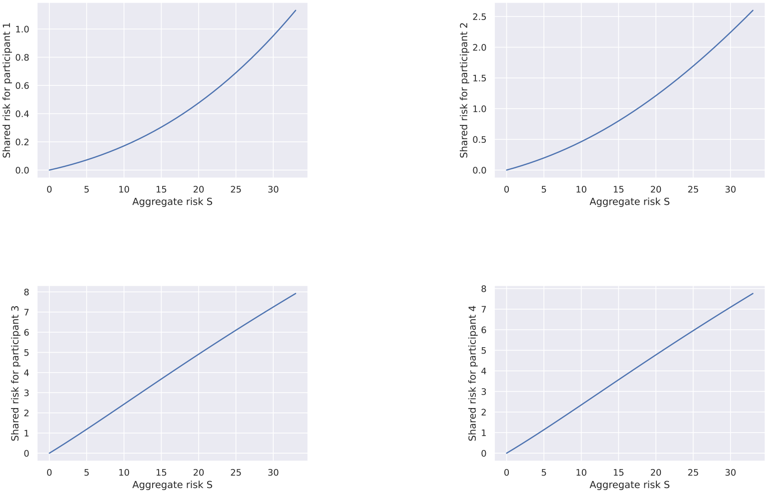


Figure: Density function of the aggregated risk $S = \sum_{i=1}^{n} X_i$


Shared risk for participant 1
Aggregate risk S
Shared risk for participant 2
Aggregate risk S
Shared risk for participant 3
Aggregate risk S
Shared risk for participant 4
Aggregate risk S

Multivariate Bernoulli with Archimedean copulas

- $\boldsymbol{I} = (I_1, \ldots, I_n)$ be a multivariate Bernoulli distribution
- $X_i = b_i \times I_i$, with $b_i \in \mathbb{N}^+$, for $i \in \{1, \ldots, n\}$
- $\mathscr{P}_{\boldsymbol{X}}(t_1, \ldots, t_n) = E\left[\prod_{i=1}^{n}\left(1 - r_i^{\Theta} + r_i^{\Theta} t_i^{b_i}\right)\right] = \int_0^{\infty} \prod_{i=1}^{n}\left(1 - r_i^{\theta} + r_i^{\theta} t_i^{b_i}\right) \mathrm{d}F_{\Theta}(\theta)$
- $\mathscr{P}_S(t) = \sum_{\theta=1}^{\theta^*} \Pr(\Theta = \theta) \prod_{i=1}^{n}\left(1 - r_i^{\theta} + r_i^{\theta} t^{b_i}\right).$


Shared risk for participant 1
1.0
0.8
0.6
0.4
0.2
0.0
0 5 10 15 20 25 30
Aggregate risk S
Shared risk for participant 2
2.5
2.0
1.5
1.0
0.5
0.0
0 5 10 15 20 25 30
Aggregate risk S
Shared risk for participant 3
8 7 6 5 4 3 2 1 0
0 5 10 15 20 25 30
Aggregate risk S
Shared risk for participant 4
8 7 6 5 4 3 2 1 0
0 5 10 15 20 25 30
Aggregate risk S

Opportunities in Africa

1. We are by default in group (small) $\Longrightarrow$ easy to manage
2. The "tontine" system behaves in the same manner
3. Appropriate with our society (in the cultural and religious sense)
4. Informal economy
5. Respect for the hierarchy

Challenges

1. IT constraints
2. Fraud problem
3. Cyber risks
4.