Compound risk and index insurance: a WTP experiment in Mali

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Introduction

- Index insurance is promising in theory (transaction costs, moral hazard, ..)
- In practice, low uptake despite efforts
  - Lack of trust
  - Lack of understanding
  - Design of the index itself
- Basis risk and how it is perceived by farmers
Index insurance from the farmer’s point of view: a compound lottery:

- **Farmer’s yield**
  - **High**
    - Triggered
    - Not Triggered
  - **Low**
    - Triggered
    - Not Triggered

- **Index**
  - Triggered
  - Not Triggered

- **Basis risk**
Background: People dislike probabilistic insurance

- Empirical evidence: Whakker et al. (1997): They demand more than 20% reduction in the premium to compensate for 1% default risk
- One explanation: the weighting function of prospect theory
- Our explanation: violation of reduction of compound lottery axiom (ROCL)
### Compound lotteries and ambiguity aversion

- The compound lottery structure is a potential source of ambiguity
Ambiguity as aversion to compound lotteries: Smooth model of ambiguity aversion

\[ E_{f_y}[v(E_{f X/y}u(X))] \]

\[ U \] External function: attitude towards “ambiguity”

\[ u \] Internal function: attitude towards “simple” risk

\[ v' > 0 \quad v'' \leq 0 \]
Modeling aversion to compound risk: a numerical example

\[ a + b = 10 \]

\[ E_{f_y} [v(E_{f_{X/y}} u(I X))] = 0.7 \ast v[0.9u(a) + 0.1u(b)] + 0.3 \ast v[0.2u(a) + 0.8u(b)] \]
Framework: How does a farmer think about Index insurance?

He reduces compound lottery

WTP = basis risk premium

He doesn’t reduce compound lottery

WTP = function of basis risk premium and compound risk premium
Framework: How does a farmer think about Index insurance?

He reduces compound lottery

WTP = basis risk premium

He doesn’t reduce compound lottery

WTP = function of basis risk premium and compound risk premium
Notations

Index Insurance contract

\[ y_{IX} \] Farmer’s revenue

\[ f_y \] pdf of the yield

\[ f_X \] pdf of the index

Individual insurance contract

\[ y_{I} \] Farmer’s revenue

\[ f_y \] pdf of the yield
EUT: \( WTP = \text{Basis risk premium} \)

Index Insurance contract

\[
E_{f_{yx}} u(y_1 | x) = E_{f_y} u(y_1)
\]

Objective function

Basis risk premium, \( \rho \), is solution to:

\[
E_{f_{yx}} u(y_1 | x) = E_{f_y} u(y_1 - \rho)
\]
Modeling aversion to compound risk

\[ E_{f_y}[v(E_{f_{x/y}}u(IX))] \quad \text{Objective function} \]

\[ \mathcal{U} \quad \text{External function: attitude towards “compound” risk} \]

\[ \mathcal{U} \quad \text{Internal function: attitude towards “simple” risk} \]

\[ v' > 0 \quad v'' \leq 0 \]
WTP to avoid Index Insurance

\[ E_{f_y}[v(E_{f_{X/y}} u(IX))] = E_{f_y} u(y_I - \rho^t) \]
**Compound risk premium**

\[
E_{f_y} [v(E_{f_{X/y}} u(y_{I/X})] = E_{f_y} u(y_{I/X} - \rho^c)
\]

**Objective function**

\[
E_{f_y} u(y_{I/X})
\]
Basis risk premium

\[ E_{f_{yx}}u(y_{IX}) \]

\[ E_{f_y}u(y_I) \]

Objective function

**Basis risk premium**, \( \rho \), as a solution to:

\[ E_{f_{yx}}u(y_{IX}) = E_{f_y}u(y_I - \rho) \]
Testable hypothesis

- If $u$ is CRRA, then the 2nd order Taylor approximation of total WTP is:

$$
\left( \frac{\bar{I}}{r} + \rho^t \right)^2 \approx \left( \frac{\bar{I}}{r} + \rho \right)^2 + \left( \frac{\bar{X}}{r} + \rho^C \right)^2 - \left( \frac{\bar{X}}{r} \right)^2
$$

- If averse to compound risk, then WTP is larger than basis risk premium.
- If neutral to compound risk, then WTP is the same as the basis risk premium.
The experiments

Game 1
- Basis risk premium

Game 2
- WTP avoid index insurance

Versus
Farmers decide whether they want an individual insurance contract, if so they choose among 6 coverage levels.

Assuming CRRA and EUT, we can derive the WTP to avoid index insurance, which is also the basis risk premium.
Presenting the index insurance contract:

- Keep the price of the index insurance contract constant, vary the price of the individual insurance contract
- Elicit the price at which he will switch from the individual insurance contract to the index insurance contract
60% of the farmers are averse to compound risk

They are willing to pay up to 27% extra-premium for an individual insurance contract to compensate for 20% probability of absence of payment.
Policy implications

- cost effectiveness of index insurance
- Implications for impact evaluation of index insurance:
  - heterogeneity of farmers implies heterogeneous impacts
  - Offer alternative contracts for compound risk averse farmers?
Next step:

- More empirical work
- Predict the uptake of index insurance using the findings of the experiments
Thank you!
APPENDIX
The Basis risk premium

\[ E_{f_{y|x}} u(y_{IX}) = E_{f_y} u(y - \rho) \]

2nd order Taylor approximation:

\[ E u(y_{IX}) \approx u(\bar{y}_{IX}) + \frac{1}{2} \sigma_{y_{IX}}^2 u''(\bar{y}_{IX}) \]

\[ E u(y_I - \rho) \approx u(\bar{y}_I) - \rho \cdot u'(\bar{y}_I) + \frac{1}{2} (\rho^2 + \sigma_{y_I}^2) u''(\bar{y}_I) \]

Solving for basis risk premium:

\[ \rho \approx \frac{u'(\bar{y}_I) - \sqrt{\Delta}}{u''(\bar{y}_I)} \]

\[ \Delta = (u'(\bar{y}_I))^2 - 2 \cdot u''(\bar{y}_I) [u(\bar{y}_I) - u(\bar{y}_{IX}) + \frac{1}{2} \sigma_{y_I}^2 u''(\bar{y}_I) - \frac{1}{2} \sigma_{y_{IX}}^2 u''(\bar{y}_{IX})] \]
The Compound risk premium

\[ E_{f_y}[v(E_{f_{X/y}} u(y_{IX}))] = E_{f_y} u(y_{IX} - \rho^c) \]

2\textsuperscript{nd} order Taylor approximation:

\[ E_{f_y}[v(E_{f_{X/y}} u(y_{IX}))] \approx v(u(y_{\tilde{I}X}) + \frac{1}{2} \sigma^2_{y_{IX}} v''(u(y_{\tilde{I}X}))(u'(y_{\tilde{I}X}))^2 + \frac{1}{2} \sigma^2_{y_{IX}} v'(u(y_{\tilde{I}X}))u''(y_{\tilde{I}X}) \]

\[ E u(y_{IX} - \rho^c) \approx u(y_{\tilde{I}X}) - \rho^c * u'(y_{\tilde{I}X}) + \frac{1}{2} (\rho^c^2 + \sigma^2_{y_{IX}}) u''(y_{\tilde{I}X}) \]

Solving for compound risk premium:

\[ \rho^c \approx \frac{u'(y_{\tilde{I}X}) - \sqrt{\Delta^c}}{u''(y_{\tilde{I}X})} \]

\[ \Delta^c = (u'(y_{IX}))^2 - 2u''(y_{\tilde{I}x})[u(y_{\tilde{I}X}) - v(u(y_{\tilde{I}X})) + \frac{1}{2} \sigma^2_{y_{IX}} u''(y_{\tilde{I}X}) - \frac{1}{2} \sigma^2_{y_{IX}} v''(u(y_{\tilde{I}X}))(u'(y_{\tilde{I}X}))^2 - \frac{1}{2} \sigma^2_{y_{IX}} v'(u(y_{\tilde{I}X}))u''(y_{\tilde{I}X})] \]
\[ E_{f_y} [v(E_{f_{X/y}} u(IX))] = E_{f_y} u(y_I - \rho^t) \]

2\(^{nd}\) order Taylor approximations:

\[ E_{f_y} [v(E_{f_{X/y}} u(IX))] \approx v(u(y_{1X}) + \frac{1}{2} \sigma^2_{yIX} v''(u(y_{1X}))(u'(y_{1X}))^2 + \frac{1}{2} \sigma^2_{yIX} v'(u(y_{1X}))v''(y_{1X}) \]

\[ E u(y_I - \rho^t) \approx u(\bar{y}_I) - \rho^t * u'(\bar{y}_I) + \frac{1}{2} (\rho^t)^2 + \sigma^2_{\bar{y}_I} u''(\bar{y}_I) \]

Solving for WTP:

\[ \rho^t \approx \frac{u'(\bar{y}_I) - \sqrt{\Delta^t}}{u''(\bar{y}_I)} \]

\[ \Delta^t = (u'(y_I))^2 - 2* u''(\bar{y}_I) [u(\bar{y}_I) - v(u(\bar{y}_{1X})) + \frac{1}{2} \sigma^2_{y_I} u''(\bar{y}_I) - \frac{1}{2} \sigma^2_{y_{1X}} v''(u(y_{1X}))(u'(y_{1X}))^2 - \frac{1}{2} \sigma^2_{y_{1X}} v'(u(y_{1X}))v''(y_{1X})] \]
The yield distribution
## Game I

<table>
<thead>
<tr>
<th>Rendement</th>
<th>250</th>
<th>450</th>
<th>645</th>
<th>740</th>
<th>880</th>
<th>1530</th>
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<td>Sans assurance</td>
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<td>d10400</td>
<td>d18200</td>
<td>d22000</td>
<td>d27600</td>
<td>d53600</td>
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<th>d10280</th>
<th>d18080</th>
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<td>Contrat à 4 cubes (d2700)</td>
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**Game II: Eliciting the WTP**

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The index insurance contract

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<td>d27000</td>
<td>d53600</td>
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</tbody>
</table>

Contrat à trois sacs (d1740)

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<th>d18600</th>
<th>d18600</th>
<th>d20600</th>
<th>d25600</th>
<th>d52200</th>
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</thead>
<tbody>
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<td>d9000</td>
<td>d16800</td>
<td>d20600</td>
<td>d26200</td>
<td>d52200</td>
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</tbody>
</table>
Preliminary results