Weather-based Insurance Market Development: Challenges and Potential Solutions

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Weather-based insurance market development

- Weather based insurance (WBI) is better suited to cope with asymmetric information problems.
- Launch of first WBI pilots in India and Morocco in the early 2000s.
- Most of WBI contracts are designed to provide coverage against risk of drought.
- Rationale: to promote adoption of higher income but riskier technologies.
- Low participation of farmers in WBI.
What determines demand for WBI?

- Effectiveness of WBI
- Insurance costs
- Farm-specific factors
- Market development

How to improve WBI contract design to make WBI more effective and affordable for farmers?
WBI effectiveness & affordability

Critical aspects

- basis risk
- model prediction uncertainties
- presence of more affordable alternatives
How does it work?

- Selection of a weather index
- Indemnity payment (I): \( I = p \max [x_s - x, 0] \)

\( x \) is actual realisation of weather index

\( x_s \) strike level of the index

\( p \) is a tick size

if \( x \) falls below its strike value \( x_s \) the insurance pays: \( p[x_s - x] \)
Basis risk

- Mismatches between insurance payouts and actual yield losses
- Empirical investigations show that WBI
  - can provide considerable yield risk reduction
  - may be a good alternative to farm yield insurance
- Most studies use
  - aggregate yield data
  - measure risk reduction ex post
## Model prediction uncertainties

### Downside risk reduction: ex post vs. ex ante assessments

<table>
<thead>
<tr>
<th>sample means (40 farms)</th>
<th>farm insurance</th>
<th>national yield insurance</th>
<th>rayon yield insurance</th>
<th>weather-index insurance (Selyaninov)</th>
<th>weather-index insurance (Ped)</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean squared negative prediction error</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ex post approach</td>
<td>46%</td>
<td>52%</td>
<td>66%</td>
<td>35%</td>
<td>32%</td>
</tr>
<tr>
<td>ex ante approach</td>
<td>40%</td>
<td>19%</td>
<td>49%</td>
<td>-2%</td>
<td>20%</td>
</tr>
</tbody>
</table>

Bokusheva & Breustedt, 2012
Model prediction uncertainties

When ex-post risk reduction may exhibit a poor predictive power?

(a) historical time series might be too short to represent adequately the true joint distribution of yields and the underlying weather variable

(b) temporary changes in the joint distribution of crop yield and weather variables.
Use of lower cost alternatives

- Informal insurance
- Technological options

can be

- more effective
- affordable and
- sustainable in the long term
Is there any need for WBI?

- basis risk
- model prediction uncertainties
- presence of more affordable alternatives

WBI can be an effective instrument of coping with extreme weather events
Modeling yield-weather dependence

- Dependence structure can be different for extreme realizations compared to moderate values of a weather variable.
- Dependence of crop yields on weather can be modeled in a more consistent and flexible way by means of copulas.
- Standard regression analysis applies all realizations of the weather variable to estimate expected conditional yield, i.e.
  \[ \tilde{\mu} = E(Y|W = w) \]
- Use of copulas allows to condition expected yield on the weather realizations below a selected level of VaR of the weather variable, i.e.
  \[ \tilde{\mu}^* = E[Y|W \leq \text{VaR}_\alpha(W)] \]
Weather variable distribution
Cumulative rainfall distribution (April-July), Akmola weather station
Ways to model dependence structure

Joint distribution of cumulative rainfall and wheat yield for a study farm
Capturing adequate dependence structure

Empirical distribution

Gaussian copula with Normal margins, $r=0.69$

Gumbel surv. copula with Weibull margins, $\theta=2.11$
WBI rating by using copulas

- Two copula models: **survival Gumbel** and Joe copulas
- Contract design: 3 quantiles of the weather index distribution
  \[(q=0.1, 0.2, \text{ and } 0.3)\]
- Comparisons between 3 copula-based contracts and 3 regression-based contracts
- Risk reduction is measured in terms of expected shortfall (ES)
Data

- wheat yield data for 47 large grain producers from five counties (rayons) in Northern Kazakhstan, 1971-2010
- yield were tested for structural breaks and autocorrelation and detrended
- weather data from corresponding weather stations, 1971-2010 (one in each county)
- Two weather indices: Cumulative rainfall and Ped drought indexes
- Normal, Lognormal, Gamma, Logistic, and Weibull distributions to model marginal distributions
Downside risk reduction

Expected shortfall estimates

<table>
<thead>
<tr>
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<tr>
<td></td>
<td></td>
<td>q=0.1</td>
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<tr>
<td>copula-based contract</td>
<td>0.90</td>
<td>0.48</td>
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<tr>
<td>regression-based contract</td>
<td>0.66</td>
<td>0.29</td>
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![Graphs showing expected shortfall estimates for different quantiles](image_url)
Social welfare perspective

Effective and efficient not only from the farmer point of view

- More efficient instrument of disaster assistance than ad-hoc payments
- Reduction of negative impact on ecosystems
Conclusions

- Crop insurance should play a complementary role to other potentially more effective and sustainable strategies for risk reduction.

- WBI against catastrophic events can be more effective and demanded compared to standard WI contracts. Three important aspects:
  - coping with extreme events (limited alternative options)
  - willingness to pay
  - fast settlement of insurance claims

- Application of the copula approach might improve performance of weather index insurance designed to cope with extreme events.

- Selection of an adequate weather index is still an issue.
Weather-based insurance pilots map

based on Mahul & Stutley, 2010
Downside risk reduction by catastrophic WBI

Lower partial moment

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LPM, q=0.1

LPM, q=0.2

LPM, q=0.3
Changes in weather variable distributions

Summer temperature anomaly distribution

Hansen et al., 2012
Changes in the dependence structure

Rainfall deficit index
Wheat yields: 10 study farms
1961-1982 - blue line
1983-2003 - red dashed line

Bokusheva, 2011
Changes in the dependence structure

- Effect of climate change
- Long-term effect of a technology
- Decreasing resilience of eco-systems