Agricultural Insurance Pricing and Systemic Risk Transfer: Application to Forage Insurance in France

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Presentation

1. Introduction to Crop Yield Risk and Insurability
2. Literature Review : Systemic Risk Management
3. Models & Data
4. Results & Discussion

1. Introduction
1.1. Crop Yield Risk

Crop yield risk:

- Endogenous factors (farmers' practices and know-how)
- Exogenous factors bringing spatial correlation (weather, pests, wars, …)

Risk insurability:

- Data availability (towards index insurance?)
- Losses independance (pooling arrangement possible?)

1. Introduction
1.2. Towards a working insurance market

Miranda & al (1997):

- **the systemic nature of yield fluctuations causes insurance market failure**
- **Insurers need risk-sharing solutions**

Support & hedge from:

- State (last resort)
- Reinsurance companies (enough financial capacity?)
- Investors (Cat bonds?)

Aim : To transfer the systemic component of risk
Focus : How to include this transfer in the insurance pricing strategy

2. Literature Review
2.1. Systemic Risk Simulation

How may insurers account for the systemic risk in their risk assessment?

By introducing correlation between yields at several levels (country, states, counties)
- Mason & al (2001)

By using copulas for yield simulation
- Xu & al (2010a)

By considering covariances between the premiums of adjacent areas
- Shen & al (2013)

2. Literature Review
2.2. Systemic Risk Isolation

Systemic risk isolation to facilitate its transfer

Crop yield risk = Systemic and idiosyncratic components (either additive or multiplicative)

- Mahul (2001)

Classic yield decomposition : $z_{i,t} = \mu_i + \beta_i(z_t - \mu) + \varepsilon_{i,t}$

- Miranda (1991)
- $z_{i,t}$ is the yield of farm i on year t and μ_i its long-term average,
- z_t the yield taken at an aggregated level in year t and μ its long-term average,
- β_i is the correlation between the local yield $z_{i,t}$ and the aggregated yield z_t,
- $\varepsilon_{i,t}$ reflects the non-systemic variation of the local yield

3. Models & Data
3.1. Insurance Premium

Insurance Pure Premium:

$$\pi_i = \mathbb{E}\left[L_i(z_{i,t})\right] * \frac{1}{K_i} * insured\ capital$$

K_i: reference level of yield (includes the deductible : $K_i = \ \mu_{\boldsymbol{i}} * (1 - \alpha)$)

L : loss function, generally taken as :

$$L_i\left(z_{i,t}\right) = \left(K_i - z_{i,t}\right)^+ \qquad \text{Model (0)}$$

3. Models & Data
3.2. Systemic risk isolation

Aim : To isolate the systemic component of the risk

The loss function becomes :

$$\left(K_i - z_{i,t}\right)^+ = \left[K_i - (\mu_i + \beta_i(z_t - \mu) + \varepsilon_{i,t})\right]^+ \qquad \text{Model (0)}$$

$$= \left(\beta_i(\mu - z_t) + K_i - \mu_i - \varepsilon_{i,t}\right)^+$$

$$\leq [\boldsymbol{\beta}_{\boldsymbol{i}}(\boldsymbol{\mu} - \boldsymbol{z}_{\boldsymbol{t}})]^+ + \left[\boldsymbol{K}_{\boldsymbol{i}} - \boldsymbol{\mu}_{\boldsymbol{i}} - \boldsymbol{\varepsilon}_{\boldsymbol{i},\boldsymbol{t}}\right]^+ \qquad \text{Model (1)}$$

↑ Systemic part

3. Models & Data
3.3. A deductible for the transferred risk

The risk-sharing partners are not expected to intervene each year, a deductible on the transferred risk is introduced :

- $K = \mu * (1 - \alpha')$

$$\left(K_i - z_{i,t}\right)^+ = \left[K_i - (\mu_i + \beta_i(z_t - \mu) + \varepsilon_{i,t})\right]^+ \qquad \text{Model (0)}$$

$$= \left(\beta_i(\mu - K + K - z_t) + K_i - \mu_i - \varepsilon_{i,t}\right)^+$$

$$\leq [\beta_i(K - z_t)]^+ + \left[\beta_i(\mu - K) + K_i - \mu_i - \varepsilon_{i,t}\right]^+ \qquad \text{Model (2)}$$

or

$$\leq [\beta_i(K - z_t)]^+ + [\beta_i(\mu - \max(K; z_t))]^+ + \left[K_i - \mu_i - \varepsilon_{i,t}\right]^+ \qquad \text{Model (3)}$$

Systemic component to be transferred

3. Models & Data
3.4. Loss adjustment

$$(K_i - z_{i,t})^+ = [K_i - (\mu_i + \beta_i(z_t - \mu) + \varepsilon_{i,t})]^+ \quad \text{Model (0)}$$

$$= f(z_t) + \left((K_i - z_{i,t})^+ - f(z_t)\right) \quad \text{Model (4)}$$

With $f(z_t)$ taken from Models (1) or (2) depending on the risk transfer strategy:

$f(z_t) = [\beta_i(\mu - z_t)]^+$ for a full systemic risk transfer (Model (4a))

$f(z_t) = [\beta_i(K - z_t)]^+$ for a limited systemic risk transfer (Model (4b))

3. Models & Data
3.5. Summary

Model	Loss function $\boldsymbol{L_i(z_{i,t})}$
(0)	$L_i^{\,0}(z_{i,t}) = (K_i - z_{i,t})^+$
(1)	$L_i^{\,1}(z_{i,t}) = [\beta_i(\mu - z_t)]^+ + [K_i - \mu_i - \varepsilon_{i,t}]^+$
(2)	$L_i^{\,2}(z_{i,t}) = [\beta_i(K - z_t)]^+ + [\beta_i(\mu - K) + K_i - \mu_i - \varepsilon_{i,t}]^+$
(3)	$L_i^{\,3}(z_{i,t}) = [\beta_i(K - z_t)]^+ + [\beta_i(\mu - \max(K; z_t))]^+ + [K_i - \mu_i - \varepsilon_{i,t}]^+$
(4)	$L_i^{\,4}(z_{i,t}) = f(z_t) + \left((K_i - z_{i,t})^+ - f(z_t)\right)$

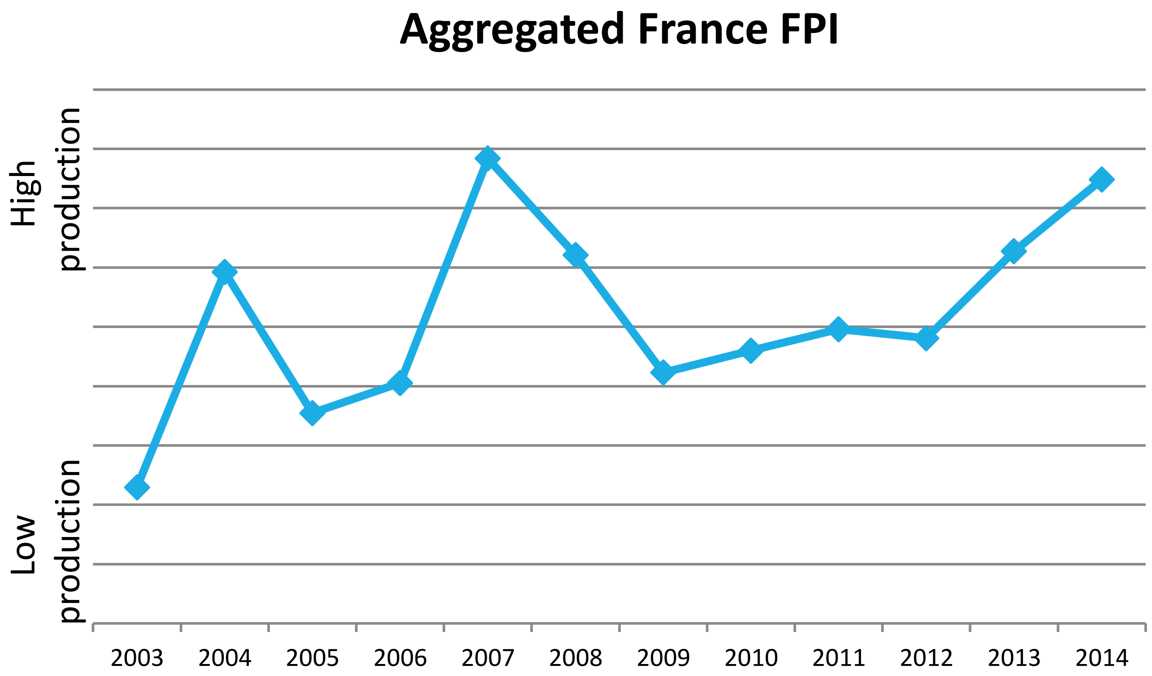
3. Models & Data
3.6. Index Presentation

The Forage Production Index (FPI)

- Remote-sensed indicator of biomass

- Available for every French zip-code (> 30,000)

Example of the index behavior over the years:



4. Results and Discussion
4.1. Premium levels (deductibles : α=20%; α'=30%)

Losses relative to the component :	Model (0)	Model (1)	Model (2)	Model (3)	Model (4a)	Model (4b)
$(K_i - z_{i,t})^+$	2.17% (100%)					
$[\beta_i(\mu - z_t)]^+$		4.97% (81%)			4.97% (229%)	
$[\beta_i(K - z_t)]^+$			0.4% (5%)	0.4% (7%)		0.4% (18%)
$[\beta_i(\mu - \max(K; z_t))]^+$				4.57% (75%)		
$[K_i - \mu_i - \varepsilon_{i,t}]^+$		1.17% (19%)		1.17% (19%)		
$[\beta_i(\mu - K) + K_i - \mu_i - \varepsilon_{i,t}]^+$			7.33% (95%)			
$(K_i - z_{i,t})^+ - f(z_t)$					-2.8% (-129%)	1.77% (82%)
Total pure premium	**2.17%**	**6.13%**	**7.73%**	**6.13%**	**2.17%**	**2.17%**

4. Results and Discussion
4.2. Loss variance (deductibles : α=20%; α'=30%)

The optimal pricing strategy is a trade-off between insurance policy cost and loss variation

	Model (0)	**Model (1)**	**Model (2)**	**Model (3)**	**Model (4a)**	**Model (4b)**
Premium levels	2.17%	6.13%	7.73%	6.13%	2.17%	2.17%
Coefficient of variation of the losses retained by the insurer	147%	98%	48%	121%	NC	144%

Perspectives

Systemic risk isolation and transfer:

- Improving insurers' risk knowledge and management
- Increasing insurers' involvement in the agricultural market
- Opening the door for new schemes of insurance risk transfer (cat bonds)

Thanks for your attention !