Risk in Agriculture: Modeling Revenue Insurance for Crop Farms in Belgium

Kristiana Hansen and Bruno Henry de Frahan

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Author Affiliations and Contact Information:

Kristiana Hansen
Dept. of Agricultural & Applied Economics
University of Wyoming
1000 East University Avenue
Laramie, WY 82070
USA

Bruno Henry de Frahan
Unité d'économie rurale
Université catholique de Louvain
Place de la Croix du Sud, 2/15
B-1348 Louvain-la-Neuve
Belgium

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Kristiana Hansen
University of Wyoming
Bruno Henry de Frahan
Université catholique de Louvain

1. Motivation

With recent reforms of the Common Agricultural Policy, farms within the European Union are increasingly exposed to the risk of fluctuations in output prices. We model the effects of a constructed revenue insurance scheme on farm gross margins and land allocation patterns among arable crop farms in the Region of Wallonia of Belgium.

2. Data description

Sample: A subset of 18 farms from the Farm Accountancy Data Network from 1995 to 2006.

Five output categories: chicory, other cereals, potatoes, sugar beets, winter wheat

Seven input categories: fertilizers, pesticides, seeds, contract services, other variable inputs (insurance, electricity, gasoline), capital (building, machinery), cropland

Three agricultural soil regions of Wallonia: Condroz, Sandy-Silty, and Silty (see map)

3. Method outline

3.1. Estimation of farm-specific *ex-ante* flexible cost functions

- Using a Symmetric Generalized McFadden functional form
- Using expected yields rather observed yields
- Imposing the theoretical restrictions without destroying global concavity in input prices
- Using the GMM estimator on a farm fixed-effect model

3.2. Simulation model

- Maximizing farm expected utilities of a profit function assuming constant relative risk aversion subject to farm-specific sugar quota and region-specific cropland availability
- Embedding each estimated farm flexible cost functions into each farm profit functions

3.3. Simulation of revenue insurance scenarios

- Using farm-specific probability distribution of yields-in-value for wheat observed between 1995 and 2006
- Different annual premia ranging from 0 to 10 €/ha in exchange for revenue insurance
- Revenue compensations triggered when yields-in-value lower than a proportion of farm-specific yield-in-value average from 0.5 to 0.9
- Insurance indemnities based on a proportion of farm-specific yields-in-value average

4. Simulation Model Specification

4.1. Deterministic Model

Farms choose a set of land allocations denoted by the function L, assigning a non-negative acreage to each cropping activity in C, so as to maximise farm gross margin. We indicate the land allocation assigned by L to a cropping activity m on farm f at time s by L_{ms} in the following basic objective function for a single farm:

$$\underset{L:C\to\Re_{\geq 0}}{Max}\left[\sum_{m\in C}\Theta_{mt}L_{ms}+S_t-\hat{C}_s(\ell_s,w_{rt},\hat{q}_t,t)-\varepsilon_t\right] \quad (1)$$

$Y_{ms} \leq \hat{Q}_{mt}L_{ms}$ Yield relationship for $m\in C$ (2)

$Y_{SUGQ,fs} \leq Y_{SUGQ,ft}$ In-quota sugar beet constraint (3)

Out-of-quota sugar beets (4)

$$Y_{SUGO,fs}/Y_{SUGQ,fs} = Y_{SUGO,ft}/Y_{SUGQ,ft}$$

Θ_{mt}	Observed yield-in-value for crop m
L_{ms}	Land allocated to crop m
S_t	Total farm subsidy
$\hat{C}_s(\ell_s,w_{rt},\hat{q}_t,t)$	Estimated farm cost function
ℓ_s	Vector of land allocations (L_{ms} is one element)
w_{rt}	Vector of input prices in region R
$\hat{q}_t$	Vector of expected crop yields ($\hat{Q}_{mt}$ is one element)
ε_t	Error term of the estimated cost function

4.2. Random Model: Expected Utility without Insurance

$$\underset{L:C\to\Re_{\geq 0}}{Max}\ EU_s=\int_0^{+\infty}\frac{1}{1-\rho_s}\left[\tilde{\Theta}_{Ws}L_{Ws}+\sum_{m\in C'}\overline{\Theta}_{mt}L_{ms}+S_t-\hat{C}_s(\ell_s,w_{rt},\hat{q}_t,t)-\varepsilon_t\right]^{1-\rho_s}f(\tilde{\Theta}_{Ws})d\tilde{\Theta}_{Ws} \quad (5)$$

$\tilde{\Theta}_{Ws}$	Random yield-in-value for winter wheat
$\overline{\Theta}_{m\neq Ws}$	Farm-specific yield-in-value average for crops $m\in C$
$f(\tilde{\Theta}_{Ws})d\tilde{\Theta}_{Ws}$	Probability density function for wheat yield-in-value
ρ_s	Risk aversion parameter (CRRA)

4.3. Random Model: Expected Utility with Insurance

We add revenue insurance to the model. In general terms, the expression for expected utility is the following:

$$\underset{L:C\to\Re_{\geq 0}}{Max}\ EU_s=\int_0^{\gamma_{Ws}}U\left[\pi_c(\ell_s,\tilde{\Theta}_{Ws},\overline{\Theta}_{m\neq Ws})\right]f(\tilde{\Theta}_{Ws})d\tilde{\Theta}_{Ws}+\int_{\gamma_{Ws}}^{+\infty}U\left[\pi_n(\ell_s,\tilde{\Theta}_{Ws},\overline{\Theta}_{m\neq Ws})\right]f(\tilde{\Theta}_{Ws})d\tilde{\Theta}_{Ws} \quad (6)$$

where:

$$U\left[\pi(\ell_s,\tilde{\Theta}_{Ws},\overline{\Theta}_{m\neq Wt})\right]=\frac{1}{1-\rho_s}\left[\phi_s\overline{\Theta}_{Ws}L_{Ws}+\sum_{m\in C'}\overline{\Theta}_{mt}L_{ms}+S_t-\beta_{Ws}L_{Ws}-\hat{C}_s(\ell_s,w_{rt},\hat{q}_t,t)-\varepsilon_t\right]^{1-\rho_s} \quad (7)$$

and

$$U\left[\pi(\ell_s,\tilde{\Theta}_{Ws},\overline{\Theta}_{m\neq Wt})\right]=\frac{1}{1-\rho_s}\left[\tilde{\Theta}_{Ws}L_{Ws}+\sum_{m\in C'}\overline{\Theta}_{mt}L_{ms}+S_t-\beta_{Ws}L_{Ws}-\hat{C}_s(\ell_s,w_{rt},\hat{q}_t,t)-\varepsilon_t\right]^{1-\rho_s} \quad (8)$$

γ_{ws} Insurance trigger below which farm receives fixed yield-in-value for wheat

ϕ_s Proportion of yield-in value average

β_{Ws} Per-hectare insurance premium

Objective functions in equations (5) and (6) are also subject to equations (2) to (4).

5. Questions of interest:

- For a reasonable range of values for the premium and payment trigger parameter would farms adopt revenue insurance if it were available?

- To what extent would a farm's expected utility and land allocation across crops change with an insurance mechanism compared to without an insurance mechanism?

6. Simulation results

Table 1. Percentage Change in Gross Margins with Insurance

Insurance trigger	Premium (€/ha)	Sandy-Silty	Silty	Condroz	Three-Region Total
φ=0.5	0	112.67	108.72	100.00	109.88
	5	104.43	103.06	100.00	103.47
	10	100.00	100.00	100.00	100.00
φ=0.7	0	112.67	109.25	100.00	110.26
	5	104.43	103.06	100.00	103.47
	10	100.00	100.00	100.00	100.00
φ=0.9	0	113.03	110.39	100.00	111.17
	5	104.46	103.27	100.00	103.62
	10	100.00	100.00	100.00	100.00

Table 2. Number of Farms that Take Advantage of Insurance

Insurance trigger	Premium (€/ha)	Sandy-Silty	Silty	Condroz	Three-Region Total
φ=0.5	0	2	5	0	7
	5	1	1	0	2
	10	0	0	0	0
φ=0.7	0	2	7	0	9
	5	1	1	0	2
	10	0	0	0	0
φ=0.9	0	3	8	0	11
	5	1	2	0	3
	10	0	0	0	0
Number of Farms		3	12	3	18

7. Concluding remarks

- Insurance may be of interest in the silty agricultural region, where yields are more variable.

- However, only when the cost of insurance is zero are most farms interested in acquiring it.

- Need to perform sensitivity analysis on other parameters

- Need to introduce random yields-in-value for other crops to observe the effect on model results

Contacts: khanse18@uwyo.edu
bruno.henrydefrahan@uclouvain.be