Dealing with corner solutions in multi-crop micro-econometric models: An endogenous switching regime approach with regime fixed costs

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Objectives

❖ **To present an econometric multi-crop model accounting for corner solutions in acreage choices with two original features:**

- This model is fully consistent from a microeconomic viewpoint. It defines farmers' production choice models as resulting from a profit maximization problem.
- This model accounts for production regime fixed costs, i.e. for implementation costs specific to the subset of produced crops.

Motivations

❖ **Corner solutions in acreage choices are pervasive in multi-crop production datasets and raise significant modelling issues**

- The numerous null acreages observed in farm level crop production datasets (see, e.g., Table 1) must be modelled as farmers' choices.
- Yield and input use levels are not observed for the crops not produced by farmers. As these unobserved netput levels might explain why farmers don't produce some crops, endogenous selection issues arise.

❖ **While acreage choices with corner solutions are modelled as censored regression systems (CRS) …**

- See, e.g., Fezzi and Bateman (2011) or Platoni *et al* (2012).
- CRS models addresses the corner solution issue from a statistical viewpoint but they lack economic consistency (Arndt *et al*, 1999).
- To understand why farmers choose to produce or not some crops is crucial for studying policies aimed at fostering crop acreage diversification.

❖ **… we propose an Endogenous Regime Switching (ERS) approach**

- The production regime of an observation is defined as the subset of crops actually produced in this observation.
- In the considered ERS model:
  - Farmers are assumed to select the profit maximizing production regime, according to standard producers' theory assumptions.
  - An acreage choice model is defined for each feasible production regime, an feature of the ERS approach that eliminates the inconsistencies arising with the CRS approach.
  - Fixed regime fixed costs can alter farmers' regime choices. Such fixed costs account for crop marketing costs or/and for specific constraints imposed by production regimes.

Data

Table 1: Descriptive statistics (779 farmers, 2006-2011, in northern France)

Regime number	Crops produced in the regime: Winter crops	Corn	Spring Barley	Sugar beet	Alfalfa	Peas	Rape-seed	Regime frequency	Average gross return (€/ha)
1	■	■	■	■	■	■	■	5.3%	767
2	■		■	■	■	■	■	16.6%	797
3	■	■	■	■	■		■	10.9%	851
4	■		■	■	■		■	43.8%	884
5	■	■	■	■			■	4.4%	868
6	■	■	■				■	4.3%	719
7	■		■	■			■	6.6%	870
8	■		■	■	■			2.8%	997
9	■	■					■	2.8%	765
10	■		■				■	2.5%	648
Average acreage share	38.6%	2.6%	18.7%	14.7%	8.9%	1.1%	15.4%		

Theoretical modelling framework

❖ **Farmers' acreage choice problem, basic assumptions:**

- Farmers are assumed to be expected profit maximizers**.** They consider the crops included in the crop set $\mathcal{K}$ and the production regimes included in the feasible regime set $\mathcal{R}$.
- Farmers simultaneously choose the crop set to be produced and the acreages of the produced crops. Crops with null acreages are simply those that are not produced

❖ **Farmers' acreage choice problem, decomposition:**

- Farmers' acreage choice problem can be decomposed into two steps according to a backward induction approach
- **Step 1**: Computation of the optimal profit level in each feasible regime. This steps yields, for each feasible regime r, the optimal acreage choices:

$$\mathbf{s}^*(r) = \arg\max_{\mathbf{s}\geq 0}\left\{\begin{array}{c}\sum_{k\in\mathcal{K}} s_k\pi_k - C(\mathbf{s})\\ \text{s.t.}\\ \sum_{k\in\mathcal{K}} s_k = 1 \text{ and } s_k = 0 \text{ for } k\in\mathcal{K}^0(r)\end{array}\right\}$$

and the congruent expected profit level:

$$\Pi^*(r) = \sum_{k\in\mathcal{K}} s_k^*(r)\pi_k - C\left(\mathbf{s}^*(r)\right)$$

where:

s_k : acreage share of crop k with $\mathbf{s} \equiv (s_k : k\in\mathcal{K})$

π_k : expected return of crop k

$C(\mathbf{s})$: implicit management cost of acreage $\mathbf{s}$

$\mathcal{K}^0(r)$: subset of crops not produced in regime r.

- **Step 2**: Computation of the optimal production regime, regime fixed costs included

$$r^* = \max_{r\in\mathcal{R}}\left\{\Pi^*(r) - g(r)\right\}$$

where:

$g(r)$: fixed cost of implementing production regime r.

- Of course, farmers' optimal acreage choice is that defined by the optimal acreage choice in the optimal regime, $\mathbf{s}^*(r^*)$.

Structure of the ERS multi-crop model

❖ **The ERS multi-crop econometric model is composed of six parts**

1. **A system of crop yield supply equations describes the yield levels obtained by farmers.**
   - The crop yield supply models define famers' crop yield levels as crop functions of the crop and variable input prices.
   - Only the observed yield levels are modelled.
2. **A system of crop variable input demand equations describes farmers' variable input uses**.
   - The variable input demand models define famers' crop yield levels as crop functions of the crop and variable input prices.
   - Only the observed input uses are modelled.
   - In the application, fertilizers, pesticides and seeds are aggregated in single variable input
3. **The crop expected returns are constructed within the model.**
   - They are obtained from the data and the parameters that are estimated in the yield supply and variable input demand equation systems.
   - These returns are the main drivers of farmers' acreage choices.
4. **A system of acreage share choice equations describes the acreages of the crops that are produced by farmers**.
   - The crop acreage choice models are defined as functions of the crop expected returns.
   - The functional of this acreage share equation system depends on the regime of the modelled crop acreage.
5. **The regime expected profit levels constructed within the model.**
   - There are obtained from the data, the estimated crop returns and the parameters that are estimated in the acreage choice equation system.
   - These regime expected profit levels are, together with the regime fixed costs, the main drivers of farmers' regime choices.
6. **A probabilistic discrete choice model describes farmers' production regime choices**.
   - This model is specified as a standard discrete choice model.
   - It assumes that farmers choose the regime that yields the maximal profit level, regime fixed cost included.

❖ **Specification details:**

- The crop yield supply and variable input demand models (and the related crop expected returns) are obtained by assuming **quadratic yield functions** (see, e.g. Carpentier and Letort, 2014).
- The acreage shares are modelled as (3 level) **Nested Multinomial Logit acreage shares** (see, e.g. Carpentier and Letort, 2014).
  - This modelling is especially suitable for ERS models as it yields the regime profit levels in (smooth) analytical closed forms.
- The ERS multi-crop model are defined as **random (farmer specific) parameter model** for accounting for farms and farmers' unobserved heterogeneity.
- The estimated ERS multi-crop econometric model is fully parametric. This allows for constructing farm specific simulation models based on the farm specific parameter estimates.

❖ **Estimation details:**

- Estimates of the model parameters are obtained from a Maximum Likelihood estimator that is computed via the Stochastic Approximate Expectation-Maximization algorithm of Delyon *et al* (1999), with:
  - The random parameters are simulated with the Importance Sampling approach proposed.
  - The regime choice probability functions (conditionally on the random parameters) are integrated by using Laplace expansions..
  - The observed yield and input used levels are accounted for by using standard incomplete data EM algorithm.
- Because all production choices are interrelated the ERS multi-crop model cannot be broken into independent estimation sub-procedures.
  - In particular, the observed production choices – yields, input uses and acreages of the produced crops – cannot be considered without the production regime model due to endogenous selection issues

Selected results

❖ **Fit performances of the estimated model**

- Most of the model parameter are precisely estimated.
  - In particular, these results also show that unobserved heterogeneity matters as the farm specific parameters significantly vary across farms
- Fit criteria tend to show that the model with farm specific parameter estimates reproduce the observed production choices relatively well
  - Around 75% of the observed regime choices are correctly predicted.

❖ **Production regime fixed costs matter**

- Comparisons of the model estimates with and without regime fixed costs and simultations clearly show that :
  - The regime fixed costs play a crucial role for predicting the regime choices, in combination with the estimated regime profit levels
  - These costs especially matter for the less frequent regime choices

❖ **Regime switching accounts for a significant part of farmers' acreage share responses to economic incentives**

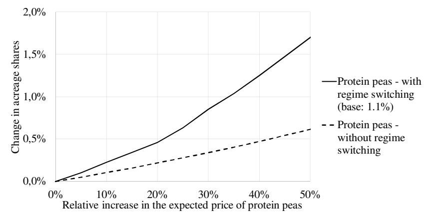
- Crop acreage own-price elasticities can be decomposed as the sum of
  - The acreage share elasticity holding production regimes constant
  - The expected change due to regime switching holding the regime acreage levels constant
- For instance, around 50% (25%) of the average pea (sugar beet) acreage elasticity is due to regime switching in our sample (see Table 2)

Table 2: Average own-price crop acreage elasticities

	Winter wheat	Corn	Spring barley	Sugar beet	Alfalfa	Peas	Rape-seed
Average acreage share	38.6%	2.6%	18.7%	14.7%	8.9%	1.1%	15.4%
Production frequence	100%	29%	97%	90%	79%	22%	98%
Average acreage own price elasticity	0.51	3.84	0.82	2.72	0.95	1.50	1.06
Due to acreage changes within regimes	0.50	2.94	0.75	2.19	0.78	0.91	1.00
Due to switches across regimes	0.00	0.90	0.07	0.53	0.17	0.59	0.06

- A protein price increase would increase the average acreage share of this crop (see Figure 1):
  - Regime switches would account for about half (two thirds) of the acreage increase following a 20% (50%) price increase

Figure 1: Average effects of pea price increases on the pea acreage shares



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