The CAP Mid-Term Reform Impacts to French Cereal-Oriented Farms

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Abstract

The agricultural policy reform to be implemented by 2005, has been marked by a three-step process, a first proposition of the E.C. in July 2002, then an adaptation of that proposition in January 2003 that clearly alleviated the economic impacts and finally the Luxembourg compromise in June 2003. In order to provide insights for discussion in the French Ministry of Agriculture and the farmers' professional organisations, cereal-oriented farms in central regions of France, which are particularly sensitive to agricultural policy, have been studied. 'Ex ante' simulations have been run using a regional model of sequential linear programming that optimises over the annual farmers' incomes in the period 2002-2012 integrating as well the evolution of farm structure. Thanks to the interrogation of this tool, the impacts of the reform have been estimated on a) crop mix especially regarding cereal and crop precedent in rotation, b) on agricultural incomes per hectare and farm, c) possibilities of land left idle, and d) evolution of farm structure and number of farms.

It can be concluded that the final compromise on the C.A.P. stabilises the farmers' income in the 2012 horizon due to the size adjustment upwards of cereal farms under the condition that agro-environmental measures do not penalise them and that rapeseed prices keep increasing. Re-coupling to avoid idle land is no more necessary after the Luxembourg compromise whereas farm business disappearance does not seem to accelerate. Enlargement and mechanical equipment economies of scope may be the proper response to new conditions and in any case decoupling is not expected to enhance the extensive use of the land factor, intended by the proponents of the eco-conditionality of subsidies.

Keywords: CAP, Linear programming, cereals, oil crops.

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Introduction

A sample of cereal-oriented farms of the intermediate regions[1] has been chosen since they are highly sensitive to changes brought by the Common Agricultural Policy (CAP). This situation results from three main characteristics:

First, these farms show moderate agricultural incomes at 146€/ha in 2002, highly dependent on cereal prices and CAP payments; the latter amount to 346€/ha, which represents more than twice the agricultural income.

Secondly, the production involves homogeneous rotations dominated by cereals (55%) and oil crops (35%). Yields are moderate: in 2002, the means were 73q for wheat and 33q for rapeseed.

Then, it can also be pointed out that an important part of the land in these regions is set aside (close to the obligatory 10% level) since there are few crops outside the surface cultivated by cereal, oil crops and pulses.

Last, these regions are characterised by large-sized farms (mean size of 154 ha), with 104 hectares by unit of labour. The latter ratio ranges from 50 to more than 170 ha/UL. The average fixed costs amount to 546€/ha (see table 1).

Table 1. Structural characteristics of the reference sample (2002)

	Number of farms	Average area (ha)	Fixed costs (€/ha)	Head of farms' average age
Less than 50 ha	21	40	365	57
50 to 99 ha	112	84	539	47
100 to 149 ha	88	123	555	43
150 to 199 ha	76	179	499	46
More than 200 ha	101	263	576	46
Total	398	154	546	46

Agenda 2000 had already severely hit the agricultural incomes of these farms by reducing the payments of the oil crops to the cereals' level. The loss of income has been estimated to 150€/ha of oil crops (Sourie, 2002). Moreover, due to their large size and their small number of workers, these farms have also been highly penalised by the modulation of the payments set up in 1999 in order to finance for the Environmental Contracts[2].

[1] Regions located around the *Bassin Parisien*

[2] *Contrats Territoriaux d'Exploitation, CTE*. Contract signed between the farmer and the State.

Methodology and mathematical formulation

General architecture of the model

A regional model[3] has been developed to represent the arable agricultural sector using linear programming to cope with decision making within different productive units. These units are independent farms in a context of perfect competition such as in the arable agriculture sector. This sector model is built upon a common sort of structure which arises in multi-plant models, known as a block angular structure. One common row is always the objective row whereas diagonally placed blocks of coefficients denote sub-models, each one corresponding to a representative farm. It is supposed that there are no other common rows (or common constraints), that is there is no question of allocation of scarce resources across farms. Therefore optimising this model it simply amounts to optimising each sub-problem with its appropriate portion of the objective that is equivalent to treating each farm as autonomous. However, the farms are linked together by a global land constraint.

The model takes into account the heterogeneity of cereal oriented farms and simulates their adaptation regarding the rotation of crops and the structures as well.

Price and Yields hypothesis

According to the hypothesis regarding the evolution of prices, payments and yields (table 2), the model maximises the sum of agricultural incomes from a group of professional farms (398 farms) representative of the regions studied.

Table 2. characteristics of the sample for year 2002

Area (ha)	154
Wheat yield (q/ha)	73
Rapeseed yield	33
Wheat price (€/q)	9.5
Rapeseed price (€/q)	19.8
Wheat gross margin (€/ha)	729
Rapeseed gross margin (€/ha)	678
Variable costs (€/ha)	286
Gross margin (€/ha)	692
Fixed costs (€/ha)	546
Agricultural income (€/ha)	146
Coupled payment (€/ha)	346

[3] The software GAMS IDE has been chosen to run the model.

This maximisation is subject to a number of constraints at the elementary farm level regarding the land, the rotation of crops, the outlets and the set-aside. The optimal activity levels illustrate in an annual basis (from 2002 through 2012) the evolution of the crop mix and the main economic figures (gross margins, agricultural incomes). The model also takes into account endogenously an evolution of the structures and the number of farms, thus giving an insight into the scale effects.

At the end of each annual optimisation period, simple rules are applied to control the evolution of the number of farms and their structure.

Thus, the disappearance of a farm may occur either when the head of the farm retires (the retiring age is set at 65 years) or if the income by worker is lower than 15 000€. Moreover, a farm may disappear if its debt rate is higher than 80% or if the agricultural income becomes negative.

In the model, the enlargement of the farm may only occur if its debt rate is lower than 65%. The ratio "Agricultural area/Workers" limits the possible enlargement: this ratio can't exceed 170ha/worker. The enlargement only implies a small fall in the labour fixed costs per hectare[4].

The land made available by the farms that have disappeared are then taken over by the remaining farms that show the best marginal valorisation of their land.

Equations of the model

The function being maximised is the total agricultural income.

The program writes simply, as shown below:

$$\underset{\{X_1, X_2, \ldots, X_f, \ldots, X_F\}}{MAX} \sum_{f \in F} \left({}^{t}\mathrm{M}_f . X_f \right)$$

$$s.t. \begin{Bmatrix} A^{(1)}.X_1 \leq B_1 \\ \vdots \\ \vdots \\ A^{(f)}.X_f \leq B_f \\ \vdots \\ \vdots \\ \vdots \\ A^{(F)}.X_F \leq B_F \end{Bmatrix} and \sum_{f \in F} \left(E_f + AA_f \right) \leq \overline{AA} \tag{1}$$

[4] The FADN data suggest that an enlargement doesn't lead to a fall in mechanization fixed costs.

where:

$$\forall f \in [\![1,F|]\!]\ {}^{t}X_f = \left(x_{1,f},\ldots,\ldots,x_{c,f},\ldots,\ldots,x_{C,f},\sigma_{C+1,f},\ldots,\ldots,\sigma_{C+j,f},\ldots,\ldots,\sigma_{C+J,f}\right)$$

X_f is the vector of R_+^{C+J} containing the areas dedicated to each crop $\{x_c\}_{c\in[\![1,C|]\!]}$ and the binary variables related to the structure of the farm $\{\sigma_{C+j}\}_{j\in[\![1,J|]\!]}$ in farm f.

The structure activities are binary variables which describe the state of the farm, namely: enlargement, farm with idle land, farm with cropping activities (J=3).

$$\forall f \in [\![1,F|]\!]\ {}^{t}M_f = \left(\mu_{1,f},\ldots,\ldots,\mu_{c,f},\ldots,\ldots,\mu_{C,f},-\eta_{C+1,f},\ldots,\ldots,-\eta_{C+j,f},\ldots,\ldots,-\eta_{C+J,f}\right)$$

M_f is the vector of R^{C+J} containing the gross margins related to each crop $\{\mu_c\}_{c\in[\![1,C|]\!]}$ and the fixed costs related to each structure activity of the farm $\{\eta_{C+j}\}_{j\in[\![1,J|]\!]}$ in farm f.

$$\forall f \in [\![1,F|]\!]\ A^{(f)} = \begin{pmatrix} a_{1,1}^{(f)} & \cdots & \cdots & \cdots & \cdots & a_{1,C}^{(f)} & a_{1,C+1}^{(f)} & \cdots & \cdots & a_{1,C+J}^{(f)} \\ \vdots & \ddots & & & & & & & & \vdots \\ \vdots & & \ddots & & & & & & & \vdots \\ \vdots & & & \ddots & & & & & & \vdots \\ \vdots & & & & a_{k,h}^{(f)} & & & & & \vdots \\ \vdots & & & & & \ddots & & & & \vdots \\ \vdots & & & & & & \ddots & & & \vdots \\ \vdots & & & & & & & \ddots & & \vdots \\ \vdots & & & & & & & & \ddots & \vdots \\ a_{K,1}^{(f)} & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & a_{K,C+J}^{(f)} \end{pmatrix}$$

each row $R_k, k \in [\![1,K|]\!]$ contains the technical coefficients related to constraint k. each column $C_c, c \in [\![1,C|]\!]$ contains the technical coefficients related to the crop c.
each column $C_{C+j}, j \in [\![1,J|]\!]$ contains the technical coefficients related to the binary activity j

$$\forall f \in [\![1,F|]\!]\ {}^{t}B_f = \left(b_{1,f},\ldots,\ldots,b_{k,f},\ldots,\ldots,b_{K,f}\right)$$

B_f is the vector of R^K containing the upper bounds of the constraints in farm F.

The different crops are as shown below:

$$\{C\} = \begin{pmatrix} \text{barley, wheat, industrial wheat, industrial wheat on set - aside land,} \\ \text{rapeseed, industrial rapeseed, industrial rapeseed on set - aside land,} \\ \text{winter barley and spring barley, sunflower, industrial sunflower,} \\ \text{industrial sunflower on set - aside land, field bean, peas} \end{pmatrix}$$

Finally, we denote E_f is the area gained by farm f (in ha), E_f as the area of farm f before gaining size and AA as the total agricultural land considered in the sample.

Assessing the variable costs per crop

One of the most important data needed in the model are the gross margin per hectare and per crop, i.e. $\{u_c\}_{c\in[\![1,|C|]\!]}$. Thanks to the FADN, the quantity of each crop, as well as the price at which it is sold are known. The problem lies in determining the variable costs for each crop, in each farm, which we will name $\Psi_{c,f}^{estimated}$.

This latter piece of information is not available in the FADN, at least not directly. The FADN only enables us to know the total expenses at the farm level for three inputs, namely fertilizers, pesticides and seeds. For the model to be implemented, it was then necessary to apportion the total expenses of inputs at the farm level for each crop *c*.

For the distribution of the total costs of inputs towards each crop to be feasible, it was necessary to add an exogenous data to the available FADN data: the **objective** variable costs per crop (and per ha) $\Psi_{c,f}$.

They are obtained as follows:

- First, a regression is conducted thanks to technical and economic information given by agricultural accounting centers. A linear relation is derived giving variable costs by crop function of the yield. $\overline{\Psi_c} = \beta.Y_c + \alpha$ (2)
- Second, we generate the values $\Psi_{c,f}$ for each farm, using the linear relation above, and adding a Gaussian residue $\varepsilon_{f,c}$ whose probability law is $N(0,1)$: $\Psi_{c,f} = \beta.Y_{f,c} + \alpha + \varepsilon_{f,c}$ (3)

Having these supplementary data, it is now possible to estimate the variable costs per crop $\Psi_{c,f}^{estimated}$.

For this purpose, a minimisation of the (weighted) absolute values of the gap between the **objective** and the **estimated** variable cost is led.

The objective is to minimise the subsequent function, in each farm *f*.

$$\forall f \in \mathrm{F},\ \Phi_f = \sum_{c\in C}\left(\rho_c \times \overline{\theta}_{c,f} + \rho_c \times \underline{\theta}_{c,f}\right) + \sum_{l\in L}\left(\alpha_{l,f}^{+} + \alpha_{l,f}^{-}\right) \quad (4)$$

This equation is constrained by three equalities (or inequalities):

$$\forall l \in L,\ \ \Omega_{l,f} = \sum_{c \in C} z_{l,c,f} \times A_{c,f} + \alpha^{+}_{l,f} - \alpha^{-}_{l,f} \tag{5}$$

$$\forall c \in C, \begin{cases} \Psi_{c,f} \leq \sum_{l \in L} z_{l,c,f} + \overline{\theta}_{c,f} \\ and \\ -\Psi_{c,f} \leq -\sum_{l \in L} z_{l,c,f} + \underline{\theta}_{c,f} \end{cases} \tag{6}$$

$$\forall (l,c) \in L \times C, \begin{cases} z_{l,c,f} \leq z^{MAX}_{l,c} \\ and \\ z_{l,c,f} \geq z^{MIN}_{l,c} \end{cases} \tag{7}$$

Where:

- ρ_c is the economic weight given to crop c, regarding its importance in the farm's total income
- $\Omega_{l,f}$ is the total expenses of farm *f* for input *l* (data directly given by the FADN).
- $A_{c,f}$ is the area in ha for crop *c* in farm *f*.
- $\Psi_{c,f}$ is the **objective** variable cost per crop *c*, in each farm *f*.
- $z_{l,c,f}$ is the variable cost in €/ha for input *l*, concerning crop *c*, in farm *f*.
- The **estimated** variable cost per crop *c*, $\Psi^{estimated}_{c,f} = \sum_{l \in L} z_{l,c,f}$ must converge towards $\Psi_{c,f}$.
- $\overline{\theta}_{c,f}$ (respectively $\underline{\theta}_{c,f}$) is the maximal gap in absolute value between $\Psi_{c,f}$ and $\Psi^{estimated}_{c,f}$
- $\alpha^{+}_{l,f}$ (respectively $\alpha^{-}_{l,f}$) is the positive gap (respectively negative) between the total variable cost for input *l* in farm *f*: $\Omega_{l,f}$ (which is a data available from FADN) and the value stemming from the estimated variable cost per each crop.

Rules for the sequential model

The major interest of this modelling certainly lies in the possibility of the farms sample to evolve from year *y* to year *y+1*. Here we describe more thoroughly the way this evolution operates.

Once an optimal solution is reached for year *y*, some modifications are brought into the model, i.e. some farms disappear either because of age reaching retirement (if the head of the farm is older than 65), or because of excess indebtness or because of insufficient incomes.

Rules for Enlargement

As far as enlargement is concerned, six main rules apply to manage the farms: a) Structures must stay within boundaries b) The maximum reachable size should not exceed 170ha/worker, c) The annual enlargement may not exceed 20% of the total agricultural area of the farm, d) No enlargement is possible if the debt rate exceeds 65%, e) A farm with idle land cannot gain size and f) The fixed costs by hectare are constant, except for workers fixed costs, which decrease with the total area.

Rules for farms' disappearance

The rules about farms' disappearance are the following: a) A farm excessively indebted will disappear (irrespective of the head of the farm's age), b) A farm whose manager is older than 65 years old will disappear if a minimum level of incomes is not met, c) Conversely, if the age of the manager is greater than 65 and a minimum threshold of incomes is crossed, the farm will be taken over by a younger manager (35 years old).

Rules for a farm with idle land

The management of the possibility of idle land imposes the following rules to the model: a) The choice to have some idle land cannot be partial (if only a part of the farm is idle land, the decrease of fixed costs is not sufficient): either the entire area is idle, or the land is occupied by crops (except for the 10% to 30% of set-aside land), b) A farm with its land gone idle saves on fixed costs, but cannot increase its area nor go back into the production process. c) Of course, such a farm may disappear in the subsequent years.

Hypotheses and scenarios chosen

Scenario 1 (EC Proposal of January 2003)

This scenario is characterized by a total decoupling, a fall in the intervention price from 101€/t to 95€/t, partially compensated by a supplementary payment of 3€/t (over a total payment of 346€/ha) to the surface cultivated by cereal, oil crops and pulses. The payments are graded and modulated according to 2 levels of income: 12.5% in year 2012 for the bracket 5 000€-50 000€ and 19% beyond 50 000€.

Scenario 2 (June 2003's compromise)

The intervention prices are maintained at 101€/t, but the supplementary payments of 3€/t for the surface cultivated by cereal, oil crops and pulses as well as the 50% monthly increased allowance disappear. The gradation (modulation) also disappears; a 5% modulation is maintained, which can be implemented in 2007.

Scenario 2'

Same as above, the only difference lies in the fall in oil crops prices for food and energy crops so as to anticipate a durable low-prices situation on the world food markets.

Table 3. key figures of the CAP scenarios studied

	Scenario 1 EC Proposal, January 2003		Scenario 2 Compromise, June 2003		Scenario 2 bis
Year	**2002**	**2012**	**2002**	**2012**	**2012**
Wheat price (€/t)	95	81	95	87	87
Rapeseed price (€/t)			198		175
Sunflower price (€/t)			213		192
Average payment (€/ha)	346	309	346	328	328
Wheat yield (t/ha)	73	84	73	84	84
Rapeseed yield (t/ha)	32	35	32	35	35

In year 2012, the price of wheat received by the farmers is fixed at the intervention level. The prices of the other cereals are indexed on wheat.

We assume that technical progress enhances yields of wheat to increase by 1 q/year, whereas this increase amounts to 0.3q/year as far as rapeseed is concerned. Gains in value terms are compensated at a level of 20% by a rise in the use of inputs.

Results

The risk of idle land

Contrary to the coupled payments, the decoupled payments are not conditioned to any productive activity. Therefore, a farmer may want to set aside the entire land of his farm if the economies in fixed costs exceed the loss in gross margin, since only minimal equipment and labour is needed to maintain the land in good conditions.

Scenario 1 optimal solution leads to idle land for 9% of the farms (8% of the total area). Such farms are smaller than the average and have higher fixed costs (150 to 200 €/ha higher than the average). In order to avoid this situation, the model shows that a 25% re-coupling is necessary. On the other hand, the idle land rate is highly sensitive to the cereals' prices. That's why scenario 2 leads to no idle land.

Anticipating the evolution of agricultural incomes

As a matter of fact, it is quite difficult to foresee what the agricultural markets will look like by 2012. The prices scenarios have therefore been chosen voluntarily low, so as to try to assess a reasonable risk level for farmers. The scenarios chosen are quite different from EC's prospective studies (Prospects for Agricultural Markets 2002-2009, June 2002).

The amounts taken off the incomes in scenario 1 exceeded by far the rise in incomes per hectare but also per farm, in spite of the scope effects that stem from enlargement. Thus, the income's index (starting from 100 in 2002) ends down to 88.7 by year 2012.

With scenario 2, the agricultural income per farm should remain even or increase a little (+4%). However, incomes per hectare will go down, from index 100 to 91.2. This evolution shows fixed costs that decrease from 540€/ha to 527€/ha, caused by the hypothesis of a better efficiency of permanent agricultural workers. This trend is general; however, the farms that won't be able to enlarge nor diversify their activities are bound to be hit by a significant damage in their incomes.

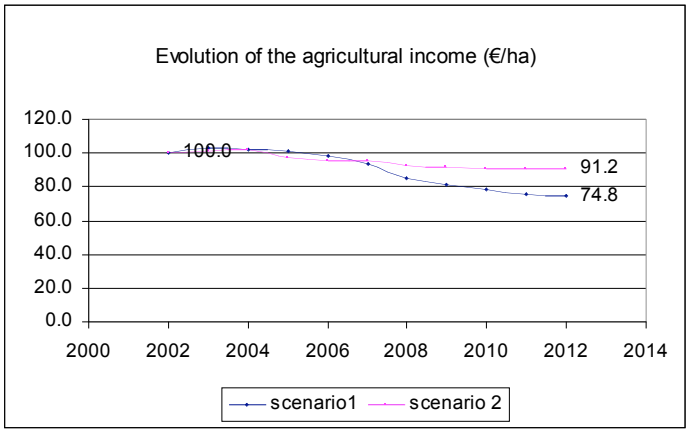

Figure 1.

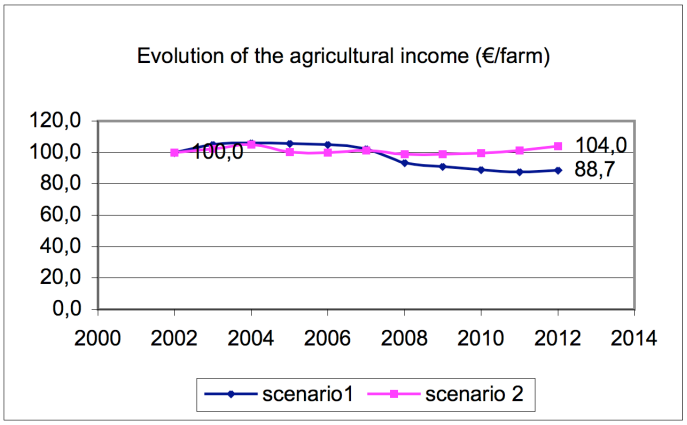

Figure 2.

Evolution of the structures

Both scenarios lead to similar evolution in the structures. This rigidity stems from the fact that the farms' disappearance only occurs when the head of farm retires and strongly depends on the population pyramid. Moreover, the disappearance will mainly hit the small farms (this stems from the rule of the 15,000 € ratio of agricultural income per unit of worker). However, this kind of farms are scarce in the panel studied.

Finally, the number of farms decreases by 12% (i.e. -1.3% by year) and the area increases by 22% (i.e. +1.4% by year). Indeed, it may be observed that the rate of farms' disappearance as far as cereal-oriented farms are concerned used to be higher (-20% in the 1990-1999 period, Blogowski, Pingault, 2002), even if the latter period was characterized by massive pre-retirements. The results from the simulation may lead to think that a slowdown in the disappearance pace be observed in the years to come.

Evolution in rotation and techniques

In spite of the flexibility brought in the rotations thanks to the possibility of cropping "second winter wheat" the de-coupling scarcely modifies the equilibrium between cereals and oilseeds. This result is hardly surprising since the pre-reform payments were identical.

Areas cropped in "second winter wheat" don't exceed 10% of the area of wheat involved in agronomic rotations. As far as durum wheat is concerned, its areas are maintained in spite of the suppression of its specific additional payment but thanks to its high level of prices.

Rapeseed cropped for energy purposes[5] is important in this region since it permits to reduce set-aside land. The reform stimulates the production of energetic rapeseed outside the mandatory set-aside with a 45€/ha carbon premium. This incentive could be effective if the supply of energy crops should exceed the production possibility set that represents the mandatory set-aside land or if the rate of set-aside land should decrease.

Effects of a price decrease for food and non-food oilseeds

Oilseeds (rapeseed mainly) are important crops in these regions. If the market perspectives are less positive than the EC's predictions, the model shows the subsequent results as far as supply of cereals and oilseeds, as well as agricultural incomes are concerned:

Table 4. Impacts of a fall of oilseeds prices

	Scenario 2	Scenario 2 bis
Year	2012	2012
Percentage of cereals	54.6	56.8
Percentage of oilseeds	39.9	38.2
Income per ha (100 in 2002)	88.7	82.0
Income per farm (100 in 2002)	104.0	94.0

The incomes per hectare decrease quite notably, the incomes per farm as well; the latter decreases faster than the per hectare income since no enlargement can compensate for the drop

[5] For a more detailed study of energy crops, see Tréguer (2004).

in oilseeds prices. The equilibrium between cereals and heads of rotations is modified in favour of the cereals, but no "explosion" of the area cropped in cereals is observed, in spite of the technical possibility of this eventuality brought in by the "wheat on wheat" possibility.

Conclusions

The Luxembourg compromise (scenario 2) has modified the most damageable measures contained in the initial EC proposal, as far as cereal-oriented farms of the intermediate regions are concerned, that is to say the fall in the intervention price and in the payments. With scenario 2, it may be observed that the average agricultural income (in constant €) will remain even by 2012 thanks to enlargement. This is conditioned to the fact that cross-compliance measures won't affect notably this income and that rapeseed price is maintained to a level of around 200€/t. While re-coupling was necessary in scenario 1 in order to stop the land from going idle (in any way of little span), it appears far less justified as far as Luxembourg compromise is concerned.

If we anticipate a market conjuncture worse than in scenario 2 (175€/t for rapeseed), agricultural incomes of the intermediate regions will fall since agricultural incomes per farm decrease. It seems that this reform will not accelerate the pace of farms' disappearance. On the contrary, the simulations tend to show that this trend will slow down.

Finally, de-coupling may not favour the extensification of the land factor, which seems to be the analysis conducted by the fathers of the reform who have introduced cross-compliance.

These results, obtained thanks to a simulating model that integrates the evolutions of the agricultural structures, should not be considered in any way as previsions. Their only goal is to give rise to further thinking. They intend to show what could happen for cereal-oriented farms of the intermediate regions, should the world prices become considerably low. The careful reader will have noticed that the possibilities of diversification made easier by the de-coupling (diversification in the rotations or towards non-agricultural activities) have not been looked at in this study.

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Appendix

Here we describe in more details the constraints that apply to the maximization program.

Indices

$y \in Y$ year's index
$r \in R$ region's index
$f \in F$ farm's index

$c \in C$ crop index

$$c_1 = \begin{pmatrix} \text{barley, wheat, industrial wheat, industrial wheat on set - aside land,} \\ \text{rapeseed, industrial rapeseed,} \\ \text{industrial rapeseed on set - aside land, winter barley and spring barley} \end{pmatrix}$$

$$c_2 = (\text{rapeseed, industrial rapeseed, industrial rapeseed on set - aside land})$$

$$c_3 = (\text{sunflower, industrial sunflower, industrial sunflower on set - aside land})$$

$$c_4 = (\text{field bean, peas})$$

$k \in K$ Constraints indices

- flexibility constraints:
  - k_1 for land cropped in cereals
  - k_2 for land cropped in rapeseed
  - k_3 for land cropped in sunflower
  - k_4 for land cropped in protein crops
- outlets constraints:
  - k_8, k_9 control of the crops preceding wheat in the rotations
  - k_{10} control of the wheat after wheat areas
  - k_{11} control of the crops preceding winter barley
  - k_{12} control of the crops preceding lucern

BSA blank set-aside land (without energetic crops)

Parameters

L_r	Regional agricultural area
$L_{r,f}$	Agricultural area at the farm level, within region *r*
$\mu_{r,f,c}$	Gross margin of crop *c*, in the farm *f*
$C_{r,y,f,c}$	Variable cost of crop *c*, in farm *f*, during year *y*
$C_{r,y,f}$	Total variable cost of crop *c*, in farm *f*, during year *y*
$i_{c,k}$	Technical coefficient of crop *c* linked to rotation constraints, k_8 to
$\pi_{set-aside}$	Share of the set-aside land that doesn't take part in the crops rotation
$\omega_{r,k}$	Outlets constraints
$\overline{\lambda_{r,f}}$	Enlargement costs for farm *f*
$\underline{\lambda_{r,f}}$	Fixed costs decrease for farm *f* (if farm *f* has idle land)
$\overline{E}_{r,f}$	Enlargement coefficient of farm *f*, located in region *r*
P	Average payment per hectare

Decision variables

$x_{r,f,c}$	Agricultural area dedicated to crop *c*, in farm *f*
$E_{r,f}$	Annual enlargement of farm *f*, located in region *r*
$1_{r,f}$	Binary function of farm *f* in region *r* : $\begin{cases} 1_{r,f} = 1 \text{ if f exists} \\ 1_{r,f} = 0 \text{ otherwise} \end{cases}$
$IL_{r,f}$	Binary function of farm *f* in region *r* : $\begin{cases} IL_{r,f} = 1 \text{ if f has idle land} \\ IL_{r,f} = 0 \text{ otherwise} \end{cases}$

The total gross margin is maximised:

$$\begin{cases} \Phi^+ = \sum_{r \in R} \sum_{f \in F} \sum_{c \in C} x_{r,f,c} \cdot \mu_{r,f,c} \\ \Phi^- = \sum_{r \in R} \sum_{f \in F} -\left(\overline{\lambda_{r,f}} - P\right) E_{r,f} + \underline{\lambda_{r,f}} \cdot IL_{r,f} \\ \Phi = \Phi^+ + \Phi^- \end{cases} \tag{8}$$

$$MAX\ \Phi$$

Constraints

The regional total agricultural area is constant and shall not be exceeded

$$\sum_{r \in R} \sum_{f \in F} \left(1_{r,f} \cdot L_{r,f} + E_{r,f} \right) \leq \sum_{r \in R} L_r \tag{9}$$

Enlargement is limited at the farm level:

$$\begin{aligned} &\forall r \in R, \forall f \in F, \\ &E_{r,f} \leq 1_{r,f} \cdot \overline{E}_{r,f} \end{aligned} \tag{10}$$

The total area taken up by crops must be lower than the total agricultural area at the farm level:

$$\forall r \in R, \forall f \in F, \qquad \sum_{c \in C} x_{r,f,c} \leq S_{r,f} \cdot 1_{r,f} \cdot E_{r,f} \tag{11}$$

Each crop group mustn't go beyond a certain limit of the agricultural area:

$$\forall r \in R, \forall f \in F, \ \forall j \in [1;5], \qquad \sum_{c_j \in C} i_{c_j,k_j} \cdot x_{r,f,c_j} \leq (S_{r,f} - x_{r,f,set-aside} \cdot \pi_{set-aside}) \cdot \omega_{r,k_j} \cdot 1_{r,f} + A_{r,f} \cdot \omega_{r,kj_1} \tag{12}$$

Each crop must hold its right position in the crop rotation:

$$\forall r \in R, \forall f \in F, \qquad \sum_{c \in C} i_{c,k_2} \cdot x_{r,f,c} \leq 0 \tag{13}$$