LAND ECONOMY WORKING PAPER SERIES

Number 26: Modelling Regional Agricultural Output Adjustments in Scotland in Response to CAP Reform

Corresponding Author:

Cesar Revoredo-Giha
Land Economy Research Group
Research Division
SAC Edinburgh
EH9 3JG

Tel: 0131 535 4344
E-Mail: Cesar.Revoredo@sac.ac.uk

Modelling Regional Agricultural Output Adjustments in Scotland in Response to CAP Reform[1]

Cesar Revoredo-Giha, Philip Leat and Catherine Milne

Abstract

The purpose of the paper is to present an agricultural supply model for Scotland used to estimate regional changes in agricultural outputs due to the 2003 Common Agricultural Policy (CAP) reform. Supply functions were estimated for several farm types based on generalised trans-logarithmic multiproduct cost functions (Caves, Christensen and Tretheway, 1981). The data used for the estimation were an unbalanced panel dataset constructed using farm level data from the Scottish Government's Farm Accounts Scheme (FAS) survey. Using the estimated supply adjustments, individual farm level responses to subsidy and price changes were aggregated using agricultural census weights to estimate the output changes for different regions.

Key words: Regional models, CAP reform, agricultural production econometrics

1 Introduction

Since its introduction Europe's Common Agricultural Policy (CAP) has supported increased farm production with great success. In Scotland, in particular, the importance of CAP support payments to farm businesses can be seen in the proportion of total farm income derived from direct subsidy payments. For example, at one extreme, specialist sheep farms in Less Favoured Areas (LFA) on average derived around 45 per cent of total farm output from direct subsidies over the period 1997/98 to 2003/04. By comparison, on average approximately 6 per cent of total farm output from Scottish dairy farms during this period was direct subsidy (SERAD, 2000; SEERAD, 2001; SEERAD, 2002; SEERAD, 2005; SEERAD, 2005a;).

Although the Luxembourg agreement on CAP reform was made in June 2003, key implementation decisions were not made until 2004. Prior to the June 2003 agreement, several assessments had been made which indicated that the then proposed measures would have a very significant effect on EU agricultural production (e.g. Defra, 2003; Revell and Oglethorpe, 2003). Within Scotland, two significant studies had been undertaken on the future development of Scottish agriculture, including the impact of CAP reform. These focused on the Highlands and Islands Enterprise area in the north west of the country (Cook and Copus, 2002) and the Borders in the south (Kerr and Mitchell, 2003). Both studies indicated quite significant developments in the nature, scale and distribution of stocking and cropping. Furthermore, the differences in the results of these studies indicated that one should expect important regional effects from the reform.

The purpose of the paper is to present an agricultural supply model for Scotland which was used to estimate regional changes in agricultural outputs due to the 2003 CAP reform and its associated consequences for agricultural returns.

[1] This paper derives from research conducted under a Scottish Executive Environment and Rural Affairs Department (SEERAD) funded project on the implications of CAP reform (IMCAPT) (SAC, 2006), conducted between April 2004 and June 2006.

The paper starts with an overview of the model that has the purpose of guiding the discussion, followed by a description of the data used and the methodology for the estimation of the cost functions. Next, we present how the simulation model is assembled and the change in prices used in the exercise. Finally, we discuss the results.

2 Empirical work

2.1 Overall description of the model

The purpose of this section is to present an overview of the approach used in the paper to evaluate the impact of possible changes in output prices.

The main reason for selecting a detailed supply side model instead of a regional partial equilibrium model is due to the difficulty in estimating regional demands, for which we do not possess information. Instead, the strategy used here consisted of estimating possible price changes and evaluating them through the supply model in order to observe the change in regional production.

The introduction of the Single Farm Payment by the 2003 reform is difficult to approximate, because whilst economic logic indicates that the impact on production of a decoupled payment should be nil, in practice, farmers may decide due to their own motives, to subsidise their production, i.e., producing, given the current market prices, at levels that are above the profit maximisation level (i.e., they are subsidising their production because they are using part of their Single Farm Payment as if it were a coupled subsidy).

Figure 1 presents a flowchart of the model. The Scottish Farm Accounts Scheme survey data were used to estimate the cost functions, which are the core of the supply response model. Similarly, changes in prices were estimated from various sources (e.g., FAPRI projections). Both, the cost functions and the price changes were integrated into profit maximisation farm models to predict the changes in different farm products. The evaluation has been undertaken at the farm level and the individual farm type responses have been weighted up using agricultural census data to obtain the estimated production changes at the regional level.

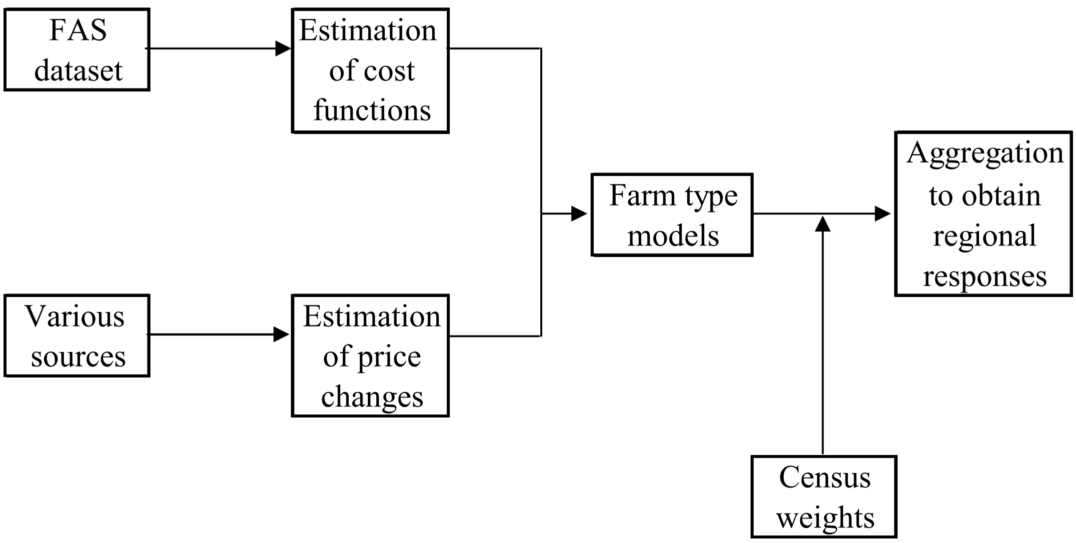

Figure 1. Flowchart of the model

2.2 Available data

The Farm Accounts Scheme (FAS) annually records a wide range of financial and non-financial data for a selection of full-time farms across Scotland. It is part of the Farm Accounts Data Network, which monitors farm performance across the EU. The data used cover the eight year period of 1997/98 to 2004/5 (i.e., the crop years of 1997 to 2004). The criteria used to select the farms were that they should be present in the 2004/05 survey, and also that they were in the sample for at least five years. This resulted in an unbalanced panel dataset of 358 individual farms. Table 1 summarises this sample by farm types and their respective main outputs. The FAS dataset does not include information on pigs, poultry or horticultural producers.

Table 1. Summary of sample by farm type

Farm type group	Number of farms in the sample	Main outputs
Dairy	50	Milk, cattle
Specialist sheep 1/	31	Sheep, cattle
Cattle and sheep	58	Cattle, sheep, cereals
Cereals and general cropping	65	Cereals
Mixed	154	Cereals, cattle, sheep
Total	358	

Source: Derived from FAS data
Notes:
1/ Specialist sheep farms are all located in less favoured areas (LFA). However, other farm types include farms in both the LFA and non-LFA.

Costs and outputs by farm type were computed directly from the FAS data. Costs were allocated to one of four groups: materials (e.g., feed, fertiliser); purchased services (e.g., contract work, crop protection costs); labour (e.g., all labour used including that of the farmer, farm family, business partners and hired workers); and capital (e.g., rent and depreciation). The outputs considered were cereals, potatoes, oilseed rape, cattle, sheep, milk and milk products, wool and eggs.[2]

The estimation of cost functions requires input prices. However, a shortcoming of the FAS data for the estimation of cost functions (and also of other similar datasets such as the Farm Business Survey for England and Wales) is that it only presents input expenditures and not the prices paid for inputs (or quantities used). Therefore, Defra's (UK Department for Environment, Food and Rural Affairs) input price data for the United Kingdom were used for agricultural materials, services and capital, as an estimate of those prices paid by FAS farmers over the study period (Defra, 2006). The labour input price was estimated from FAS data.

2.3 Estimation of cost functions

Data availability played an important role in our choice of methodology for estimating the cost functions. The maximum number of periods available in our panel was 8 years (80 per cent of the sample), whilst 8 per cent of the sample had 6 consecutive years or less. Therefore, we chose to estimate the cost functions using a panel data fixed effects model (i.e., the within estimator, Hsiao, 1993). The fixed effect terms can be understood as terms representing farm efficiency. In addition, in

[2] The sample farms produced minimal quantities of pigs, poultry and vegetables.

order to test the presence of possible technical change, we included a quadratic trend in the cost equation. The trend variable took the value of one in 1997, two in 1998 and so forth.

The fixed effects cost function can be written in the following way (Kumbakhar and Knox Lovell, 2003), where i denotes farms and t the periods:

$$(1) \qquad \ln E_{it} = \ln C(Q_{it}, W_{it}, \tau_t; \Omega) + v_{it} + u_i$$

In equation (1) $\ln E_{it}$ is the logarithm of the observed expenditure, $\ln C(Q_{it}, W_{it}, \tau_t; \Omega)$ is the logarithm of the deterministic cost function that depends on the outputs Q_{it}, the input prices W_{it}, a deterministic trend, τ_t, to capture technological change, and a vector of parameters Ω. The statistical error is represented by v_{it}, which is assumed to be independent and identically distributed with mean zero and variance σ_v^2. The time invariant inefficiency term u_i is positive.

A generalised multiproduct translog cost function (Caves, Christensen and Tretheway, 1980) was selected for the term $\ln C(Q_{it}, W_{it}, \tau_t; \Omega)$ because it imposes less a-priori restrictions than other functional forms commonly used for the task. As explained by Caves, Christensen and Tretheway in the context of multiproduct estimation, some outputs might not be present on a farm, and therefore the logarithm used in the translog function will produce an error. Instead, they propose the use of a Box-Cox transformation to substitute for the logarithm of the output terms. Thus, for the case of n inputs and m outputs, and naming $f(\cdot)$ as the Box-Cox transformation with parameter λ[3], the cost function is given by:

$$(2) \qquad \ln C(Q_{it}, W_{it}, \tau_t; \Omega) = \alpha_0 + \varphi_0 \tau_t + \varphi_0 \tau_t^2 + \sum_{j=1}^{n} \alpha_j \ln W_{jt} + \frac{1}{2} \sum_{j=1}^{n} \sum_{k=1}^{n} \beta_{jk} \ln W_{jt} \ln W_{kt}$$
$$+ \frac{1}{2} \sum_{j=1}^{m} \sum_{k=1}^{n} \delta_{jk} f(Q_{jit}) \ln W_{kt} + \sum_{j=1}^{m} \gamma_j f(Q_{jit}) + \frac{1}{2} \sum_{j=1}^{m} \sum_{k=1}^{m} \rho_{jk} f(Q_{jit}) \cdot f(Q_{kit})$$

As the stochastic cost frontier is a cost function, it has to satisfy the properties of any cost function (Chambers, 1988). Price homogeneity and symmetry were directly imposed in (2) through the following restrictions to the parameters (3):

$$(3) \qquad \sum_{j=1}^{n} \alpha_j = 1; \ \sum_{j=1}^{n} \delta_{jk} = 0; \ \sum_{j=1}^{n} \beta_{jk} = 0; \ \sum_{k=1}^{n} \beta_{jk} = 0; \ \sum_{j=1}^{n} \sum_{k=1}^{n} \beta_{jk} = 0; \beta_{jk} = \beta_{kj}$$

As previously noted, the dataset does not contain input prices for each farm. In the context of cross section estimation, the approach is to assume that all farmers face the same prices. However, when estimating a cost function using panel data it is possible to introduce prices, assuming that all the farmers face the same input prices within a year (i.e., across farms), but that prices change over time.[4] Thus, the parameters associated with input prices can be estimated from the cost share equations,

---

[3] The Box-Cox transformation with parameter λ is given by: $f(x) = \begin{cases} \frac{x^\lambda - 1}{\lambda} & \lambda \neq 0 \\ \log(x) & \lambda = 0 \end{cases}$

[4] In a different context, similar assumptions can be found in the estimation of demand systems, where price elasticities are sometime estimated from time series because of the lack of variability of prices in cross sectional datasets (Hsiao, 1993, p.206).

where the fixed effect terms do not appear. The final equation to be estimated is presented in (4), where the intercept in (4) is $\alpha_{0i} = \alpha_0 + u_i$.

$$(4) \qquad \ln E_{it} = \alpha_{0i} + \varphi_0 \tau_t + \varphi_0 \tau_t^2 + \sum_{j=1}^{n} \alpha_j \ln W_j + \frac{1}{2} \sum_{j=1}^{n} \sum_{k=1}^{n} \beta_{jk} \ln W_j \ln W_k + \frac{1}{2} \sum_{j=1}^{m} \sum_{k=1}^{n} \delta_{jk} f(Q_{jit}) \ln W_k + \sum_{j=1}^{m} \gamma_j f(Q_{jit}) + \frac{1}{2} \sum_{j=1}^{m} \sum_{k=1}^{m} \rho_{jk} f(Q_{jit}) \cdot f(Q_{kit}) + v_{it}$$

Equation (4) was estimated for four inputs (i.e., n=4) and a maximum of eight outputs (i.e., m=8). Given the high number of parameters to be estimated (i.e., 97 parameters in the maximum case) and the fact that the Box-Cox transformation added a non-linear component to the estimation, the following econometric procedure was employed.

First, the Box-Cox parameter λ was estimated through a grid-search routine. For each given value of λ, the log-likelihood of the system of $(n-1)$ cost shares was computed, using iterative Seemingly Unrelated Regression Equations (SURE) and imposing the constraints in (3). This produced a relationship between log-likelihoods and alternative values of λ, from which the λ with the maximum log-likelihood value was selected. This step also provided the values for all the terms in (4) that were associated to input prices.

Second, all the remaining parameters -except the fixed effect terms- of the cost function, i.e., output terms not associated with prices, were estimated using the within estimator (ordinary least squares applied to the variables expressed as deviations of the means by farm, Hsiao, 1993).

Finally, the fixed effect terms were estimated from equation (4) by evaluating the function at the mean value of the variables by farm (Atkinson and Cornwell, 1993; Kumbakhar and Lovell, 2003, Pierani and Rizzi, 2003). The estimated equations are presented in the Annex.

It is important to note that in addition to the cost function properties introduced by directly imposing constraints (3) in the estimated equations (i.e., the cost functions were estimated by farm type), a well behaved cost function requires its input demand functions to be strictly positive and to satisfy concavity in input prices (Chambers, 1988). Thus, we tested for all the points in the sample, the former by examining the positiveness of the predicted cost shares, and the latter by computing the hessian matrices (second derivative matrices with respect to the input prices and evaluated at each point in the sample) and testing their negative semifiniteness. All the predicted cost shares were positive and the negative semidefiniteness of the hessian matrices was satisfied for most of the points of the sample (87.3 per cent of the sample points in the case of dairy farms, 95.9 for cereals and general cropping, and for the entire sample in the case of the other farm types). Therefore, for most of the sample we could not reject the proposition that the estimated cost functions were consistent with the solution of cost minimisation problems.[5]

2.4 Agricultural supply side model

To evaluate the responses to prices, we assumed that each farmer (identified by the sub-index f) maximises his/her profits (π_f), where Q_i are the farm outputs, P_i are the farm output prices and

[5] It should be noted that while the homogeneity and symmetry properties were imposed in the estimation, the properties of concavity and cost share positiveness were not. If the last two properties had not been satisfied by the cost function, this function would have been rejected as the solution of a cost minimisation problem.

$C(W,Q)$ is the farm cost function that depends on a vector of input prices (W) and the outputs, such as in (5):

$$(5) \qquad \underset{Q_i}{\text{Max}} \quad \pi_f = \sum_{i=1}^{n} P_i Q_i - C(W, Q_1, \cdots, Q_n)$$

Theoretically, having estimated the cost function, one should solve a system such as (6), which is obtained by differentiating the profit function with respect to all of the outputs. System (6) states the classical condition that the marginal cost for each output ($MC(W,Q)$) should be equal to its price. As is customary under perfect competition with atomistic producers, input and output prices are assumed exogenous and the endogenous variables in the system are the farm outputs.

$$(6) \qquad \begin{pmatrix} MC_1(W, Q_1, \cdots, Q_n) \\ \vdots \\ MC_n(W, Q_1, \cdots, Q_n) \end{pmatrix} = \begin{pmatrix} P_1 \\ \vdots \\ P_n \end{pmatrix} \qquad \text{for } Q_1, \ldots, Q_n > 0$$

In practice, for a complex cost function such as the one used in this exercise (i.e., the generalised multi-product translog cost function, see Caves et al, 1980), to solve a system such as (6) to obtain the equilibrium outputs, is quite difficult. Instead, we will consider an alternative system that expresses (6) in terms of supply elasticities and percentage changes in outputs and output prices. Differentiating the system and expressing it in terms of rates of change, we obtain the following system that can be used to approximate the effect of changes in output prices on the output portfolio. The matrix multiplying the change in the quantities is the inverse of the supply elasticities matrix (7).

$$(7) \qquad \begin{pmatrix} \frac{\partial MC_1(\bullet)}{\partial Q_1} \cdot \frac{Q_1}{P_1} & \cdots & \frac{\partial MC_1(\bullet)}{\partial Q_n} \cdot \frac{Q_n}{P_1} \\ & \vdots & \\ \frac{\partial MC_n(\bullet)}{\partial Q_1} \cdot \frac{Q_1}{P_n} & \cdots & \frac{\partial MC_n(\bullet)}{\partial Q_n} \cdot \frac{Q_n}{P_n} \end{pmatrix} \begin{pmatrix} \frac{dQ_1}{Q_1} \\ \vdots \\ \frac{dQ_n}{Q_n} \end{pmatrix} = \begin{pmatrix} \frac{dP_1}{P_1} \\ \vdots \\ \frac{dP_n}{P_n} \end{pmatrix}$$

Therefore, the required changes in output due to changes in output prices are given by (8):

$$(8) \qquad \begin{pmatrix} \frac{dQ_1}{Q_1} \\ \vdots \\ \frac{dQ_n}{Q_n} \end{pmatrix} = \begin{pmatrix} \frac{\partial MC_1(\bullet)}{\partial Q_1} \cdot \frac{Q_1}{P_1} & \cdots & \frac{\partial MC_1(\bullet)}{\partial Q_n} \cdot \frac{Q_n}{P_1} \\ & \vdots & \\ \frac{\partial MC_n(\bullet)}{\partial Q_1} \cdot \frac{Q_1}{P_n} & \cdots & \frac{\partial MC_n(\bullet)}{\partial Q_n} \cdot \frac{Q_n}{P_n} \end{pmatrix}^{-1} \begin{pmatrix} \frac{dP_1}{P_1} \\ \vdots \\ \frac{dP_n}{P_n} \end{pmatrix}$$

$$(8') \qquad \frac{\Delta Q}{Q} = A \cdot \frac{\Delta P}{P}$$

The first step to solve the system (8') is to estimate a cost function in order to compute the terms of the supply elasticity matrix A. Since for the simulations using the model, input prices will remain unchanged, it is convenient to create the following expressions (i.e., 9-a to 9-d) in order to simplify the cost function expression:

$$(9-a)\quad H_0^W = \sum_{j=1}^{4} \alpha_j \ln W_j$$

$$(9-b)\quad H_1^W = \tfrac{1}{2}\sum_{j=1}^{4}\sum_{h=1}^{4} \beta_{jh} \ln W_j \ln W_h$$

$$(9-c)\quad H_f = \alpha_f + H_0^W + H_1^W$$

$$(9-d)\quad \delta_i^* = \delta_i + \sum_{j=1}^{4} \Psi_{ij} \ln W_j$$

Replacing the previous expressions into the translog function (4) the function becomes:

$$(10)\qquad \ln C_f = H_f + \sum_{i=1}^{8} \delta_i^* f(Q_i) + \tfrac{1}{2}\sum_{i=1}^{8}\sum_{k=1}^{8} \gamma_{ik} f(Q_i)\cdot f(Q_k)$$

The marginal cost function for each output i is given by (11), which incorporates the Box Cox expression. Notice that the marginal cost for each product (and also for the factor demands) are different for each farm, since the term H_f varies from farm to farm due to the fixed effect term.

$$(11)\qquad MgC_i = Q_i^{\lambda-1}\cdot \exp\left\{ H_f + \sum_{i=1}^{8} \delta_i^* \frac{\left(Q_i^{\lambda}-1\right)}{\lambda} + \tfrac{1}{2}\sum_{i=1}^{8}\sum_{k=1}^{8} \gamma_{ik} \frac{\left(Q_i^{\lambda}-1\right)}{\lambda}\cdot\frac{\left(Q_k^{\lambda}-1\right)}{\lambda} \right\} \cdot \left\{ \delta_i^* + \tfrac{1}{2}\sum_{k=1}^{8} \gamma_{ik}\cdot \frac{\left(Q_k^{\lambda}-1\right)}{\lambda} \right\}$$

To construct the matrix A we need to differentiate the different marginal costs with respect to each one of the outputs. Thus, the diagonal and off-diagonal terms of the matrix are given by:

Diagonal terms of matrix A

The diagonal terms are given by (12):

$$(12)\qquad \frac{\partial MgC_i}{\partial Q_i} = \exp\{\ln C_f\}\cdot\left\{ \left(\frac{\partial f(Q_i)}{\partial Q_i}\right)^2 \left(S_{Q-i}^{\,2} + \gamma_{ii}\right) + \frac{\partial^2 f(Q_i)}{\partial Q_i \cdot \partial Q_i}\cdot S_{Q-i} \right\}$$

Which simplifies to an expression such as (13)

$$(13)\qquad \frac{\partial MgC_i}{\partial Q_i} = \exp\{\ln C_f\}\cdot\left\{ \left(Q_i^{\lambda-1}\right)^2 \left(S_{Q-i}^{\,2} + \gamma_{ii}\right) + Q_i^{\lambda-2}\cdot S_{Q-i} \right\}$$

Using the expressions (13a to 13c):

$$(13-a)\qquad S_{Q-i} = \delta_i^* + \tfrac{1}{2}\sum_{k=1}^{8} \gamma_{ik}\cdot\left(\frac{Q_k^{\lambda}-1}{\lambda}\right)$$

$$(13-b) \qquad \frac{\partial f(Q_i)}{\partial Q_i} = Q^{\lambda-1}$$

$$(13-c) \qquad \frac{\partial^2 f(Q_i)}{\partial Q_i \partial Q_i} = (\lambda-1) \cdot Q_i^{\lambda-2}$$

Off -diagonal terms of matrix A

The off-diagonal terms are given by (14)

$$(14) \qquad \frac{\partial MgC_i}{\partial Q_k} = \exp\{\ln C_f\} \cdot \left\{ \left(Q_i^{\lambda-1} \right) \cdot \left(S_{Q-i} \cdot S_{Q-k} + \tfrac{1}{2} \cdot \gamma_{ik} \right) \right\}$$

Where:

$$(14-a) \qquad S_{Q-k} = \delta_k^* + \tfrac{1}{2} \sum_{h=1}^{8} \gamma_{kh} \cdot \left(\frac{Q_h^{\lambda} - 1}{\lambda} \right)$$

2.5 Prices used for the simulation

Projected price changes used in the model were assumed to consist of two components: first, the change (or elimination) of direct subsidies, and second, the change in market price. To approximate the first component, we subtracted from the total output value for cereals, cattle and sheep, the value of their direct subsidies, and divided the resulting net of subsidy value by the output quantity. This operation produced the farm level, implicit price for cereals, cattle and sheep. The second component (i.e., change in market prices) was approximated by adjusting (onto a Scottish basis) FAPRI's forecasted change in prices for the EU under the CAP reform scenario. Table 2 presents the estimated changes in prices for cereal and livestock for the time horizons 2004-2012.

Table 2. Scotland: Estimation of price changes for major products

Grain	Quantities 1/	Weighted Cereal Prices					
		With AAPS 2004	Without AAPS 2004	Change due to elimination of AAPS 5/	Change in market price 2004-12 2/	Final price 2012	Change in price 2004/12
	(tonnes)	(£/tonne)	(£/tonne)	(%)	(%)	(£/tonne)	(%)
Wheat	20,456.9	124.5	96.6	-22.4	-9.0	87.9	-29.4
Barley	61,000.5	116.1	79.1	-31.9	-9.7	71.4	-38.5
Oats 3/	4,300.9	116.8	77.8	-33.4	-9.7	70.3	-39.8
Cereals 4/	85,758.3	118.1	83.2	-29.6	-9.5	75.3	-36.3
Livestock	**Animals 1/**	**Weighted Livestock Prices**					
		With subsidies 2004	Without subsidies 2004	Change due to elimination of subsidies	Change in market price 2004-12 2/	Final price 2012	Change in price 2004/12
	(heads)	(£/head)	(£/head)	(%)	(%)	(£/head)	(%)
Cattle	39,535	487.4	314.1	-22.4	5.4	330.9	-32.1
Sheep	191,974	42.8	30.0	-31.9	8.1	32.4	-24.3

Source: Own computations based on FAS survey data.

Notes

1/ Survey figures.
2/ Market prices were approximated by FAPRI's projection for the EU under the CAP reform scenario.
3/ In the absence of price projection the change in oats' price was approximated by the change in barley's price.
4/ Weighted averages by quantities.
5/ AAPS stands for Arable Area Payments Scheme.

3 Results and discussion

It is important to start by pointing out some of the limitations of this analysis, in order to provide a good understanding of the results. The first limitation is that CAP reform might be considered as a structural change as it modified the way farmers' incomes were supported. As the performed econometric analysis is based on the available information (i.e., historical information), models and inferences may not fully represents future events.

The second limitation is related to the fact that the estimated models are long term static models, and so are the estimated elasticities. Therefore, the results are not from dynamic models that differentiate between the short term and long term, or in other words, they do not show the path of future development.

Two sets of findings were computed using the model; they are meant to produce a representation of extreme situations. The first set, presented in Table 3, relates to changes in output as a response to estimated market price changes only. It should be noted that whilst CAP reform does not directly affect potatoes, wool and eggs, the adjustments shown in the following tables arise because of adjustments in farmers' enterprise mixes as they attempt to maximise profits as prices adjust.

Table 3. Simulated changes in farm outputs due to a change in market prices only, 2004-2012 by region and output (Percentage changes with respect to 2004)

Region	Outputs							
	Cereals	**Potatoes**	**Oilseed Rape**	**Cattle**	**Sheep**	**Dairy**	**Wool**	**Eggs**
Changes in prices	-9.5	0.0	0.0	5.4	8.1	-10.8	0.0	0.0
Changes in outputs								
Scotland	-2.0	0.0	0.0	6.3	7.7	-0.5	9.6	1.7
North West	-0.7	0.0	0.0	6.5	2.2	0.0	2.2	..
North East	-2.8	0.0	-0.1	2.9	7.7	0.0	4.2	..
South East	-2.8	0.1	-0.1	9.5	11.2	0.1	13.7	2.8
South West	-0.1	-0.4	0.0	7.0	10.7	-0.6	14.4	-0.1

Source: Based on FAS data and own computations

The weakening of dairy and cereal prices leads to production declines, although modest in scale, whilst the improvement in prices for cattle and sheep lead to increases in production which are greatest in the South East and South West. However, farmers may well not react to price changes alone. Instead, they may respond to the combined effect of price changes and the removal of production-related subsidies, thereby reacting to the overall change in revenue associated with an enterprise. Table 4 provides estimates of output changes in response to price changes and production-related, subsidy removal.

Table 4. Simulated changes in farm outputs due to a change in effective output prices, 2004-2012 by region and output (Percentage changes with respect to 2004)

Region	Outputs							
	Cereals	**Potatoes**	**Oilseed Rape**	**Cattle**	**Sheep**	**Dairy**	**Wool**	**Eggs**
Changes in prices	-36.3	0.0	0.0	-32.1	-24.3	-10.8	0.0	0.0
Changes in outputs								
Scotland	-9.4	-0.1	0.6	-38.0	-21.2	-2.2	-18.9	-9.9
North West	-5.4	0.0	-0.1	-48.2	-6.7	-0.4	-2.3	..
North East	-14.8	0.1	0.7	-40.7	-42.2	0.0	-28.3	..
South East	-8.3	-0.9	1.1	-40.5	-32.5	-0.2	-28.7	-15.5
South West	-8.7	2.3	0.3	-27.4	-23.9	-2.6	-25.9	-0.1

The much greater changes in effective prices (e.g. 36 per cent decline for cereals, 32 per cent decline for beef, 24 per cent decline for sheep) give rise to larger production falls. Thus, how farmers regard the Single Farm Payment, and how they use it to maintain their farming activities will be critical to how Scottish agriculture adjusts. If farmers seek to protect their SFP, by not using it to support their farming activities, then the scale of decline in Table 4 is possible. Cereals would see greatest decline in the North East, where the barley crop is most vulnerable because of a regional surplus of supply over local demand. Cattle production would decline massively across the whole country, with the decline greatest in the North West (with considerable areas of relatively extreme LFA land), and least in the South West (where the alternative farming enterprises are more limited). Sheep production would also fall markedly, with the decline in the North West restricted by the lack of alternatives. However, if a large-scale withdrawal from farming occurred in the North West then sheep numbers would decline substantially.

Results related to changes in output as a response to estimated market price changes only, show that the projected weakening of dairy and cereal prices leads to production declines, although modest in scale. By comparison the projected improvement in prices for cattle and sheep lead to increases in production which are greatest in the South East and South West of Scotland.

When the combined effect of price changes and the removal of production-related subsidies are considered, the result is much greater changes in effective prices (e.g. 36 per cent decline for cereals, 32 per cent decline for beef, 24 per cent decline for sheep), which give rise to larger production falls. In this situation, the greatest decline in cereals would occur in the North East, where the barley crop is most vulnerable due to a regional surplus of supply over local demand. Cattle production would decline across the whole country but by the greatest proportion in the North West, and least in the South West (where the alternative farming enterprises are more limited). Sheep production would also fall markedly, with the decline in the North West restricted by the lack of alternatives. However, if a large-scale withdrawal from farming occurred in the North West then sheep numbers would decline substantially.

The analysis illustrates the importance of farmers' motivations and objectives in determining the implications of the CAP reform. Moreover, there may well be potential marked differences in product and regional adjustments arising from the reforms. Such differences may well give rise to regional variations in economic and other consequences, both on and off farms, and may thus generate a mixed pattern of rural development challenges across the country if welfare levels are to be maintained in rural areas.

4 References

Atkinson, Scott E. and Cornwell, Christopher, 1993. Measuring Technical Efficiency with Panel Data: A dual approach, Journal of Econometrics 59(3): 257-62.

Caves, D. W., Christensen, L. R. and Tretheway, M. W., 1980. Flexible Cost Functions for Multiproduct Firms, Review of Economics and Statistics, 62, 477-81.

Cook, P. and Copus, A., 2002. Agricultural Forecasts for the Highlands and Island Enterprise Area, A report by Scottish Agricultural College for HIE, December.

Chambers, R. G., 1988. Applied production analysis: A dual approach. New York, Cambridge University Press.

Hsiao, Cheng, 1993. Analysis of Panel Data. Econometric Society Monographs No. 11, New York: Cambridge University Press.

Kerr G. and Mitchell M., 2003. A Future for Borders Agriculture. Confidential report to Scottish Borders Council and Scottish Enterprise Borders by SAC Rural Business Unit, May.

Kumbhakar, S. C. and Knox Lovell, C. A., 2003. Stochastic Production Frontier. New York: Cambridge University Press. Second edition.

Pierani, Pierpaolo and Rizzi, Pier Luigi, 2003. Technology and efficiency in a panel data dairy farms: an SGM restricted cost function approach, Agricultural Economics 29(2): 195-209.

Revell, B. and Oglethorpe, D., 2003. Decoupling and UK agriculture – a whole farm approach. Study by Harper Adams University College and SAC for DEFRA.
Available online: http://www.defra.gov/esg/reports/decoupling/HAdSAC.pdf

Scottish Agricultural College (SAC), 2006. The implications of CAP reform and other agricultural supply influences for the Scottish red meat, milk and cereal supply chains (IMCAPT). Project Final Report to SEERAD, Edinburgh: SEERAD.

Scottish Executive Rural Affairs Department, 2000. Farm Incomes in Scotland 1998/99, Edinburgh: SERAD.

Scottish Executive Environment and Rural Affairs Department (SEERAD), 2001. Farm incomes in Scotland 1999/00, Edinburgh: SEERAD.

Scottish Executive Environment and Rural Affairs Department, 2001a. A Forward Strategy for Scottish Agriculture. Edinburgh: SEERAD.

Scottish Executive Environment and Rural Affairs Department, 2002. Farm Incomes in Scotland 2000/01. Edinburgh: SEERAD.

Scottish Executive Environment and Rural Affairs Department, 2005. Farm Incomes in Scotland 2003/04. Edinburgh: SEERAD.

Scottish Executive Environment and Rural Affairs Department, 2005a. Scottish Agriculture - Output, Input and Income Statistics 1995-2004. Edinburgh: SEERAD.

UK Department for the Environment Food and Rural Affairs (Defra), 2003. Brief Summary of Key Research Findings.
Available online: http://statistics.defra.gov.uk/esg/reports/decoupling/dcplgsummary.pdf

UK Department of Environment, Food and Rural Affairs (DEFRA), 2006. Agriculture in the United Kingdom 2005.
Available online: http://statistics.defra.gov.uk/esg/publications/auk/2005/4-1.xls

Annex I: Cost Functions by Farm Type

Variables	Farm type														
	Dairy			Cereals and General Cropping			Cattle and Sheep			Specialist Sheep			Mixed Farms		
	Coefficient	Std. Error	Signif. 2/	Coefficient	Std. Error	Signif. 2/	Coefficient	Std. Error	Signif. 2/	Coefficient	Std. Error	Signif. 2/	Coefficient	Std. Error	Signif. 2/
Observations	395			487			444			243			1188		
Number of Farms	50			65			58			31			154		
Hessian 3/	87.3			95.9			100.0			100.0			100.0		
Cost shares 4/	100.0			100.0			100.0			100.0			100.0		
Adjusted R^2	0.980			0.975			0.975			0.973			0.971		
Log likelihood	564.2			381.7			507.4			242.6			1294.1		
Box-Cox λ	0.550000			0.150000			0.150000			0.650000			0.400000		
Trend	-0.027213	0.005862	**	-0.010648	0.010256		-0.003882	0.007551		0.011762	0.011508		0.002612	0.004822	
Squared trend	0.002064	0.000634	**	-0.000160	0.001095		0.000752	0.000807		-0.001644	0.001244		-0.000051	0.000517	
W_1	0.213710	0.014505	**	0.188580	0.004384		0.198880	0.021029	**	0.200470	0.013769	**	0.198220	0.007418	**
W_1W_1	0.147470	0.031209	**	0.073537	0.020254	**	0.034131	0.034705		0.060874	0.051865		0.050148	0.023501	**
W_1W_2	-0.004703	0.022706		-0.063699	0.021393	**	0.019953	0.022854		-0.001699	0.032558		-0.030406	0.019273	
W_1W_3	-0.098141	0.018741	**	-0.032134	0.009275	**	-0.124070	0.022019	**	-0.030048	0.022661		-0.086150	0.013048	**
W_1W_4	-0.044624	0.029075		0.022296	0.017807	**	0.069982	0.029315	**	-0.029128	0.046557		0.066407	0.020131	**
$W_1f(Q_1)$	-0.000265	0.000190		-0.000015	0.000192		-0.000221	0.000489		0.000523	0.001237		0.000598	0.000195	**
$W_1f(Q_2)$	-0.006956	0.004781		0.000428	0.000254								-0.000720	0.000982	
$W_1f(Q_3)$	0.003199	0.003518		0.000674	0.000456								-0.001426	0.000988	
$W_1f(Q_4)$	0.000222	0.000482		0.005501	0.000300		0.018943	0.002733	**	0.001455	0.000436	**	0.002702	0.000494	**
$W_1f(Q_5)$	0.000631	0.000344		0.000289	0.000315	**	-0.001155	0.001387		0.000125	0.000105		0.000947	0.000309	**
$W_1f(Q_6)$	0.000423	0.000052	**	0.001323	0.000079		0.003944	0.000740	**				0.001007	0.000176	**
$W_1f(Q_7)$	-0.000378	0.000255		-0.000149	0.000263	**	-0.001871	0.001254		-0.000216	0.000077	**	-0.000230	0.000245	
$W_1f(Q_8)$	0.000006	0.000062		-0.000133	0.000226		-0.000472	0.001490							
W_2	0.072863	0.006863	**	0.117080	0.003409		0.089812	0.009192	**	0.063117	0.005797	**	0.087855	0.003895	**
W_2W_1	-0.004703	0.022706		-0.063699	0.021393	**	0.019953	0.022854		-0.001699	0.032558		-0.030406	0.019273	
W_2W_2	0.052992	0.040033		0.095016	0.038286	**	-0.075899	0.041273		-0.119390	0.056516	**	0.083258	0.034202	**
W_2W_3	0.002509	0.010984		-0.036073	0.007978	**	0.037834	0.011618	**	0.020916	0.010337	**	-0.029353	0.008158	**
W_2W_4	-0.050798	0.023083	**	0.004756	0.022070	**	0.018112	0.022378		0.100170	0.034379	**	-0.023500	0.018927	
$W_2f(Q_1)$	0.000508	0.000090	**	0.002310	0.000147		0.001441	0.000213	**	0.003340	0.000511	**	0.001376	0.000102	**
$W_2f(Q_2)$	0.004808	0.002257	**	0.001122	0.000195	**							0.001271	0.000514	**
$W_2f(Q_3)$	0.004191	0.001658	**	0.002172	0.000350	**							0.001571	0.000517	**
$W_2f(Q_4)$	-0.000939	0.000228	**	-0.000792	0.000230	**	-0.001320	0.001192		0.000404	0.000180	**	0.000220	0.000259	
$W_2f(Q_5)$	-0.000299	0.000163		-0.000709	0.000242	**	-0.000636	0.000606		-0.000085	0.000044		-0.000490	0.000162	**
$W_2f(Q_6)$	0.000121	0.000025	**	-0.000533	0.000061	**	-0.000841	0.000325	**				-0.000164	0.000092	
$W_2f(Q_7)$	0.000210	0.000120		-0.000412	0.000202	**	-0.000050	0.000547		0.000059	0.000032		0.000072	0.000129	
$W_2f(Q_8)$	-0.000037	0.000029		-0.000570	0.000173	**	0.000462	0.000649							
W_3	0.408820	0.015924	**	0.338470	0.004885	**	0.316560	0.024471	**	0.363930	0.012772	**	0.397970	0.008227	**
W_3W_1	-0.098141	0.018741	**	-0.032134	0.009275	**	-0.124070	0.022019	**	-0.030048	0.022661		-0.086150	0.013048	**
W_3W_2	0.002509	0.010984		-0.036073	0.007978	**	0.037834	0.011618	**	0.020916	0.010337	**	-0.029353	0.008158	**
W_3W_3	0.085975	0.023574	**	0.106400	0.011608	**	0.116410	0.028388	**	0.117220	0.024401	**	0.150440	0.016261	**
W_3W_4	0.009658	0.021186		-0.038195	0.010507	**	-0.030177	0.021398		-0.108090	0.021756	**	-0.034938	0.014060	**
$W_3f(Q_1)$	-0.000613	0.000209	**	-0.003284	0.000226	**	-0.002001	0.000573	**	0.000376	0.001273		-0.002688	0.000220	**
$W_3f(Q_2)$	-0.000815	0.005243		0.000149	0.000299	**							0.001225	0.001110	
$W_3f(Q_3)$	-0.004003	0.003862		-0.002916	0.000537								0.001548	0.001117	
$W_3f(Q_4)$	0.000057	0.000527		-0.002434	0.000353	**	-0.007919	0.003202	**	-0.001254	0.000448	**	-0.006096	0.000559	**
$W_3f(Q_5)$	-0.000063	0.000378		-0.000013	0.000370	**	-0.000341	0.001621		0.000241	0.000103	**	-0.000460	0.000349	
$W_3f(Q_6)$	-0.000630	0.000058	**	-0.000717	0.000093		-0.002277	0.000867	**				-0.000203	0.000198	
$W_3f(Q_7)$	-0.000217	0.000280		0.000365	0.000309	**	0.002028	0.001468		-0.000124	0.000077		0.000474	0.000277	
$W_3f(Q_8)$	-0.000018	0.000068		0.001151	0.000266		-0.001978	0.001745							

Continued

Annex I: Cost Functions by Farm Type – cont.

Variables	Farm type														
	Dairy			**Cereals and General Cropping**			**Cattle and Sheep**			**Specialist Sheep**			**Mixed Farms**		
	Coefficient	Std. Error	Signif. 2/	Coefficient	Std. Error	Signif. 2/	Coefficient	Std. Error	Signif. 2/	Coefficient	Std. Error	Signif. 2/	Coefficient	Std. Error	Signif. 2/
W_4	0.304600	0.014888	**	0.355870	0.004918	**	0.394750	0.020020	**	0.372490	0.013231	**	0.315960	0.007661	**
W_4W_1	-0.044624	0.029075		0.022296	0.017807	**	0.069982	0.029315	**	-0.029128	0.046557		0.066407	0.020131	**
W_4W_2	-0.050798	0.023083	**	0.004756	0.022070		0.018112	0.022378		0.100170	0.034379	**	-0.023500	0.018927	
W_4W_3	0.009658	0.021186		-0.038195	0.010507		-0.030177	0.021398		-0.108090	0.021756	**	-0.034938	0.014060	**
W_4W_4	0.085764	0.037821	**	0.011144	0.023943	**	-0.057917	0.034301		0.037046	0.053690		-0.007970	0.025136	
$W_4f(Q_1)$	0.000370	0.000196		0.000989	0.000216		0.000780	0.000462		-0.004239	0.001194	**	0.000714	0.000202	**
$W_4f(Q_2)$	0.002963	0.004928		-0.001699	0.000286	**							-0.001776	0.001016	
$W_4f(Q_3)$	-0.003388	0.003625		0.000070	0.000515	**							-0.001692	0.001022	
$W_4f(Q_4)$	0.000660	0.000499		-0.002275	0.000338		-0.009704	0.002584	**	-0.000605	0.000421		0.003174	0.000512	**
$W_4f(Q_5)$	-0.000270	0.000355		0.000433	0.000356	**	0.002132	0.001316		-0.000281	0.000102	**	0.000003	0.000319	
$W_4f(Q_6)$	0.000086	0.000054		-0.000073	0.000089		-0.000826	0.000699					-0.000640	0.000182	**
$W_4f(Q_7)$	0.000385	0.000263		0.000196	0.000297		-0.000107	0.001187		0.000282	0.000074	**	-0.000316	0.000254	
$W_4f(Q_8)$	0.000048	0.000064		-0.000448	0.000255		0.001988	0.001409							
$f(Q_1)$	0.005153	0.001475	**	0.005193	0.002336		0.004063	0.004045		0.054488	0.008898	**	0.003847	0.002705	
$f(Q_2)$	0.012075	0.002011	**	-0.003129	0.002322	**							-0.001897	0.006860	
$f(Q_3)$	-0.012768	0.002083	**	-0.004009	0.004073								0.003042	0.005115	
$f(Q_4)$	0.000322	0.001152		-0.001733	0.004298		0.039044	0.013102	**	0.004533	0.001769	**	0.009009	0.002814	**
$f(Q_5)$	0.000007	0.000504		-0.001665	0.001253		0.000293	0.003395		0.000169	0.000354		0.004865	0.001073	**
$f(Q_6)$	0.000623	0.000391		-0.003290	0.001956		0.017419	0.003647	**				0.002063	0.000436	**
$f(Q_7)$	0.003631	0.000484	**	0.002871	0.001011		0.002018	0.002602		0.000980	0.000457	**	0.000527	0.001046	
$f(Q_8)$	-0.000308	0.000054	**	0.000270	0.000913	**	0.004221	0.001689	**						
$f(Q_1)f(Q_1)$	-0.000008	0.000070		-0.000156	0.000243		0.005013	0.001320	**	0.000001	0.000512		0.000722	0.000149	**
$f(Q_1)f(Q_2)$	-0.000453	0.000197	**	-0.000085	0.000052								0.000790	0.000353	**
$f(Q_1)f(Q_3)$	-0.000367	0.000054	**	0.000466	0.000122	**							-0.000295	0.000255	
$f(Q_1)f(Q_4)$	0.000008	0.000056		0.000223	0.000191		-0.001790	0.000808	**	-0.002972	0.001148	**	0.000130	0.000136	
$f(Q_1)f(Q_5)$	0.000055	0.000027	**	-0.000076	0.000105		0.000735	0.000369		0.000044	0.000053		-0.000002	0.000057	
$f(Q_1)f(Q_6)$	-0.000014	0.000008		-0.000064	0.000043		-0.001187	0.000397	**				-0.000103	0.000049	**
$f(Q_1)f(Q_7)$	-0.000056	0.000028		0.000057	0.000093		0.000129	0.000230		-0.000109	0.000038	**	-0.000003	0.000059	
$f(Q_1)f(Q_8)$	-0.000138	0.000075		-0.000989	0.000393	**	-0.000179	0.000277							
$f(Q_2)f(Q_2)$	0.003429	0.000571	**	-0.000138	0.000334								0.001815	0.000728	**
$f(Q_2)f(Q_3)$	0.001854	0.000866	**	-0.000855	0.000290	**							0.000366	0.001305	
$f(Q_2)f(Q_4)$	0.000235	0.000394		0.001087	0.000706								-0.000731	0.000518	
$f(Q_2)f(Q_5)$	0.000246	0.000107	**	0.000395	0.000449								-0.000145	0.000248	
$f(Q_2)f(Q_6)$	0.000024	0.000022		-0.000743	0.000225	**							-0.000818	0.000173	**
$f(Q_2)f(Q_7)$	-0.000212	0.000053	**	0.000383	0.000231								-0.000078	0.000092	
$f(Q_2)f(Q_8)$	0.000159	0.000029	**	0.000247	0.000293										
$f(Q_3)f(Q_3)$	0.006986	0.000941	**	-0.003019	0.001446	**							-0.000343	0.000852	
$f(Q_3)f(Q_4)$	0.000100	0.000129		0.001057	0.000787								0.000393	0.000367	
$f(Q_3)f(Q_5)$	0.000065	0.000274		0.000048	0.000354								-0.000130	0.000150	
$f(Q_3)f(Q_6)$	-0.000038	0.000007	**	-0.000587	0.000170	**							-0.000832	0.000172	**
$f(Q_3)f(Q_7)$	-0.001928	0.000264	**	-0.000435	0.000313								0.000294	0.000157	
$f(Q_3)f(Q_8)$	0.000186	0.000029	**	0.000163	0.000308										
$f(Q_4)f(Q_4)$	0.000125	0.000100		-0.000067	0.000609		0.001453	0.002546		0.000325	0.000207		0.000712	0.000321	**
$f(Q_4)f(Q_5)$	0.000040	0.000032		0.000698	0.000135	**	0.000578	0.000456		0.000019	0.000013		-0.000066	0.000088	
$f(Q_4)f(Q_6)$	0.000000	0.000007		0.000023	0.000102		-0.003612	0.001057	**				-0.000110	0.000053	**
$f(Q_4)f(Q_7)$	-0.000040	0.000026		-0.000464	0.000132	**	-0.002599	0.000482	**	-0.000038	0.000012	**	0.000008	0.000066	
$f(Q_4)f(Q_8)$	0.000024	0.000006	**	-0.000471	0.000266		-0.000064	0.000275							

Continued

Annex I: Cost Functions by Farm Type – cont.

Variables	Farm type														
	Dairy			**Cereals and General Cropping**			**Cattle and Sheep**			**Specialist Sheep**			**Mixed Farms**		
	Coefficient	Std. Error	Signif. 2/	Coefficient	Std. Error	Signif. 2/	Coefficient	Std. Error	Signif. 2/	Coefficient	Std. Error	Signif. 2/	Coefficient	Std. Error	Signif. 2/
$f(Q_5)f(Q_5)$	-0.000108	0.000022	**	-0.000533	0.000149	**	0.000003	0.000610		-0.000003	0.000002		0.000009	0.000048	
$f(Q_5)f(Q_6)$	0.000002	0.000005		0.000096	0.000033	**	0.000546	0.000171	**				0.000019	0.000036	
$f(Q_5)f(Q_7)$	0.000022	0.000012		-0.000113	0.000074		0.000030	0.000221		0.000001	0.000001		-0.000107	0.000033	**
$f(Q_5)f(Q_8)$	0.000134	0.000057	**	0.000413	0.000305		0.000263	0.000171							
$f(Q_6)f(Q_6)$	0.000006	0.000002	**	-0.000037	0.000046		0.003286	0.000791	**	-0.000002	0.000001	**	0.000054	0.000034	
$f(Q_6)f(Q_7)$	-0.000015	0.000004	**	-0.000059	0.000027	**	-0.000147	0.000124					-0.000052	0.000028	
$f(Q_6)f(Q_8)$	-0.000001	0.000001		-0.000018	0.000021		-0.001611	0.000268	**						
$f(Q_7)f(Q_7)$	-0.000020	0.000022		0.000334	0.000153	**	0.003730	0.000802	**				0.000141	0.000037	**
$f(Q_7)f(Q_8)$	-0.000361	0.000064	**	-0.000924	0.000274	**	-0.000420	0.000165	**						
$f(Q_8)f(Q_8)$	-0.000001	0.000000	**	0.000086	0.000083		-0.003554	0.001086	**						

Notes

1/ Q_1=cereals, Q_2=potatoes, Q_3=oilseed Rape, Q_4=cattle, Q_5=sheep, Q_6=milk and products, Q_7=wool, Q_8=eggs, W_1=material price, W_2=services price, W_3=labour price, W_4=capital price. Prices are expressed in logarithm. Two consecutive variables such f(Qi)f(Qj) indicate a variable made of the product of f(Qi) and f(Qj).

2/ ** denotes significantly different than zero at 5 per cent.

3/ Indicates the percentage of total number of observations that satisfies the semi-negative definiteness of the Hessian matrix.

4/ Indicates the percentage of the total number of observations that produce positive shares.