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Number 16. Explaining Cost Efficiency of Scottish Farms: A Stochastic Frontier Analysis

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Explaining Cost Efficiency of Scottish Farms: A Stochastic Frontier Analysis[1]

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Abstract

In this paper the cost efficiency of Scottish farms is determined, variables that explain the relative cost efficiency by farm type are identified and implications discussed. A cost efficiency approach was selected as it can deal with farms producing multiple outputs (in contrast to production frontiers), and second because it can accommodate output constraints imposed by the Common Agricultural Policy (CAP). To estimate the stochastic cost frontier, a generalised multi-product translog cost function was estimated for five farm types: dairy, cereals and general cropping, cattle and sheep, specialist sheep and mixed farms. Eight farm outputs and four inputs were considered. The data for the estimation were drawn from the Farm Accounts Scheme (FAS) survey for the period 1997-2004, which allowed the construction of an unbalanced panel dataset for 358 farms. Cost efficiency was measured as a fixed effect term and this was used to construct an indicator of relative cost efficiency by farm type. Further analysis, to explain the efficiency results, indicated the presence of important farm size and regional effects. However, other variables used in the analysis, whilst statistically significant, did not produce a consistent effect across the different farm types.

Keywords: Stochastic cost frontier analysis, cost efficiency, Scottish farms, Common Agricultural Policy.

I. Introduction

For almost half a century, Europe's Common Agricultural Policy (CAP) supported increased farm production with great success. Unacceptable levels of overproduction, accusations of inappropriate market protection and distortion, and expansion of the EU, along with concerns about the environmental impact of agricultural intensification, all contributed to growing support for fundamental reform of the CAP.

The importance of CAP support payments to Scottish farm businesses can be seen in the proportion of total farm income derived from direct subsidy payments. For example, at one extreme in Scotland, 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 (SEERAD, 2002; SEERAD, 2005; SEERAD, 2005a; SERAD, 2000; SEERAD, 2001).

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[1] This paper derives from a SEERAD funded project on the implications of CAP reform (IMCAPT) (SAC, 2006), conducted between April 2004 and June 2006.

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The new agricultural policy measures adopted by EU farm ministers in 2003, seek to reform the CAP in ways that will enable EU farmers and their businesses to become more market orientated, competitive and sustainable, both economically and environmentally. The main element of this reform is the de-coupling of support from production. This de-coupling is viewed with some trepidation, particularly in relation to sheep and cattle farms in hill and upland areas of Scotland, because of the high proportion of total farm output previously derived from direct subsidies.

Achieving profitability from agricultural production in the absence of support payments is certain to be a challenge for the industry. However, it is uncertain just how individual farm businesses will respond to the new support regime, and how that response will be affected by their ability to adjust business structures and production systems. One of the possible sources of adjustment is related to input use. This poses two questions that this paper tries to answer: first, how heterogeneous are Scottish farms in terms of their efficiency with respect to input use (i.e., cost efficiency) and second, if such heterogeneity exists, what explains it?

The approach followed to answer these questions is similar to that of Parikh et al. (1995) in their analysis of Pakistani agriculture, in the sense that they followed a two-stage process consisting of, first, deriving efficiency measures for Pakistani agriculture and, second, analysing those variables which seem to explain the relative distribution of efficiency amongst farms. Our paper extends the methodology of Parikh et al. by explicitly considering the multi-output character of farms through the estimation of a generalised translog multi-output cost frontier function and by using a panel dataset, which in comparison with cross section datasets, as pointed out by Atkinson and Cornwell (1993), allows the estimation of an inefficiency indicator with less restrictive distributional assumptions.

Further analysis to explain the efficiency results, indicates the presence of important farm size and regional effects. However, other variables used in the analysis, whilst statistically significant, did not produce the same effect across the different farm types.

II. Measurement of Relative Cost Efficiency in Scotland

This section starts with a brief review of the stochastic cost frontier methodology, followed by a presentation of the data used, the multi-product cost estimation and the computation of the relative cost efficiency indices.

II.1 Stochastic cost frontier methodology

A cost frontier $C^F(\cdot)$ can be expressed by

$$(1) \qquad C_i \geq C^F(y, w; \beta)$$

where C_i is the actual cost incurred by the producer "i", y is the vector of outputs, w is a vector of input prices and β is a vector of technology parameters to be estimated. The cost frontier in (1) is deterministic and ignores the fact that the cost might be affected by random shocks outside the control of producers. If instead, the cost frontier is considered as stochastic, (1) can be written as in (2):

$$(2) \qquad C_i \geq C^F(y, w; \beta) \cdot \exp\{v_i\}$$

where $C^F(y, w; \beta) \cdot \exp\{v_i\}$ is the stochastic cost frontier. This comprises two terms: one deterministic $C^F(y, w; \beta)$, which is common to all producers, and a producer-specific random part $\exp\{v_i\}$, which captures the effects of random shocks on each producer. For the stochastic cost frontier, the measure of cost efficiency is given by (3) (Kumbakhar and Knox Lovell, 2003, pp. 137-8):

$$(3) \qquad CE_i = \frac{C^F(y, w; \beta) \cdot \exp\{v_i\}}{C_i}$$

II.2 Data used for the estimation

The Farm Accounts Scheme (FAS) records a wide range of financial and non-financial data for a selection of farms across Scotland on an annual basis. It is part of the Farm Accounts Data Network, which monitors farm performance across the EU. These data were used for the period 1997/98 to 2003/4 (i.e., the information covered the years 1997 to 2004), which resulted in an unbalanced panel data set (cross sectional/time series) of 358 individual farms. The criteria used to select the farms were that they should be present in the 2003/04 survey, and also that they were in the sample for at least five years. Table 1 summarises this sample by farm types and their respective main outputs.

Table 1: Summary of sample by farm type

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

Source: Own computation based on FAS data

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, etc.); purchased services (e.g. contract work, crop protection costs, etc.); labour; and capital (e.g. rent and depreciation). The outputs considered were: cereals, potatoes, oilseed rape, cattle, sheep, milk and milk products, wool and eggs.

The estimation of cost functions requires input prices. This is a shortcoming of the FAS data (and also of other similar datasets such as the Farm Business Survey for England and Wales), which only presents the input expenditures and not the prices paid. Therefore, Defra's input price indices 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, as the implicit price paid by farmers.

II.3 Cost frontier estimation

The estimation of the cost frontier requires the choice of a functional form. The multi-output, translog cost function was selected because it imposes less 'a-priori' restrictions than other functional forms commonly used for the task. The non-homothetic, translog cost function can be envisaged as a second order approximation in logarithms to an arbitrary cost function. The translog cost function for the case of m outputs and n inputs for the farm i at time t is given by:

$$(4) \qquad \ln C_{it} = \alpha_0 + \sum_{j=1}^{n} \alpha_j \ln W_{jt} + \frac{1}{2}\sum_{j=1}^{n}\sum_{k=1}^{n} \beta_{jk} \ln W_{jt} \ln W_{kt} + \frac{1}{2}\sum_{j=1}^{m}\sum_{k=1}^{n} \delta_{jk} \ln Q_{jit} \ln W_{kt} + \sum_{j=1}^{m} \gamma_j \ln Q_{jit} + \frac{1}{2}\sum_{j=1}^{m}\sum_{k=1}^{m} \rho_{jk} \ln Q_{jit} \cdot \ln Q_{kit}$$

Since the translog cost function does not satisfy "per se" all the required cost function properties, homogeneity and symmetry were imposed through the following restrictions to the parameters (5). Additionally, concavity was tested at each observation of the dataset.

$$(5) \qquad \sum_{j=1}^{n} \alpha_j = 1; \quad \sum_{j=1}^{n} \delta_{jk} = 0; \quad \sum_{j=1}^{n} \beta_{jk} = 0; \quad \sum_{k=1}^{n} \beta_{jk} = 0; \quad \sum_{j=1}^{n}\sum_{k=1}^{n} \beta_{jk} = 0; \quad \beta_{jk} = \beta_{kj}$$

The panel structure of the dataset was especially useful for introducing prices into the cost function. It was assumed that all of the farmers faced the same input prices within the year (across farms), but that prices changed over time.

Given the high number of parameters to estimate in equation (4), the following procedure was adopted. First, the Box-Cox parameter was estimated through a grid-search that maximised the log-likelihood of the system of cost shares, using Seemingly Unrelated Regression Equations (SURE) and imposing the constraints in (5). Second, the remaining parameters of the cost function were estimated (i.e. output terms not associated with prices). Finally, the fixed effect terms for each farm used in the construction of the relative cost efficiency indices were estimated (Atkinson and Cornwell, 1993, Kumbhakar and Lovell, 2003, Pierani and Rizzi, 2003).[3]

In addition to the cost function properties introduced by directly imposing constraints (5) in the estimated equations, 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.[4] The estimated equations are presented in the Annex.

For the case of the translog cost function, the relative cost efficiency index (CEI_i) was defined as by Kumbhakar at al., (2003), where for the most cost efficient producers it has a value equal to one:

$$(6) \qquad CEI_i = \exp\{-(\hat{\alpha}_{0i} - \min_i\{\hat{\alpha}_{0i}\})\} \qquad i = 1,..., N$$

II.4 Relative cost efficiency results

The distribution of individual farm, cost efficiency levels by farm type are shown in Figures 1 to 5. All are skewed to the right, having a higher mean than median cost efficiency level.

It is important to note that the mean value of the relative cost efficiency indices for a farm type can give an indication of how dispersed the farms are in terms of cost efficiency. Thus a low mean value indicates that most of the farms are relatively distant (in terms of cost efficiency) from the most efficient farmer of the farm type group.

The highest mean (also median) of the relative cost efficiency estimates was apparent for dairy farms (mean of 0.58). Dairy farms are thus generally closer in terms of efficiency to the most efficient dairy farm, than is the case for the other farm type groups. This can also be seen in Figures 1-5, where the lowest band of efficiency index is in the range of 0.30-0.35 for dairy farms and below this for other farm type groups.

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[3] The farm level estimated fixed effects used to compute the relative cost efficiency indices were assumed to be constant over time due to the short period covered by the sample (in the best case information was available for some farms for eight years) (Kumbakhar and Lovell, 2003, pp. 170).

[4] It should be noted that while the homogeneity and symmetry properties were imposed in the estimation, the properties of concavity and 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.

Figure 1: Distribution of relative cost efficiency for dairy farms (50 farms)

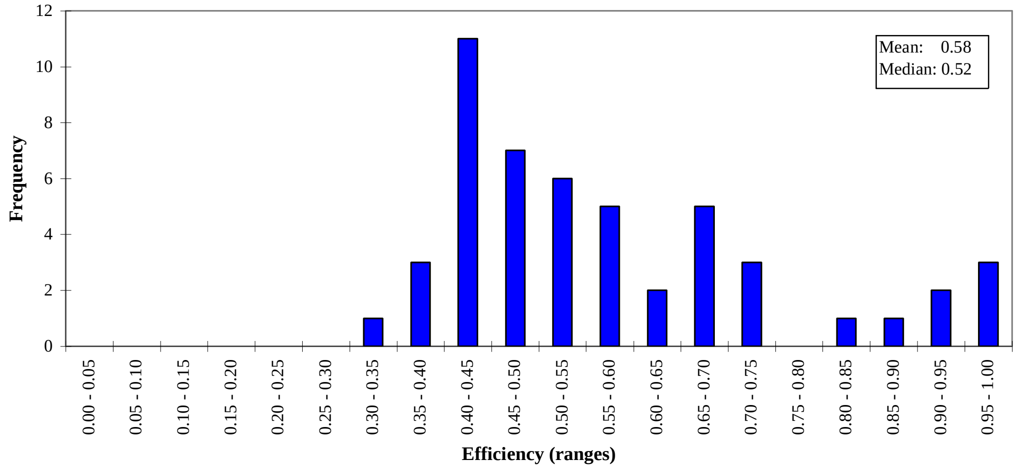
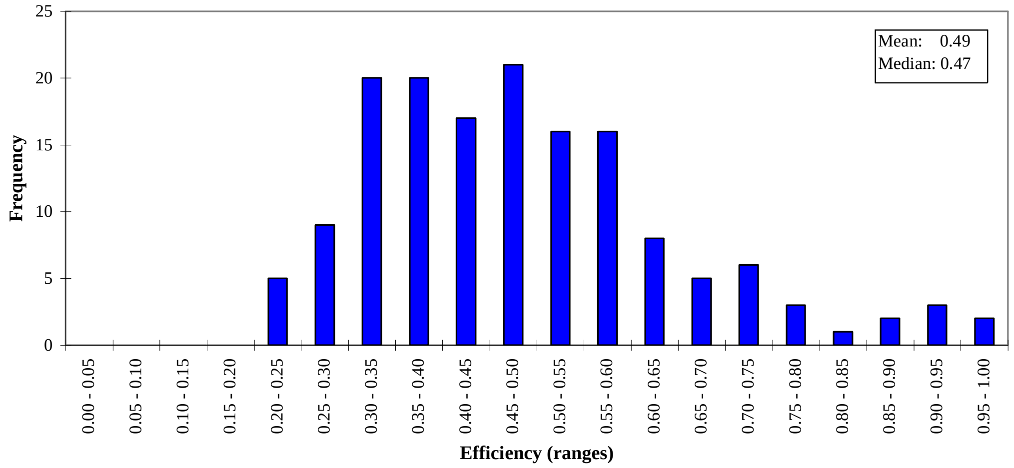


Figure 2: Distribution of relative cost efficiency for mixed farms (154 farms)



The intermediate situation with respect to relative cost efficiency levels is achieved by mixed farms and cattle and sheep farms, with mean indices of greater than 0.40 (0.49 and 0.46 respectively), see Figures 2 and 3. Both cattle and sheep and mixed farms have quite similar cost efficiency distributions.

At the other end of the spectrum are specialist sheep, and cereal and general cropping farms, with mean cost efficiency indices of 0.39 and 0.31 respectively, see Figures 4 and 5. It should be noted that in both cases the value of the median is far below that of the mean value (the median for the cereal and general crop group is 0.23, whilst for the specialist sheep group it is 0.31) indicating that a large part of the group has low efficiency scores. This is also reflected in the coefficient of variation (i.e., mean to standard deviation ratio) of both groups, which are equal to 68.7 per cent for the former and 52.4 for the latter. Furthermore, the cereals and general cropping group has a mode (i.e., the most typical value) that is quite low (in the range of 0.15-0.20 as shown in Figure 5), whilst the mode for specialist sheep is between 0.25-0.30 (see Figure 4).

Figure 3: Distribution of relative cost efficiency for cattle and sheep farms (58 farms)

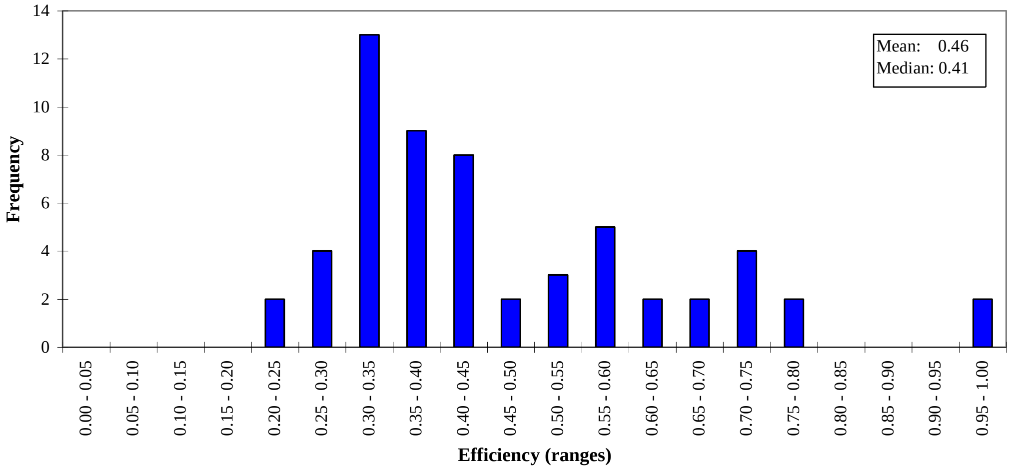


Figure 4: Distribution of relative cost efficiency for specialist sheep farms (31 farms)

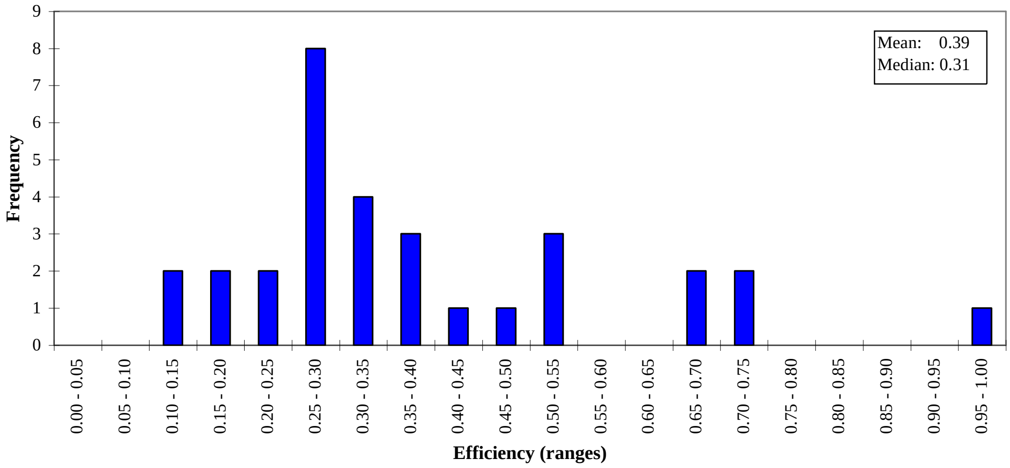
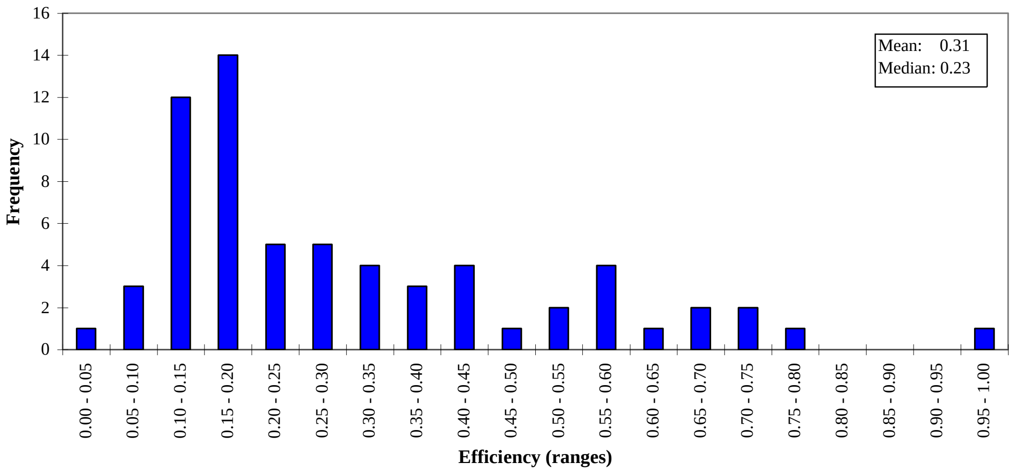


Figure 5: Distribution of relative cost efficiency for cereals and general cropping farms (65 farms)



Overall, these findings suggest that there is considerable scope for cost efficiency improvement across the Scottish farming industry. Those sectors which have had high levels of direct subsidy, such as cereals and general cropping, and specialist sheep (cereal and general cropping and LFA sheep farms had direct subsidies during the 2003/04 crop year equal to 225 per cent (cereals), 130 per cent (general cropping), and 248 per cent (LFA specialist sheep) of Net Farm Income (NFI), respectively),[5] appear to have experienced the greatest levels of inefficiency. In contrast, the dairy sector, which has been most exposed to market forces (direct subsidies represented 60 per cent of NFI in 2003/04), has had relatively less of an inefficiency problem. It should be noted, however, that not all farms can achieve the efficiency levels of the most efficient, because of differences in their resource attributes and the business objectives of their owners / managers.

III. Explaining cost efficiency in Scotland

The purpose of this section is to analyse and identify those variables that explain the results obtained with the relative cost efficiency indices. A database of possible explanatory variables based on previous works (Santarossa, 2003 and Barnes, 2005) was constructed. Table 2 presents the coding of these variables. The descriptive statistics of the main variables used in the analysis are presented in Annex II.

The variables were grouped according to different categories: farm size, region, less favoured area, tenancy, productive diversification, contracting and participation in associations, financial situation and farmers' personal characteristics. Linear regressions were estimated between the cost efficiency indicators by farm type and the possible explanatory variables. The results are presented in Table 3.

The adjusted R squares indicate good overall equation fit, ranging from 0.54 for the case of mixed farms to 0.78 for specialist sheep holdings. Since the estimations used a cross section dataset, the standard deviations of the coefficients were computed using a heteroskedasticity-consistent, variance-covariance matrix.

Before commenting on the results by category, the first striking outcome to note from Table 3 is that each farm type has a different set of explanatory variables. Furthermore, despite several of these variables being statistically significant, they change their signs across farm types. It may be that their effects are either affected by unobserved influences or they are restricted to a specific farm type.

As shown in Table 3, four of the farm types (dairy, cereals and general cropping, cattle and sheep and mixed farms) have strong farm size effects. Small size farms exhibit greater efficiency than medium or large farms.

A regional effect was identified for all farm types, dairy and cereal and general cropping farms in the Northeast and Southeast showed higher efficiency than in other regions. The opposite effect

[5] In 2004/05 subsidies as a percentage of NFI increased substantially to 2,510 per cent for cereals, 790 per cent for general cropping and 300 per cent for LFA specialist sheep.

was observed for cattle and sheep, specialist sheep and mixed farms in the Southwest, which showed lower efficiency. This result tends to conform with the observation that more productive and versatile land exists in the Northeast and Southeast.

Table 2: Definition of the variables used in the analysis

Farm Size
Medium - takes the value of 1 if the farm is medium size, 0 otherwise.
Large - takes the value of 1 if the farm is large size, 0 otherwise.
Region
Northeast - takes the value of 1 if the farm is in the Northeast, 0 otherwise.
Southeast - takes the value of 1 if the farm is in the Southeast, 0 otherwise.
Southwest - takes the value of 1 if the farm is in the Southwest, 0 otherwise.
Less Favoured Area (LFA)
Farmland is not in LFA - takes the value of 1, 0 otherwise.
Farmland is totally in LFA - takes the value of 1, 0 otherwise.
Tenancy
Farmer is the owner - takes the value of 1, 0 otherwise.
Farmer is a tenant - takes the value of 1, 0 otherwise.
If the farmer has a family partnership - takes the value of 1, 0 otherwise.
Productive Diversification
Diversification index (Herfindahl index based on share in revenues).
Specialisation - takes the value of 1 if one of the outputs explains more than 70 per cent of total income.
Number of farm outputs (number from 1 to 8).
Contracting and Participation in Associations
If farmer has a production contract - takes the value of 1, 0 otherwise.
Farm is part of a group or cooperative - takes the value of 1, 0 otherwise.
Farm participates in a marketing group - takes the value of 1, 0 otherwise.
The farm uses productive services from group - takes the value of 1, 0 otherwise.
Financial Situation
Total indebtness to net worth (ratio of all the farm debts, i.e., short, medium and long term, to farm net worth).
Farmer Personal Characteristics
Farmer's age.
Education (categorical).
Farmer possesses agricultural education - takes the value of 1, 0 otherwise.
Farm has a personal computer (PC) - takes the value of 1, 0 otherwise.
Farm uses PC for business - takes the value of 1, 0 otherwise.
Farm uses PC for specialised enterprises - takes the value of 1, 0 otherwise.
Farmer uses Internet - takes the value of 1, 0 otherwise.
Farmer uses Internet for business - takes the value of 1, 0 otherwise.

Table 3: Regressions Explaining Relative Cost Efficiency by Farm Type

Variables 1/	**Farm type**														
	Dairy			**Cereals and General Cropping**			**Cattle and Sheep**			**Specialist Sheep**			**Mixed Farms**		
	Coefficient	t-statistic	Significance	Coefficient	t-statistic	Significance	Coefficient	t-statistic	Significance	Coefficient	t-statistic	Significance	Coefficient	t-statistic	Significance
Number of observations	50			65			58			31			154		
Adjusted R^2	0.778			0.759			0.641			0.780			0.545		
Intercept	0.790	4.971	0.000	0.379	4.511	0.000	0.578	15.233	0.000	1.708	11.075	0.000	0.698	20.830	0.000
Farm Size															
Medium (d)	-0.334	-9.310	0.000	-0.299	-6.269	0.000	-0.221	-7.935	0.000	--	--	--	-0.157	-9.537	0.000
Large (d)	-0.456	-10.841	0.000	-0.365	-7.785	0.000	-0.254	-4.817	0.000	--	--	--	-0.209	-8.076	0.000
Region															
Northeast (d)	0.096	2.482	0.018	0.071	1.657	0.104	--	--	--	--	--	--	--	--	--
Southeast (d)	0.216	9.739	0.000	0.046	1.618	0.112	--	--	--	--	--	--	--	--	--
Southwest (d)	--	--	--	--	--	--	-0.051	-1.951	0.057	-0.258	-5.024	0.000	-0.092	-5.145	0.000
Less Favoured Area (LFA)															
Farmland is not in LFA (d)	0.063	2.504	0.017	0.078	2.379	0.022	0.190	1.778	0.082	--	--	--	0.061	1.843	0.067
Farmland is totally in LFA (d)	0.096	3.973	0.000	0.174	5.455	0.000	0.086	2.370	0.022	-0.529	-10.271	0.000	--	--	--
Tenancy															
Farmer is the owner (d)	--	--	--	--	--	--	--	--	--	0.145	3.308	0.005	--	--	--
Farmer is a tenant (d)	--	--	--	0.092	4.514	0.000	--	--	--	0.224	8.425	0.000	--	--	--
If the farmer has a family partnership (d)	0.113	4.419	0.000	--	--	--	-0.050	-1.751	0.086	-0.135	-3.505	0.003	-0.047	-2.702	0.008
Productive Diversification															
Diversification index (Herfindahl index)	0.341	2.267	0.030	--	--	--	--	--	--	--	--	--	--	--	--
Specialisation (d)	-0.144	-4.598	0.000	--	--	--	--	--	--	--	--	--	--	--	--
Number of farm outputs (1 to 8)	0.029	1.756	0.088	-0.015	-1.981	0.054	--	--	--	-0.166	-6.421	0.000	-0.022	-2.170	0.032
Contracting and Participation in Associations															
If has a production contract (d)	--	--	--	0.152	3.346	0.002	--	--	--	--	--	--	-0.121	-2.533	0.012
Farm is part of a group or cooperative (d)	--	--	--	-0.023	-3.900	0.000	--	--	--	--	--	--	--	--	--
Farm participates in a marketing group (d)	--	--	--	--	--	--	0.101	2.921	0.005	-1.495	-4.836	0.000	--	--	--
The farm uses productive services from group (d)	--	--	--	0.066	1.902	0.063	--	--	--	--	--	--	-0.052	-3.046	0.003
Financial Situation															
Total indebtness to net worth (ratio)	--	--	--	-0.082	-2.411	0.020	--	--	--	--	--	--	0.023	1.941	0.054
Farmer Personal Characteristics															
Farmer's age	-0.004	-3.800	0.001	0.002	1.816	0.076	--	--	--	-0.003	-2.061	0.057	--	--	--
Education (categorical)	--	--	--	0.015	1.911	0.062	--	--	--	-0.057	-3.667	0.002	--	--	--
Farmer possesses agricultural education (d)	--	--	--	-0.119	-3.801	0.000	0.078	2.583	0.013	-0.187	-4.448	0.001	0.043	1.761	0.080
Farm has a personal computer (PC) (d)	--	--	--	--	--	--	--	--	--	0.227	4.600	0.000	-0.054	-2.960	0.004
Farm uses PC for business (d)	0.229	7.336	0.000	-0.119	-3.776	0.000	--	--	--	1.605	4.358	0.001	--	--	--
Farm uses PC for specialised enterprises (d)	0.071	1.809	0.079	--	--	--	--	--	--	-0.510	-3.439	0.004	--	--	--
Farmer uses Internet (d)	--	--	--	--	--	--	--	--	--	-0.243	-4.434	0.001	--	--	--
Farmer uses Internet for business (d)	-0.291	-7.071	0.000	0.081	3.265	0.002	-0.070	-2.706	0.009	-1.683	-4.507	0.000	--	--	--

Notes:

-- stands for either not applicable or not significant.

1/ (d) stands for dichotomous variable.

The relationship between cost efficiency and land quality, as defined by LFA classification, is more complex. For most farm types, farms which are either wholly non-LFA or LFA show a positive effect on cost efficiency relative to those farms that have mixed areas (both LFA and non LFA), possibly indicating that production on more homogeneous land is more efficient. In contrast, for specialist sheep farms the effect of being a total LFA farm has a strong negative impact.

Tenancy variables showed a mixed effect on efficiency, as they were not significant for all of the farms types and their signs changed from one farm type to another. In the case of specialist sheep farms, ownership of the farm had a positive impact on efficiency. However, if the farmer was a tenant this also had a positive effect for specialist sheep farms and cereal and general cropping farms. Partnership with family member(s) had a negative effect on efficiency in most cases, except for dairy farms, where it was positive and strongly significant.

With respect to product diversification, the diversification index and the specialisation variable (which that takes the value of one if at least 70 per cent of the farm output is committed to one product) were only significant in the case of dairy farms and indicated that the higher the specialisation level (i.e., the lesser the number of produced outputs in the farm), the lower the relative cost efficiency. The number of outputs produced had the same effect (positive) as the diversification index in the case of dairy farms. In the case of cattle and sheep it was not statistically significant and in all the other cases (cereals and general cropping, specialist sheep and mixed farms) its effect was negative, indicating that the greater the number of outputs from the farms, the lower the efficiency.

Regarding the contracting and participation in cooperatives variables, they suffer from the problem that they are represented by only a few cases, and this is the probable reason why they give rise to contradictory responses across farm types. For example, in the case of cereals and general cropping, if the farm has a production contract it has a positive effect, whilst in the case of mixed farms it has a negative effect. This pattern was also evident for the other variables in this group (participating in a marketing group and getting productive services from the group).

Financial situation variables have been used in other efficiency studies for Scotland (Santarossa, 2003 and Barnes, 2005). The degree of indebtedness ratio is used here as an approximation of financial health. The results obtained, as reported in the literature, are mixed; they appear negative in the case of cereals and general cropping, but positive for mixed farms.

Among personal characteristics, we considered the farmer’s age, education, agricultural education, presence and use of a computer and presence and use of the internet. Despite the fact that the mean age of all the groups is very similar (around 55 years old), age showed a negative effect on efficiency in the case of dairy farms and specialist sheep farms, but positive for cereals and general cropping farms. The level of education showed a positive effect for cereals and general cropping farms, but negative in the case of specialist sheep farms. Similar results were obtained for agricultural education, which was only positive for cattle and sheep farms and for mixed farms.

The use of a PC for business was found to have a strongly positive influence on cost efficiency for dairy and specialist sheep farms, whilst there was a negative impact on cost efficiency amongst cereals and general cropping businesses. Mixed results were obtained for the use of the Internet, which showed a positive effect in the case of cereals and general cropping, but negative effects in several other cases. The quality of the information accessed and the wisdom with which it is used are clearly of relevance to these results.

IV. Final Remarks and Conclusions

The main driver behind this paper is the fact that improvements in farm performance are seen as important for achieving farm sustainability in the context of the recent CAP reforms.

Amongst the various features of farm performance, the analysis has focused on cost efficiency. Therefore, the purpose of the paper has been to establish the recently prevailing pattern of relative cost efficiency amongst Scottish farms (i.e., how dispersed are similar types of farms in terms of their cost efficiency) and to analyse those variables that are important in explaining the relative cost efficiency of farms.

Cost efficiency in the paper has been estimated through a distance to a stochastic cost frontier approach, from which the efficiency indices have been derived. To estimate the cost frontier, a generalised multi-product, translog cost function was estimated with an unbalanced panel dataset for 358 farms of five farm types: dairy, cereals and general cropping, cattle and sheep, sheep specialist and mixed farms. Eight farm outputs and four inputs were considered.

The profiles of relative cost efficiency produced for each farm type indicate wide variation in the cost efficiency levels achieved within and between farm type groups. Moreover, those sectors that have been most heavily supported by direct subsidies at the farm level, exhibit the greatest variation in cost efficiency performance. Dairying, for which direct subsidies have been relatively less significant, and market price pressure from multiple retailers has been very fierce, has less variation in the cost efficiency of its constituent producers. On the face of things, these findings imply that there is considerable scope for cost efficiency improvement across much of the Scottish farming industry. Furthermore, they provide some support for the underlying philosophy of the 2003 CAP reforms, that decoupling and support reduction will increase the cost competitiveness of Scottish farms.

Further analysis to explain the efficiency results indicated the presence of important farm size and regional effects. An increase in farm or enterprise size may well be the eventual reaction of some farmers to CAP reform. Indeed, the IMCAPT study (SAC, 2006) has ascertained that 18 per cent of a sample of 611 Scottish beef and sheep farmers anticipate an increase in scale, in response to the CAP reforms. However, the analysis here suggests that an increase in scale by itself may not achieve cost efficiency improvements. It is suggested that it will need to be matched by improved resource utilisation and combination, and improved production and marketing practices. However, none of the selected variables seem to explain the achievement of cost efficiency across the farm types, and therefore their effects can only be associated with particular farm types.

The finding that the relative cost efficiency distribution of Scottish farming is relatively dispersed, and that for a significant part of the industry cost efficiency is low, is perhaps understandable. Although Scottish agricultural policy has been seeking to drive costs down, it has simultaneously pursued a strong quality strategy (SEERAD, 2001a; Leat, et al. 1998). The quality strategy in itself will serve to increase costs, but will simultaneously improve competitiveness as long as the market will pay a premium over the costs involved.

The most recent Scottish agriculture policy strategy pronouncement (SEERAD, 2006) is trying to ensure a prosperous and sustainable farming industry that is competitive in markets, a driver of rural development and renowned for its high environmental standards. The pursuit of such diverse objectives will have a variety of sometimes conflicting implications for cost efficiency, some positive (e.g. assisting the removal of relatively unproductive labour as the rural economy develops) and some negative (e.g. introducing costs of high environmental standards). However, the strategy has a variety of actions directed at cost control, improved management, training and skill development, and greater connection with markets, which will serve to encourage greater cost efficiency whilst better meeting market demands.

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Annex I. Generalised Translog Multiproduct Cost Functions by Scottish Farm Type 1/

	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	0.989			0.987			0.987			0.986			0.986		
Log likelihood	2209.0			2168.8			2325.5			1230.0			1229.9		
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							
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	**						

Continues

	Farm type														
	Dairy			**Cereals and General Cropping**			**Cattle and Sheep**			**Sheep Specialist**			**Mixed Farms**		
	Coefficient	Std. Error	Signif. 1/	Coefficient	Std. Error	Signif. 1/	Coefficient	Std. Error	Signif. 1/	Coefficient	Std. Error	Signif. 1/	Coefficient	Std. Error	Signif. 1/
$f(Q_1)f(Q_1)$	-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							
$f(Q_5)f(Q_5)$	-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.

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.

Annex II. Descriptive Statistics of the Main Variables Used in the Analysis

Variables	Statistics			
	Mean	Standard Deviation	Minimum	Maximum
Efficiency indices				
Dairy	0.57	0.17	0.33	1.00
Cereals and General Cropping	0.31	0.21	0.04	1.00
Cattle and sheep	0.46	0.18	0.22	1.00
Sheep specialist	0.39	0.20	0.12	1.00
Mixed farms	0.49	0.16	0.21	1.00
Farm Size				
Small (d)	0.47	0.50	0.00	1.00
Medium (d)	0.41	0.49	0.00	1.00
Large (d)	0.12	0.33	0.00	1.00
Region				
Northwest (d)	0.16	0.37	0.00	1.00
Northeast (d)	0.24	0.43	0.00	1.00
Southeast (d)	0.18	0.39	0.00	1.00
Southwest (d)	0.41	0.49	0.00	1.00
Less Favoured Area (LFA)				
Farmland is not in LFA (d)	0.23	0.42	0.00	1.00
Farmland is totally in LFA (d)	0.62	0.49	0.00	1.00
Tenancy				
Farmer is the owner (d)	0.47	0.50	0.00	1.00
Farmer is a tenant (d)	0.24	0.43	0.00	1.00
If the farmer has a family partnership (d)	0.54	0.50	0.00	1.00
Productive Diversification				
Diversification index (Herfindahl index)				
Dairy	0.57	0.13	0.34	0.87
Cereals and General Cropping	0.64	0.25	0.00	1.00
Cattle and sheep	0.52	0.12	0.38	1.00
Sheep specialist	0.81	0.16	0.50	0.97
Mixed farms	0.63	0.19	0.29	1.00
Specialisation (d)				
Dairy	0.52	0.50	0.00	1.00
Cereals and General Cropping	0.52	0.50	0.00	1.00
Cattle and sheep	0.12	0.33	0.00	1.00
Sheep specialist	0.84	0.37	0.00	1.00
Mixed farms	0.53	0.50	0.00	1.00
Number of farm outputs				
Dairy	3.24	1.08	2.00	6.00
Cereals and General Cropping	2.48	1.28	0.00	6.00
Cattle and sheep	3.22	0.70	1.00	4.00
Sheep specialist	2.52	0.51	2.00	3.00
Mixed farms	2.99	1.06	1.00	5.00
Contracting and Participation in Associations				
If has a production contract (d)	0.01	0.12	0.00	1.00
Farm participates in a marketing group (d)	0.02	0.14	0.00	1.00
The farm uses productive services from group (d)	0.23	0.42	0.00	1.00
Financial Situation				
Total indebtness to net worth (ratio)	0.07	0.40	-5.09	4.06
Farmer Personal Characteristics				
Farmer's age	56.78	11.05	32.00	83.00
Education (categorical)	2.32	1.39	1.00	7.00
Farmer possesses agricultural education (d)	0.19	0.40	0.00	1.00
Farm has a personal computer (PC) (d)	0.74	0.44	0.00	1.00
Farm uses PC for business (d)	0.61	0.49	0.00	1.00
Farm uses PC for specialised enterprises (d)	0.06	0.24	0.00	1.00
Farmer uses Internet (d)	0.68	0.47	0.00	1.00
Farmer uses Internet for business (d)	0.52	0.50	0.00	1.00

Notes:
1/ (d) stands for dichotomous variable.