DAIRY FARMS: ECONOMIC PERFORMANCE AND LINKS WITH ENVIRONMENTAL PERFORMANCE

A report based on the Farm Business Survey

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Summary

1. 'Efficiency' in this report refers to economic efficiency, i.e. the farm's efficiency at turning economic input into output (in this case mainly the value of livestock). This definition was chosen in order to give a criterion which would identify farms that were viable and competitive, and therefore able to contribute to Defra's aim of sustainable food production. The report analyses data from all English FBS farms that were classified as dairy farms in at least three years between 2003 and 2010.
2. There is a high level of variation in efficiencies of dairy farms. Under 2% of the variation in output is related to large-scale geographic factors (e.g. regional differences in soil and climate). Just over 70% is related to other between-farm differences in efficiency, such as differences in management ability and local geographic effects (e.g. small-scale variation in land quality), whilst around a quarter represents year-to-year variation in the performance of farm businesses.
3. A number of factors help to explain the variation in efficiency between farms, including the following:
   Debt: low efficiencies are strongly associated with high debt.
   Farmer age: farm business performance increases slightly with age.
   Tenure: owner-occupied farms perform better than tenanted farms on Full Agricultural Tenancies, which in turn perform better than those on Farm Business Tenancies.
   Moorland area: farm containing moorland have lower agricultural efficiencies, but there is no significant difference for the farm business as a whole.
   Specialisation: on average, farms with a range of agricultural activities (including those growing their own fodder crops and rearing dairy calves) perform better than those focused entirely on milk production, although the magnitude of the difference varies between years.
   Diversification: diversification outside agriculture is associated with reduced agricultural efficiency, but has no significant impact on business-level efficiency.
   Foot and Mouth Disease: farms culled for FMD had reduced agricultural performance between 2003 and 2005, whilst the deleterious effect on the business as a whole seems to be longer lasting.
   Unpaid family labour: there is no significant relationship between the proportion of family labour and efficiency when 'unpaid' labour is costed at its full economic value. When it is costed at the minimum wage, farms with greater proportionate use of family labour perform better in terms of agricultural outputs.
   Organic status: organic dairy farms perform better at both the Farm Business level and for the agricultural cost centre. The magnitude of the advantage varies from year to year.
4. Average efficiencies show little relationship with the economic size of farms in the unadjusted dataset. However, the fitted model reveals that there are inherent economies of scale up to around £500,000 costs per annum, provided the effects of the confounding factors described above are allowed for. Similarly, analysis of costs shows that larger herds tend, on average to have lower costs and higher margins, but that there is a high level of variation, with the best small and medium sized herds achieving similar performance to the largest ones.
5. Economic performance of dairy farms is less strongly related to membership of agri-environment schemes than is the case for either cereal farms or grazing livestock farms. Nevertheless, membership of ELS does seem to be related to improved performance at the farm business level. Very few farms in the sample have joined HLS, making it difficult to assess its impact on dairy farms.

6. Business management practices are linked to economic efficiency. High performing businesses are more likely to:
    - use management accounting practices
    - have a PC and use the internet for submitting forms electronically
    - have a business plan
    - plan ahead using information from the farming media and discussions with other farmers.
    - adopt risk management strategies, particularly selling on contract basis with agreed price.
7. Farms ceasing to produce milk were more likely to:
    - be older than average
    - be in an area with fewer other dairy farms
    - have proportionately less income from SPS and agri-environment schemes
    - receive a lower than average price for their milk
    - have lower agricultural performance
    - have lower veterinary costs

    Where farms continued in agriculture, the majority became grazing livestock farms, with smaller numbers being classified as mixed, cereals or general cropping farms.
8. Analysis of costs suggests that control of costs is critical in ensuring a positive net margin, with the best producers keeping costs low in all areas.

Dairy farms: economic performance and links with environmental performance.

A report based on the Farm Business Survey

1. <u>Introduction</u>

The first of Defra's three priorities, as set out in the business plan announced in November 2010[1] is to 'Support and develop British farming and encourage sustainable food production'. Sustainable food production can only be achieved if the economic performance of individual farms allows them to remain viable and competitive. The first objective of this report is therefore to examine how economic performance varies between dairy farms, and to examine the characteristics of the best performing farms.

In examining the economic performance of farms, a key issue that has stimulated much debate over many decades is the degree of association between performance and farm size. Clearly there are potential economies of scale that mean that larger farms *may* be, on average, more efficient than smaller ones. There may also be economies of scope, where larger firms are able to spread their costs over a greater number of enterprises. However, some have argued that there are also diseconomies of scale that may counteract these. Whilst this might seem a rather academic argument, it has real implications for the degree of structural change that faces English agriculture in the future, and the pace at which that change must happen. This in turn will have a major impact on the viability of those rural communities where agriculture is still an important part of the economy.

The second Defra priority is to 'Help to enhance the environment and biodiversity to improve quality of life'. In the past, there has certainly been some tension between the environment and agricultural production, with some measures adopted to achieve economic efficiency causing damage to the environmental sustainability of the countryside. The second objective of the report is therefore to consider the correlation between economic performance and environmental performance, in order to see whether conflict remains between Defra's first two priorities.

This report deals with dairy farms and builds on similar work already published for cereals farms[2] and grazing livestock farms[3]. However, in view of the different issues currently facing the dairy industry at present, this report contains some extra material, including a chapter on the characteristics of those farms leaving the industry and another dealing with the cost of production of milk.

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[1] http://www.defra.gov.uk/corporate/about/what/business-planning/

[2] http://www.defra.gov.uk/statistics/files/defra-stats-foodfarm-environ-obs-research-arable-cereals-110505.pdf

[3] http://www.defra.gov.uk/statistics/files/defra-stats-foodfarm-environ-obs-research-cattle-grazingrep-120308.pdf

2. Methods: Data and statistical models

2.1. Data

Data was taken from the Farm Business Survey of England for 2003-2010; this period was chosen to include two years of data prior to implementation of the most recent Common Agricultural Policy (CAP) reforms, including the Single Payment Scheme (SPS). Farms were included in the analyses in Chapters 3-6 if they were classified to 'robust' type[4] dairy in at least three of these years. 402 farms met this condition, with 87 of these surveyed in all eight years, and 226 providing data in at least five years. Farms were excluded from the analyses if they had less than 20 dairy cows in any year; this avoided including farms that had ceased dairying but remained in the FBS as a different farm type.

2.2. Variables used in the analysis

The principal variables used are shown in Table 2.1. Models are either fitted for the entire farm business (i.e. using 'fbout' and 'fbcosts' from Table 2.1), or just for the agricultural cost centre (i.e. using 'agoutput' and 'agcosts').

Table 2.1: principal variables used in the analysis

Variable name	FBS database name	Description
fbout	Farm.business.output	Output in £k including that from diversified enterprises as well as traditional farming sources.
fbcosts	Farm.business.costs	All fixed and variable costs relating to traditional farming, agri-environment schemes and diversified enterprises. It does not include a notional cost of unpaid family labour.
agoutput	crop.output.excl.subsidies + livestock.output.excl.subsidies	Output in £k from agricultural enterprises, excluding direct and indirect government support.
agcosts	agriculture.variable.costs + agriculture.fixed.costs	All fixed and variable costs relating to traditional farming. It does not include a notional cost of unpaid family labour. On owner occupied farms it does not include any notional rent.
Unpaid	Unpaid.labour	Notional cost of unpaid labour provided by the farmer, spouse and other family members. The costs are estimated by the researcher based on the hourly rate for skilled labour in the area.

[4] http://www.defra.gov.uk/statistics/files/defra-stats-foodfarm-farmmanage-fbs-UK_Farm_Classification.pdf

2.3. 'Unpaid' family labour

Family labour is an important issue when considering farm efficiencies, and the way it is treated can have important implications for the results (Britton and Hill, 1975). The most common approach is to impute a cost equivalent to the amount that the unpaid staff could earn in similar work elsewhere. This is generally justified as an estimate of the 'opportunity cost'; i.e. the income foregone by the farmer and spouse because they are working on the farm rather than earning money in employment. In this respect it is an imperfect estimate of the true opportunity cost, since some farmers, particularly on the larger farms, will have skills that could command higher rates than the figures for agricultural workers which are generally used.

There are other problems with this approach. When speaking with small farmers ('small' in terms of economic size!) it is often clear that some of them do not expect their business to provide the same monetary returns that they would receive in other alternative employment. Whilst there is no hard data to indicate how common this attitude is, there are good reasons why it should apply to many farmers. This is because the farming family receives other non-monetary benefits from working on the farm, and it is logical for them to discount their monetary payment to allow for this, producing a 'shadow price' below the standard wage rate, particularly on smaller farms (Chavas, 2008). Examples of these benefits will include:

- Housing. Particularly for small tenant farmers, the farmhouse accommodation will frequently be far superior to anything that they could hope to buy or rent if working off the farm.
- Proximity to work. In rural areas long journeys would frequently be required to find alternative work, and these journeys would generally need to be made by private car. It is therefore logical for farmers to accept a lower rate of return for work on the farm in order to avoid this time and expense.
- Independence and status. Many farmers value the freedom to be their own boss. Despite the low financial returns for small farmers, they retain a high status in the minds of many in rural communities.
- Enjoyment of work. Farmers may enjoy the work and consider it more satisfying than alternative employment.

In practice it is not possible to estimate a suitable shadow rate, allowing for these other benefits, not least because they vary according to individual circumstances. They are likely to be significant in comparison to the imputed value for many small farmers, and hence any estimation using the imputed values will tend to underestimate the efficiency and sustainability of the smaller businesses. For the larger farms, the proportionate use of unpaid labour is less, so the issue is of less importance.

In the previous document on cereals farms[5] the approach adopted was to analyse the data with and without imputed costs for unpaid labour, presenting just the results without imputed costs, except where marked differences were present. This approach worked well for cereals farms, but was less satisfactory for grazing livestock farms because labour makes up a higher proportion of total costs. A third approach was therefore adopted, with family labour being charged at a rate equivalent to the national minimum wage[6] and this is also used in this document; whilst this is a somewhat arbitrary figure, it does represent the

[5] http://www.defra.gov.uk/statistics/files/defra-stats-foodfarm-environ-obs-research-arable-cereals-110505.pdf

[6] Rates are taken from the 'historical rates' table at http://www.lowpay.gov.uk/

minimum return for employment within the wider economy and, in practice, gives a discount of around £2.50 per hour compared to the imputed values for dairy farms.

2.4. Statistical models used

To allow a proper exploration of economic performance statistical models were fitted to the data rather than relying on simple statistics such as the ratio of outputs to inputs. The response variable was the log-transformed total outputs (logfbout for all farm business costs or logagout for agricultural outputs, see Table 2.1):

$$logout_{ij} = y_j + b_1*logcosts_{ij} + ef_i + e_{ij} \qquad \text{(Equation 1)}$$

Where:
$logout_{ij}$ is the log-transformed output of farm i in year j (calculated using fbout or agout)
y is an effect of the jth year (e.g. allowing for high prices, or poor weather)
$logcosts_{ij}$ is the log-transformed input costs of farm i in year j (calculated using fbcosts or agcosts)
b_1 is the regression slope for logcosts
ef_i is an effect of the ith farm (e.g. allowing for differences in fertility of the land or competence of the farm staff)
e_{ij} is a random error term for farm i in year j (e.g. allowing for random events such as disease losses)

Two variants on this model were used, relating to the form of the farm effects:

1. Frontier model: in this model the farm effects were constrained to be negative and thus measure the distance of the farm from the efficient frontier. The model was fitted using maximum likelihood in the specialist program FRONTIER[7].
2. Mixed effects model: farm effects were normally distributed about a line representing the average efficiency of farms. The model was fitted using restricted maximum likelihood (REML) in GenStat[8].

In practice, the correlation between the farm effects from the two models was found to be very high (around 0.99), meaning that there was little to be gained by using the two different measures of efficiency. Therefore most of the analyses presented here use the REML models, since these can be fitted in standard software and are easily extended to more complex models. Figure 2.1 shows the models in graphical terms.

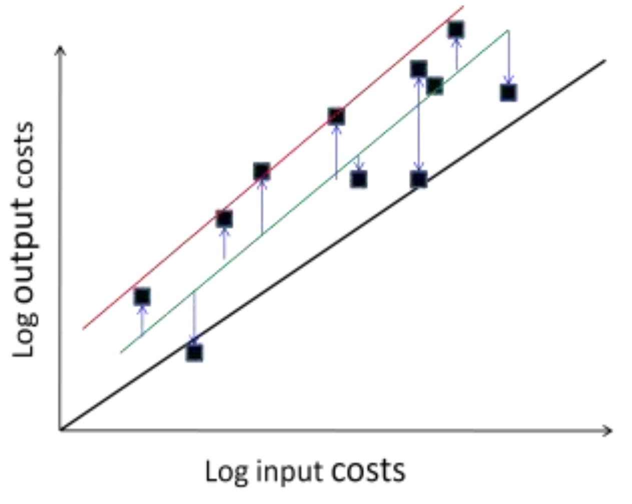


Figure 2.1: graphical representation of the model of equation 1. The black line represents equal inputs and outputs, the green line is the average efficiency (REML) and the red line is the efficient frontier. The blue arrows represent the efficiencies of each farm relative to the average.

Equation 1 assumes that the farm effect remains constant over time, which is perhaps unrealistic over the eight year period considered in this report. A random slopes REML model was therefore used, in which each farm's efficiency can increase or decrease over

[7] http://www.uq.edu.au/economics/cepa/software.htm

[8] http://www.vsni.co.uk/software/genstat/

time:

$\text{logout}_{ij} = y_j + b_1*\text{logcosts}_{ij} + ef_i + s_i*y_j + e_{ij}$ (Equation 2)

Where s_i represents the trend in efficiency for the ith farm.

The model of equations 1 and 2 assumes a linear relationship on the log scale between the output value and input cost. Polynomial terms for costs were fitted to check that this approximation was appropriate, with quadratic and higher terms being retained if they were significant at the conventional 5% level. Interactions between the year effects and input costs were also checked.

2.5. Impact of price changes

In a frontier analysis the goal is generally to relate outputs to input quantities in order to estimate technical efficiency (i.e. efficiency in terms of the quantity of outputs produced from a given quantity of inputs[9]). Where the inputs are measured in monetary terms it is therefore sensible to deflate them to ensure that they are proportional to the quantities even if prices change over the period of the study.

In this work, by contrast, the objective was to relate output value to input costs in order to estimate economic efficiency[10]. Over the course of the study, prices will change and farmers will respond to these changes; this is a real feature of the system and it would not be sensible to deflate the input or output values to 'correct' for this. For example, if the price of fertiliser dropped sharply farmers might decide to apply more of it, to increase the outputs obtained, where this was possible subject to regulatory and agronomic constraints. This might well increase economic efficiency in terms of the ratio of outputs to inputs, since the optimal rate of application increases when the fertiliser price falls, but any attempt to correct for the price change by adjusting the cost back to the previous higher price would be inappropriate, since the farmer would not have made the purchase had that higher price applied. In this instance the increased fertiliser application would probably lead to a reduction in technical efficiency, despite being a sensible economic decision.

2.6. Factors correlated with efficiency

When investigating factors associated with efficiency, it is best to include these factors within the main efficiency model, using either the frontier or REML approach. The REML model then becomes:

$\text{logout}_{ij} = y_j + b_1*\text{logcosts}_{ij} + d_1*z_1 + ... + d_p*z_p + ef_i + s_i*y_j + e_{ij}$ (Equation 2)

Where d_1 to d_p are regression slopes for p explanatory variables z_1 to z_p which help to explain the differences in efficiency between farms.

However, for initial exploratory analyis a two stage approach was adopted, in which the efficiencies for each farm are estimated as described above and then used as the dependent variable in a regression. This allows for easy graphical display of relationships in order to assist with identification of non-linearities and interactions.

The spatial pattern of efficiencies was also investigated. This is important since any clustering of efficiencies might indicate that geographic factors (e.g. soils, rainfall) were important, limiting the scope of individual farmers to improve their efficiency. For confidentiality reasons, geographic co-ordinates of farms are only recorded to the nearest

[9] See the book by Coelli et al. cited in the references (Section 10) for more information.

[10] 'Economic efficiency' is used in this report to refer to the optimal ratio of output value to input costs. This is similar to the terminology used by Coelli et al. (see p51) and is the result of both allocative efficiency and technical efficiency. Use of the term is not intended to imply pareto efficiency.

10km; when results are displayed in map form, farms were plotted at a random location within the 10km square to avoid co-incident points.

2.7. Modelling approach

As has been pointed out by Armsworth et al. (2009), the way in which regression models are applied differs between econometrics and scientific disciplines such as ecology and medicine. Economists tend to be more interested in theoretical basis of the models, and are concerned about endogeneity. Scientists often regard regression models more as an exploratory technique for describing empirical relationships between variables, and value parsimony in model selection.

The modelling approach used here is much closer to the empirical scientific approach than it is to the traditional econometric approach, and the results need to be interpreted in that light. Thus significant relationships do not necessarily imply a causal relationship. Estimates derived from the model are not necessarily unbiased estimates of the true causal model, but are approximately unbiased estimates of the relevant parameters for the FBS population of farms.

3. Results: economic efficiency

3.1. Efficiency models and returns to scale

Results of the efficiency models are shown in Figure 3.1. The vertical axis is displayed as a ratio of outputs/inputs, rather than as log output costs as in Figure 2.3, as this makes it easier to appreciate the comparatively subtle changes in returns to scale (i.e. the slope of the lines). There is a significant quadratic relationship between inputs and outputs. The red line represents the efficient frontier (from the FRONTIER model); most farms lie below this line, but a few are above it as a result of a high positive residual, indicating exceptional performance in a particular year. The green REML line represents the best fit to the data and therefore passes through the black crosses representing each farm.

The black horizontal line on each graph in Figure 3.1 represents equality between outputs and inputs and so the vertical distance of a point above this line represents the margin of outputs over inputs. In most years both the red frontier line and the green average line slope upwards for low input costs, then reach a maximum before heading downwards. This suggests that medium-sized farm businesses tend, on average, to be proportionately

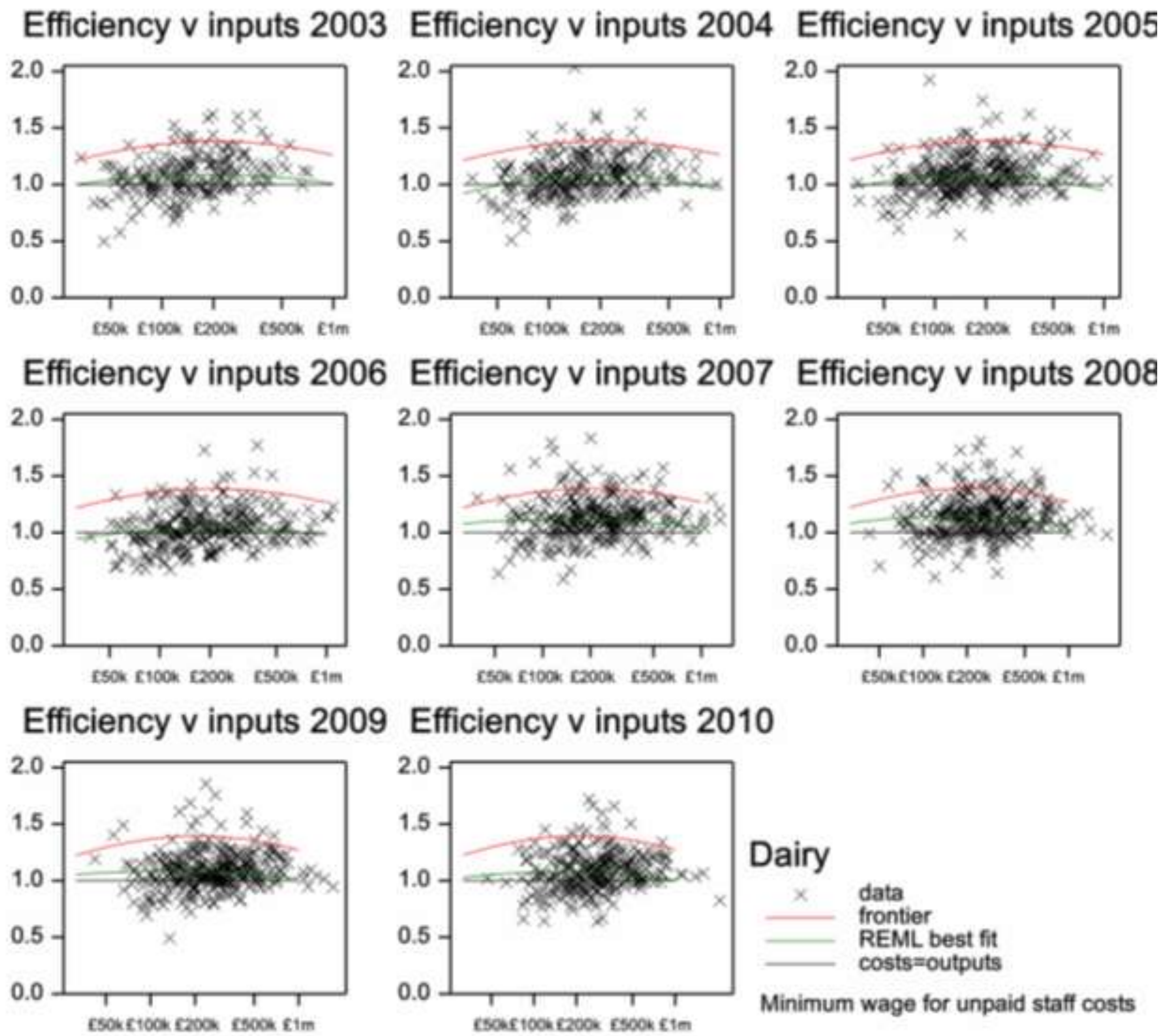
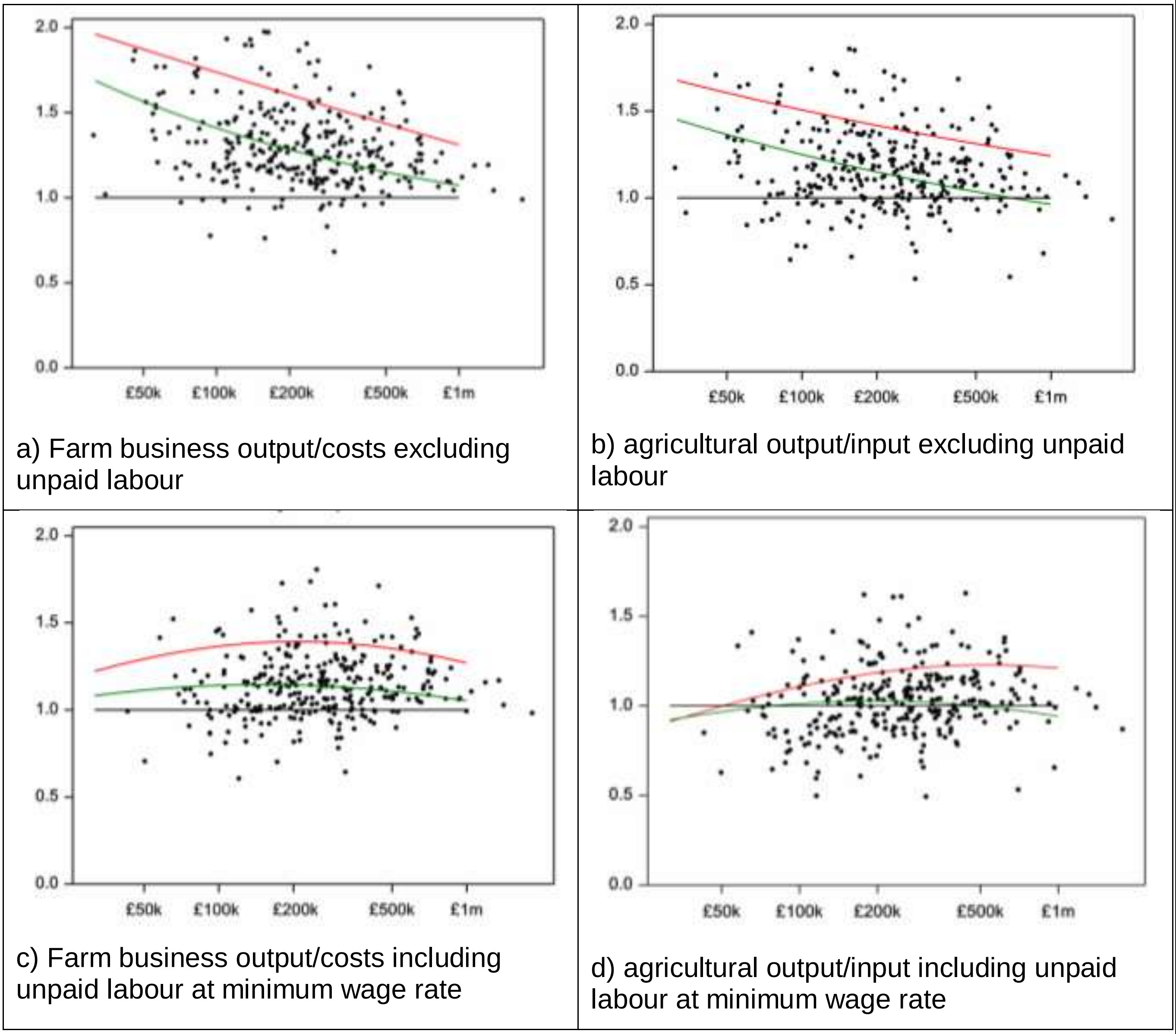


Figure 3.1: REML efficiency models for farm business output. The vertical axis shows the ratio of outputs to inputs, and the horizontal axis input costs, with family labour costed at the national minimum wage. The red line is the frontier from a stochastic frontier model and the green line is the REML fitted line describing the average relationship.



a) Farm business output/costs excluding unpaid labour

b) agricultural output/input excluding unpaid labour

c) Farm business output/costs including unpaid labour at minimum wage rate

d) agricultural output/input including unpaid labour at minimum wage rate

Figure 3.2: efficiency models fitted to the different datasets for 2008. The vertical axis shows the ratio of outputs to inputs, and the horizontal axis input costs. The red line is the stochastic frontier and the green line is modelled average value.

more efficient in turning inputs into outputs in terms of the monetary value.

The pattern of returns to scale varies somewhat depending on whether the model is based on the whole farm business, or just the agricultural enterprises (Figure 3.2); however, this difference is less than for some other farm types since the agricultural cost centre tends to make up a larger proportion of the total business for dairy farms.

The treatment of family labour has a greater impact, as can be seen by comparing the top and bottom scatterplots in Figure 3.2. When family labour costs are excluded, the lines have a strong downward slope, indicating that smaller farms, which use proportionately more family labour, are much more efficient.

3.2. *Spatial pattern in efficiency*

Figure 3.3 shows the spatial distribution of farm efficiencies based on agricultural inputs and outputs. The overall distribution of points on the map broadly reflects the overall distribution of dairy farms in England, with highest densities towards the West, particularly in counties such as Devon, Cheshire and Lancashire.

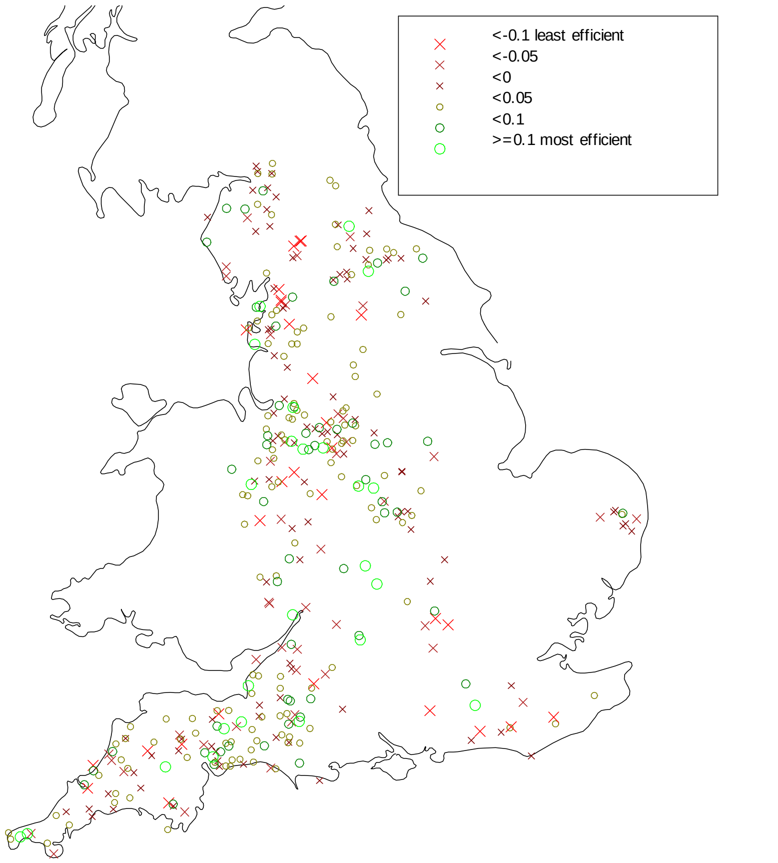


Figure 3.3: Spatial distribution of farm efficiencies. Efficiencies are based on the model for agriculture only, with family labour charged at the national minimum wage. To preserve confidentiality farms are shown at random locations within the 10km square and results are suppressed for 10km squares with less than 5 dairy farms in 2010.

More interesting is the distribution of levels of efficiency, shown by the different symbols and colours in Figure 3.3. Whilst there is some evidence for local clustering within about 15km, there is little sign of any wider regional effects, with most areas having a mix of efficient (circles) and less efficient (crosses) farms. The exception to this is the east of the country, where there are signs of an excess of crosses in Kent, Sussex and East Anglia. Despite this, Table 3.1 indicates that the spatial component, modelled at the National Character Area[11] (NCA) level, accounts for under 2% of the total variability in agricultural outputs. When a similar model is fitted to farm business outputs none of the variation is explained by NCAs, due in part to some more positive efficiencies for farms in Kent and Sussex. These figures will underestimate the true figure due to the limited geographic information available for FBS farms, but it is nevertheless much lower than the variability between farms, which accounts for over 70% of the total variation. Variability between farms will be due to factors such as the skill of the farmer and the livestock kept, as well as more local geographic factors such as soil characteristics. Around a quarter of the total variation in agricultural outputs is unexplained year to year variation within farms, caused by factors such as poor grass growth or disease problems. Gradual changes in efficiency over the eight years of data, such as the improvements that may happen when management passes from one generation to the next, will also contribute to the year to year variation.

[11] National Character Areas, formerly known as Joint Character Areas (JCAs) are a subdivision of England into 159 areas based on landscape features. See http://www.naturalengland.org.uk/ourwork/landscape/englands/character/areas/default.aspx

Table 3.1: proportion of variance at different levels in the data

	Farm business outputs			Agricultural outputs		
	Variance	s.e.	% total	Variance	s.e.	% total
Spatial variation (NCA)	0.0000	-	0.0%	0.0001	0.00021	1.8%
Farm to farm variation	0.0035	0.00027	71.1%	0.0055	0.00045	73.6%
Random year to year variation	0.0014	0.00005	28.9%	0.0018	0.00006	24.6%

Based on a REML model of log transformed agricultural output value with terms fitted for log-transformed input costs and their interaction with year. Family labour is charged at the national minimum wage. This model does not include a term for random slopes.
The spatial variation is based on National Character Areas and does not include more local geographic factors.

3.3. Estimating the Frontier

Variance estimates like those displayed above are not easy to interpret, and so this section will attempt to quantify the efficiency of grazing livestock farms by comparing the performance of average farms with those on the economic frontier.

One way to do this is to use stochastic frontier analysis to estimate the frontier of best performing farms, in terms of output produced for a given level of input. Comparing the green line of average performance with the red frontier line in Figures 3.1 reveals that the average dairy farm operated at 90% of the efficiency of frontier farms[12]. This compares to 84% for lowland grazing farms, 81% for LFA grazing livestock and 76% for cereals farms.

Whilst these figures are all calculated on the same basis, care must be taken in interpreting both the absolute values and the differences between them. Estimating a frontier can be done with accuracy when the distribution of performance is skew, with many firms clustered close to the frontier and a tail of less efficient firms. Unfortunately, this is seldom the case with farm data, as can be seen in Figures 3.1 and 3.2, where the high level of stochastic variation makes it difficult to identify where the frontier lies. In this situation estimates of the frontier can be volatile and easily influenced by a few outliers.

Table 3.2 takes a different approach to the issue, showing what the distribution of performance might mean in terms of the value of outputs from a farm of average economic size. These figures are based on the REML analysis indicated by the green lines in Figure 3.1 Estimates are shown between the 10th and 90th percentiles of performance; estimates at the extreme tails of the distribution will be unreliable and are therefore not shown. Note how a farm at the tenth percentile produces roughly £40,000 more output than one at median efficiency (50th percentile), and this in turn produces around £30,000 more than one at the 90th percentile. These figures exclude the impact of random year to year fluctuations in performance; if this were included there would be even more variation in the output produced.

[12] To provide consistency with the earlier reports, these statistics are calculated using a cross-sectional Frontier analysis on individual years, rather than the panel-based models used in Figure 3.1. The cross-sectional analysis tends to ascribe more of the variation to within farm random effects, leading to higher average efficiencies than would be expected from the panel models of Figure 3.1.

Table 3.2: predicted outputs for a farm with input costs of £200,000 at various points on the distribution of performance.

Performance percentile	Farm Business output £000s
(most efficient) 10%	271.4
25%	246.5
50%	228.5
75%	209.9
(least efficient) 90%	196.1

Note: based on the REML model with family labour charged at the national minimum wage. Estimates are based on 2008 prices and trading conditions, but represent average returns expected over a number of years

4. Results: factors correlated with efficiency

Tables 4.1a and 4.1b shows the significant variables in a stepwise REML analysis of log output against the various predictor variables. As with any stepwise regression, some caution is needed in interpreting the results since there may be alternative models which are equally good in explaining the data. This is particularly the case where predictor variables are highly correlated. For example, models including either %interest (interest payments as a percentage of total costs) or %gearing (gearing ratio) were equally effective; fortunately in this case the interpretation of results remains the same whichever variable is chosen.

This caveat is also important for interaction terms, when the impact of one variable depends on the value of another (e.g. the interaction Organic.Year means that the performance of organic farms relative to conventional ones varies between different years). The aim of the modelling process was to identify those interaction terms that were stable and not dependent on one or two extreme observations. Hence the absence of an interaction term does not necessarily imply that no interaction was present, but rather that it was not sufficiently strong to be clearly apparent in the data.

It can be seen that there are many differences in the models fitted to the farm business and to agriculture only. However, these are sometimes differences in detail, often relating to whether the term has an interaction with another variable.

Table 4.1a: significant terms from a stepwise REML analysis of log farm business output (costing family labour at the national minimum wage) against the explanatory variables.

Term	F statistic	df1	df2	P	Notes
Costs	11.79	1	1454.2	<0.001	quadratic on log scale
Average costs	32.47	1	1193.7	<0.001	Costs averaged over all years
Interest costs	7.96	1	2022.2	0.005	cubic
Farmer age	5.83	1	861.7	0.016	
Agri-env scheme	2.65	3	1755.9	0.047	
Adjusted area	6.74	1	522.6	0.010	Adjusted area on log scale
Tenancy status	11.61	2	597.1	<0.001	Owned, FAT, FBT
Dairy cows	11.99	1	1511.5	<0.001	Quadratic on log scale
Dairy cow trend	4.00	3	392.5	0.008	Trend in cow numbers
Interaction cows/cost	20.86	1	1575.4	<0.001	On log linear scale for both
FMD cull	8.53	2	393.0	<0.001	Culled for foot & mouth
Interaction Organic.Year	5.35	7	1459.2	<0.001	Organic status of dairy enterprise
Interaction specialisation.Year	2.58	7	1523.6	0.012	Proportion of SLR from dairy enterprise

Notes: where variables are fitted as polynomial terms (quadratic or cubic) the F-statistic shown is for the highest order term. Interactions with such terms only involve the linear component.

Table 4.1b: significant terms from a stepwise REML analysis of log agricultural output (costing family labour at the national minimum wage) against the explanatory variables.

Term	F statistic	df1	df2	P	Notes
Average costs	15.35	1	1293.4	<0.001	quadratic on log scale
Interest costs	4.96	1	2002.0	0.026	quadratic
Agri-env scheme	2.05	3	1793.9	0.105	
Tenancy status	9.69	2	619.8	<0.001	Owned, FAT, FBT
%Unpaidlabour	8.76	1	1200.2	0.003	% of labour unpaid
Interaction cows/cost	14.25	1	787.3	<0.001	On log linear scale for both
FMD cull 2003	15.96	1	810.4	<0.001	Culled for foot & mouth
FMD cull 2004	4.72	1	1348.5	0.030	Culled for foot & mouth
FMD cull 2005	3.28	1	1856.3	0.070	Culled for foot & mouth
%Moor	19.16	1	414.7	<0.001	% moorland
Interaction Organic.Year	7.89	7	1455.2	<0.001	Organic status of dairy enterprise
Interaction specialisation.Year	2.35	7	1481.7	0.022	Proportion of SLR from dairy enterprise
%DIVCOST	4.99	4	376.7	<0.001	Diversified costs as % total

Notes: where variables are fitted as linear and quadratic terms the F-statistic shown is for the quadratic term. Interactions with such terms only involve the linear component. 'FMD cull 2003' refers to the impact of FMD culls during the epidemic of 2001 on economic efficiency in 2003.

There is, as would be expected a highly significant relationship between outputs and costs and, in the case of farm business output, this is quadratic in form and varies according to the number of cows. As well as the term for the actual input costs in each year, the models also include a term for the average input costs over the five year period. Despite the high correlation (0.97) between these variables, both are highly significant, indicating that the output of a farm in any one year depends on the inputs in the other years, as well as the inputs used in the current year. This may be partially because of carry-over effects; for example due to the effects of fertilisers applied in one financial year leading to increased output in the following year. Conversely, there may be a tendency for businesses to be more generous with inputs following a highly profitable year. However, it probably also indicates that rapid increases in inputs may not yield the expected increase in outputs due to constraints of the farm infrastructure.

The following sections deal with each variable in turn. For ease of reference, each section starts with a short summary of the impact of the variable.

4.1. Debt

The effect of indebtedness is large and highly significant, with average efficiencies much lower for farms with high interest payments. This is apparent both at the farm business level and for the agricultural cost centre (i.e. excluding diversification, agri-environment schemes and support payments).

The relationship is illustrated by Table 4.2 which shows the predicted level of outputs from a farm with £200,000 of inputs per annum, 100 dairy cows and 100ha of land (approximately the median levels when family labour costs are included) for various levels of debt. The absolute values in this and subsequent tables should be treated with caution since they are estimated at a combination of average values of the other variables which may not be realistic in practice. Nevertheless, the differences between the rows give a useful summary of the impact of the variable of interest. In this case, the estimated output from £200,000 of inputs falls markedly as the level of debt increases. As would be expected, returns are much less when only agricultural output is considered (i.e. excluding input and output costs associated with SPS, environmental stewardship and diversification), but the trend is similar in both cases.

Table 4.2: Level of debt (interest as % total costs). The table shows predicted outputs from the REML model for a farm with £200,000 of inputs per annum, 100ha of land, 100 dairy cows and average values of the other variables in the model. Figures are for 2008. Standard errors are approximate.

		Farm business output		Agricultural output	
Interest as % of total costs	N farms	Estimated output (£000s)	Standard error	Estimated output (£000s)	Standard error
<0.1%	121	241	3.4	205	3.4
0.1-0.99%	135	239	3.3	203	3.3
1-4.99%	248	232	3.1	198	3.1
5-9.99%	161	224	3.2	189	3.1
10% or more	65	217	3.7	176	3.4

Note: family labour charged at the national minimum wage. Farm business output includes agricultural output, plus support payments (SPS etc.), agri-environment payments and diversified income.

Previous reports in this series have commented on a strong relationship between the level of debt and farm size, with smaller farms tending to have much lower levels of debt. Whilst

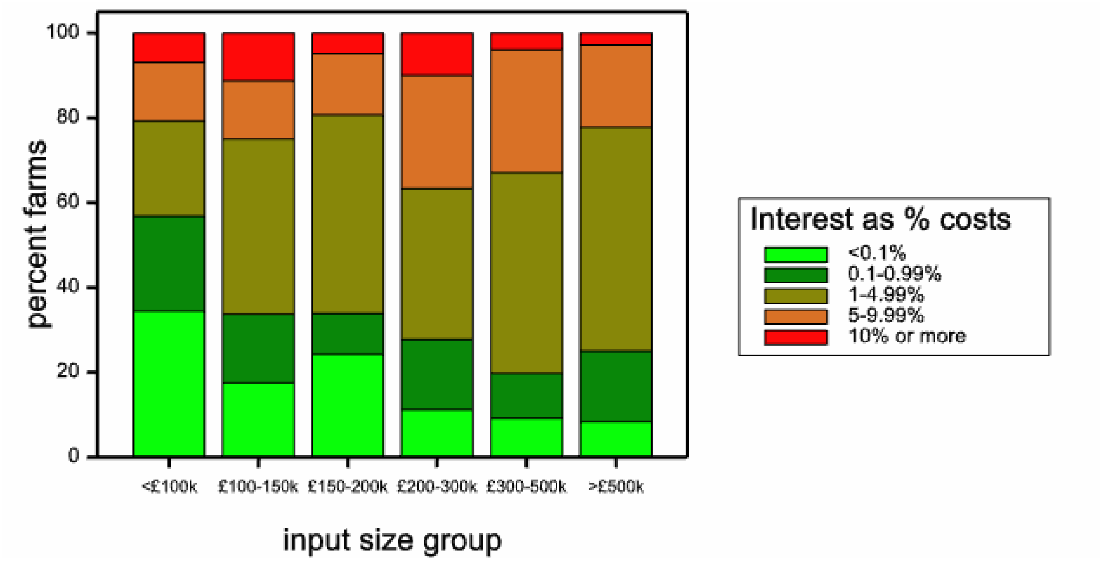


Figure 4.1: percentage of farms with different levels of debt by input size group.

this is somewhat less marked for dairy farms (Figure 4.1), on average debt levels do increase with economic size. One possible reason for this, which was mentioned in the grazing livestock and cereals reports, was that the smaller farms have not needed to borrow; this is perhaps less likely with dairy farms because of the greater need for investment in, for example, new parlours or slurry stores. The alternative explanation is that smaller farms with extensive debt have failed to survive. Whatever the reason, this relative lack of debt will contribute significantly to the relatively good economic performance of small farms in Figure 3.2.

4.2. Farmer age

Older farmers are, on average, more economically efficient than younger ones for the farm business as a whole, but there is no statistically significant relationship for the agricultural cost centre.

Table 4.3 shows the effect of the farmer age on output levels for the farm business as a whole. There is a linear increase in output with age, which may be due to greater experience, or may reflect that established farmers tend to have the more profitable farms on average. Interestingly the relationship is not statistically significant for the agricultural cost centre; if it is forced into the model, the slope is less than half of that for the whole business. Unlike with grazing farms, there is no tendency for output to decrease for very old farmers, perhaps because dairying is a branch of farming where it is not possible to coast into retirement, continuing the business in a half-hearted way. Older dairy farmers must either retire completely or continue to run an efficient business.

Table 4.3: Age of farmer. The table shows predicted outputs from the REML model for a farm with £200,000 of inputs per annum, 100ha of land, 100 dairy cows and average values of the other variables in the model. Figures are for 2008. Standard errors are approximate.

	N farms	Farm business output	
Age group		Estimated output (£000s)	Standard error
<40	89	230	3.5
40-49	192	233	3.2
50-59	201	235	3.1
60+	111	238	3.4

Note: family labour charged at the national minimum wage. Farm business output includes agricultural output, plus support payments (SPS etc.), agri-environment payments and diversified income.

4.3. Tenure

Tenure type has a large impact on economic performance at both the level of the farm business and for the agricultural cost centre. Owner occupied farms perform better than tenanted farms, and farms with FAT tenancies perform better than those with FBTs.

Table 4.4: Tenancy status. The table shows predicted outputs from the REML model for a farm with £200,000 of inputs per annum, 100ha of land, 100 dairy cows and average values of the other variables in the model. Figures are for 2008. Standard errors are approximate.

		Farm business output		Agricultural output	
Tenancy status	N farms	Estimated output (£000s)	Standard error	Estimated output (£000s)	Standard error
owner-occupied	253	243	3.3	208	3.2
tenanted FAT	91	233	3.7	198	3.8
tenanted FBT	76	227	3.8	193	4.0

Note: family labour charged at the national minimum wage. Farm business output includes agricultural output, plus support payments (SPS etc.), agri-environment payments and diversified income.

Table 4.4 shows the relationship between tenure and economic performance. Owner occupied farms perform best, which is to be expected since the costs used do not include an imputed rent for owner-occupiers, but do include the actual rent paid by tenants. In this analysis rented farms are split into Full Agricultural Tenancies (FATs) and Farm Business Tenancies; the latter perform significantly worse on average.

To investigate these relationships further, all agricultural property costs (including both rents and expenses such as depreciation and insurance) were removed from the cost calculations, and the model was then refitted for the agricultural cost centre. Whilst the magnitude of the differences was reduced (particularly the difference between owner-occupiers and the two rented groups), they remained statistically significant. This suggests that the cause is something more than the differing costs facing the three groups. One possibility is the difference in security of tenure; in a sector which requires long-term investment in fixed assets, owner occupiers have the strongest position and those on the relatively short-term FBTs have the weakest.

4.4. Upland farms

Upland farms tend to perform less well for the agricultural cost centre, but there is no significant difference for the farm business as a whole.

Uplands farm can be identified by means of Less Favoured Areas (LFAs) and if a grouped variable for LFA is fitted it is statistically significant for the agricultural cost centre ($F=2.29$ with 6 and 364 d.f., $P=0.035$). However, an even stronger relationship (see Table 4.1b for details) is with the percentage of the farm that consists of moorland (identified on the basis of SPS entitlements), presumably because this variable picks out the more extreme upland farms. This does not necessarily imply that the dairy enterprises on these farms are less efficient than their lowland counterparts; the upland farms also have beef or sheep enterprises and so it is likely that the poorer returns from these are dragging down the overall agricultural efficiency.

Table 4.5: moorland area. The table shows predicted outputs from the REML model for a farm with different economic sizes (in terms of inputs per annum), and average values of the other variables in the model. Figures are for 2008. Standard errors are approximate. Moorland predictions are for a farm with 40% of its area as moorland.

		Agricultural output	
Moorland status	N farms	Estimated output (£000s)	Standard error
No moorland	374	200	3.2
With moorland	28	178	5.2

Note: family labour charged at the national minimum wage. Farm business output includes agricultural output, plus support payments (SPS etc.), agri-environment payments and diversified income.

At the farm business level, there is no significant relationship with the percentage of moorland, suggesting that these farms are to some extent compensating, perhaps by means of agri-environment schemes and other payments to uplands farmers. If the term is nevertheless included in the farm business model, it has a negative coefficient, suggesting that these farms may still be at a slight disadvantage, but the magnitude of the effect is roughly a quarter of that for the agricultural cost centre.

4.5. Dairy specialisation

On average, those farms with other agricultural enterprises perform better than those that specialise in dairy, both at the farm business level and for the agricultural cost centre.

The degree of specialisation of each farm in dairy was assessed by examining the proportion of the Standard Labour Requirement (SLR) from the dairy enterprise. Results are displayed for three levels of dairy specialisation in Table 4.6, with the predictions being for the mean of the observed values in each category. Since SLRs are assigned to grassland and fodder crops, even the most specialised dairy unit has less than 100% of its SLR from dairy.

The more specialised dairy farms tend to perform less well than those with a greater diversity of enterprises (Table 4.6). To put these results into context, the most important other activities are other cattle rearing, sheep and cereals. There is a significant interaction with year for both the business as a whole and the agricultural cost centre; this is not unexpected since the relative performance of other sectors relative to dairy will vary from year-to-year. Nevertheless, it is striking that the model suggests that the less specialised farms always perform better; it is merely the extent of the difference that varies from year to year.

Table 4.6: Specialisation. The table shows predicted outputs from the REML model for a farm with £200,000 of inputs per annum, 100ha of land, 100 dairy cows and average values of the other variables in the model. Standard errors are approximate.

a) Farm Business Output

	Percent Standard Labour Requirement associated with dairy					
	<60% dairy (106 farms)		60-80% dairy (292 farms)		>=80% dairy (156 farms)	
Year	Est. output (£000s)	Standard error	Est. output (£000s)	Standard error	Est. output (£000s)	Standard error
2003	213	4.2	199	2.9	192	3.5
2004	211	3.9	202	2.8	197	3.3
2005	213	3.7	205	2.7	201	3.2
2006	205	3.5	196	2.5	192	3.0
2007	224	3.7	219	2.8	216	3.4
2008	237	4.2	234	3.1	232	3.7
2009	225	4.2	219	3.0	217	3.6
2010	230	4.5	221	3.1	217	3.8

b) Agricultural Output

	<60% dairy (106 farms)		60-80% dairy (292 farms)		>=80% dairy (156 farms)	
Year	Est. output (£000s)	Standard error	Est. output (£000s)	Standard error	Est. output (£000s)	Standard error
2003	190	4.6	177	3.2	171	3.6
2004	185	4.1	178	3.1	175	3.5
2005	177	3.7	169	2.8	165	3.1
2006	166	3.5	158	2.5	154	2.8
2007	188	3.8	182	2.9	179	3.2
2008	207	4.4	199	3.2	195	3.5
2009	191	4.1	183	2.9	179	3.3
2010	201	4.6	187	3.1	179	3.5

Note: family labour charged at the national minimum wage. Farm business output includes agricultural output, plus support payments (SPS etc.), agri-environment payments and diversified income.

4.6. Diversification

Diversification outside agriculture is associated with reduced agricultural efficiency. There are signs that low levels of diversification may benefit the business as a whole, although the relationship is not statistically significant, and higher levels of diversification are not associated with improved efficiency.

The previous section looked at specialisation within agriculture. A related issue is whether farms perform better if they concentrate on agriculture, or whether they are helped by diversification into other enterprises, such as tourism or renting out buildings. This is examined in Table 4.7 which measures the extent of diversification by looking at the proportion of business costs associated with diversified enterprises. Results are only statistically significant for the agricultural cost centre and indicate that farms with high levels of diversification tend to be less successful in terms of output for a given level of input costs. This may indicate that farms with extensive diversification have less time for the core business and hence agricultural performance falls. Some caution is needed in interpreting these results since the number of farms with over 5% of diversified costs is small, and also because the poor performance might not be caused by the diversification; an alternative explanation is that farms where the agricultural business is struggling are the ones seeking diversified income[13].

Table 4.7: Proportion of input costs associated with diversified enterprises. The table shows predicted outputs from the REML model for a farm with £200,000 of inputs per annum, 100ha of land, 100 dairy cows and average values of the other variables in the model. Figures are for 2008. Standard errors are approximate.

		Agricultural output	
Diversified costs as % total costs	N farms	Estimated output (£000s)	Standard error
<0.1%	260	210	2.7
0.1-0.99%	73	210	4.1
1-4.99%	43	209	4.8
5-9.99%	14	186	6.9
10% or more	12	185	7.4

Note: family labour charged at the national minimum wage. Farm business output includes agricultural output, plus support payments (SPS etc.), agri-environment payments and diversified income.

Whilst there is no significant relationship between diversification and farm business performance, the term can be forced into the model to give some indication of the likely impact. If this is done, there is a suggestion of a quadratic trend, with low levels of diversification giving a slight increase in farm business output, but higher levels having a neutral or possibly negative effect. Thus it appears that minor diversification projects, which will include things like renting out unused buildings, are not deleterious to the core dairy production and may improve the profitability of the business as a whole. The evidence for the successful integration of dairy farming and more demanding diversification projects is not apparent from this data.

4.7. Foot and mouth disease

Farm assurance schemes have a positive impact on performance for both the farm business and for the agricultural cost centre.

[13] Levels of diversified income tend to remain fairly constant for the same farms over time. Hence the estimates in Table 4.7 rely on between-farm differences. Had substantial numbers of farms changed their level of diversification over time, it would have been easier to distinguish between these two explanations.

The outbreak of foot and mouth disease (FMD) in 2001 had profound implications for dairy farms, particularly those directly affected. This is demonstrated in Table 4.8. Farm businesses culled for FMD show reduced performance (Table 4.8a) and this seems to continue for a number of years after the outbreak (although only a few farms that were culled remained in the survey until 2010). For the agricultural cost-centre, there is a more short-term effect which is most evident in 2003, but is also of borderline significance in 2004 and 2005.

Table 4.8: FMD status (whether farm animals were culled during 2001 outbreak). The table shows predicted outputs from the REML model for a farm with £200,000 of inputs per annum, 100ha of land, 100 dairy cows and average values of the other variables in the model. Standard errors are approximate.

a) Farm business output (estimates are for 2005)

FMD status		Estimated output (£000s)	Standard error
not culled	194	234	3.1
culled	12	209	7.1
unknown	196	227	2.8

b) Agricultural output

	2003		2004		2005	
FMD status	Est. output (£000s)	Standard error	Est. output (£000s)	Standard error	Est. output (£000s)	Standard error
Not culled	178	3.2	179	3.1	170	2.8
culled	154	6.0	166	6.3	160	5.8

Note: family labour charged at the national minimum wage. Farm business output includes agricultural output, plus support payments (SPS etc.), agri-environment payments and diversified income.

4.8. Unpaid family labour

Unpaid family labour has a significant impact on efficiency for the agricultural cost centre (i.e. excluding diversification, agri-environment schemes and support payments), but only if it is charged at the minimum wage rate. When it is charged at the commercial rate there is no significant relationship with agricultural efficiency. The proportion of unpaid labour used has no significant relationship with farm business performance, even when charged at the minimum wage.

Table 4.9 shows the effect of unpaid labour on agricultural outputs when costed at the minimum wage rate. Those farms with high amounts of unpaid labour (usually from the farmer and family members) perform better than those relying mainly on paid labour. However, unlike for grazing livestock and cereals farms, this difference vanishes if the unpaid labour is costed at the full economic rate for the job. There is no significant relationship at the farm business level, regardless of whether unpaid labour is costed at the minimum wage or the full rate.

Table 4.9: Proportion of unpaid labour. The table shows predicted outputs from the REML model for a farm with £200,000 of inputs per annum, 100ha of land, 100 dairy cows and average values of the other variables in the model. Figures are for 2008. Standard errors are approximate.

		Agricultural output	
Proportion labour unpaid	N farms	Estimated output (£000s)	Standard error
up to 50%	135	192.7	3.5
50-74%	150	197.0	3.1
75% & above	234	201.5	3.4

Note: family labour charged at the national minimum wage.

4.9. Size of farm and returns to scale

Larger farmed areas are associated with improved performance at the Farm Business scale. However, the magnitude of the effect is small, and it is not statistically significant for the agricultural cost centre. Input costs and dairy cow numbers are more strongly associated with outputs and, considering all three size variables together, there are increasing returns to scale, although the extent of this declines with increasing size. Returns to scale are probably approximately constant for the largest businesses, although it is difficult to estimate this precisely.

The analyses presented here essentially use input costs as a measure of the economic size of the farm. For dairy farms, size can also be measured in terms of the number of cows and the physical area of the farm, and these three measures of size will clearly have a strong and complex relationship.

In the case of farm business outputs, results are displayed in Table 4.10 in the form of estimates of the impact on output value of increasing the size variables by 1%. Whilst land area (adjusted to allow for the lesser value of rough grazing) is significantly related to output, its impact is small if the number of cows and the input costs remain constant, with just a 0.04% increase in output for a 1% change in land area; this probably relates to the increase in SPS and agri-environment payments with the greater area, since agricultural output is not significantly related to land area. A 1% increase in cost delivers an increase of between 0.68% and 0.81% increase in outputs without any increase in the other two factors, whilst a 1% increase in cows delivers 0.29-0.32% increase in output.

For most farms, increasing both cows and costs by 1% together delivers an increase in outputs of over 1%, but for the very largest ones an increase in area is also needed. In fact, despite a significant interaction between cows and costs, the effect of the three factors is approximately additive over the range of sizes shown (e.g. for small farms 0.32+0.04+0.81=1.17%, which is approximately equal to the increase with all three, apart from rounding errors).

Looking at the percentage increases when all three factors are increased by 1%, it can be seen that the figure falls from 1.18% for 50 cow herds to only 1.02% for 400 cow herds. This demonstrates that there are increasing returns to scale for most farms, but the magnitude decreases, so that returns to scale are little better than constant for the largest farms. The exact point at which constant returns to scale are reached is dependent on the detail of the model fitted and so cannot be estimated with confidence, particularly given the limited number of data points for very large herd sizes.

Table 4.10: Effects of farm size on Farm Business output. The table shows predicted percentage increase in output value from the REML model when the size variables are increased by 1%. The diagonal cells (grey background) show the increase when a single size variable is increased, the off-diagonal cells show the result of increasing two of the variables, whilst the final cell below each matrix shows the impact of changing the number of cows, the area and the input costs by 1% each simultaneously

a) Small farm (50 cows, 50ha, £100k input costs)

	Number cows	Adjusted area	Input costs
Number cows	0.32%		
Adjusted area	0.37%	0.04%	
Input costs	1.13%	0.86%	0.81%
All 3 increased by 1%	1.18%		

b) Medium-sized farm (100 cows, 100ha, £200k input costs)

	Number cows	Adjusted area	Input costs
Number cows	0.31%		
Adjusted area	0.35%	0.04%	
Input costs	1.08%	0.81%	0.77%
All 3 increased by 1%	1.12%		

c) Large farm (200 cows, 200ha, £400k input costs)

	Number cows	Adjusted area	Input costs
Number cows	0.30%		
Adjusted area	0.34%	0.04%	
Input costs	1.03%	0.77%	0.73%
All 3 increased by 1%	1.07%		

d) Very large farm (400 cows, 400ha, £800k input costs)

	Number cows	Adjusted area	Input costs
Number cows	0.29%		
Adjusted area	0.33%	0.04%	
Input costs	0.97%	0.73%	0.68%
All 3 increased by 1%	1.02%		

Table 4.11 shows similar results for the agricultural cost centre, but excluding area since it has no significant impact on agricultural output. Again, despite the interaction, the two effects are approximately additive and the returns to scale are smaller for larger farm sizes.

Table 4.11: Effects of farm size on Agricultural output. The table shows predicted percentage increase in output value from the REML model when the size variables are increased by 1%. The diagonal cells (grey background) show the increase when a single size variable is increased, the off-diagonal cell shows the result of increasing both the number of cows and the input costs by 1%.

a) Small farm (50 cows, 50ha, £100k input costs)

	Number cows	Input costs
Number cows	0.48%	
Input costs	1.23%	0.75%

b) Medium-sized farm (100 cows, 100ha, £200k input costs)

	Number cows	Input costs
Number cows	0.45%	
Input costs	1.18%	0.72%

c) Large farm (200 cows, 200ha, £400k input costs)

	Number cows	Input costs
Number cows	0.42%	
Input costs	1.12%	0.69%

d) Very large farm (400 cows, 400ha, £800k input costs)

	Number cows	Input costs
Number cows	0.40%	
Input costs	1.06%	0.67%

Returns to scale are illustrated graphically in Figure 4.3, before and after adjusting for other confounding variables in the model. The trend displayed in the graphs is very similar for both the entire business and the agricultural cost centre. In both cases, the unadjusted line shows a very gentle increase in efficiency up to around £200,000 of input costs and then falls away for larger input costs. After adjustment, there is a steeper increase in efficiency as economic size increases, up to a maximum at around £500,000 per annum.

The adjusted lines in Figure 4.3 are estimated for the average numbers of cows and average areas in the sample for each level of input costs. In practice, farms that are larger

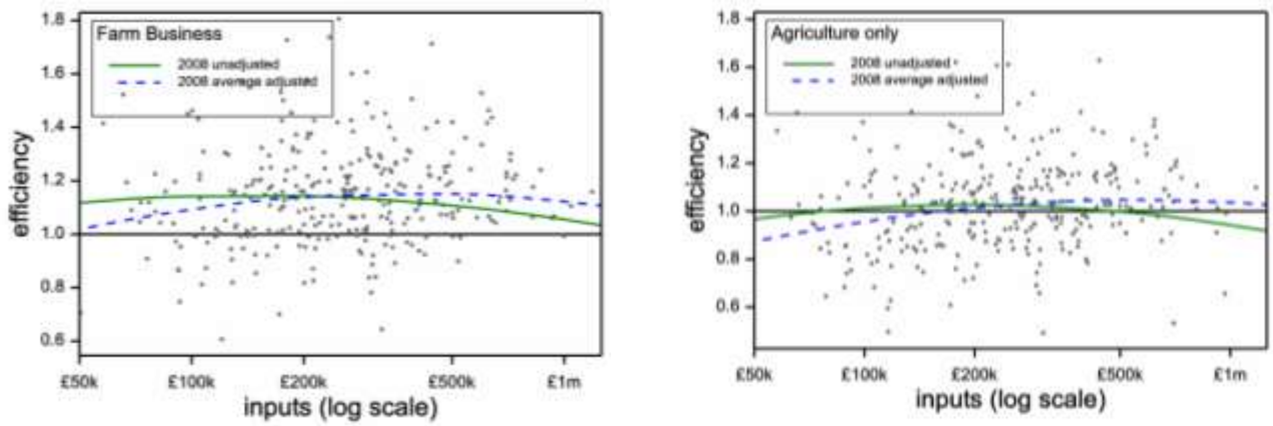


Figure 4.3: the relationship between efficiency and input costs for the whole farm business (left) and agriculture only for 2008. The green line is the best fitting line before adjustment, whilst the blue line is after adjusting for the factors listed in Table 4.1 and 4.2. Imputed costs for family labour are included at the minimum wage rate. Lines are averages across lowland and LFA farms.

in economic terms are more likely to have other enterprises, and so the empirical ratio of cows or land area to costs tends to decrease with size. It is possible to use the model to construct a curve assuming cow numbers and land areas increased in direct proportion to costs, so that both cow numbers and land area doubles when costs double. This is closer to the approach of Tables 4.10 and 4.11. The resulting curves are even steeper than the blue curves in Figure 4.3 and peak further to the right, between £500,000 and £1 million. This result should be treated with some caution since it involves extrapolating the model into the extreme edge of the observed data space, but nevertheless it does strengthen the conclusion that there are inherent economies of scale in dairy farming, up to a maximum level, after which returns to scale are approximately constant and may start to decline.

4.10. Dairy cow trend

Businesses with an increasing trend in dairy cow numbers tend to have higher performance than those reducing numbers.

Table 4.12 relates the trend in dairy cow numbers on each farm to predicted output at the farm business level (there is no significant relationship for the agricultural cost centre). Generally, performance is better for farms with a more positive trend in cow numbers, although the relatively small group with the largest increase performs less well than those increasing numbers more gradually. These results need to be interpreted with caution, since it may be that the more successful farms are the ones with the money to expand (i.e. it may be effect rather than cause). Nevertheless, this does suggest that the best performing farms tend to gradually increase numbers over time.

Table 4.12: Trend in dairy cow numbers. The table shows predicted outputs from the REML model for a farm with £200,000 of inputs per annum, 100ha of land, 100 dairy cows and average values of the other variables in the model. Standard errors are approximate. For simplicity, predictions are only shown at the extreme values (i.e. all cattle or all sheep)

		Farm Business Output	
Trend in dairy cow numbers		Estimated output (£000s)	Standard error
Decline (5% or more p.a)	40	225	4.9
Decline (<5% p.a)	123	237	3.6
Increase (<5% p.a)	175	241	3.4
Increase (5% or more p.a)	64	235	4.4

Note: family labour charged at the national minimum wage. Dairy cow trends for each farm are averaged over all years for which FBS data is available.

4.11. Organic farming

Organic farms tend to perform better than conventional ones at both the farm business level and for the agricultural cost centre. The magnitude of these effects varies from year to year, which appears to be due to changes in the relative price of organic milk.

Organic production appears to have an impact, but the effect varies significantly from year to year (Table 4.13). Until 2006, when extra organic farms were deliberately selected for inclusion, the number of organic farms in the FBS was low, so estimates for 2003-2005 should be treated with caution. Nevertheless it appears from this small sample that the performance of organic farms was roughly similar to conventional ones during this time, with a relatively small price differential between organic and conventional milk.

In 2006 the price differential increased markedly, leading to better performance from dairy farms at both the entire business level and for the agricultural cost centre. Over the final two years, the price differential reduced somewhat, and by 2010 agricultural performance was very similar for organic and conventional farms.

Table 4.13: Organic status. The table shows predicted outputs from the REML model for a farm with £200,000 of inputs per annum, 100ha of land, 100 dairy cows and average values of the other variables in the model. Standard errors are approximate. Organic status is modelled as the proportion of the UAA farmed organically (including in conversion), but the vast majority of farms are either fully conventional or fully organic and so predictions are shown for these values. Figures in small italic font are based on less than 20 farms.

a) Farm business output

	Conventional (364 farms)		Organic (46 farms)	
Year	Estimated output (£000s)	Standard error	Estimated output (£000s)	Standard error
2003	200	2.9	201	6.7
2004	202	2.8	200	6.1
2005	206	2.7	204	5.6
2006	197	2.5	221	5.3
2007	219	2.8	234	5.2
2008	234	3.1	243	5.3
2009	220	3.0	230	5.1
2010	222	3.1	226	5.3

b) Agricultural output

	Conventional (364 farms)		Organic (46 farms)	
Year	Estimated output (£000s)	Standard error	Estimated output (£000s)	Standard error
2003	178	3.2	*173*	*6.5*
2004	179	3.1	*174*	*5.9*
2005	170	2.8	*171*	*5.2*
2006	159	2.5	184	4.9
2007	182	2.9	195	4.8
2008	200	3.2	208	5.0
2009	183	2.9	189	4.6
2010	188	3.1	188	4.9

Note: family labour charged at the national minimum wage. Farm business output includes agricultural output, plus support payments (SPS etc.), agri-environment payments and diversified income.

4.12. Other relationships

A large number of other variables were examined for significance. These included farmer education, veterinary costs, NVZ status, sharing of machinery, contract rearing and farm assurance scheme membership. A couple of variables are worthy of further comment.

Those farms that grow more of their own feed tend to perform better at the business level. However, this relationship is only of borderline significance ($F=2.43$ with 3 and 2014 d.f., $P=0.063$) at the farm business level and is not significant for the agricultural cost centre.

There was a tendency for farms making more use of contractors to perform better for the agricultural cost centre. Whilst this is significant when fitted as a grouped variable averaged over time ($F=3.69$ with 3 and 371 d.f., $P=0.012$), the pattern is not clear and is not significant when fitted as a linear or quadratic trend. It has therefore not been included in the final model.

5. Results: relationship between economic efficiency and environmental factors

5.1. Agri-environment scheme membership

ELS has a positive effect of borderline statistical significance on farm business output, whereas the classic schemes and HLS have little impact. For the agricultural cost centre ELS again appears to have a small positive effect, whilst HLS may have a negative effect, although the sample size is small.

Table 5.1 shows predictions of output from different agri-environment schemes for the farm business as a whole and for the agricultural cost centre. A categorical variable is used representing the type of scheme which each farm belonged to in each year; where a farm received payments from more than one scheme in a year, the highest value scheme is used. These relationships are of borderline statistical significance (Table 4.1).

At farm business level, ELS seems to deliver a small increase in output, whereas farms in the classic schemes and HLS produce similar outputs to farms not in a scheme, although the sample size is small for HLS.

Table 5.1: Agri-environment status. The table shows predicted outputs from the REML model for a farm with £200,000 of inputs per annum, 100ha of land, 100 dairy cows and average values of the other variables in the model. Figures are for 2008. Standard errors are approximate.

		Farm business output		Agricultural output	
Agri-environment scheme	N farms	Estimated output (£000s)	Standard error	Estimated output (£000s)	Standard error
None	283	233	3.1	200	3.2
ELS	201	237	3.0	203	3.1
Classic (CSS/ESA)	95	234	3.5	199	3.5
HLS	20	233	5.1	196	5.0

Note: family labour charged at the national minimum wage.

5.2. Agri-environment expenditure – Countryside Management Module

More information on farm expenditure relating to agri-environment activities can be obtained from the FBS Countryside Maintenance and Management module[14]. This asked for information on costs of agri-environment measures in 27 categories, including both activities funded by schemes and those undertaken without payment. A subset of the full FBS panel were asked to complete the module, with data collected from 235 of the 404 farms considered here in the 2008-09 module.

Average efficiency is also dependent on whether the activity is funded under an agri-environment scheme. Those farms carrying out activities without receiving payments have lower average efficiencies than those where the activities are largely funded under an agri-environment scheme (Table 5.2). Interestingly, this effect is clear for the agricultural cost centre as well as the business as a whole, suggesting that it is not purely the result of the income received from the scheme. It may therefore be the case that those farmers making use of the schemes to fund agri-environment use are equally efficient in other areas of agriculture, so that the results of Table 5.2 stem from this general efficiency, rather than being a direct result of scheme membership.

[14] http://www.defra.gov.uk/statistics/foodfarm/farmmanage/fbs/envcountryman/

Table 5.2: mean farm business efficiencies (REML farm effects, before adjustment for confounding factors such as debt) tabulated by funding of agri-environment activity.

	Farm Business efficiency			Agricultural efficiency		
Funding of activities	No. of farms	Mean efficiency	s.e.	No. of farms	Mean efficiency	s.e.
Not funded by scheme	43	-0.025	0.0086	43	-0.029	0.0110
Partially funded	19	0.007	0.0119	19	0.013	0.0143
Funded by scheme	97	0.014	0.0054	97	0.012	0.0072

Notes: 'not funded' includes farms where less than 10% of the costs of activities were funded by schemes, whilst 'funded' includes those where at least 90% of the costs were funded.

5.3. Water Usage Module

The 2009 FBS included a module on water usage which was completed by 170 of the farms considered here. The data was used to look for any relationship between efficiency and the following variables:

- Volume of water used for washing down per dairy cow
- Volume of drinking water per dairy cow
- Proportion of water used taken from rainfall, as opposed to the mains or abstracted from rivers.

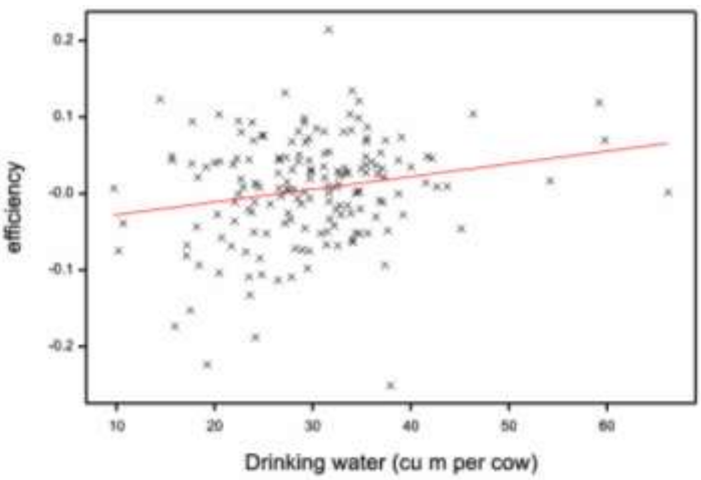


Figure 5.1: efficiency of farms based on agricultural costs and output plotted against drinking water use per dairy cow. Farms with substantial numbers of other livestock types are excluded from this analysis to ensure that most drinking water usage relates to dairy cattle.

The only statistically significant relationship is with the volume of drinking water, with more efficient farms tending to use more water. Figure 5.1 shows this relationship for the agricultural cost centre, but it is also significant for the whole business, both with and without adjustment for confounding factors. This is largely due to the strong relationship between drinking water usage and milk yield per cow. Interestingly, when milk yield per cow is added to the regression model, the coefficient for drinking water usage becomes negative (but not significantly different to zero), suggesting that there may be an underlying tendency for efficient farms to make more effective use of drinking water. Some caution is perhaps needed about these conclusions, as not all farms may be able to allocate water usage accurately.

5.4. Energy Usage Module

There is a significant relationship between economic efficiency and energy usage expressed on a per cow basis, but this appears to be an artefact caused by farms with non-dairy enterprises. There is no sign of a relationship between fertiliser usage and efficiency. However, the lack of a relationship may be due to the limitations of the data.

Energy usage data was collected in 2007 for around 76 farms in this study. Much of this data relates to CO_2 emissions from machinery usage and has been analysed in a separate study by Cranfield University[15]. As well as data on energy usage in the form of electricity, diesel and other fuels, the module collected information on fertiliser use and the management of farm woodlands.

Unfortunately, interpretation of this data is hindered by considerations such as the use of contractors and the amount of imported feed. There are signs of a relationship between agricultural efficiency and energy usage per cow (Figure 5.2), with efficiencies highest for those with low energy usage. However, this graph may be distorted by farms with substantial non-dairy agricultural activities (indicated by the green circles in Figure 5.2, and the relationship is no longer significant if this is allowed for in the model. Similar comments apply to the relationship between farm business efficiency and energy use per cow.

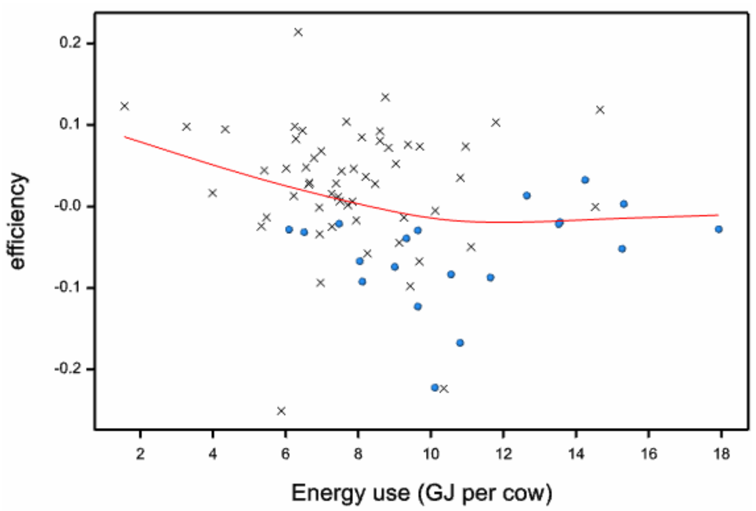


Figure 5.2: efficiency of farms based on agricultural costs and output plotted against energy usage per cow. Blue circles are farms with other agricultural enterprises accounting for more than 40% of the standard labour requirement. The red line is from a general additive model with 2 d.f. (F=3.52 with 2 and 73 d.f., P=0.035).

There is no sign of a relationship between fertiliser usage per hectare and efficiency for either the agricultural cost centre or for the entire business. This is perhaps not surprising, given the varying proportions of arable land amongst these farms. There is also no relationship between woodland management and efficiency, but this may be due to the sample size as a result of only around half of the farms having farm woodland.

[15] https://dspace.lib.cranfield.ac.uk/handle/1826/6506

6. Results: Business management module[16]

As with the agri-environment module, data on business management is only available for a subset of farms and so analysis involves relating the data to the farm-level estimates of efficiency, rather than directly including the business management data in the model. This process was carried out using the farm-level efficiencies both before and after fitting the explanatory variables described in Tables 4.1 and 4.2. Interestingly, the strongest relationships were with efficiencies before allowing for the explanatory variables, whereas after allowing for them the relationships were little stronger than would be expected by chance. This suggests that the business management characteristics examined are associated with the explanatory variables, for example because indebted farmers are less likely to display some of these skills.

The module consisted of a series of blocks of questions, with each block relating to a different area of business management expertise. The questions all had a simple yes/no response, with a 'yes' response indicating that the particular skill or practice (see Section 10 for a full list) was used in the farm business (except for the first question in each block which is phrased as a negative). In the sections below, each skill area is discussed in turn. Management accounting

Relationships between these questions and economic efficiency seem to be stronger for the business as a whole than for the agricultural cost centre (Table 6.1), with discussion groups being particularly beneficial.

Table 6.1: mean efficiencies (REML farm effects, before allowing for explanatory variables) tabulated by questions on use of management accounting. Note that the first question is expressed the other way around, so that a positive response indicates that practices are not adopted.

	Whole Farm Business			Agriculture cost centre		
	no	yes	sig	no	yes	sig
Management accounting not applicable	*0.003*	*-0.029*	*	*0.002*	*-0.021*	*NS*
Uses gross margins prepared for enterprises on the business	-0.001	0.001	NS	0.001	-0.001	NS
Uses cash flows prepared for the business	0.006	-0.013	*	0.006	-0.010	NS
Reviews the profit and loss account in depth	-0.008	0.003	NS	-0.007	0.004	NS
Prepares partial budgets to inform business decisions	-0.001	0.002	NS	-0.001	0.003	NS
Prepares a budget for the year	0.002	-0.006	NS	0.002	-0.005	NS
Frequently benchmarks and compares business performance with others	-0.005	0.006	NS	-0.006	0.008	NS
Regularly attends discussion groups or meetings on business management issues	-0.005	0.011	*	-0.007	0.016	*
Regularly attends discussion groups or meetings on other issues , eg farm walks/meeetings on cross compliance, new regulations, environmental matters.	-0.012	0.009	**	-0.010	0.008	10%

Note: 'sig' refers to the statistical significance: *** very highly significant (P<0.001), ** highly significant (P<0.01), * significant (P<0.05), 10% almost significant (P<0.1), NS not significant (P>0.1). Italics indicate that less than 30 farms gave a positive response.

For the agricultural cost centre, higher performing farms tend to attend discussion groups, both on business management and other issues. The discussion group effect is even stronger for the business as a whole, with those attending groups on general issues

[16] See http://www.defra.gov.uk/statistics/foodfarm/farmmanage/fbs/publications/farmmanagepractice/ for more information on this module.

performing particularly well. It is interesting to speculate whether this is a direct effect of such groups, or whether the groups appeal to those who are already competent farmers. Overall use of management accounting and the use of cash flows are also associated with higher farm business performance.

6.1. Management practices skills gaps

There is a significant relationship between skills gaps in environmental maintenance and poor performance for the agricultural cost centre.

There is only one significant relationship for this section and this results from those farms which have gaps in their knowledge relating to environmental maintenance having lower than average agricultural performance. The reasons for such a relationship are not obvious and, given the weak statistical significance (P=0.039), the small number of positive responses and the large number of statistical tests being used, it may be that this is a chance effect.

Table 6.2: mean efficiencies (REML farm effects, before allowing for explanatory variables) tabulated by questions on management practices skills gaps. Note that the first question is expressed the other way around, so that a positive response indicates that computers are <u>not</u> used.

	Whole Farm Business			Agriculture cost centre		
	no	yes	sig	no	yes	sig
N o identified business competence knowledge or skills gap	0.004	-0.002	NS	0.003	-0.001	NS
Needs to know more about management accounting	-0.002	0.013	NS	-0.002	0.012	NS
Needs to know more about people management	-0.002	0.015	NS	0.000	0.007	NS
Needs to know more about risk management	-0.002	0.013	NS	0.001	0.000	NS
Needs to know more about marketing	0.000	-0.001	NS	0.002	-0.006	NS
Needs to know more about environmental maintenance eg hedge maintenance, woodland management	*0.002*	*-0.020*	*NS*	*0.003*	*-0.034*	*
Needs to know more about impact of farming practices on biodiversity, habitats, nature conservation e.g. timing of operations, winter vesus spring cereals, residual effects of agrochemicals	0.000	-0.003	NS	0.001	0.000	NS

Note: 'sig' refers to the statistical significance: *** very highly significant (P<0.001), ** highly significant (P<0.01), * significant (P<0.05), 10% almost significant (P<0.1), NS not significant (P>0.1). Italics indicate that less than 30 farms gave a positive response.

6.2. IT skills

Information technology (IT) skills are associated with high performing farm businesses, both for the business as a whole and the agricultural cost centre (Table 6.3).

For both the farm business as a whole and the agricultural cost centre, those farmers who do not use a PC on the farm have significantly lower economic efficiency than those that do. Those using the internet for submitting forms have higher performance at both levels; this may be because of the time saving from electronic submission, but it is more likely that this question is indicative of a good level of computer competence, which then helps many aspects of the farm's performance. Similar comments apply to the results for broadband internet access and skills in applications such as Excel and Word, where the improved performance may well be related to general computer competence, rather than these particular aspects of IT.

It is also worth noting that the level of IT use is much higher on dairy farms than some other sectors, with less than 10% of the farmers who completed this module reporting that there was no PC used on the farm.

Table 6.3: mean efficiencies (REML farm effects, before allowing for explanatory variables) tabulated by questions on use of IT. Note that the first question is expressed the other way around, so that a positive response indicates that computers are not used.

	Whole Farm Business			Agriculture cost centre		
	no	yes	sig	no	yes	sig
There is no PC used on the farm	*0.002*	*-0.033*	*	*0.003*	*-0.047*	**
There is a PC used on the farm but not used by the business	*0.001*	*-0.010*	*NS*	*0.001*	*-0.005*	*NS*
There is a PC used on the farm which is used occasionally for some management purposes.	-0.005	0.005	NS	-0.004	0.005	NS
The business has a computer that has broadband internet access	-0.010	0.005	10%	-0.011	0.007	10%
The [farm team] is proficient in Excel/Word/E-mail and web-searching	-0.007	0.005	10%	-0.010	0.009	*
Uses the internet to purchase and/or sell material for the farm	0.001	-0.005	NS	0.003	-0.006	NS
Uses the internet to improve the performance of the farm e.g. benchmarking	-0.002	0.009	NS	-0.002	0.013	NS
The main farm business documents (Business Plan/Finance Accounts etc) are all managed on the computer	-0.002	0.002	NS	-0.003	0.005	NS
Internet used for submitting forms e.g. CTS/BCMS documents, VAT returns, PAYE forms	-0.010	0.006	*	-0.013	0.009	*
Only uses the computer to submit the SP5	-0.001	0.039	NS	0.000	0.052	NS
Regularly communicates with other farms using the computer	-0.002	0.007	NS	0.000	0.004	NS

Note: 'sig' refers to the statistical significance: *** very highly significant (P<0.001), ** highly significant (P<0.01), * significant (P<0.05), 10% almost significant (P<0.1), NS not significant (P>0.1).
Italics indicate that less than 30 farms gave a positive response.

6.3. *Technical advice*

No relationships were significant at the 5% level, but farmers paying for advice perform better than others at the farm business level and this difference is close to statistical significance.

Technical advice was identified by nearly all farmers and, perhaps because of this almost universal uptake, few significant differences are apparent. However, for the farm business there is an almost significant difference between those obtaining paid advice and those relying on 'free' technical advice from suppliers, with the former group having higher performance.

Table 6.4: mean efficiencies (REML farm effects, before allowing for explanatory variables) tabulated by questions on use of technical advice. Note that the first question is expressed the other way around, so that a positive response indicates that practices are not adopted.

	Whole Farm Business			Agriculture cost centre		
	no	yes	sig	no	yes	sig
No technical advice identified	*0.000*	*-0.024*	*NS*	0.001	-0.061	NS
Through talking to other farmers	0.002	-0.001	NS	0.000	0.001	NS
Through the farming media	-0.009	0.002	NS	-0.009	0.002	NS
Through events and demonstrations	-0.006	0.003	NS	-0.009	0.006	NS
Through discussion groups, farm walks or workshops	-0.005	0.004	NS	-0.005	0.005	NS
Through technical advice supplied with no direct charge (e.g. from input supplier)	0.001	-0.001	NS	-0.001	0.001	NS
Through technical advice supplied for a charge	-0.006	0.008	10%	-0.005	0.008	NS

Note: 'sig' refers to the statistical significance: *** very highly significant (P<0.001), ** highly significant (P<0.01), * significant (P<0.05), 10% almost significant (P<0.1), NS not significant (P>0.1).
Italics indicate that less than 30 farms gave a positive response.

6.4. Uptake of business managament advice

There are no significant associations between these questions and economic performance, either at the farm business level or for the agricultural cost centre.

6.5. Business planning

There is some association between business planning and successful farms, with the strongest relationship being, as might be expected, at the farm business level.

Table 6.5: mean efficiencies (REML farm effects, before allowing for explanatory variables) tabulated by questions on business planning. Note that the first question is expressed the other way around, so that a positive response indicates that practices are not adopted.

	Whole Farm Business			Agriculture cost centre		
	no	yes	sig	no	yes	sig
No formal or informal business plan	0.006	-0.018	**	0.005	-0.012	NS
Has sufficient confidence for the future but no formal business plan is produced.	-0.008	0.015	**	-0.007	0.016	*
The [farm team] meet at least once a year to discuss the direction of the farm but does not record plans formally.	0.001	-0.003	NS	0.002	-0.003	NS
Measures farm's performance by the profit/loss made at the end of the year	-0.005	0.006	NS	-0.006	0.010	10%
Business plan produced in response to a request from a third party e.g.bank. No other use is made of it.	0.001	-0.017	NS	0.002	-0.009	NS
Business plan is shared with the [farm team], reviewed and updated annually.	0.000	-0.005	NS	0.001	-0.004	NS
Business plan is shared with the [farm team], updated annually and reviewed regularly during the year	0.000	-0.005	NS	0.002	-0.009	NS

Note: 'sig' refers to the statistical significance: *** very highly significant (P<0.001), ** highly significant (P<0.01), * significant (P<0.05), 10% almost significant (P<0.1), NS not significant (P>0.1).
Italics indicate that less than 30 farms gave a positive response.

Those farms without any formal or informal business plan have significantly lower efficiencies than those with them. This difference is only statistically significant at the farm business level, but there appears to be a similar, but not significant, trend for the agricultural cost centre. There is also a significant relationship between those with confidence for the future and efficiency at both levels, but this is of less interest since these farmers are presumably more confident because their businesses are performing well.

Unfortunately numbers responding positively for the final three questions are too small to provide precise estimates, making it difficult to assess the impact of these options.

6.6. How the business plans ahead

There are some strong and significant associations between these questions and economic performance for both the farm business and the agricultural cost centre.

Table 6.5: mean efficiencies (REML farm effects, before allowing for explanatory variables) tabulated by questions on how the business plans ahead. Note that the first question is expressed the other way around, so that a positive response indicates that practices are not adopted.

	Whole Farm Business			Agriculture cost centre		
	no	yes	sig	no	yes	sig
Not applicable	*0.003*	*-0.050*	***	*0.003*	*-0.047*	**
On basis of information picked up in farming media	-0.011	0.014	**	-0.014	0.019	***
On basis of information picked up by talking to other farmers	-0.007	0.010	*	-0.008	0.011	*
On basis of discussion within farm household	-0.015	0.004	*	-0.017	0.005	10%
On basis of feedback/discussions with FBS research officer	-0.004	0.012	10%	-0.004	0.012	NS
On basis of business management exercises carried out within the farm	-0.002	0.004	NS	-0.002	0.004	NS
On basis of discussions with customers	-0.001	0.003	NS	-0.001	0.002	NS
On basis of purchased business consultancy, (not including routine discussions with the accountant)	-0.002	0.003	NS	-0.003	0.005	NS
On basis of routine discussions with the accountant	-0.003	0.006	NS	-0.002	0.005	NS

Note: 'sig' refers to the statistical significance: *** very highly significant (P<0.001), ** highly significant (P<0.01), * significant (P<0.05), 10% almost significant (P<0.1), NS not significant (P>0.1).
Italics indicate that less than 30 farms gave a positive response.

Over 90% of the dairy farmers for whom data is available plan ahead in some way and these farms perform better than those that do not. Interestingly, whilst there are significant relationships for a number of approaches to planning in Table 6.5, the strongest relationship is with those who plan on the basis of information in the farming media. This may indicate the importance of up-to-date business information in this fast-moving sector of agriculture.

6.7. Setting targets for business and environmental improvement

For this section there are some significant relationships with economic efficiency at the farm business level, but none for the agricultural cost centre on its own.

Only one relationship is statistically significant for this section; those businesses keeping and regularly reviewing environmental records perform less well for the agricultural cost centre. The reasons for this difference are not entirely clear, but it may be that those farmers pursuing record keeping with such enthusiasm are neglecting the more basic agricultural aspects of their business.

Table 6.6: mean efficiencies (REML farm effects, before allowing for explanatory variables) tabulated by questions on targets for business and environmental improvements. Note that the first question is expressed the other way around, so that a positive response indicates that practices are not adopted.

	Whole Farm Business			Agriculture cost centre		
	no	yes	sig	no	yes	sig
None identified	0.003	-0.004	NS	0.002	-0.002	NS
The business has forecast budgets prepared and reviews these at least every six months	*0.000*	*0.000*	*NS*	*0.000*	*-0.001*	*NS*
The business has forecast budgets prepared and reviews these at least annually	*0.002*	*-0.013*	*NS*	*0.002*	*-0.011*	*NS*
The business keeps environmental records to monitor the environmental impact of what it is doing and reviews these at least every six months	*-0.001*	*0.005*	*NS*	*0.000*	*0.008*	*NS*
The business keeps environmental records to monitor the environmental impact of what it is doing and reviews these at least annually	0.003	-0.013	NS	0.005	-0.022	*
The business puts into practice the action it needs to take to bring about environmental improvements	-0.004	0.006	NS	-0.003	0.006	NS

Note: ‘sig’ refers to the statistical significance: *** very highly significant (P<0.001), ** highly significant (P<0.01), * significant (P<0.05), 10% almost significant (P<0.1), NS not significant (P>0.1).
Italics indicate that less than 30 farms gave a positive response.

6.8. Customer relations

There are some statistically significant relationships between agricultural performance and customer relations questions. However, those engaging in customer relations perform worse than other farms and it may be that this is a chance result arising from the rather small sample sizes.

There are two statistically significant relationships between agricultural performance and these questions on customer relations but, in both cases, those engaging in these activities perform worse than other farms. The first relationship suggests that those proactively dealing with customers perform less well; this seems inherently implausible, but it may be that those needing to be proactive with their milk company have some issues which also explain the poor performance. The second relationship relates to using customer testimony to promote the farm business, which is something that will not be applicable to most farmers, leading to a small sample size

Table 6.7: mean efficiencies (REML farm effects, before allowing for explanatory variables) tabulated by questions on customer relations. Note that the first question is expressed the other way around, so that a positive response indicates that practices are not adopted.

	Whole Farm Business			Agriculture cost centre		
	no	yes	sig	no	yes	sig
No discussions with customers	-0.001	0.002	NS	0.000	0.003	NS
Dealings with customers are mostly concerned with transactions	0.005	-0.006	NS	0.005	-0.005	NS
Has a planning meeting with customers once a year	-0.001	0.008	NS	-0.002	0.016	NS
Customers provide regular feedback on the quality of products/services	-0.005	0.005	NS	-0.006	0.008	NS
Has a collaborative approach with customers, aimed at improving mutual business	0.000	-0.001	NS	0.002	-0.009	NS
Proactive in dealing with customers, and fully understands why they buy the farm business's products	0.003	-0.016	10%	0.005	-0.023	*
Uses customer testimony to actively promote farm business	*0.001*	*-0.024*	*NS*	*0.003*	*-0.046*	*
Looks beyond immediate customers and studies the consumers/market for business's product/services	-0.001	0.005	NS	0.000	0.004	NS

Note: 'sig' refers to the statistical significance: *** very highly significant (P<0.001), ** highly significant (P<0.01), * significant (P<0.05), 10% almost significant (P<0.1), NS not significant (P>0.1).
Italics indicate that less than 30 farms gave a positive response.

6.9. Application of skills in marketing

There are no significant associations between these questions and economic performance, at the farm business level. Market research on non-agricultural activity is significantly associated with poor agricultural performance, but this is based on a small sample size.

Since the majority of dairy farms only have a single buyer for their milk, there is limited scope for marketing and this is reflected in the lack of positive responses to this section of the module. The only statistically significant result relates to market research for non-agricultural activities being associated with poor agricultural performance. Farms may well undertake such research when the core milk business is struggling and so the negative relationship is not that surprising, particularly given the very small sample size.

Table 6.8: mean efficiencies (REML farm effects, before allowing for explanatory variables) tabulated by questions on marketing. Note that the first question is expressed the other way around, so that a positive response indicates that practices are not adopted.

	Whole Farm Business			Agriculture cost centre		
	no	yes	sig	no	yes	sig
Not applicable	0.000	0.000	NS	-0.004	0.002	NS
Regularly undertakes market research for the agricultural commodities the business produces	0.000	-0.002	NS	0.001	-0.001	NS
Regularly undertakes market research for the non-agricultural activities the business is engaged in (eg tourism enterprise)	*0.001*	*-0.015*	*NS*	*0.003*	*-0.045*	*
Regularly engaged in promoting and/or selling the agricultural commodities the business produces	*0.000*	*0.000*	*NS*	*0.001*	*-0.002*	*NS*
Regularly engaged in promoting and/or selling the non-agricultural activities the business is engaged in	*0.000*	*0.001*	*NS*	*0.002*	*-0.032*	*NS*

Note: 'sig' refers to the statistical significance: *** very highly significant (P<0.001), ** highly significant (P<0.01), * significant (P<0.05), 10% almost significant (P<0.1), NS not significant (P>0.1).
Italics indicate that less than 30 farms gave a positive response.

6.10. Application of risk management

Risk management strategies are associated with improved performance, particularly at the farm business level.

Table 6.9: mean efficiencies (REML farm effects, before allowing for explanatory variables) tabulated by questions on risk management. Note that the first question is expressed the other way around, so that a positive response indicates that practices are not adopted.

	Whole Farm Business			Agriculture cost centre		
	no	yes	sig	no	yes	sig
No risk management strategy	0.004	-0.011	10%	0.004	-0.009	NS
Range of crops/enterprises to spread risk	-0.004	0.011	10%	0.000	0.001	NS
Markets some commodities on contract basis with agreed price	-0.005	0.023	**	-0.004	0.023	*
Uses selling groups and pools to market some or all of commodities	0.000	-0.001	NS	0.001	-0.005	NS
Purchases some inputs on contract basis with agreed price	-0.004	0.004	NS	-0.007	0.009	10%
Makes use of 'options'	*-0.001*	*0.023*	*NS*	*-0.001*	*0.028*	*NS*
Animal health insurance	0.000	-0.002	NS	0.001	-0.002	NS
Animal health insurance considered but not pursued	0.000	-0.002	NS	0.000	0.001	NS
Crop damage insurance	*-0.001*	*0.021*	*NS*	*0.000*	*0.008*	*NS*

Note: 'sig' refers to the statistical significance: *** very highly significant (P<0.001), ** highly significant (P<0.01), * significant (P<0.05), 10% almost significant (P<0.1), NS not significant (P>0.1).
Italics indicate that less than 30 farms gave a positive response.

Those farms having risk management strategies in place have higher mean efficiencies at the business level than those without, although this relationship is only of borderline significance. The only relationship that is clearly statistically significant is the improved performance of those that market commodities on contract with an agreed price. Where milk is sold to the big milk supplies the price is generally dictated by the supplier, and so those responding positively to this question (under 20% of the total) are either in an usually strong marketing position (e.g. because they sell into a specialist market), or are marketing other commodities.

The other relationship that is close to significance is with the purchasing of inputs on an agreed basis. This is the most commonly cited risk management strategy for dairy farmers and is likely to relate mainly to the purchase of fertilisers. Given the high cost of nitrogen fertiliser, and the rapid changes in those prices, it is not surprising that those using these arrangements have greater agricultural efficiency.

6.11. Skills acquired through diversification

Sample sizes are small due to the relatively low number of dairy farms diversifying. Skills in marketing and promotion acquired through diversification are associated with poor agricultural performance, presumably because it is often poorly performing dairy businesses that seek to market diversified activities.

The level of diversification, particularly positive diversification rather than simply rental of surplus buildings, is comparatively low amongst dairy farms and so there are few positive responses for most of these questions. The only relationship that is both statistically significant and based on a reasonable sample size is the association between marketing and promotion skills and poor agricultural performance. As with the market research question in section 6.10, this is probably because it is frequently those farms with struggling dairy businesses that seek to market diversified activities.

Most of the remaining questions have small numbers of positive responses (indicated by italics in Table 6.10), so the results should be treated with caution. The other row that has sufficient numbers and a statistically significant result for the agricultural cost centre is 'marketing and promotion'; those that have acquired these skills through diversification have lower mean efficiencies than the rest (i.e. those that have either not diversified, or have diversified but have not acquired these skills).

Table 6.10: mean efficiencies (REML farm effects, before allowing for explanatory variables) tabulated by questions on skills acquired through diversification. Note that the first question is expressed the other way around, so that a positive response indicates that practices are not adopted.

	Whole Farm Business			Agriculture cost centre		
	no	yes	sig	no	yes	sig
Not applicable	-0.003	-0.002	NS	-0.014	0.004	10%
None identified (see text above)	*-0.002*	*0.000*	*NS*	*0.000*	*-0.015*	*NS*
Management accounting	*-0.003*	*0.006*	*NS*	*0.000*	*-0.015*	*NS*
Market research	*0.000*	*-0.028*	*10%*	*0.002*	*-0.055*	**
Marketing and promotion	0.000	-0.009	NS	0.005	-0.032	**
People management	-0.002	-0.008	NS	-0.001	-0.024	NS
Risk management	-0.002	0.015	NS	-0.002	-0.011	NS
Regulations etc, eg planning permission, licensing, food hygiene, health and safety	-0.001	-0.012	NS	-0.001	-0.019	NS

Note: 'sig' refers to the statistical significance: *** very highly significant (P<0.001), ** highly significant (P<0.01), * significant (P<0.05), 10% almost significant (P<0.1), NS not significant (P>0.1).
Italics indicate that less than 30 farms gave a positive response.

6.12. Diversification skills needed

There are no significant associations between the questions asking about skill acquired through diversification and economic performance at the farm business level, but this may be because the number of positive responses is extremely low.

6.13. Integrated farm management (IFM) whole farm audit

Very few farms gave a positive response to the questions in this section but the very small number applying IFM have higher than average performance both for the farm business and for the agricultural cost centre.

Those farms implementing IFM performed significantly better than others for both the business as a whole and the agricultural cost centre. However, less than ten farms responded positively and so these results should be treated with caution.

Table 6.11: mean efficiencies (REML farm effects, before allowing for explanatory variables) tabulated by questions on integrated farm management. Note that the first question is expressed the other way around, so that a positive response indicates that practices are not adopted.

	Whole Farm Business			Agriculture cost centre		
	no	yes	sig	no	yes	sig
None identified	0.018	-0.006	**	0.021	-0.006	*
No - the business has looked into this but does not consider it worthwhile	*-0.001*	*0.010*	*NS*	*-0.001*	*0.011*	*NS*
No - the business does not have enough information about the benefits of a whole farm audit	*-0.002*	*0.014*	*NS*	*-0.002*	*0.021*	*NS*
No - although this is something the business intends to introduce within the next six months	*No positive responses*					
Yes, the business does this.	*-0.002*	*0.049*	**	*-0.002*	*0.047*	*

Note: 'sig' refers to the statistical significance: *** very highly significant (P<0.001), ** highly significant (P<0.01), * significant (P<0.05), 10% almost significant (P<0.1), NS not significant (P>0.1).
Italics indicate that less than 30 farms gave a positive response.

7. Farms ceasing dairying

The majority of this report concentrates on farms continuing in dairy production and, where a farm ceases production, data from the year of exit is excluded from the analysis. In this section, by contrast, we look specifically at these farms and look for variables that distinguish these farms from the majority that continue in milk production.

The analysis was conducted on 568 farms which had more than 20 dairy cows in at least two years between 2003 and 2010; this criterion was used to maximize the sample size for analysis and include mixed farms as well as specialist dairy farms. Any farm falling permanently below the threshold of 20 cows was considered to be an exit, although, since many farms left the FBS at this point, it is not possible to be absolutely certain that they did not subsequently resume milk production. The 20 cow threshold was used because some former dairy farms retained small numbers of cows for some years after ceasing commercial milk production. Using this definition, 66 of the 568 farms ceased production.

The analysis used a binomial mixed model, the dependent variable being whether or not a farm ceases dairying in a given year. Most dependent variables examined were averaged over all years for each farm; this approach avoided spurious relationships resulting from anomalous data in the year of exit. A wide range of possible causal variables were examined, the final model being selected using a stepwise procedure, starting with those terms which looked important on the basis of scatterplots. Terms were included in the final model if they if they were significant at the 10% level; this was chosen as there were a number of explanatory variables of borderline significance, leading to a number of alternative models of approximately equal explanatory power if the conventional P=0.05 criterion was used.

The terms in the final model are shown in Table 7.1 and all the fitted terms are discussed in more detail in the following sections. The tables of predicted probabilities shown for each variable are intended to illustrate the impact of each variable separately, removing the confounding effects of other factors; as a result they are not unbiased estimates of the overall probability of farms leaving dairying, which are better obtained from other sources.

Table 7.1: significant terms from a stepwise GLMM analysis of the probability of exit from dairying. Year and farm were also fitted, but as random terms.

Term	X^2	d.f.	P	Estimate	s.e.	notes
AGE	4.26	1	0.039	0.0302	0.0146	Farmer age
logcat10km	3.27	1	0.071	-0.407	0.225	Log cattle in 10km square
%outother	16.46	1	0.000	-0.102	0.025	% output from SPS, schemes, etc.
Priceimp	3.67	1	0.055	-0.110	0.058	Milk price relative to annual average
prag	4.21	1	0.040	-1.712	0.835	Performance ratio for agricultural cost centre
vetpercow	3.64	1	0.056	-9.87	5.18	Vet costs per cow per year
Agcosts x LOGAREA	10.29	1	0.001	2.71	0.844	Interactions between agricultural costs (economic size) and log farm area.

7.1. *Farmer Age*

The probability of a farm exiting increases approximately linearly with farmer age. This is presumably driven by the desire of older farmers to either retire totally or to switch to a less demanding farming enterprise, if they do not have a younger successor to take over.

Table 7.2: predicted percentage probability of exit from dairying at different ages.

Age (years)	% leaving dairying	Standard error
40	1.9%	0.75
50	2.5%	0.83
60	3.4%	1.11
70	4.5%	1.78

7.2. *Non-agricultural output*

The total output for the business was divided into the percentage shares for agriculture, diversified activities and other (mainly SPS and payments from schemes, including agri-environment schemes). Table 7.3 shows that there is a general tendency for those farms with little income from other sources to be more likely to exit. This indicates the value of such payments in supplementing the milk cheque and other agricultural income. It may also indicate that those considering leaving farming are unwilling to enter into agri-environment schemes and similar activities which demand a long-term commitment.

Table 7.3: predicted percentage probability of exit from dairying for different proportions of total output from sources other than pure agriculture and diversification.

% output from other sources	% leaving dairying	Standard error
5%	5.5%	1.91
10%	3.4%	1.08
15%	2.1%	0.70
20%	1.3%	0.52

Interestingly the percentage of output from diversified enterprises (including rental, tourism, etc.) shows little sign of a relationship with the probability of exit.

7.3. *Density of dairy cattle*

Mapping the results suggested that there might be some tendency for more exits outside the core dairying areas. This was tested in the model by adding a term for the log-transformed number of dairy cows in the appropriate 10km grid square, based on the June Survey. As anticipated there is a relationship of borderline statistical significance, with more exits in squares with few dairy cattle.

Table 7.4: predicted percentage probability of exit from dairying for different numbers of dairy cattle in the 10km grid square.

Dairy cows in 10km grid square	% leaving dairying	Standard error
100	4.3%	1.69
1,000	2.9%	0.92
5,000	2.2%	0.80

7.4. *Economic and physical size*

Both the economic and the physical size of the farm have an impact on the probability of exit, with farms that are small in economic terms (measured by their agricultural costs), but large in terms of land area, being most likely to exit (Table 7.5). The high exit rate from businesses that are small in economic terms will reflect the lack of economies of scale, but might also reflect the hard work and long hours required to make such a business viable. Interestingly, the economic size of the business is a stronger predictor than the number of cows, and the number of cows is not statistically significant, after allowing for economic size by fitting agricultural costs.

The inverse relationship between land area and exit rate for a given economic size is also interesting, and may relate to the potential for alternative agricultural enterprises. Farms leaving dairying but remaining in agriculture frequently switch to beef production, perhaps because they are used to working with cattle. Extensive beef enterprises are only likely to be viable where the land area is relatively large.

Table 7.5: predicted percentage probability of exit from dairying for different physical and economic sizes. The annual costs for the agricultural cost centre are used as a proxy for economic size.

	Costs £100k p.a.		Costs £200k p.a.	
Farm area	**% leaving dairying**	**Standard error**	**% leaving dairying**	**Standard error**
25ha	0.7%	0.43		
50ha	2.2%	0.79	0.4%	0.22
100ha	6.5%	2.14	1.4%	0.50
200ha			3.0%	0.97

Note: estimates are not shown for £100k costs and 200ha, or for £200k costs and 25ha, since these values are outside the range observed.

7.5. Milk price

Milk prices were averaged over all years (apart from the year of exit, where the data is often atypical) for each farm, expressed relative to the average in each year. Almost 90% of farms were within 4p of the average, with a small number more than 4p per litre less than the average, and a rather large number above this range, usually due to selling organic or Channel Islands milk. Milk price had a relationship of borderline significance with the probability of exit (Table 7.6), with farms with a relatively low price much more likely to exit.

Table 7.6: predicted percentage probability of exit from dairying for different milk prices.

Milk price (p/l) relative to average	% leaving dairying	Standard error
3p below average	3.6%	1.21
average	2.6%	0.86
3p above average	1.9%	0.80

7.6. Agricultural performance

Agricultural performance, expressed as the ratio of agricultural outputs to agricultural costs, was significantly related to the probability of exit, with poor performers more likely to cease milk production (Table 7.7).

Table 7.7: predicted percentage probability of exit from dairying for different agricultural performance.

Performance ratio	% leaving dairying	Standard error
0.8	3.5%	1.16
1.0	2.5%	0.82
1.2	1.8%	0.75

7.7. Veterinary costs

There is a linear relationship of borderline statistical significance between the veterinary costs per cow per year and the probability of exit, with high spenders more likely to remain in the industry. This may be a direct effect, due to increased spending leading to better cow health and hence better performance. However, since this relationship remains after adjusting for agricultural performance, it may be an indicator of the commitment of the farmers.

Table 7.8: predicted percentage probability of exit from dairying for different veterinary costs per cow per annum.

Vet costs per cow per year	% leaving dairying	Standard error
£40	3.3	1.08
£60	2.7	0.88
£80	2.3	0.80
£100	1.9	0.78

7.8. Business changes on ceasing dairying

Of the 66 farms exiting from milk production, 47 remained within the FBS for at least one year allowing the business changes subsequent to exit to be studied. Of these 47 farms, 24 became grazing livestock farms and another 9 were subsequently classified as mixed. The remaining 13 became cereals or general cropping farms; in many cases these were previously classified as mixed, rather than specialist dairy, due to a mixture of dairying and arable crops. Figure 7.1 shows the locations of these farms. It is possible that in some cases these changes were a prelude to full retirement, so these changes should not necessarily be taken to mean that the restructured farm businesses were all viable in the long term.

Of the 19 farms that did not remain in the FBS, exit information is available for ten farms. Seven of these were listed as either 'retired' or 'sold up', whilst one was continuing in business, but was now below the FBS minimum size threshold. The other two were no longer interested in being in the FBS but presumably remained in business.

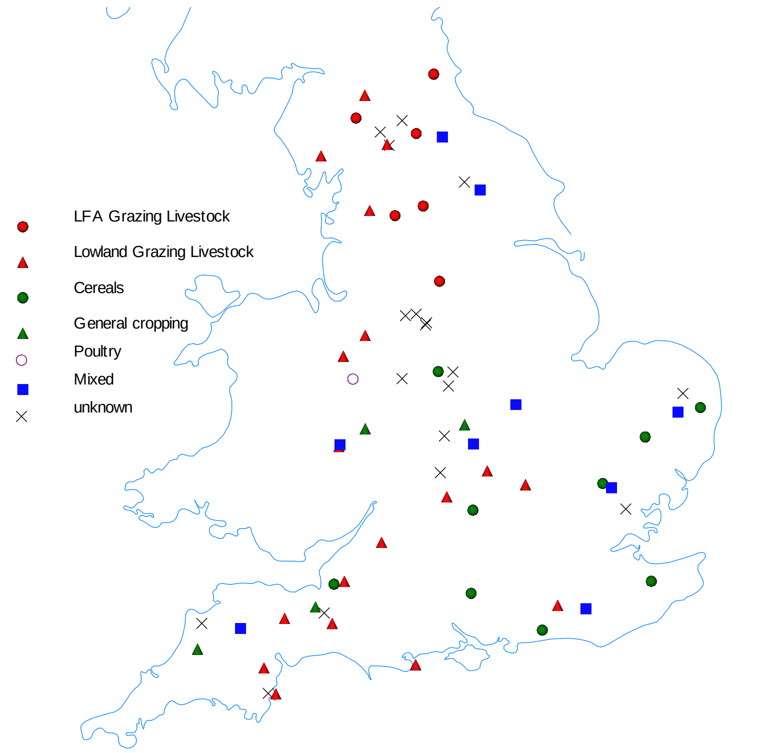


Figure 7.1: locations of farms leaving dairying, labelled by their new farm type. To preserve confidentiality, farms are shown at a random point within 30km of their true location.

It is also interesting to look at the size of the restructured business, following loss of the diary enterprise. This is shown in Figure 7.2. Particularly at the smaller end (outputs less than £100k p.a.) most businesses are smaller, often substantially so, after ceasing milk production. This is not surprising since dairying will have made up the vast majority of the output value from these small dairy farms.

Some larger farms do manage to retain outputs at a similar magnitude following exit, or even increase them. Cereals farms have performed particularly well in this respect, presumably helped by the increased returns to arable land.

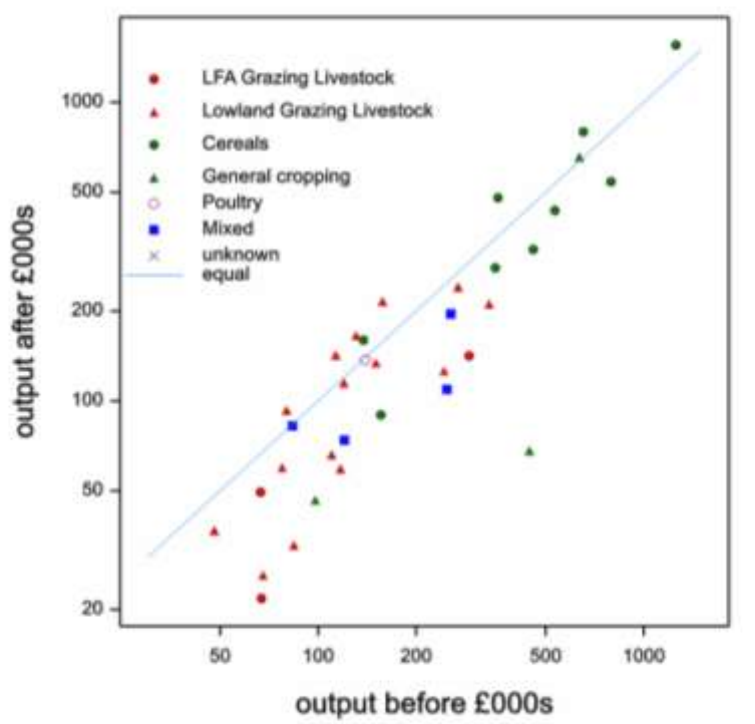


Figure 7.2: total output of each farm business after exiting dairying, plotted against the equivalent total output before exit.

8. Costs of milk production

8.1. Introduction

This chapter covers results from analysis of 2010/11 Farm Business Survey data investigating the production costs of English dairy enterprises and how these relate to milk prices, farm characteristics and net margins. Unlike the previous sections, which consider the business as a whole, this chapter uses costs and outputs for the dairy enterprise only. It also weights the data so that they are representative of the national population of dairy herds; the analyses in the previous sections are primarily aimed to establish relationships, rather than to produce national estimates, and therefore use unweighted data[17].

Data was taken from the Farm Business Survey of England for 2010-2011; this period was chosen as the most recent available at the time. Farms were included in the analyses in this chapter if they had a milk production of at least 1,000 hectolitres in 2010/11 and had also responded to Section M of the FBS covering costs and margins. 326 observations met these conditions and include 24 farms that are not classified to 'robust' type dairy.

8.2. Costs and the deconstruction of Net Margin

The cost base for milk production in this analysis has been taken to be everything contributing to costs in the calculation of net margins. This comprises of variable costs plus fixed costs but also livestock depreciation and farmer and spouse unpaid labour. A figure was also deducted from costs in respect of managerial input, although a value for this was only recorded by three of the 326 farms. To arrive at net margin, costs as described above were subtracted from revenue, which had three sources; milk sold (94.5% of revenue), milk used/consumed on the farm (0.7%) and non-milk revenue (4.8%, mostly from calf sales). Throughout this chapter, these measures have been expressed in pence per litre of milk produced to aid comparison and for consistency with producer prices. Price received on milk sold is expressed per litre of milk sold, which is on average 99.1% of milk produced.

To provide some context for analysis, farms were split into four quarters, each containing 25% of farms in the population (as opposed to the sample) depending on their cost per litre of milk produced. Quarter 1 contains the lowest cost producers, rising to the highest cost producers in quarter 4.

8.3. Costs split by cost quarters

Table 8.1 shows the top five contributors to costs and indicates that the costs break down into very similar proportions regardless of the cost of production. Only results for 'Other livestock costs' show a statistically significant deviation from the average for all farms. This suggests that farmers who keep total costs low do so through attention to detail across the board rather than targeting specific areas and that the practices of farms with different production costs are unlikely to be drastically different. Concentrated feed stuffs make up by far the largest single cost which helps to demonstrate the impact of rising feed costs on the dairy industry. Whilst we know that expenditure on feedstuffs (and other commodities such as fertiliser and seeds) are similar for the four cost quarters, we do not know the volumes involved, which might reveal that lower cost producers are getting more for their money.

[17] See Korn and Graubard (1999, *Analysis of Health Surveys*, Wiley) for a discussion of the merits of weighting survey data in different types of analysis.

Table 8.1 Specific costs as a % of all costs per litre of milk produced, split by cost quarters

The final column indicates the statistical significance of differences (*** = P<0.001 very highly significant, ** = P<0.01 highly significant, *=P<0.05 significant, 10%=P<0.1 almost significant, NS= not significant).

	Q1: Lowest cost per litre	Q2	Q3	Q4: Highest cost per litre	All farms	Statistical significance
Concentrated feedingstuffs	27.3%	29.2%	27.4%	27.2%	27.8%	NS
Livestock depreciation	10.7%	10.2%	9.5%	10.2%	10.1%	NS
All unpaid labour (unpaid, farmer, spouse)	8.8%	9.6%	9.3%	11.4%	9.7%	NS
Paid labour	9.4%	7.2%	9.0%	8.4%	8.5%	NS
Other livestock costs	7.8%	8.1%	9.1%	8.0%	8.3%	*
All other costs	36.0%	35.8%	35.6%	34.7%	35.6%	NS

8.4. Characteristics of dairy enterprises by cost quarters

Whilst the proportion of costs is similar across the cost quarters, the farms within them do have different characteristics (Table 8.2). As cost per litre falls, herd size increases (from 102 cows in Q4 to 170 in Q1) and other signs of efficiency emerge such as higher yield per forage hectare (pasture plus crops grown for stock feeding). Higher stocking densities where costs are lower hints at more intensive production, but other measures do not suggest this. Concentrates as % of feed costs are level across the industry and yields per cow are only lower in the highest cost quarter. Milk prices are higher for farms with higher costs, which may be partly due to premiums for added value milk from lower yielding systems (e.g. organic, Channel Island and high welfare contract herds), although it is difficult to identify these in the data. What is clear is how keeping costs low contributes to securing a positive net margin with big differences observed between the top and bottom quarters. The 25% of dairy enterprises keeping their cost of production the lowest all make a positive net margin, compared to just one in twenty of the highest cost enterprises.

Table 8.2: Dairy enterprise characteristics, split by cost quarters. Table shows mean value in the relevant quarter.

	Q1: Lowest cost per litre	Q2	Q3	Q4: Highest cost per litre	All farms	Statistical Significance
All costs (ppl)	21.5	24.8	27.2	32.1	25.6	***
Price received on milk sold (ppl milk sold)	24.9	25.2	25.4	26.3	25.3	***
Proportion of dairy farms	25%	25%	25%	25%	25%	N/A
Proportion of industry production	31%	29%	24%	16%	100%	N/A
Dairy cows	170	162	131	102	141	***
Stocking density (cows per forage ha)	2.00	1.96	1.76	1.63	1.85	**
Concentrates as % of feed costs	82%	85%	82%	84%	83%	10%
Feed as % of all costs	33%	34%	33%	32%	33%	NS
Yield per cow (l)	7,929	7,770	8,008	6,962	7,725	***
Yield per forage ha (litres)	15,828	15,194	14,121	11,376	14,321	***
Unpaid labour cost as % of all labour cost	48%	57%	51%	57%	53%	NS
All labour cost as % of all costs	18%	17%	18%	20%	18%	*
Dairy enterprise Net margin (ppl)	4.5	1.7	-0.6	-4.2	1.0	***
Farms with +ve Net Margin	100%	77%	28%	5%	52%	***
Farmer age	53.0	52.4	53.7	53.1	53.1	NS

8.5. *Herd size analysis*

The decline in the number of dairy farms has been widely reported. Between 2005 and 2009, the number of dairy holdings in England fell by about a quarter and yet the dairy herd reduced by just 7% (production also fell by 7% over this period)[18]. Clearly the average herd size has increased and along with other sectors of agriculture, expansion and specialisation are often seen as key to survival. The characteristics of dairy enterprises split by cost quarters (above) shows a link between larger herds and lower production costs per litre of milk. The next analyses split the data into three bands, based on dairy herd size (averaged across the year). Unlike the costs quarters, these bands were based on specific cut off points and therefore do not represent equal portions of dairy farms, however the end result is fairly close. The 'Small' band includes all farms with less than 100 cows, 'Medium' band farms with 100 to 170 cows and the 'Large' band is for those with more than 170 cows. These cut off points are similar to the average herd sizes for the highest and lowest cost quarters, but it should be noted that this does not mean the groups cover the same farms. These bands should also not be confused with the standard FBS size bands, based on farm output that are used in other reports.

8.6. *Costs split by herd size bands*

The breakdown of costs (Table 8.3) is seen to vary depending on herd size, particularly in relation to labour. Smaller farms are far more reliant on unpaid labour from the farmer, spouse and others (most likely family members) than larger farms. Larger herds will have increased labour requirements which cannot be met solely or mostly by family labour. Total labour costs are higher (per litre) on smaller farms, which suggests either less efficient use or unpaid labour not being factored in by farmers at its true value (see section 2.3). Concentrated feedingstuffs make up a smaller proportion of costs on smaller farms, hinting at less intensive production systems. Depreciation costs are also lower on smaller farms, suggesting a less ruthless approach to culling, however the difference is small.

Table 8.3: Specific costs as a % of all costs, split by dairy herd size bands

	Small: <100 Cows	**Medium: 100-170 Cows**	**Large: >170 Cows**	**All**	**Statistical significance**
Concentrated feedingstuffs	23.2%	28.2%	29.0%	27.8%	***
Livestock depreciation	9.1%	9.9%	10.6%	10.1%	*
All unpaid labour (unpaid, farmer, spouse)	18.8%	10.2%	6.7%	9.7%	***
Paid labour	4.4%	8.3%	9.8%	8.5%	***
Other livestock costs	8.2%	7.9%	8.5%	8.3%	NS
All other costs	36.2%	35.4%	35.5%	35.6%	NS

8.7. *Characteristics of dairy enterprises by herd size*

Larger herds had considerably lower average costs per litre of milk produced and also enjoy slightly higher prices (Table 8.4). This feeds through to the net margin which is negative for the small herds, roughly break-even for the medium herds and positive for the large herds. Large herds are three times more likely to have a positive net margin than small herds suggesting that running a large herd is not a guarantee to profits, but does make it more likely. Higher stocking densities, expenditure on concentrates and yields per forage hectare suggest more intensive production on average as herd size increases, although yields per cow are only lower for the herds with less than 100 cows.

[18] Observatory Report 14 describes herd size changes over a longer timescale: http://www.defra.gov.uk/statistics/files/defra-stats-foodfarm-environ-obs-research-cattle-dairy09-jun09.pdf

Table 8.4: Dairy enterprise characteristics, split by dairy herd size bands

	Small: <100 Cows	Medium: 100-170 Cows	Large: >170 Cows	All sizes	Statistical Significance
All costs (ppl)	28.2	26.0	24.7	25.6	***
Price received on milk sold (ppl)	24.4	25.2	25.7	25.3	***
Proportion of dairy farms	34%	35%	31%	100%	N/A
Proportion of industry production	14%	33%	54%	100%	N/A
Dairy cows	66	127	242	141	***
Stocking density (cows per forage ha)	1.5	1.8	2.0	1.9	***
Concentrates as % of feed costs	80.9%	82.5%	84.0%	83.1%	*
Feed as % of all costs	28.7%	34.1%	34.5%	33.5%	***
Yield per cow (l)	6,549	7,983	7,930	7,725	***
Yield per forage ha (litres)	9,853	14,406	16,121	14,321	***
Unpaid labour cost as % of all labour cost	81%	55%	41%	53%	***
All labour cost as % of all costs	23%	19%	16%	18%	***
Dairy enterprise Net margin (ppl)	-2.2	0.3	2.2	1.0	***
% Farms with +ve Net Margin	28%	54%	78%	52%	***
Farmer age	53.7	53.5	51.8	53.1	NS

8.8. Breakeven milk price of milk production

Figure 8.1 shows the proportion of milk production that would at least breakeven at a range of potential milk prices. The breakeven price is a little lower than the cost of production because it takes into account non milk revenues which are on average worth 1.3ppl and arise mostly from calf sales. The gradient of the cumulative production is fairly consistent between 20% and 80% of production, spanning 21.3 to 26.7ppl. Over this range a 1ppl increase in price would allow approximately 11% more production to be done so profitably. Profitability here is on the basis of making a positive net margin, which represents the return to the owners of the farm's capital. This therefore comes after all wages have been paid a market rate, including an allowance for unpaid labour. What is considered a satisfactory return on capital will vary and is unknown, however in some cases it might be near zero or even negative due to positive non-monetary benefits such as the lifestyle accompanying dairy farming.

8.9. Price received on milk sold

Figure 8.2 shows the actual price received for milk sold. Almost 70% of milk sold was at a price between 24 and 27ppl, with only 5% receiving more than 28ppl. The price range is quite narrow, as should be expected for a near homogenous commodity, however even 1ppl can make a significant difference to a farm's bottom line when the average annual production is over a million litres. Combining readings from both charts, it can be seen that whilst only 5% of milk was sold at a price of 23ppl or less, 40% of production would have at least breakeven at this price in 2010/11.

Figure 8.1: breakeven price of milk production in 2010/11. For example, at 25ppl around 60% of milk production at least breaks even.

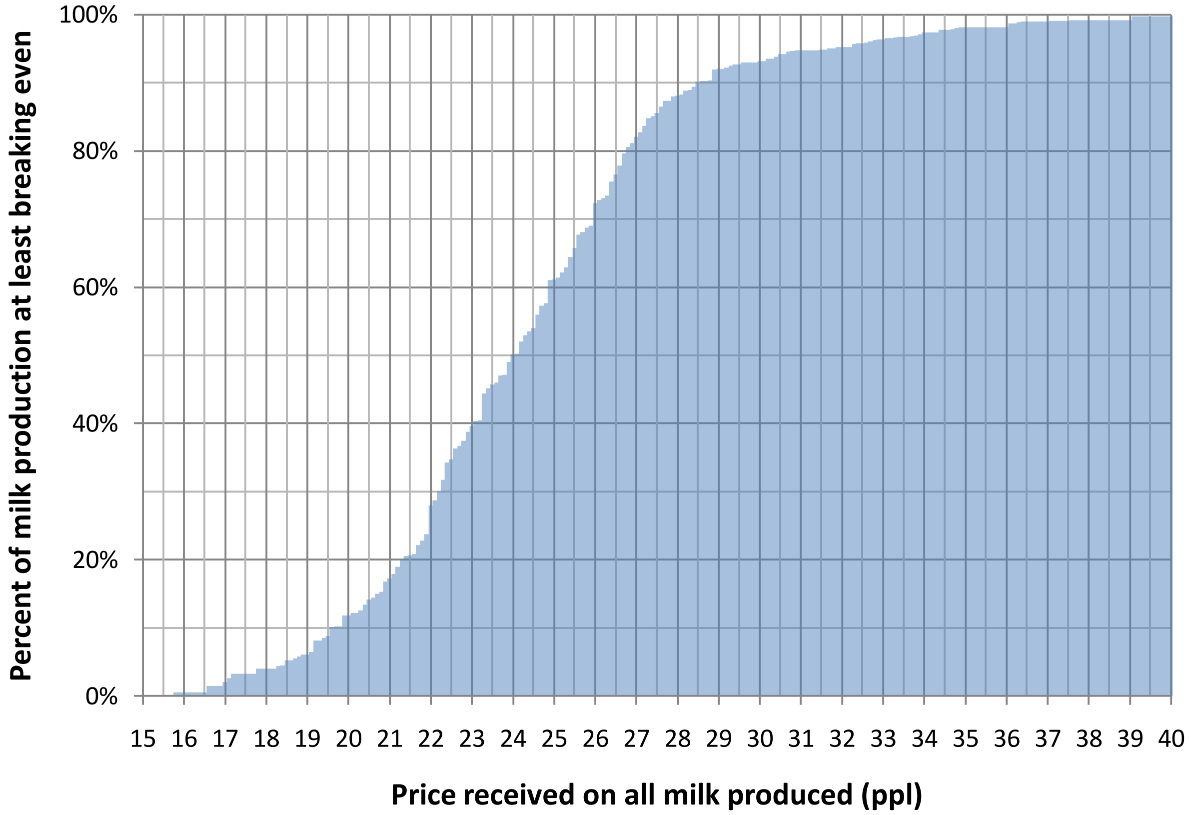


Figure 8.2: price received on milk sold in 2010/11. The graph is cumulative so, for example, 80% of milk sold received 24.0ppl or more.

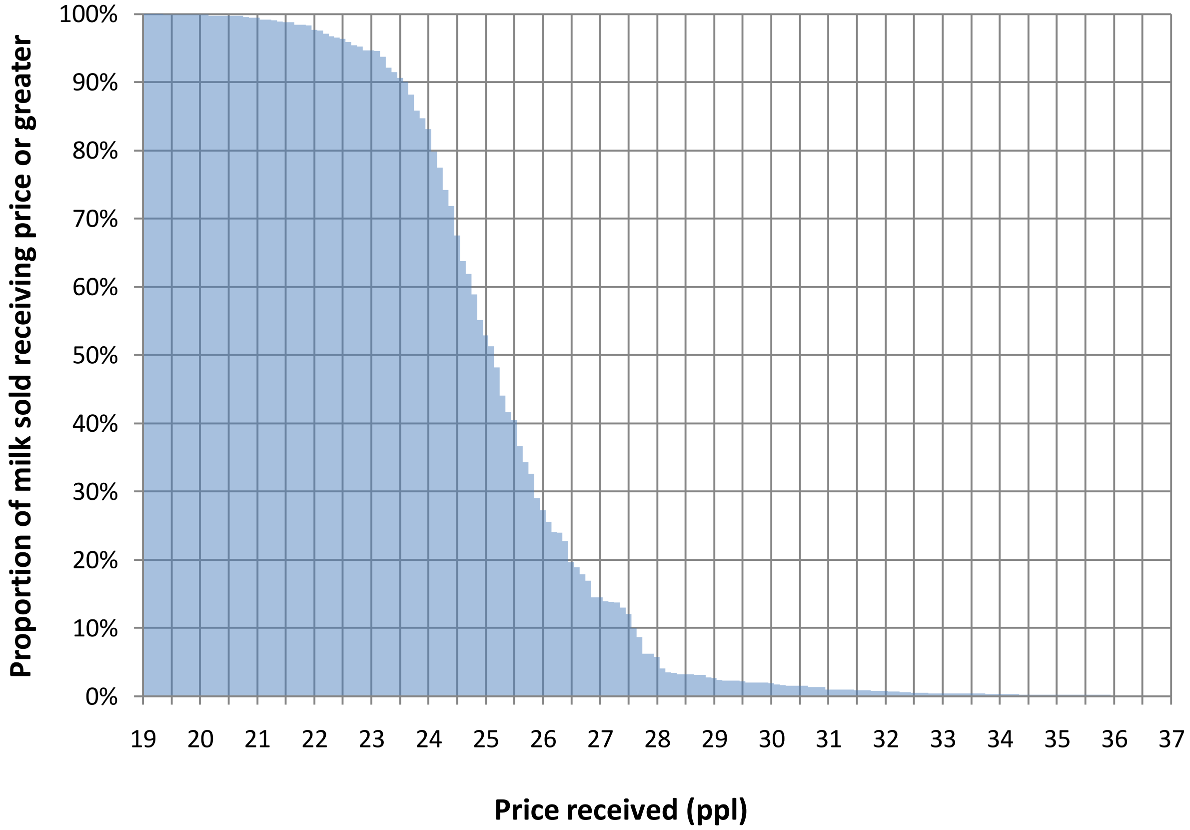
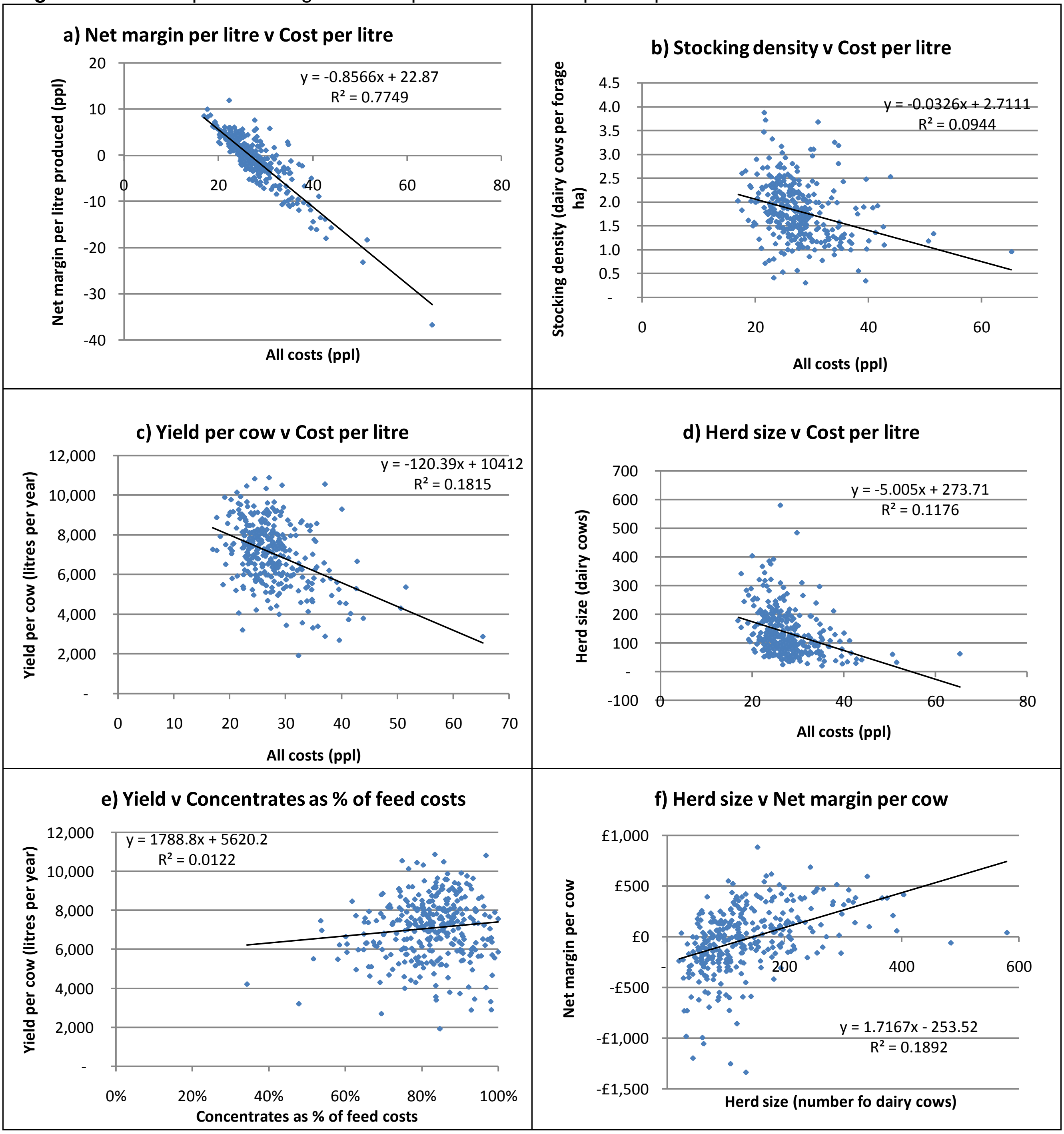


Figure 8.3: scatterplots relating to cost of production. Each point represents one farm in 2010-11.



8.10. Scatter charts

The charts in Figure 8.3 examine the relationship between farm characteristics and cost of production per litre of milk. When interpreting the charts it is vital to consider the R^2 statistic which provides the goodness of fit of the line. An R^2 close to 1 represents a good fit and a strong link, whereas an R^2 close to 0 represents a poor fit and no meaningful relationship between the two variables. Where there is a low R^2, the gradient of the line of best fit is fairly meaningless. The results show a strong link between high net margins and low costs (Figure 8.3a). This suggests that controlling costs are key to profitability and that there are relatively few high cost enterprises making profits through securing higher prices.

The other charts show weaker relationships than might be expected, indicating the considerable variability in performance, even within the same type of system. For example, Table 8.2 showed that herd sizes tended to be highest amongst the quarters with lower costs. However, Figure 8.3d shows that this relationship is quite weak, with some relatively small herds having low costs and some large herds having high costs.

It should also be remembered that the graphs of stocking density (Figure 8.3b) and yield (Figure 8.3c) against cost may be subject to competing factors as some costs may be higher in more intensive systems, balanced through increased yields. Figure 8.3f shows that net margin per cow tends to increase with herd size, but that for any given level on either axis there is a big spread in the values on the other.

9. Discussion and conclusions

9.1. Economic performance and its relationship with farm size

The results presented here indicate that there are clear economies of scale in the dairy industry once the effects of confounding factors have been allowed for and unpaid labour is appropriately costed. This is in accordance with the findings of Hadley *et al.* (2006) using earlier data from the Farm Business Survey, as well as those of Barnes et al. (2011). There is, however, a curvilinear relationship between efficiency and economic size, and efficiency tends to peak below the size of the largest farms, with the position of the asymptote dependent on the costing of unpaid labour.

The tendency for efficiency to peak has been noted before (Britton and Hill, 1975), and probably relates to the practical difficulties in increasing the size of a dairy unit. For example, as the number of cows using a parlour increases, the distances they must walk to reach grass inevitably increase, meaning that the enterprise cannot be scaled-up indefinitely without modification to the system. Of course, in the longer term systems are likely to evolve which remove these practical constraints, shifting the size of peak efficiency upwards in order to continue the trend for growth in average herd size over time. Thus these results cannot be used to form conclusions on the efficiency of very larger 'super-dairies' with thousands of cows; these will employ very different systems and simple extrapolation from the herds in the present survey is likely to be misleading.

Despite these inherent economies of scale, it is important to remember that this pattern represents the average relationship, and that individual farms frequently buck the trend. Thus the results presented here do not fully support Wilson's (2011) assertion that, in terms of net margin per cow, 'The most profitable producers operate larger, higher yielding herds'. Indeed, as the scatterplots in earlier chapters show, there is enormous variation at all sizes, and highly efficient farms are to be found throughout the size range. This is in line with DairyCo's Milkbench report (2012), which stated that 'efficient milk production is possible at almost any scale of production'.

A corollary of this is that increasing herd size is not necessarily the best approach to improving a business's efficiency, and might even lower it, particularly if expansion involves taking on additional debt. Expansion does however give some guarantee of increased income and this is probably the main driver for the continued increase in herd sizes, fuelled by factors such as rising standards of living and reduced margins. Increased life expectancy may also have an impact since, where farmers do not have formal pension schemes, the farm business needs to support more retired family members in addition to the active farming generation.

9.2. Debt

There is a very strong relationship between debt, represented by the gearing ratio, and economic efficiency, with heavily indebted businesses performing worse. This applies to the agricultural cost centre and the farm business as a whole. It is in accordance with both results from the previous reports in this series and those from a variety of other studies in the literature, across a range of farm types (e.g. Barnes *et al.,* 2011[19], Hadley et al, 2006). It does however contradict the finding of Barnes (2008) who found improved technical efficiency amongst indebted farms in Scotland.

[19] The cereals report noted that Barnes et al found the reverse relationship between technical efficiency and debt. However, errors were later found in the analysis by Barnes et al, and the modified version of their paper now agrees with the findings reported here.

It thus seems likely that, in many cases, debt leads to economic inefficiency, not least because a heavily indebted farm which is running at its overdraft limit will not be in a position to make sound financial decisions. For example, stock may be sold when money is needed to pay farm or household bills, rather than selling at the best time to maximise profit. However, whilst debt may cause inefficiency, the converse is also true; inefficiency may lead to debt. Thus, the relationship observed here may, at least partially, result from farms that have performed consistently badly over many years accumulating high levels of debt.

The level of variability in the results is also relevant here; some farms with moderate levels of debt perform well, whilst some farms with little or no debt are nevertheless amongst the least efficient farms. These results should therefore not be interpreted to mean that a farm should never take on debt to finance investment in the business. However, they suggest that the business case for such investment should be extremely sound; otherwise the inefficiencies associated with excessive debt may exceed the efficiencies generated by the investment.

9.3. Family labour

Across all three of the sectors studied in this series of reports the relationships with unpaid labour have been stronger for the agricultural cost centre than for the business as a whole, presumably indicating that the family farming system is strong at developing core agricultural skills, but less good at producing first-rate business people. However, even for the agricultural cost centre, the beneficial effect of family labour for dairy farms is less marked than for the other two sectors, and vanishes if the labour is costed at the full market rate. This may relate to the availability (e.g. through recruitment agencies) of dairy staff with high levels of expertise, comparable to, or even exceeding, the skills of family members.

9.4. Tenancy and farmer age

The previous reports in this series suggested that tenanted farms performed well in comparison with owner occupied ones. In addition, for grazing livestock, where a more detailed analysis was possible, farms with land under Farm Business Tenancies (FBTs) performed particularly well. By contrast, even after allowing for the different land costs, owner-occupied dairy farms perform significantly better than rented ones, a result that coincides with the earlier study by Hadley (2006), although his study also suggested that owner-occupiers performed better on cereals, beef, and, to a lesser extent, sheep farms as well. The results presented here also suggest that farms with FBTs perform less well than those with Full Agricultural Tenancies (FATs).

One possible explanation for these results is that dairy farming requires substantial investment in fixed assets, particularly for the parlour, buildings and slurry stores. The payback time for these assets is long, with the result that owner-occupiers are in the strongest position to borrow with the confidence that they will be able to achieve a return on the investment. At the other end of the scale, FBTs are typically for five years or less, giving little incentive to make significant investment, although there is no reason why longer FBTs cannot be created, provided both parties agree.

Another difference, is that on grazing livestock farms there were signs that older owner-occupied farmers showed signs of a reduction in economic efficiency, whereas no such effect was observed with dairy farmers; indeed older dairy farmers were, on average, more efficient. This is perhaps explained by the very different demands of the two sectors; beef and sheep farmers can reduce the intensity of their businesses, allowing them to coast into semi-retirement, without giving up totally. On the other hand, dairy farming is a full-time commitment requiring long hours of work and so the older farmer must continue to deliver that level of commitment, either directly or by employing a younger manager, unless they prefer to retire from milking altogether. The work on exits suggests that some of the latter group may switch to beef or sheep production, allowing them to maintain a connection with the farming industry in a sector more conducive to part-time working.

9.5. Specialisation

The results of the model suggest that specialisation is not beneficial to dairy businesses. This result is surprising at first sight and needs to be carefully interpreted as a result of the way the measure of specialisation is constructed from the Standard Labour Requirements of the different activities. For this purpose grassland, fodder crops and cattle other than adult dairy cows are considered separate activities, and so specialisation is effectively measured relative to a hypothetical farm that had no grazing land, bought in all feed and didn't rear its own replacements.

It is also important to remember that the analysis looks at the farm business as a whole, so that the result may reflect the returns on other enterprises relative to the returns on the dairy enterprise. Thus in years where returns from, for example, arable are good compared to milk, those less specialised farms with substantial arable areas will tend to outperform more specialised dairy farms.

Whilst this may seem rather artificial, it does reflect the reality that the overall performance of the farm reflects the sum of all enterprises, and being highly efficient in one specialised enterprise may not be the best option in times of fluctuating prices. Having a variety of agricultural enterprises is a valid risk management strategy in the current market, much more so than was the case ten or twenty years ago when prices were less volatile and production support gave a degree of isolation from the market.

9.6. Potential for improvement

This study has shown that there is enormous variation in the performance of farms, but it does not automatically follow that the worst performers can be brought up to the level of the best. A big unknown is how much of the variation in performance is due to factors such as management ability and husbandry practice which are, at least in theory, amenable to change, and how much is due to those factors that are essentially fixed, such as land quality and topography. In the cereals study at least 10% of the variation could be shown to be down to large scale geographic differences (e.g. climate and soil), whereas for both grazing and dairy farms very little of the variation in farm business performance could be explained in this way.

It must be emphasised that this result does not necessarily mean that geographic differences in economic efficiency do not exist, but rather that the current dataset is not sensitive enough to pick them up. Indeed, the concentration of the dairy industry in the West of the country in recent years, does suggest that geography is important, and the results in section 7 also give indications of this. And, of course, the FBS cannot continue to collect data from dairy farms in areas unsuitable for dairying if those farms no longer exist. Even where a few farms continue outside the core dairy areas, the geographic trend may be obscured if, as is likely, these remaining dairy farms are exceptionally highly motivated and manage to deliver profits despite the disadvantages of their geographic location.

We are currently exploring how better geographic information can be collected for FBS farms without either breeching the strict confidentiality conditions for the survey or imposing an excessive administrative burden on farmers. In the meantime, speculation is required to obtain some feel for the capacity for change.

Figure 7.1 shows the actual distribution of farm-level efficiency terms in the top graph and, below this, a hypothetical distribution based on improved performance across grazing livestock farms . The distribution of improved performance makes the assumption that improvements in efficiency might halve the overall farm-level variation, with the mean of the new distribution equal to the upper quartile of the current distribution. Applying this distribution to the REML model causes an increase in output value of 6.5% for the current level of input costs. This contrasts with a figure of 13% for grazing livestock farms, highlighting the rather tighter distribution of performances in the dairy sector.

Whilst the 50% reduction in variance and the improvement to the old upper quartile are very much guesses, this 6.5% figure does provide some indication of the scale of efficiency gains that might be achievable in practice.

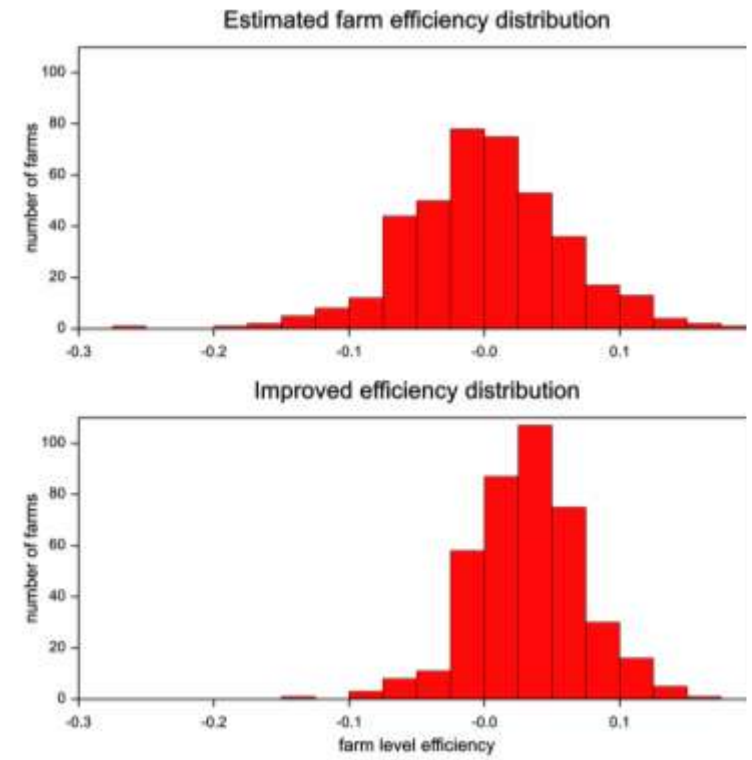


Figure 7.1: farm level efficiency distributions for the real REML model (top graph) and for the simulated improved distribution (bottom graph).

9.7. Links between economic performance and agri-environment scheme membership

As with cereals and grazing livestock farms, it has been difficult to show any unequivical links between economic efficiency and energy usage, and it is not clear whether this is because there is no relationship present or whether it is due to the limitations of the data. It will be interesting to see whether the improved energy usage model which was used in 2012 proves more successful in this respect, once the data is available for analysis. Similarly, whilst the water usage data provided tantalising glimpses of a plausible pattern, the picture was far from clear.

This leaves the agri-environment data as the one area where the larger sample size permits firm conclusions to be drawn, although, even here, relationships are only on the borderline of statistical significance. Farms in ELS appear to perform well compared to those outside any scheme; this is rather more positive than the equivalent result for grazing livestock farms, where there was very little difference between these groups. It is therefore interesting that dairy farms have comparatively low rates of ELS membership. HLS membership rates are even lower, resulting in large standard errors for the estimates for this scheme. It is likely that most dairy farmers feel that the more demanding requirements of HLS are difficult to accommodate around the needs of the core dairy business, and there is nothing in the current study that suggests that this assumption is incorrect.

The other finding worthy of note in this section is the strong economic performance of organic dairy farms, with the increase in milk price compensating for the lower production, although the extent of the benefit varies from year-to-year. 2010 figures showed little advantage for organic producers compared to conventional farms, in accordance with reports of difficult trading conditions for the wider organic sector during the recession.

9.8. Links with business management skills

As with the grazing livestock sector, there were some significant relationships between economic efficiency, particularly at the business level, and business management skills. However, these relationships explained a fairly low proportion of the variation in efficiency, suggesting that there may be other unmeasured factors which are important determinants of efficiency. In the previous report it was suggested that overall business acumen, coupled with attention to detail in all aspects of the farm, were likely to explain the success of the best farms. This conclusion fits in well with the results of chapter 8 where the best performers had low costs across all aspects of production. It also tallies with the conclusions of Rural Business Research's recent report (Wilson *et al.* 2012) into the characteristics of high-performing farms.

9.9. Exits and retirement

A large number of dairy farms have left the industry in recent years, allowing the factors associated with exiting to be studied in a way that is not possible with most other sectors. One of the most striking features of this analysis is the range of factors involved; including those relating to the economic situation of the business, its geographic location and the personal circumstances of the farmer.

Interestingly too, the factors associated with exit are not simply the converse of those associated with high performance in the earlier sections of the report. For example, older farmers were shown to be, on average, more efficient at the farm business level, but they are nevertheless also more likely to cease dairy farming.

It appears that there is a stronger geographic influence on farms leaving the industry than there is on the performance of those that remain. Only 2% of the variation in economic performance could be linked to large-scale geographic variation, whereas, despite the small sample size, there were signs of an association between dairy exits and areas with few other dairy cattle. It is possible that the weak relationship in the main dataset is because the few remaining dairy farms in these areas are amongst the most competent, and thus achieve reasonable financial performance despites the disadvantages created by their isolation. However, the higher rate of exits from areas with few dairy cattle may also be partly due to social factors as well as financial ones.

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[20] http://archive.defra.gov.uk/evidence/economics/foodfarm/reports/agriculturalefficiency/index.htm

11. List of abbreviations used

CAP Common Agricultural Policy

ELS Entry Level Stewardship

FBS Farm Business Survey

HLS Higher Level Stewardship

IT Information Technology

LFA Less favoured area

NCA National Character Area (formerly Joint Character Area, JCA)

PCA Principal Components Analysis

REML Restricted (or residual) maximum likelihood

SLR Standard Labour Requirement (a measure of economic size of farms)

SPS Single Payment Scheme

UAA Utilised agricultural area

Annex: questions from the business management module

This module was asked as a series of yes/no questions relating to use of each type of skill/practice on the farm. Note that the first question in each block is generally expressed as a negative (not applicable, none, etc.) so a response of 'yes' means that the relevant skills are not present or not applied.

Application of skills in management accounting

Not applicable

Uses gross margins prepared for enterprises on the business

Uses cash flows prepared for the business

Reviews the profit and loss account in depth

Prepares partial budgets to inform business decisions

Prepares a budget for the year

Frequently benchmarks and compares business performance with others

Regularly attends discussion groups or meetings on business management issues

Regularly attends discussion groups or meetings on other issues , eg farm walks/meeetings on cross compliance, new regulations, environmental matters.

Management practices knowledge and skills gaps

No identified business competence knowledge or skills gap

Needs to know more about management accounting

Needs to know more about people management

Needs to know more about risk management

Needs to know more about marketing

Needs to know more about environmental maintenance eg hedge maintenance, woodland management

Needs to know more about impact of farming practices on biodiversity, habitats, nature conservation e.g. timing of operations, winter vesus spring cereals, residual effects of agrochemicals

I.T. skills

There is no PC used on the farm

There is a PC used on the farm but not used by the business

There is a PC used on the farm which is used occasionally for some management purposes.

The business has a computer that has broadband internet access

The [farm team] is proficient in Excel/Word/E-mail and web-searching

Uses the internet to purchase and/or sell material for the farm

Uses the internet to improve the performance of the farm e.g. benchmarking

The main farm business documents (Business Plan/Finance Accounts etc) are all managed on the computer

Internet used for submittingforms e.g. CTS/BCMS documents, VAT returns, PAYE forms

Only uses the computer to submit the SP5

Regularly communicates with other farms using the computer

Uptake of technical advice

None identified

Through talking to other farmers

Through the farming media

Through events and demonstrations

Through discussion groups, farm walks or workshops

Through technical advice supplied with no direct charge (e.g. from input supplier)

Through technical advice supplied for a charge

Uptake of business management advice

None identified

Through talking to other farmers

Through the farming media

Through events and demonstrations, eg meetings organised by banks or accountancy firms

Through discussion groups, farm walks or workshops

Through advice supplied with no direct charge (e.g. from casual discussion with accountant or bank manager) or subsidised specific advice, eg FBAS

Through specific business managemnt advice supplied for a charge (eg via consultant)

Business Planning

No formal or informal business plan

Has sufficient confidence for the future but no formal business plan is produced.

The [farm team] meet at least once a year to discuss the direction of the farm but does not record plans formally.

Measures farm's performance by the profit/loss made at the end of the year

Business plan produced in response to a request from a third party e.g.bank. No other use is made of it.

Business plan is shared with the [farm team], reviewed and updated annually.

Business plan is shared with the [farm team], updated annually and reviewed regularly during the year

How the business plans ahead

Not applicable

On basis of information picked up in farming media

On basis of information picked up by talking to other farmers

On basis of discussion within farm household

On basis of feedback/discussions with FBS research officer

On basis of business management exercises carrried out within the farm

On basis of discussions with customers

On basis of purchased business consultancy, (not including routine discussions with the accountant)

On basis of routine discussions with the accountant

Setting targets for business & environmental improvement

None identified

The business has forecast budgets prepared and reviews these at least every six months

The business has forecast budgets prepared and reviews these at least annually

The business keeps environmental records to monitor the environmental impact of what it is doing and reviews these at least every six months

The business keeps environmental records to monitor the environmental impact of what it is doing and reviews these at least annually

The business puts into practice the action it needs to take to bring about environmental improvements

Customer relations

No discussions with customers

Dealings with customers are mostly concerned with transactions

Has a planning meeting with customers once a year

Customers provide regular feedback on the quality of products/services

Has a collaborative approach with customers, aimed at improving mutual business

Proactive in dealing with customers, and fully understands why they buy the farm business's products

Uses customer testimony to actively promote farm business

Looks beyond immediate customers and studies the consumers/market for business's product/services

Application of skills in marketing

Not applicable

Regularly undertakes market research for the agricultural commodities the business produces

Regularly undertakes market research for the non-agricultural activities the business is engaged in (eg tourism enterprise)

Regularly engaged in promoting and/or selling the agricultural commodities the business produces

Regularly engaged in promoting and/or selling the non-agricultural activities the business is engaged in

Application of risk management

No risk management strategy

Range of crops/enterprises to spread risk

Markets some commodities on contract basis with agreed price

Uses selling groups and pools to market some or all of commodities

Purchases some inputs on contract basis with agreed price

Makes use of 'options'

Animal health insurance

Animal health insurance considered but not pursued

Crop damage insurance

Areas where the business has acquired more skills through diversification

Not applicable

None identified

Management accounting

Market research

Marketing and promotion

People management

Risk managment

Regulations etc, eg planning permission, licencing, food hygiene, health and safety

Diversification: areas where the business needs to acquire more skills

Not applicable

None identified

Management accounting

Market research

Marketing and promotion

People management

Risk managment

Regulations etc, eg planning permission, licencing, food hygiene, health and safety

IFM whole farm audit

None identified

No - the business has looked into this but does not consider it worthwhile

No - the business does not have enough information about the benefits of a whole farm audit

No - although this is something the business intends to introduce within the next six months

Yes, the business does this.