CEREALS FARMS: ECONOMIC PERFORMANCE AND LINKS WITH ENVIRONMENTAL PERFORMANCE

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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 crops). There is a high level of variation in efficiencies of cereals farms. At least 10% of this variation is related to large scale geographic factors (e.g. soil and climate). 60% is related to other between-farm differences in efficiency, such as differences in management ability and local geographic effects, whilst the remaining 30% represents year-to-year variation in the performance of farms.

2. 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
   Area: for a given level of farm inputs, farms with bigger areas tend to be more efficient.
   Diversification: when only agricultural outputs are considered, diversified farms perform less well, which may indicate that the agricultural side of the business suffers as management effort is diluted through being directed to diversification. Alternatively, diversification may be more popular on those farms which are less efficient with respect to the agricultural side of the business.
   Unpaid family labour: even if 'unpaid' labour is costed at its full economic value, farms with greater proportionate use of family labour perform better.

3. Whilst the results suggest a positive correlation between farm area and economic efficiency, the relationship with the economic size of the business (as measured by input costs) is complex. Initial models excluding confounding variables indicated that smaller cereal farms were more efficient than larger ones (decreasing returns to scale). This appears to be partially because of the much lower levels of debt amongst smaller farms; over half of the smallest farms have gearing ratios of less than 1%, compared to around 10% of large ones. This may be because some heavily indebted small farms have struggled to compete and have sold up. If allowance is made for levels of debt and other factors associated with efficiency, and if imputed costs for unpaid family labour are also included, there are increasing returns to scale.

4. Whilst there are continued pressures for cereals farms to increase in economic size, these results suggest that this will not necessarily lead to increased economic efficiency, particularly where it involves increased debt and increased dependence on contractors rather than family labour. Many farms would benefit from a modest increase in area in order to achieve maximum economic efficiency. However, farms are frequently driven by a need to maximise income, rather than economic efficiency.

5. The best data on links between economic performance and environmental performance comes from analysis of payment rates for agri-environment schemes. Economic performance of farm businesses is positively correlated with scheme payments. Farms that have joined the ELS since 2005 tend to show increasing farm business performance. The more demanding classic agri-environment schemes impact adversely on the economic efficiency of the agricultural cost centre (i.e. the agricultural share of the business), but the scheme payments ensure that the overall impact on the efficiency of the whole farm business is positive.

CEREALS FARMS: ECONOMIC PERFORMANCE AND LINKS WITH ENVIRONMENTAL PERFORMANCE

1. Introduction

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 cereals 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. 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.

All the results presented in this report relate to cereals farms, but the analyses are, in most cases, equally applicable to other sectors. It is hoped that future Observatory reports will extend this works to other types of farms. Comments on Observatory work are always welcome, but methodological observations on this report will be particularly valuable since they can be incorporated in these further studies.

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

2. Methods: Data and statistical models

2.1. Data

Data was taken from the Farm Business Survey of England for 2004-2008. Farms were included in the analysis if they were classified to 'robust' type cereals in at least three of these five years. 322 farms met this condition, with 195 of these surveyed in all five years. 86% of the farms were always classified as cereals, with the remainder being classified to another farm type (usually general cropping or mixed) in a minority of years.

2.2. Variables used in the analysis

The principal variables used are shown in Table 2.1. Annex 1 contains a full list of all variables referred to in the text, including all explanatory variables used in the models.

Table 2.1: principle 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.

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, 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 it is often clear that they 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 require ownership of a 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.

The approach adopted here is therefore to analyse the data with and without imputed costs for unpaid labour. In practice, the true picture will lie somewhere between these extremes. To avoid making the results section too bulky, results without the imputed costs will generally be presented, with results including them only shown where differences exist.

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):

$logout_{ij} = y_j + b_1*logcosts_{ij} + ef_i + e_{ij}$ (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[2].

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[3].

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.

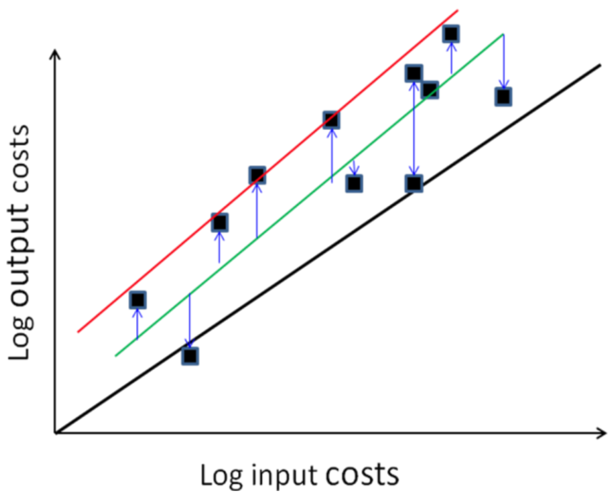


Figure 2.1: graphical representation of the model. The black line represents equal inputs and outputs, the green line is the average efficiency (REML) and the red line is the efficient frontier. The blue arrows represent the efficiencies of each farm relative to the average.

The model of equation 1 assumes a linear relationship on the log scale between outputs and input costs. 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 to relate outputs to input quantities in order to estimate technical efficiency. Where the inputs are measured in monetary terms it is therefore

2 http://www.uq.edu.au/economics/cepa/software.htm

3 http://www.vsni.co.uk/software/genstat/

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. 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. This might well increase economic efficiency in terms of the ratio of outputs to inputs, since the optimal rate of application increases when the 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:

$$logout_{ij} = y_j + b_1*logcosts_{ij} + d_1*z_1 + ... + d_p*z_p + ef_i + e_{ij} \qquad \text{(Equation 2)}$$

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

3. Results: economic efficiency

3.1. Efficiency models and returns to scale

Results of the efficiency models are shown in Figure 3.1. 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, perhaps because of an unusually good harvest 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 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. Since the graphs are on the log scale a given distance above the black line implies

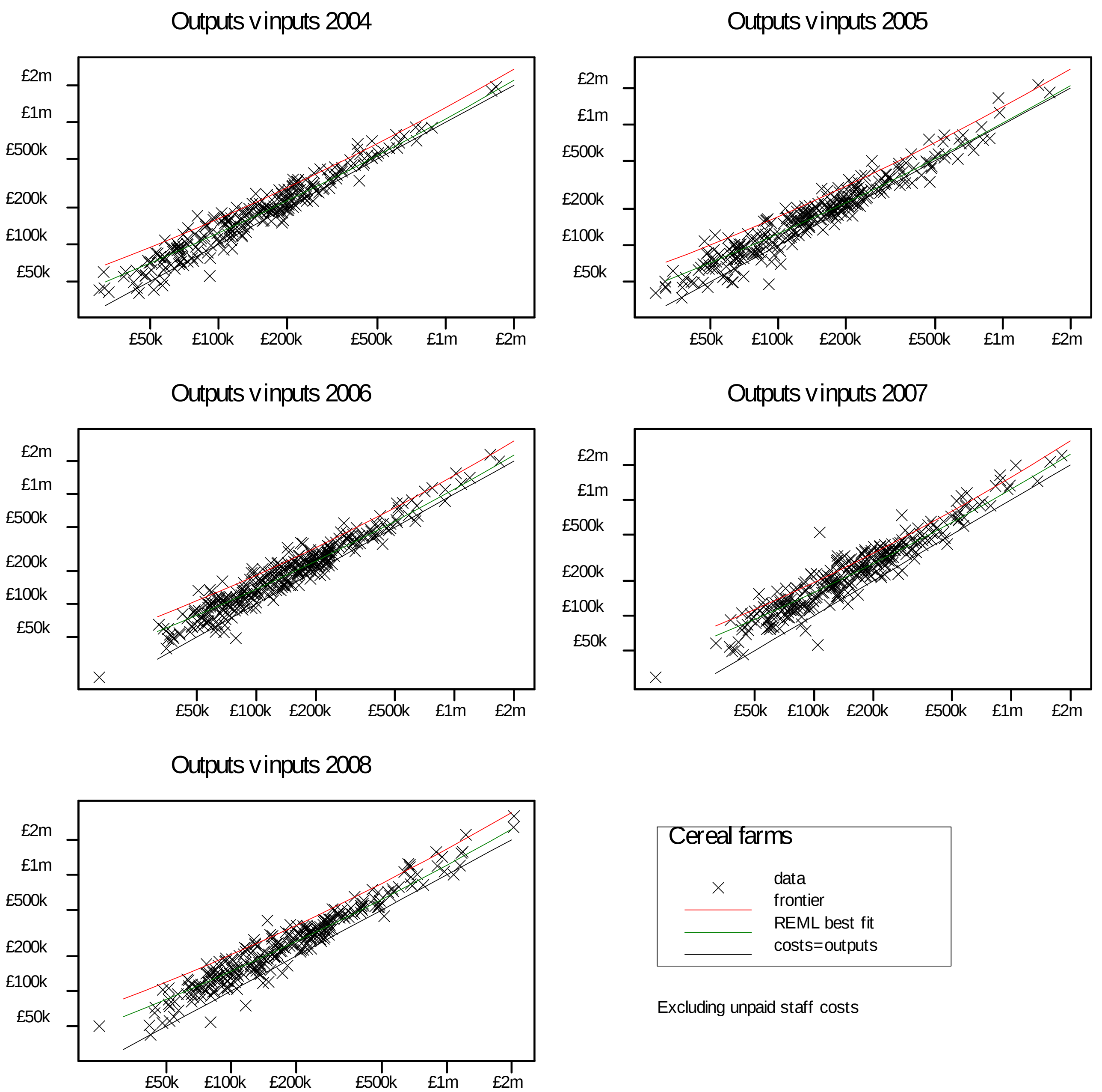
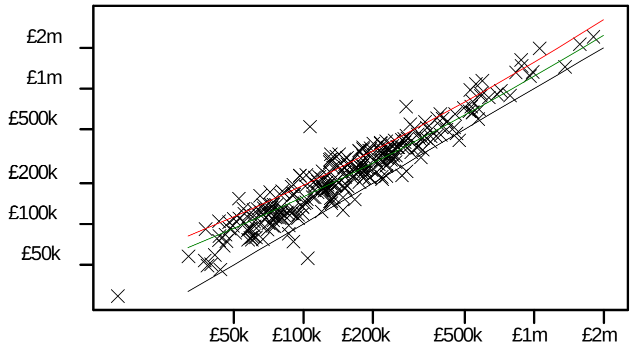
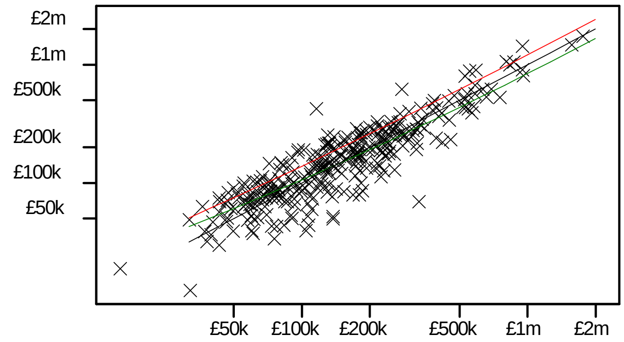


Figure 3.1: efficiency models for farm business output. Costs do not include any imputed costs for unpaid labour.

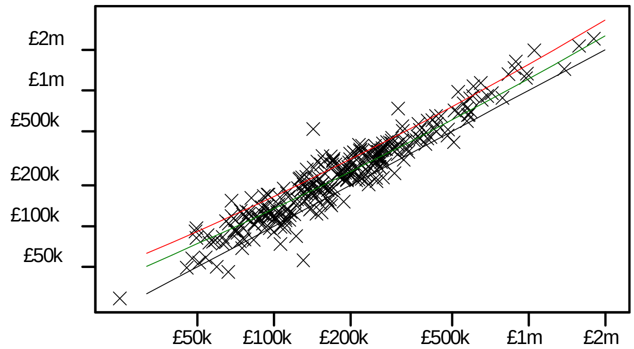
the same proportionate relationship between outputs and inputs, regardless of the position on the x-axis. Thus if, for example, all farms achieved exactly 10% more outputs than the cost of inputs, they would lie on a straight line above, but parallel to, the black equality line. The lines representing the efficient frontier (red) and the average farm (green) are indeed approximately parallel to the black line for high values on inputs in all years, but they curve away upwards towards the left hand side of each plot. This suggests that smaller farm businesses tend to be proportionately more efficient in turning inputs into outputs in terms of the monetary value (i.e. decreasing returns to scale).



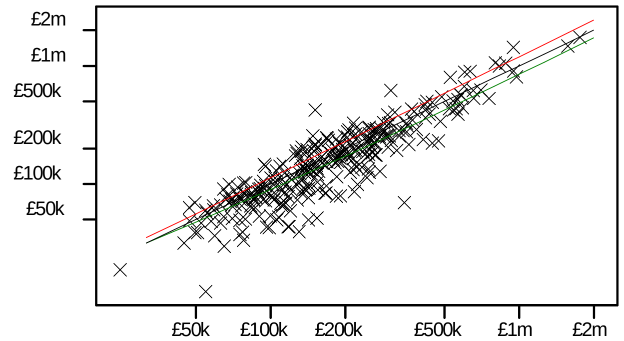
a) Farm business output/costs excluding unpaid labour



b) agricultural output/input excluding unpaid labour



c) Farm business output/costs including unpaid labour



d) agricultural output/input including unpaid labour

Figure 3.2: efficiency models fitted to the different datasets for 2007. The red line is the frontier model, the green line represents average farms (REML model) and the black line is equality of inputs and outputs. The vertical axis is output value, the horizontal one input cost.

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. It also depends on whether a notional cost is added for unpaid family labour, including that of the farmer and spouse. These differences are illustrated in Figure 3.2 and Table 3.1 using data for 2007.

Figure 3.2 shows the different models for 2007. When farm business outputs are considered and no allowance is made for the costs of unpaid family labour (Figure 3.2a, which is identical to the 2007 graph in Figure 3.1), there are clearly decreasing returns to scale as discussed above. When notional costs are added for unpaid labour (Figure 3.2c), the lines are approximately parallel to the black line representing equality of inputs and outputs for input costs above around £200,000.

Table 3.1: predicted increase in value of outputs for a 10% increase in input costs for a farm on the efficient frontier for 2010.

	Farm business (including subsidies, SPS, scheme payments, diversification)		**Agriculture only** (excluding subsidies, SPS, scheme payments, diversification)	
Average annual input costs	Excluding unpaid labour	Including unpaid labour	Excluding unpaid labour	Including unpaid labour
£50k	7.4%	8.3%	8.7%	10.1%
£100k	8.0%	8.8%	8.9%	10.2%
£200k	8.7%	9.4%	9.2%	10.2%
£500k	9.5%	10.1%	9.6%	10.3%
£1m	10.2%	10.7%	9.9%	10.3%
£2m	10.8%	11.2%	10.1%	10.4%

If just agricultural outputs are modelled (excluding receipts from subsidies, the SPS and agri-environment schemes) and unpaid labour cost are excluded (Figure 3.2b) the green line for average performance dips below the black one for farms with higher input costs, illustrating that returns to scale are again diminishing and that substantial numbers of farms have negative margins. When the notional costs of unpaid labour are added (Figure 3.2d), even more farms lie below the black line of equality of input and output costs. However, the lines are now nearly parallel, with evidence of slightly increasing returns to scale for farms on the efficient frontier.

A different presentation of the same models is shown in Table 3.1. This shows the predicted increase in outputs for a farm on the efficient frontier when inputs are increased by 10%. The first column shows results for the whole farm business excluding a notional cost for unpaid labour, as in Figure 3.2a. It is only when the annual input costs reach almost a million pounds that a ten percent increase in inputs produces a corresponding ten percent increase in outputs. At the other extreme, the final column shows results from the model based on agricultural outputs only, including unpaid labour costs. For all levels of input costs, the return on a ten percent increase in input costs is slightly greater than ten percent, indicating increasing returns to scale.

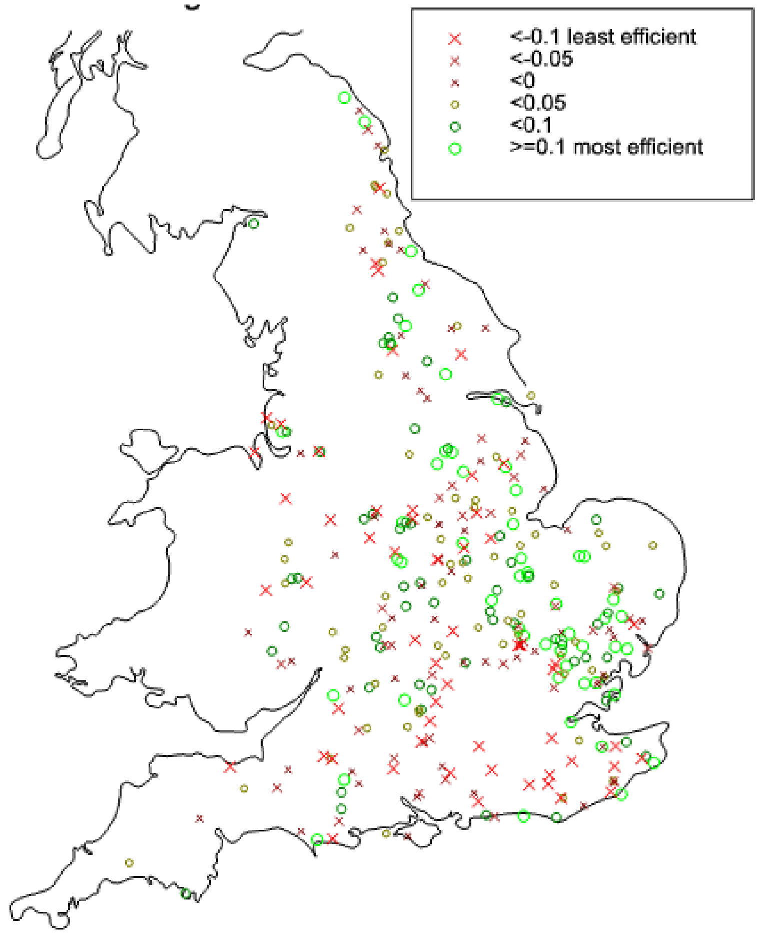


Figure 3.3: Spatial distribution of farm efficiencies. Efficiencies are based on the model for agriculture only, excluding imputed costs for unpaid labour.

3.2. Spatial pattern in efficiency

Figure 3.3 shows the spatial distribution of farm efficiencies based on agricultural inputs and outputs. There is significant spatial clustering (randomisation test based on variogram, P=0.031), with high efficiencies predominating in East Anglia, and low ones in Sussex and Hampshire. There is some similarity between the spatial pattern in Figure 3.3 and the distribution of good agricultural land in England[4]. Exploring this further is complicated by the confidentiality arrangements for the FBS which means that the location of farms is only known to the 10km square level. Figure 3.4 therefore relates the efficiencies from a model excluding geographic variables to the mean agricultural land class of land used for crops in the 10km square[5]. Farms in squares with a low average land class figure (class 1 represents the best land, class 5 the worst) are usually average or above average efficiency, whereas there is much more of a range in squares with a mean land class of greater than 2. It is striking that all farms with efficiencies below -0.15 are in squares with mean land class figures of 2.3 or more. What is not clear is whether the higher performing farms in the squares with poorer land achieve good performance because they cope better with the challenges of such land, or whether these farms are on pockets of better land.

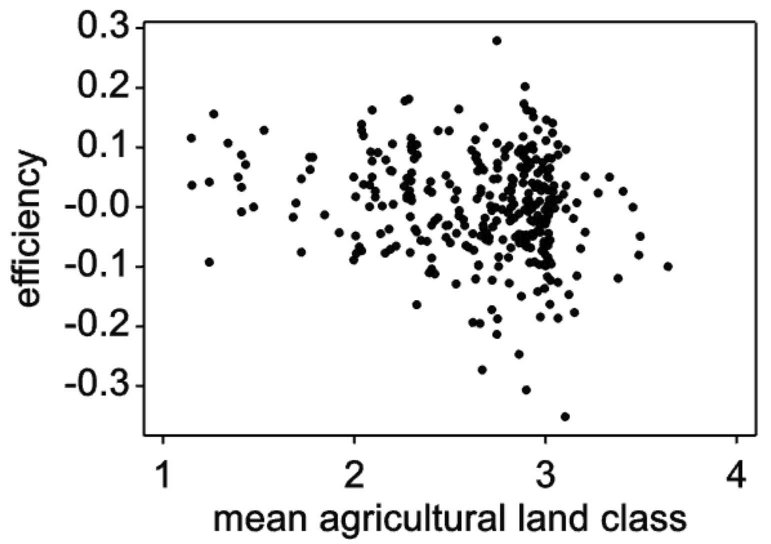


Figure 3.4: Farm efficiencies plotted against the mean agricultural land classification of arable fields within the relevant 10km square. Efficiencies are based on the model for agriculture only, excluding imputed costs for unpaid labour.

Whilst some large scale spatial pattern is present in Figure 3.3, it represents a relatively small proportion of the total variation in the dataset. This is shown in Table 3.2 where the spatial component, modelled at the National Character Area[6] (NCA) level accounts for only just over 10% of the total variability. This figure may 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 well over half the total variation. Variability between farms will be due to factors such as the skill of the farmer and the crops grown, as well as more local geographic factors such as field size and soil fertility. Around 30% of the total variation is unexplained year to year variation within farms, caused by factors such as poor weather or disease outbreaks.

[4] See http://www.magic.gov.uk/staticmaps/maps/alc_col.pdf The agricultural land classification is based on climate, topography and soil. The relationship with soil is particularly evident in Figure 3.3, with many less efficient farm on chalk or limestone (e.g. North and South Downs, Lincolnshire Wolds), whilst many efficient ones are on clay soil (e.g. Essex and Suffolk).

[5] This was calculated considering all land parcels used to grow the major crops (code OT1) in the 2006 SPS dataset. The agricultural land class of each field in the 10km square was weighted by the claimed area to arrive at an average for the square.

[6] 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 3.2: proportion of variance at different levels in the data

	Variance	s.e.	Percent of total
Spatial variation (NCA)	0.00214	0.00092	11.3%
Farm to farm variation	0.01129	0.00114	59.9%
Random year to year variation	0.0054	0.00023	28.8%

Based on a REML model of log transformed output value with terms fitted for log-transformed input costs and their interaction with year.
The spatial variation is based on National Character Areas and does not include more local geographic factors.

4. Results: factors correlated with efficiency

Table 4.1 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.

Table 4.1: significant terms from a stepwise REML analysis of log output (excluding unpaid labour) against the explanatory variables. The following terms were also examined but were not statistically significant (age, education, organic, anylfa). A random term for the NCA was used to account for the spatial variation in the data.

	Farm business output				Agricultural output			
Term	F statistic	df1	df2	P	F statistic	df1	df2	P
Logcosts.Year interaction	3.89	4	1116.0	0.004	3.18	4	1116.1	0.013
logavcosts	34.57	1	840.0	<0.001	21.05	1	769.9	<0.001
%Interest	12.10	4	307.6	<0.001	14.53	4	298.6	<0.001
Logarea	69.62	1	308.4	<0.001	16.31	1	303.7	<0.001
Year.Parable	10.15	4	1111.0	<0.001	6.98	4	1111.6	<0.001
%Divcost					6.58	4	299.5	<0.001
%Unpaid	27.90	1	302.7	<0.001	33.89	1	294.3	<0.001
Tenancy	2.68	3	307.2	0.047	2.63	3	300.6	0.050
Conrat	3.46	1	304.4	0.064	7.71	1	299.6	0.006

Notes: in the agricultural output model, conrat is fitted as a quadratic polynomial and the F-statistic shown is for the quadratic term.
Models exclude the imputed cost of unpaid labour

Considering each of the terms in Table 4.1 in turn, there is, as would be expected a highly significant relationship between outputs and inputs, and the significant interaction between log-transformed costs and year indicates that the slope of this relationship varies from year-to-year. The slopes are slightly lower in 2005, 2006 and, in the case of farm business outputs, 2007, indicating slightly less favourable returns to scale in these years.

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 (0.98) between these variables, both are highly significant, indicating that the output of a farm in any one year depends on the inputs in the preceding 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. 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.

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 illustrated by Table 4.2 which shows the predicted level of outputs from a farm with £150,000 of inputs per annum and 200ha of land (approximately the median levels) 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 £150,000 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: Interest payments as a percentage of total costs. The table shows predicted outputs from the REML model for a farm with £150,000 of inputs per annum, 200ha of land and average values of the other variables in the model. Figures are for 2007. Standard errors are approximate.

	Farm business output		Agricultural output	
Interest as % total costs	Estimated output (£000s)	Standard error	Estimated output (£000s)	Standard error
<0.1%	237	4.0	160	4.5
0.1-0.99%	232	4.7	157	5.3
1-4.99%	213	3.4	136	3.6
5-9.99%	216	4.4	136	4.5
10% or more	197	6.0	116	5.5

Note: Models exclude the imputed cost of unpaid labour

There is a strong relationship between the level of debt and farm size (Figure 4.1), with smaller farms tending to have much lower levels of debt. This could either be because the farms have not needed to borrow because they have not increased in size, or it may indicate 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. Land area

The land area of the farm also has an impact on efficiency, although care is needed in interpreting this, since land area is, unsurprisingly, correlated with the level of input costs. Table 4.3 shows the expected level of output for different land areas for farms with

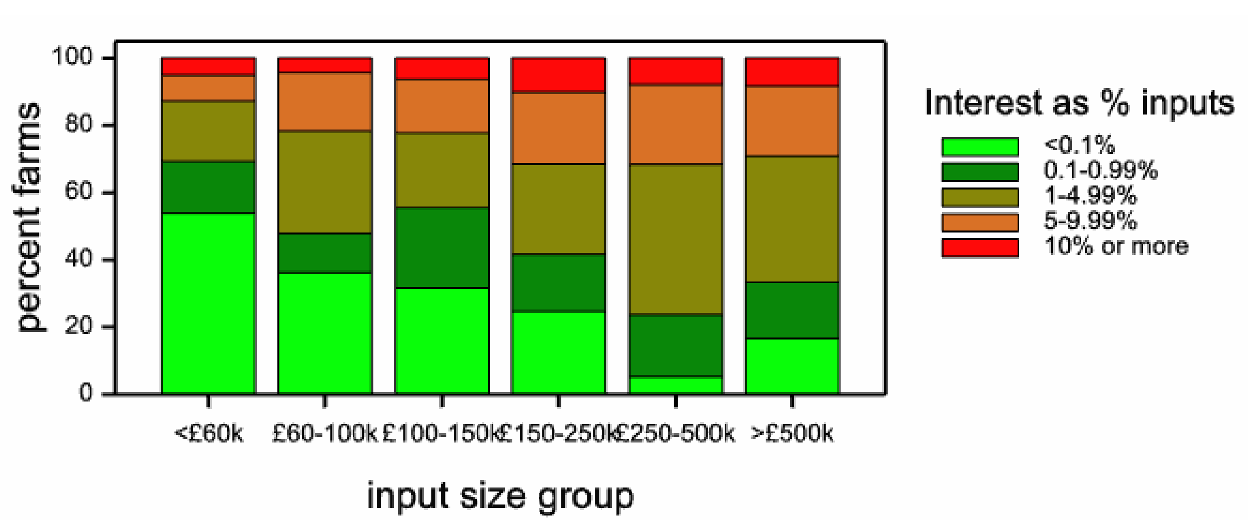


Figure 4.1: percentage of farms with different levels of debt by input size group.

£150,000 of inputs per year. The output increases with the area farmed suggesting that more extensive cereals farms achieve higher outputs for a given level of inputs. It must be remembered however that all the data used here relate to all enterprises on the farm and these other enterprises may have an impact on these results. The increase in output with area is particularly marked when the entire farm business is considered; this may be influenced by the greater potential for diversification on a larger land area. The impact of physical size of the farm on the farm business output is likely to increase in the future as the SPS switches to an entirely area based payment.

Table 4.3: Area farmed (Utilised Agricultural Area). The table shows predicted outputs from the REML model for a farm with £150,000 of inputs per annum, and average values of the other variables in the model. Figures are for 2007. Standard errors are approximate.

	Farm business output		Agricultural output	
Land area (ha)	Estimated output (£000s)	Standard error	Estimated output (£000s)	Standard error
150	203	2.9	132	3.4
200	219	2.5	140	2.8
250	231	3.1	146	3.2

Note: Models exclude the imputed cost of unpaid labour

4.3. Specialisation

Farms with a high proportion of their Standard Labour Requirement (SLR) coming from arable enterprises have higher average economic efficiency (Table 4.4). Note that because the SLR coefficients for arable crops are relatively low compared to the SGM coefficients used for farm typology, the proportions can be low, with the the lower quartile at approximately 55% arable. Whilst it is tempting to suggest that these results may indicate the benefits of specialisation, this is not the only possible explanation. It is equally possible that they are the result of the relative returns from arable and livestock enterprises, and this explanation is supported by the significant interaction with year; the benefits of having a high proportion of SLR from arable were greatest in 2007 and 2008, when arable returns were high.

Table 4.4: Proportion of Standard Labour Requirement associated with arable enterprises. The table shows predicted outputs from the REML model for a farm with £150,000 of inputs per annum, 200ha of land and average values of the other variables in the model. Figures are for 2007. Standard errors are approximate.

	Farm business output		Agricultural output	
% Arable	Estimated output (£000s)	Standard error	Estimated output (£000s)	Standard error
50%	181	2.7	135	3.5
80%	186	2.2	142	3.1
99%	189	2.8	147	3.9

Note: Models exclude the imputed cost of unpaid labour

4.4. Diversification

Table 4.5 shows the relationship with diversification, which is only statistically significant when only agricultural inputs and outputs are considered. ‘Diversification’ is used here to include activities associated with renting, tourism, retailing and recreation, and does not include environmental payments. The agricultural output produced from £150,000 of inputs falls markedly at higher levels of diversification. The most likely explanation for this is that the efficiency of the agricultural enterprises suffers because the management effort of the farmer and other key staff are concentrated on the diversified enterprises. However, it should be noted that it is not always straightforward to apportion costs accurately between different enterprises and it is possible that this pattern is exacerbated by some diversified costs being erroneously attributed to the agricultural enterprises. When the whole business is considered the diversification variable is no longer significant but, if it is forced into the model, the coefficients are positive, indicating that there is a tendency for diversified businesses to perform better than non-diversified ones.

Table 4.5: Proportion of input costs associated with diversified enterprises. The table shows predicted outputs from the REML model for a farm with £150,000 of inputs per annum, 200ha of land and average values of the other variables in the model. Figures are for 2007. Standard errors are approximate.

	Farm business output		Agricultural output	
% Costs for diversification	Estimated output (£000s)	Standard error	Estimated output (£000s)	Standard error
<0.1%	No significant relationship		152	3.7
0.1-0.99%			150	4.5
1-4.99%			140	4.1
5-9.99%			134	5.7
10% or more			125	5.4

Note: Models exclude the imputed cost of unpaid labour

4.5. Tenancy status

Tenancy status is of borderline significance in both the farm business model and the agricultural model (Table 4.1) and the relationship is explored further in Table 4.6. The most striking feature of the data is the good performance of owner occupied farms compared to tenanted ones. However, this is not surprising since the costs used in the model do not include any notional costing of the rental value of owned land. Thus the more interesting feature of the table is perhaps the strong performance of the ‘mainly tenanted’ group, which performs nearly as well as the owner occupied farms, particularly in terms of agricultural output.

Table 4.6: Tenancy. The table shows predicted outputs from the REML model for a farm with £150,000 of inputs per annum, 200ha of land and average values of the other variables in the model. Figures are for 2007. Standard errors are approximate.

	Farm business output		Agricultural output	
Tenancy group	Estimated output (£000s)	Standard error	Estimated output (£000s)	Standard error
Owner occupied	220	3.9	145	4.3
Tenanted	206	4.8	131	4.9
Mixed - mainly owner occupied	220	3.4	146	3.7
Mixed - mainly tenanted	214	4.6	143	4.8

Note: Models exclude the imputed cost of unpaid labour

4.6. Unpaid family labour

Table 4.7 shows the effect of unpaid labour and, for obvious reasons, these results are given for models including an imputed cost of the unpaid labour (Table 4.7b), as well as for the models without the imputed costs (Table 4.7a), as used in most of the other tables. Those farms with high amounts of unpaid labour (usually from the farmer and family members) perform much better than those relying solely on paid labour. This result is not in the least surprising when unpaid labour costs are excluded from the model, but it is interesting that there is still some relationship (statistically significant for agricultural output) when the 'unpaid' labour is costed at market rates.

Table 4.7: Paid and unpaid labour. The table shows predicted outputs from the REML model for a farm with £150,000 of inputs per annum, 200ha of land and average values of the other variables in the model. Figures are for 2007. Standard errors are approximate.

a) Costs excluding imputed cost of unpaid labour

	Farm business output		Agricultural output	
% unpaid labour	Estimated output (£000s)	Standard error	Estimated output (£000s)	Standard error
0% (all labour paid)	193	4.8	117	4.4
50% unpaid	210	2.8	136	3.0
100% unpaid	229	3.8	157	4.5

b) Costs including imputed cost of unpaid labour

	Farm business output		Agricultural output	
% unpaid labour	Estimated output (£000s)	Standard error	Estimated output (£000s)	Standard error
0% (all labour paid)	187	4.7	113	4.4
50% unpaid	189	2.8	120	2.8
100% unpaid	192	3.2	128	3.6

Like indebtedness, the proportion of unpaid labour is strongly correlated with farm size and this is illustrated in Figure 4.2. This suggests that the availability of cheap, experienced

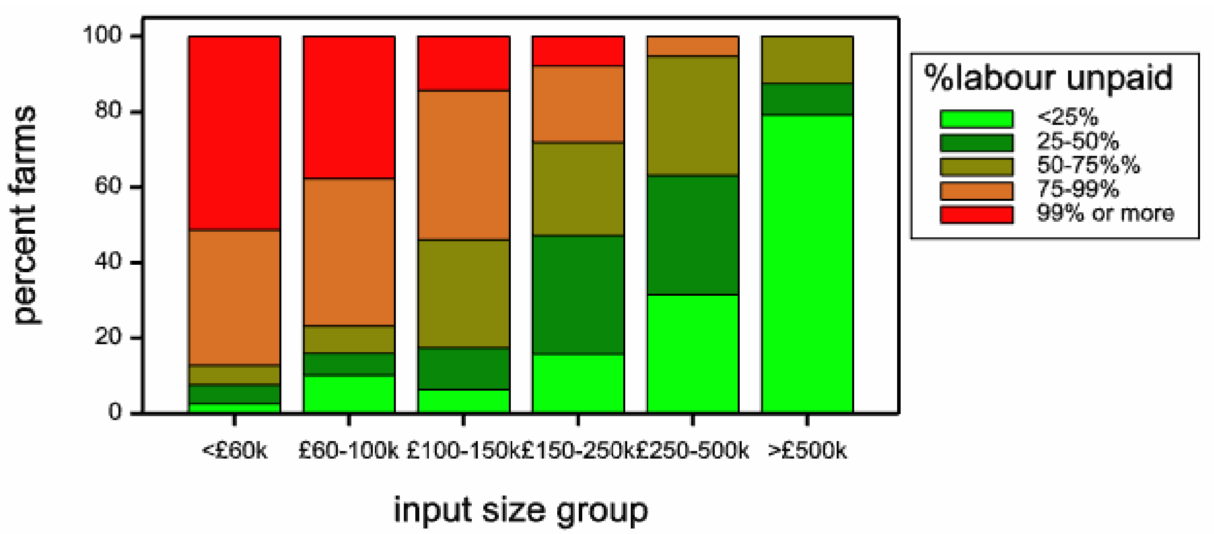


Figure 4.2: percentage of farms with different levels of unpaid labour by input size group.

family labour is important in maintaining the relatively good average economic efficiency figures observed for smaller farms.

4.7. Contract work

Table 4.8 shows the relationship between efficiency and the use of contractors. If no costs are imputed for unpaid labour, then farms with low levels of contracting are more efficient, both for the farm business as a whole and for agriculture only. There is some sign of a curvilinear relationship for the agriculture model, although the increase at very high levels must be treated with caution since so few farms were observed at these values. When imputed costs for unpaid labour are added, the relationship is reversed in the farm business model, with higher levels of contracting leading to greater efficiency. The model for agricultural outputs is now quadratic, with very limited use of contractors remaining efficient.

Table 4.8: Contract work (percentage of all contracting and machinery costs relating to contract work). The table shows predicted outputs from the REML model for a farm with £150,000 of inputs per annum, 200ha of land and average values of the other variables in the model. Figures are for 2007. Standard errors are approximate.

a) Costs excluding imputed cost of unpaid labour

	Farm business output		Agricultural output	
% contract work	Estimated output (£000s)	Standard error	Estimated output (£000s)	Standard error
5%	221	2.9	145	3.6
10%	220	2.8	142	3.1
25%	218	2.5	134	3.0
50%	215	3.1	130	3.6
75%	211	4.5	135	4.8

b) Costs including imputed cost of unpaid labour

	Farm business output		Agricultural output	
% contract work	Estimated output (£000s)	Standard error	Estimated output (£000s)	Standard error
5%	193	2.9	124	3.3
10%	193	2.8	122	2.9
25%	195	2.5	118	2.9
50%	197	2.9	118	3.3
75%	200	4.2	126	4.4

4.8. Returns to scale

Figure 4.3 shows the relationship between output value and input costs after allowing for the explanatory variables described in the previous paragraphs. These results also include the full imputed cost of family labour. The green line now represents the expected relationship between outputs and inputs, assuming that farms of all sizes had the same levels of debt, unpaid labour, etc. The graph is based on agricultural inputs and outputs only. The line now has a steeper slope than the black line representing equality of inputs and outputs, indicating increasing returns to scale. Thus it appears that large farms tend to be inherently more efficient than smaller ones, particularly when family labour is costed at market rates, but factors such as low levels of debt and availability of family labour mean that in practice smaller farms are, on average, roughly as efficient as larger ones.

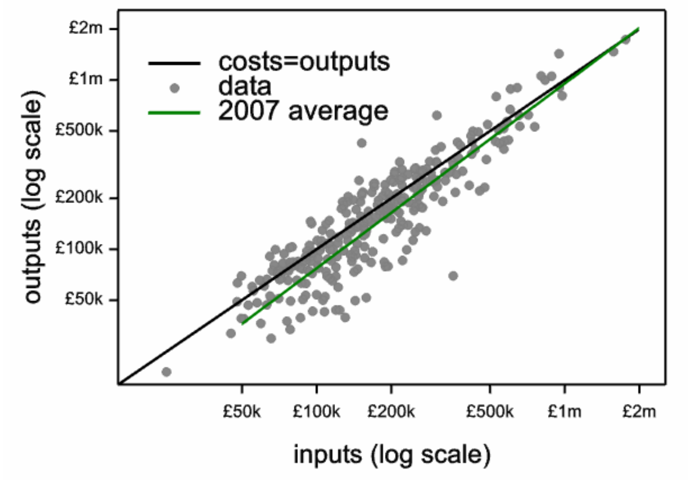


Figure 4.3: the relationship between output value and input costs for agriculture for 2007. The green line is adjusted for the factors listed in Table 3. Imputed costs for family labour are included.

5. Results: relationship between economic efficiency and environmental factors

5.1. Agri-environment scheme membership

Analysing membership of agri-environment schemes directly is complicated by the fact that the five year period covered coincides with the introduction of the ELS and HLS, so that many farms were not within schemes at the start but joined during the period. Thus, simple comparisons between farms in the different schemes and farms outside all schemes are not possible. In addition, any changes in performance after joining cannot simply be ascribed to membership due to the rapid increase in arable profitability in 2007 and 2008.

In an attempt to avoid some of these problems, scheme payments on each farm were converted to a simple £ per ha figure over the five year period. For presentation purposes these were then grouped to the three classes shown in Table 5.1. The cut off value of £30 per hectare was chosen because this is the rate of payment for ELS. Thus the over £30 per ha' group will include members of HLS and the classic schemes, whilst the 'up to £30/ha' group will mainly consist of farms in ELS, although there will also be some farms with more valuable HLS or classic schemes for part of the period or just some of their land.

Table 5.1: mean efficiencies (REML farm effects) tabulated by mean rates of stewardship payments.

a) Farm business inputs/outputs

Average payment	No. of farms	Mean efficiency	Standard error
none	47	-0.0206	0.0079
up to £30/ha	182	0.0018	0.0040
>£30/ha	93	0.0068	0.0056

b) Agriculture inputs/outputs only

Average payment	No. of farms	Mean efficiency	Standard error
none	47	-0.0169	0.0105
up to £30/ha	182	0.0126	0.0053
>£30/ha	93	-0.0161	0.0075

Note: Efficiencies are after allowing for all model terms apart from area.

Considering first results based on the farm business as a whole (Table 5.1a), there are statistically significant differences in mean levels of economic efficiency between the three groups (F=4.26 with 2 and 319 d.f., P=0.015). Mean efficiencies are higher for the up to £30 per ha group (i.e. mainly ELS) than for farms with no payments. The mean is still higher for farms receiving more than £30 per hectare, although the difference from the up to £30 per ha group is not statistically significant.

Differences are also significant when only agricultural inputs and ouputs are considered (Table 5.1b). However, the pattern is now different, with the over £30 per ha group now having a negative mean efficiency of similar magnitude to that of the farms which have never been ELS members. A random-slopes REML model was therefore fitted, making it possible to extract a measure of trend in efficiency for each farm. The efficiency trend is not significantly related to the payment categories, but, in the case of farm business costs, there is a relationship with whether a farm was in a scheme in 2004, at the start of the study period (Table 5.2b, F=4.98 with 3 and 318 d.f., P=0.002). Those farms which have joined stewardship schemes (mainly ELS) during the course of the study period show positive efficiency trends on average, whereas trends for existing members and those never in a scheme are slightly negative, although not significantly different from zero.

Trends are also positive for the new members in terms of agricultural inputs and outputs, but in this case differences between groups are not significant. At the very least this demonstrates that membership of ELS did not prevent farms from benefitting from the high arable returns of 2007 and 2008.

Table 5.2: trends in efficiencies (REML slopes for each farm) tabulated by scheme membership in 2004. A positive efficiency trend means that a farm is becoming more efficient over the five years of the study, whereas a negative value implies a decline in efficiency. The unknown category relates to farms not providing data in 2004.

a) Farm business inputs/outputs

2004 ES status	No. of farms	Mean efficiency trend	Standard error
never in ES	47	-0.0002	0.00072
joined since 2004	109	0.0014	0.00047
member in 2004	111	-0.0007	0.00047
unknown	55	-0.0012	0.00067

b) Agriculture inputs/outputs only (differences not statistically significant)

2004 ES status	No. of farms	Mean efficiency trend	Standard error
never in ES	47	-0.0006	0.00131
joined since 2004	109	0.0013	0.00086
member in 2004	111	-0.0001	0.00085
unknown	55	-0.0020	0.00121

Note: Efficiencies are after allowing for all model terms apart from area.

5.2. Agri-environment expenditure – 2008 Countryside Management Module

More information on farm expenditure relating to agri-environment activities can be obtained from the FBS 2008-09 Countryside Maintenance and Management module[7]. This asked for information on costs of agri-environment measures in 27categories. A subset of the full FBS panel were asked to complete the module, with data collected from 230 of the 322 farms considered here.

Figure 5.1 shows farm business efficiencies plotted against the reported costs of agri-environment activities expressed per hectare of farmed land. The cost figures exclude all costs, whether for a formal scheme or not, except for the costs associated with traditional farm buildings; these were excluded since a small number of farms with very high levels of expenditure in the survey year distorted the overall pattern. Whilst there is some sign of a trend, this is strongly influenced by the small number of farms with costs over £40 per ha and the relationship is not significant at the conventional 5% level. Figure 5.1 uses efficiencies allowing for confounding factors such as debt, unpaid

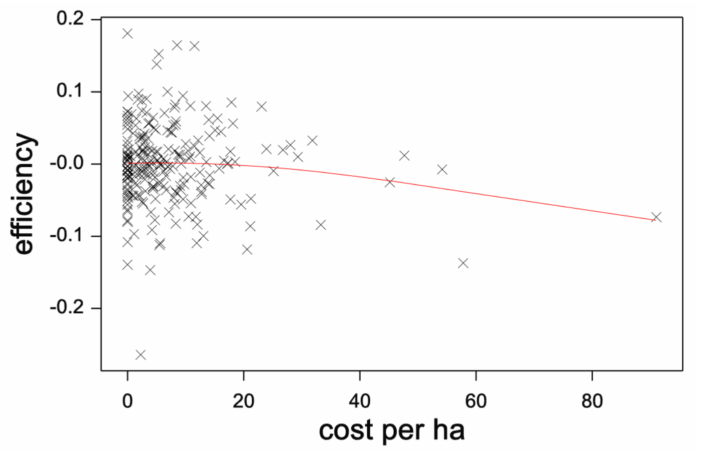


Figure 5.1: farm business efficiencies (after allowing for debt and other factors) plotted against agri-environment costs per hectare farmed. The red line is a spline with 2 d.f.

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

labour, etc. Hence, whilst economic efficiency does tend to be slightly lower for farms with high agri-environment scheme expenditure, it is not possible to exclude the possibility that this is a chance effect.

Figure 5.2 considers whether agri-environment measures are funded under a formal scheme or are undertaken on a voluntary basis. On average those farms with most of their agri-environment costs funded by schemes tend to have significantly higher farm business efficiencies than those not funded in this way ($F= 6.29$ with 2 and 182 d.f., $P=0.002$), although there is considerable variation about these means. This suggests that agri-environment payments may be important in allowing farms to undertake agri-environment work without impacting on their competitiveness. The equivalent relationship with efficiencies based on agricultural inputs and outputs is not significant, as would be expected

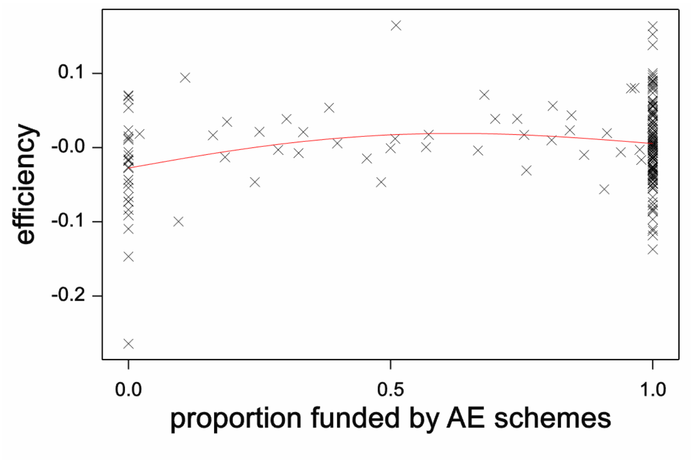


Figure 5.2: efficiencies (after allowing for debt and other factors) plotted against agri-environment costs per hectare farmed. The red line is a spline with 2 d.f.

5.3. Energy Usage Module

Energy usage data was collected in 2007 for around 75 of the cereals farms in the study. Much of this data relates to CO_2 emissions from machinery usage and has been analysed in a separate study by Cranfield University[8].

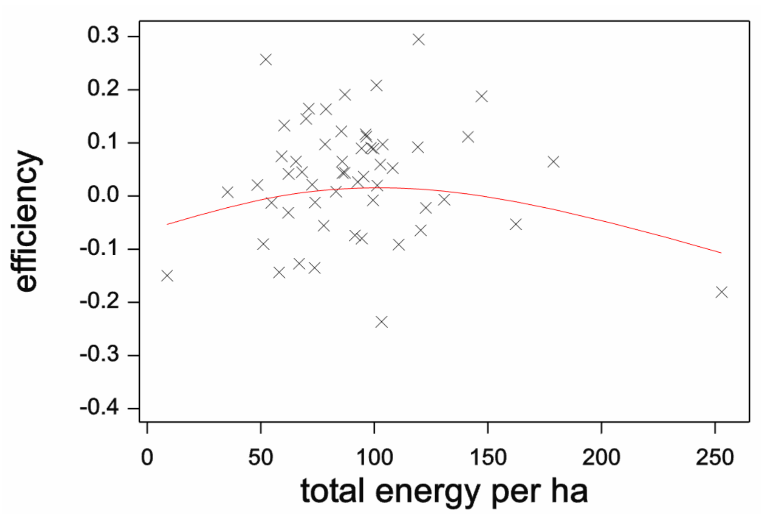


Figure 5.3: efficiency of farms based on agricultural costs and output (after allowing for debt and other factors) plotted against total direct energy usage for agriculture per hectare (excluding grain drying).

Unfortunately, interpretation of this data is hindered by the mix of work using the farm's machinery and work carried out by contractors. Recorded red diesel usage will generally exclude the fuel used on the farm by contractors. To reduce the impact of this, farms with extensive use of contractors (20% or more of machinery costs associated with contracting) have been excluded from the analysis, and a crude adjustment has been made for the use of fuel by contractors. Perhaps because of the approximate nature of these adjustments, there is little sign of a relationship between efficiency and either red diesel or overall fuel usage. This is illustrated in Figure 5.3 which

[8] http://www.defra.gov.uk/statistics/foodfarm/farmmanage/fbs/energy/

shows efficiency plotted against total direct[9] energy usage per hectare farmed. The fitted curve is not quite statistically significant, and even this weak relationship vanishes if the two extreme outliers of energy usage are excluded. There is a stronger relationship with efficiencies based on the entire farm business, but it is difficult to explain these, given the lack of association with efficiency based on the agricultural cost centre.

In addition to fuel usage, the energy module collected information on other issues related to energy usage, including fertiliser usage, tractor power, minimum tillage cultivation and woodland management.

Figure 5.4 shows the relationship between economic efficiency and fertiliser usage per hectare. The measure of fertiliser usage is based on the first axis of a principal components analysis of rates of N, P and K per hectare. There is no significant relationship between the two variables.

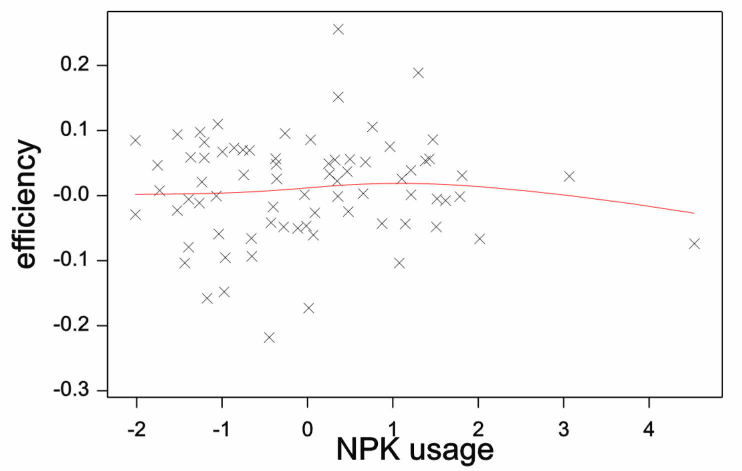


Figure 5.4: efficiency of farms based on agricultural costs and output (after allowing for debt and other factors) plotted against fertiliser usage per hectare (based on the first principal component which has positive scores for all fertiliser types).

Figure 5.5 shows the relationship between economic efficiency and the proportion of the combinable crops area that is established using ‘min til’ techniques. The curvilinear relationship shown is of borderline statistical significance (F=2.88 with 2 and 74 d.f., P=0.063), with average efficiencies increasing initially with the min til area, levelling off at around 60% min til. This result should be treated with caution, not least because the farms using min til tend to be spatially clustered, increasing the possibilities of spurious correlation with other factors.

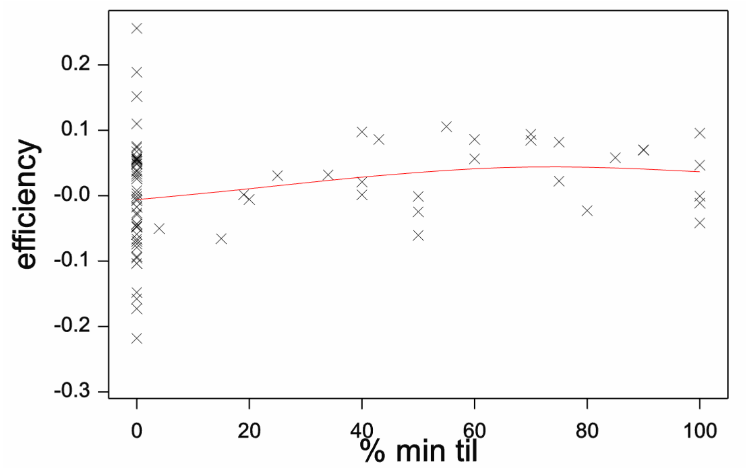


Figure 5.5: efficiency of farms based on agricultural costs and output (after allowing for debt and other factors) plotted against the proportion of the combinable cropped area that is ‘min tilled’.

In the case of woodland management, data is only available for 40 farms that reported woodland. There is no sign of any difference in economic efficiency between those actively managing their woodland and those not doing so, although the small sample size would make it difficult to detect a difference, even if there was one. Similarly, no relationship could be found between average tractor power and economic efficiency. There were signs that farms with greater numbers of tractors might be more efficient, but it is difficult to

[9] ‘Direct’ energy usage includes red diesel, petrol, electricity and gas, but excludes energy embedded in products such as fertilisers. Energy associated with grain drying is also excluded as this will vary sharply from year to year, depending on harvest conditions.

explain this relationship and it may be a spurious relationship caused by a handful of farms with large numbers of tractors.

6. Discussion and conclusions

6.1. Economic performance and its relationship with farm size

The efficiency of English farms has long been a subject of debate for both academics and civil servants, and the impact of farm size has featured heavily in the literature (see, for example, Bridges 1947, Lund and Hill 1979). Up until the 1960s, farm size was generally measured in terms of area, but, since then, the emphasis has been on some measure of economic size through metrics such as standard labour requirements or standard gross margins.

In recent times attention has tended to focus on the use of frontier models to estimate technical efficiency; they thus focus on the quantity of outputs produced from different quantities of key inputs. These have generally indicated that on average large farms are more efficient (see e.g. Handley 2006), but that there is considerable variation between farm types. In the case of cereals farms, Hadley (2006) found decreasing returns to scale for England and Wales, whilst Barnes (2008) found the reverse in Scotland. More recently, Barnes et al (2011) have also demonstrated increasing returns to scale for English cereal farms

Whilst improvements in technical efficiency are undoubtedly crucial to the long-term viability of English agriculture, it is not necessarily an appropriate indicator of the short- to medium-term competitiveness, and hence viability, of individual businesses. Instead the competitiveness of farms depends on overall financial viability of businesses, which is a function of both technical and allocative efficiency (i.e. selecting inputs in the right proportions) and exogenous support, e.g. CAP payments. The analyses reported here model that overall financial performance, and hence may, to some extent, differ from results considering only technical efficiency.

The results presented here suggest that there is an underlying tendency for larger farms (in financial terms) to be slightly more economically efficient than smaller ones, but these underlying economies of scale only become apparent when allowance is made for confounding factors and when family labour is charged at the full economic rate, which over-values it from the perspective of many farmers (see section 2.2). However, there is a very large level of variation about this relationship and the best small farms are more efficient than many large ones.

It is also likely that the overall relationship between size and efficiency represents a balance between those resources that tend to be used more efficiently on larger farms (e.g. many fixed costs) and others that are used more efficiently on smaller ones. The latter category may well include management and administration costs; these can be substantial on larger farms, although, on the best farms, these extra costs will be mitigated through optimal allocation of other resources.

6.2. Other factors associated with efficiency

The analyses reveal a number of factors that help to explain farm level differences in efficiency. Of these, perhaps the most striking is the relationship with debt. Interestingly the results here indicate that heavily indebted businesses are less efficient, in contrast to the technical efficiency analysis of cereals farms in Barnes et al (2011). It is however in accord with the predictions of the expert panel from the same report and with previous studies of the same dataset (Hadley, 2006). The conflict between the two analyses is perhaps not as surprising as it first appears; the financial pressures of the debt may force the business to increase its technical efficiency, but may nevertheless still leave the business under-performing in terms of its output/input ratio due to the burden of interest payments.

The relationship with debt is important in explaining the relationship with farm economic size. On average smaller farms carry much lower levels of debt, helping to explain why many such farms achieve high levels of efficiency, despite lacking the economies of scale. The interesting question is why smaller farms lack the debt; is it because they have never got into debt because they have not invested to finance expansion? Alternatively, is it the case that many small farms that were heavily indebted have been forced out of business, leaving mainly those without debts? There may also be some relationship with tenure; a higher proportion of small farms are owner occupied, and owner occupied farms tend to have less debt.

Figure 6.1 shows how the relationship between debt and economic size has changed over the last twenty years. The size bands used are based on the quartiles of the distribution of input costs in each year. In 1990 the relationship between debt and size is not that strong, and the smallest quartile of farms (labelled q1) has a range of different levels of debt, including over 8% in the most indebted category. By 2008 the relationship is much stronger, with q1 much more heavily skewed to the lower levels of debt.

These results are very much compatible with the 'survival of the fittest' hypothesis, with many heavily-indebted small cereals farms (often tenanted) ceasing to trade, whilst the debt-free ones can remain competitive, even without the economies of scale available to larger farms. This hypothesis, of course, does not rule out the possibility that other small businesses have invested wisely, taking on manageable levels of debt in order to become successful medium or large businesses.

In most cases results for agriculture only are similar to those for the entire business, reflecting the fact that agriculture remains the dominant

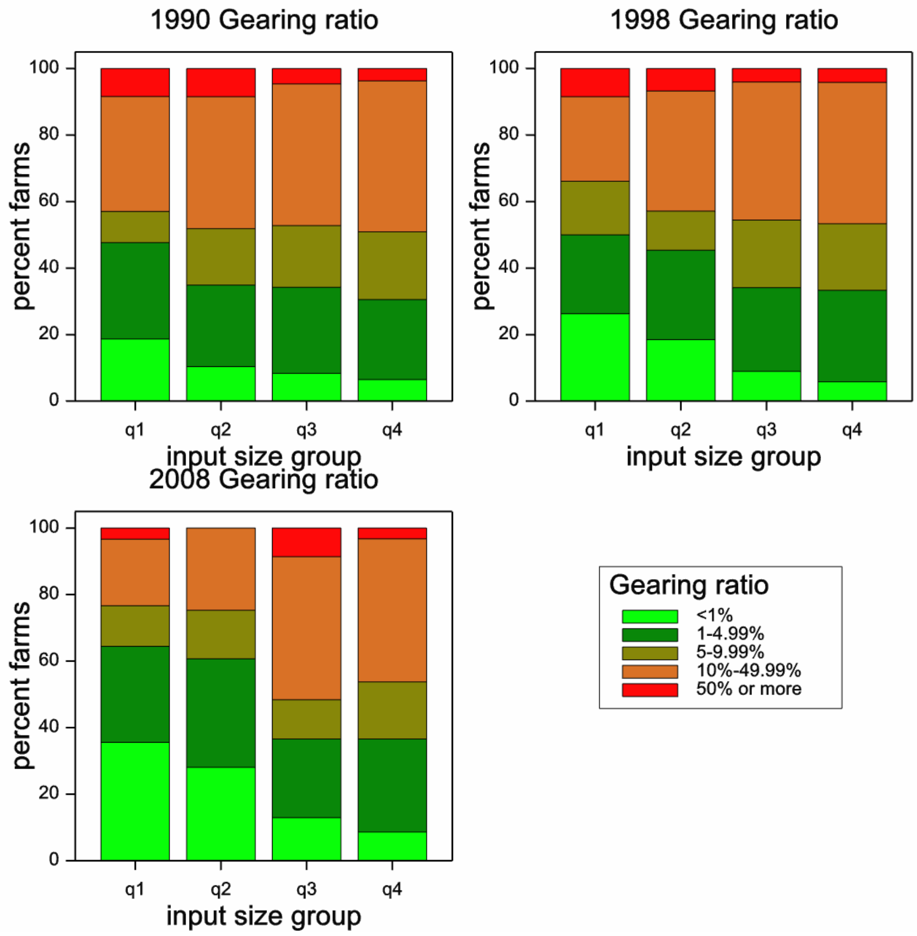


Figure 6.1: relationship between gearing ratio and economic size for 1990, 1998 and 2008. The groups q1 (smallest farms) to q4 (largest) represent size quartiles based on total input costs. Gearing ratio is total liabilities / total assets.

activity for most farms. One area where this is not the case is diversification. Heavily diversified businesses perform well overall, but there are clear signs that the agricultural enterprises suffer, perhaps because less management time is available. It may also be the case that for some heavily diversified businesses, particularly in retailing or tourism, agriculture has ceased to be an important activity in its own right, but instead largely continues in order to produce an attractive environment in which the diversified business can flourish.

The use of 'unpaid' labour on farms is another variable that is strongly correlated with farm size and may therefore explain the strong performance of many smaller farms. The variable remains statistically significant, although with a much smaller effect, even when the family labour is costed at commercial rates. Some caution is necessary here, since few farmers keep detailed records of hours worked, and estimating an annual figure is prone to error in a sector where labour demands are highly seasonal. This relationship is in accord with the expert views from Barnes et al (2011), although their formal analysis of technical efficiency, which also uses an imputed value at commercial rates, could find no significant effect. The expert view was that unpaid family labour is cheaper and more productive than waged labour, and it may also be indicative of a strong commitment to the business. The non-significant technical efficiency result is perhaps not so surprising since, regardless of the theoretical rate at which the labour is costed, in practice the marginal rate of doing an extra hour's work is close to zero for many farmers, which will not encourage efficient use of the resource.

Nevertheless, family labour is undoubtedly a key component in the survival of many smaller farms, as reflected in the results presented here. It provides a skilled resource which can be used with a high level of flexibility. Where farmers are prepared to value this resource at below market rates it will provide an important means of allowing small farms to continue trading, even though the business would be loss making if it were having to pay other staff to undertake the work.

6.3. Implications for structural adjustment

The average size of commercial cereals farms, whether measured by acreage or turnover, has slowly and steadily increased for many years, and there is nothing presented here that implies that this will not continue. Good small farms, particularly those with little debt, sufficient land and expert family labour, will continue to compete effectively with much larger businesses. It is likely that the pressure for long-term expansion will come not so much from efficiencies related to size, but from the need to maintain or increase family income. Succession may well be an issue; whilst many of the current generation of small farmers may be content to work long hours for comparatively small financial reward, their sons and daughters, particularly those who have pursued careers outside agriculture, may be unwilling to take on the family farm without greater reward. The options are then to expand the business to generate more income, or to sell up in order to realise the assets, which may be considerable on owner-occupied farms. The need to provide some form of pension for the retiring generation will frequently add to these pressures for change.

Given that this study does provide some support for the existence of economies of scale, it is tempting to assume that this gradual expansion of farms will lead to a more efficient industry. However, this is not inevitably the case for a variety of reasons.

Firstly, expansion of a farm business will frequently have to be financed by taking on additional loans and, on family farms, will almost always involve the use of proportionately more paid labour. Both these consequencies are associated with reduced efficiency and so businesses must ensure that their business case for expansion is sound.

Secondly, as Lund and Hill (1979) pointed out 'To change a small farmer into a large farmer may require more than a change in farm size'. Whilst large farms are on average more efficient than small ones, there is much variation about this relationship, with the consequent risk that a reasonably efficient small farm expands to become an inefficient larger one. This is particularly likely if the farmer lacks the managerial skills to run a larger enterprise, or if there is some other constraint on its performance.

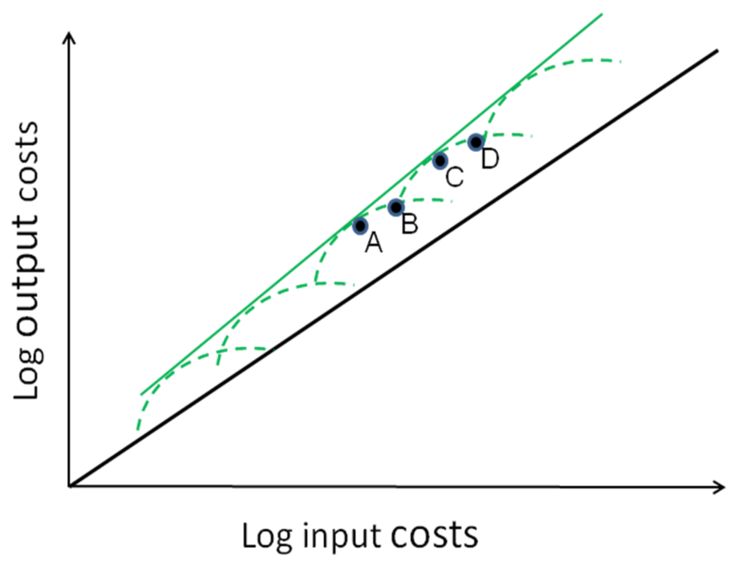


Figure 6.2: relationship between output and input costs for a hypothetical group of farms. The solid green line represents the overall frontier, whereas the dotted lines represent frontiers for particular farms reflecting the constraints of their current technologies. The black line represents equality of inputs and outputs. See text for the meaning of A-D.

It is useful to consider the diagram shown in Figure 6.2, which is adapted from Britton and Hill (1975). The figure shows a solid line representing the efficient frontier in a situation with increasing returns to scale. The dotted lines show that this frontier is actually made up of a series of smaller curves, each applicable to a particular group of farms. The farm at point A is operating at the optimum level of inputs for the constraints of the technologies it uses (e.g. the size of its machinery and the skills of its labour force). If these inputs are increased slightly, rather than move along the solid line of the overall frontier, which would give increased efficiency, it moves along the dashed line to point B, which represents the maximum level of output that can be achieved with the increased input, given the constraints of the technologies. To achieve a further increase in efficiency, more investment is needed to allow a move to a technology more suited to a larger business (which in practice might just mean buying more land), thus allowing it to reach point C on the next dotted curve.

In Figure 5.2 the efficient frontier shows increasing returns to scale. However, Chavas (2008) has suggested that in developed countries minimum average costs may be similar across a range of technologies. In the absence of strong economies of scale in output prices, this would lead to the solid line running approximately parallel with the line inputs=outputs, implying constant returns to scale over a wide range of input levels. This picture is consistent with the modest increasing returns to scale observed here even with full allowance for the costs of unpaid labour.

Whilst points such as A and C represent points of optimal efficiency, there may be good reasons why farms move to points such as B and D. Many businesses are under pressure to produce more income, perhaps to meet increasing expectations of standard of living amongst the younger generation, or to support retired family members who now have longer life expectancy. Whilst points B and D have lower values of the ratio outputs/inputs, they have higher values of the difference outputs-inputs, i.e. they generate greater income.

This may help to explain the strong relationship observed between efficiency and the area of farms. Many farms will be constrained by their physical land area, being unable to expand it either due to shortage of capital or due to a lack of available land nearby. If these farms are under pressure to increase income, they will tend to increase other inputs above the optimal level for their land area, moving them to points such as B and D which maximise income rather than efficiency. Any policy change which led to more land becoming available, or which made it more readily available to farms, would therefore allow an increase in efficiency through farms becoming less intensive, moving towards a level of inputs that maximised economic efficiency, rather than maximising income. However, this efficiency increase might be short-lived if the pressures to increase incomes continued to apply.

6.4. Links between economic and environmental performance

Whilst in theory the FBS provides a wealth of information on environmental issues, in practice much of this information provides an incomplete picture of farming's ecological performance. This does not imply a failure of the survey, but is more of an indication of the complexity of the environmental impacts of farming. For example, in the case of biodiversity, a proper assessment of a farm's impact would require intensive fieldwork by professional ecologists, preferably over a number of seasons. This is clearly beyond the scope of the survey, and the questions asked in specialist modules cannot hope to produce an equivalent level of information.

It is no coincidence that the clearest results linking environmental and economic performance come from consideration of membership of stewardship schemes; this is an area where information can more easily be captured in financial terms on a survey form. The results are broadly encouraging. Membership of schemes is positively correlated with economic efficiency of farm businesses, suggesting that they are successful in their objective of allowing farmers to look after the environment without suffering financially. In interpreting these findings, it is important to remember that the relationship will work both ways; belonging to the scheme may make businesses more efficient, but it is also possible that the better performing businesses are more likely to join schemes. In addition, some farmers do not join schemes because they lack security of tenure, and this insecurity may also impact on the economic efficiency of these businesses.

Much of the available information relates to ELS membership, since large numbers of cereals farmers have joined the scheme following its launch in 2005. Those farms that have joined have, on average, seen an increased economic performance at the farm business level. Within these businesses, the economic performance of the agricultural cost centre has remained approximately steady. These results suggest that the relatively minor adjustments to agronomic practices required by ELS have not had too much of an adverse effect on the economics of agricultural production, and that the income received from the scheme has been sufficient to make the overall impact on the business positive, giving farmers some reward for their investment.

There are also a substantial number of FBS cereals farmers belonging to more demanding stewardship schemes. A few farms will have joined the HLS since 2005, but far larger numbers belonged to the 'classic' schemes that existed prior to 2005 and which still operate for existing members until their agreements end. These schemes also seem to have a positive impact on the farm business, although the smaller sample size means that there is a high level of uncertainty about this estimate. However, as would be expected given the more demanding requirements of the schemes, the economic performance based on agriculture only (excluding the scheme payments) is worse than for farmers in the ELS group.

The number of farmers in the present study with no funding at any time for agri-environment schemes is small, making it difficult to draw conclusions about this group. However, those farms who undertake agri-environment activities outside formal schemes tend to be less efficient at the farm business level. This may suggest that payments are needed to allow farmers to implement these activities whilst remaining profitable, although an alternative explanation is that it is the less efficient farmers who fail to claim the scheme payments.

7. References

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8. Acknowledgments

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[10] This report has been temporarily removed from the Defra website in order to correct some errors in the analysis. It will be republished shortly at http://archive.defra.gov.uk/evidence/economics/foodfarm/reports/index.htm.

9. Annex 1: variable names

Variable name	FBS database name[11]	Description
logavcosts	*Farm.business.costs or agriculture.variable.costs + agriculture.fixed.costs*	Average farm business or agricultural costs (as appropriate) averaged over 2004-08
%Interest	*Interest.paid*	Interest paid as a percentage of total farm business costs (fbcosts) over the period 2004-08.
Logarea	*Section A row 20*	Log-transformed total area, including woodland, buildings, etc., averaged over 2004-08
Parable	*Slr.cereals, Slr.oilseeds, Slr.sugar.beet, Slr.field.peas.beans, Slr.maincrop.potatoes, Slr.early.potatoes, Slr.outdoor.vegetables, Slr.other.peas.beans, Slr.vining.peas*	Total of SLRs shown, divided by total SLR, averaged over 2004-08
%Divcost	*diversified_costs-diversified.net.interest.payments*	Diversified costs expressed as a percentage of total farm business costs over the period 2004-08. Interest payments are excluded from the diversified costs since these can be large and negative (i.e. interest received) for some businesses.
%Unpaid	*unpaid_labour/* (*unpaid_labour + wages_paid)*100*	Percent unpaid labour by value, averaged over 2004-08
Tenancy	*Epub.tenure.type*	Tenancy status, taken from 2006 if present, or otherwise 2007 or 2008.
Conrat	*contract_costs / (contract_costs + machinery_fuels_oils + machinery_repairs_and_other + depreciation_machinery)*	Ratio of contract costs (including machinery rental) to all costs associated with machinery and contracting work bought in. Note that this will not equal the proportion of the agricultural work done by contractors.

[11] Italics indicate that the variable is processed in some way (e.g. by taking an average over the five years, or by expressing as a ratio) – see 'Description' for details.

Variable name	FBS database name[11]	Description
Age	*age_of_farmer*	Mean age of farmer over the period 2004-08.
younger	*age_of_farmer*	Set to 1 if a younger farmer takes over during the period 2004-2008, as indicated by a reduction in variable age.
Education	*Farmer.education*	Grouped as 'education to 16 years only', 'post 16' and 'degree or higher' due to low numbers of values. If the information changes over time, the highest level is taken.
Organic	*Section A rows 56 and 57*	Any organic area (including in-conversion) in any year. The number of such holdings is too small to permit a more quantitative approach.
anylfa	*Lfa.code>1*	Set to 1 if any LFA land present, otherwise 0. 2006 data is used if available, failing that 2007 or 2008.

Environmental variables

Variable name	FBS database name[12]	Description
aesperha	*agri_environment_schemes_payments*	Payment for membership of agri-environment schemes (ESA, CSS, (O)ELS, HLS, woodland schemes), divided by total area and averaged over 2004-08.
costperha	*Section O columns 26-35 for rows 200 and 202-226 in 2008 Countryside Management module*	Total costs of countryside management activites divided by total area. Building costs are excluded because a small number of very high values dwarf other data.
pcostaes	*Rows 20 and 21 of 2008 Countryside Management module used to apportion costs.*	Proportion of costs above related to AES membership. Costs are apportioned using rows 20 and 21 so, for example, if 500m of hedge are laid and 400m is associated with AES schemes, 80% of the costs are allocated to membership.

[12] Italics indicate that the variable is processed in some way (e.g. by taking an average over the five years, or by expressing as a ratio) – see 'Description' for details.

Variable name	FBS database name[12]	Description
agmjperha	*Column 7 of Section L Energy Module in 2007-2008 FBS*	Primary energy usage for agriculture expressed as MJ per hectare of land. Conversion factors taken from Cranfield study. Grain drying is excluded as energy usage for this purpose will depend on factors such as the weather at harvest 2007.
mintil	Row 144 column 1 of Section L Energy Module in 2007-2008 FBS	Proportion of combinable crop area that is ‘min til’.
Fpc[1]	*Row 16-21 column 7 of Section L Energy Module in 2007-2008 FBS*	Overall level of fertiliser usage based on the first axis of a principal components analysis of rates of N, P and K per hectare.