Debt and farm performance

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Abstract

The relationship between debt and economic efficiency was examined using data from the Farm Business Survey for England between 2003 and 2011. A mixed model approach was used, modelling the log-transformed output value as a quadratic function of input costs. Farm effects (efficiency terms) were assumed to be normally distributed, and this assumption appeared reasonable. Initial models indicated a negative relationship with gearing ratio for most farm types. To explore this further, the effect of debt was split into between-farm effects (i.e. the extent to which better performing farms have higher average debts) within-farm effects (i.e. the extent to which farms that take on additional debt improve performance). Between-farm effects were negative for most farm types and it is suggested that this may arise from the strong temporal correlations in both debt level and efficiency; efficient farms tend to accumulate less debt and pay it off more rapidly. Within-farm effects were close to zero and non-significant for most farm types, but were significantly positive for pig farms (based only on agricultural output and costs) and negative for cereal farms.

Keywords Debt, economic efficiency, frontier, mixed model.

JEL code Q120 Micro Analysis of Farm Firms, Farm Households, and Farm Input Markets

Introduction

One of the three priorities of the UK's Department for Environment, Food and Rural Affairs (Defra), as set out in the business plan announced in November 2010[1], is to 'Support and develop British farming and encourage sustainable food production'. This is unlikely to change, regardless of the result of next month's general election. Sustainable food production can only be achieved if the economic performance of individual farms allows them to remain viable and competitive. Defra therefore has a need to examine how economic efficiency varies between farms, and to examine the characteristics of the best performing farms. One factor that has consistently been found to correlate with economic efficiency is debt.

One of the economic levers that government can use to make changes in the farming industry, is the provision of loans or grants to help improve efficiency, or to meet other government objectives such as environmental protection and animal welfare. This has been achieved in England through the Rural Development Plan for England, with almost 6,000 farms and other businesses receiving assistance between 2007 and 2013 under 'Axis 1' which seeks to improve the competitiveness of the agricultural and forestry sector.

For these reasons Defra has a strategic interest in assessing the impact of debt on farming businesses and this paper aims to explore this subject using data from the Farm Business Survey (FBS).

Background and published empirical studies

Current levels of debt on English farms have been published[2] by the Defra FBS team. The mean gearing ratio (defined as liabilities/assets) for all commercial farms is 11%, although around 50% of farms have a gearing ratio of less than 5%. This distribution of gearing ratios is shown in more detail in Figure 1, broken down by farm type. Pig and poultry farms have the highest average values at almost 30%, but even here around a quarter have gearing ratios of less than 5%

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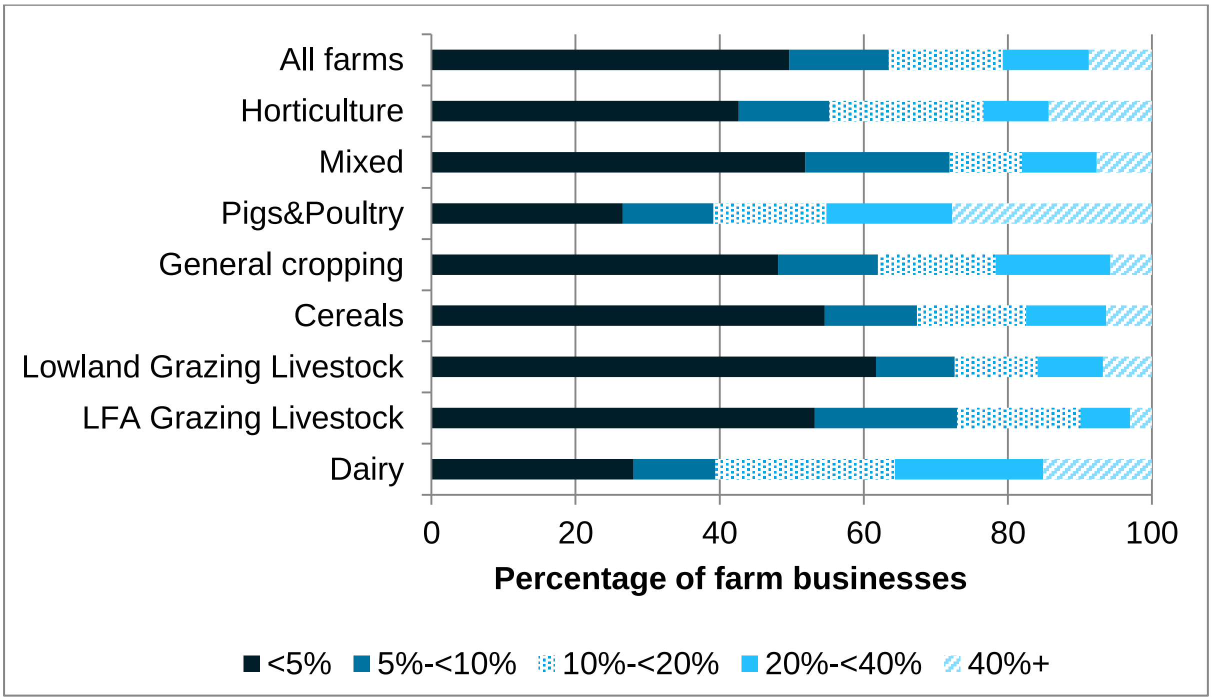
[1] http://www.defra.gov.uk/corporate/about/what/business-planning/

[2] https://www.gov.uk/government/statistics/balance-sheet-analysis-and-farming-performance-england-201011-20122013

Figure 1: gearing ratios by farm type



The recent studies of technical efficiency in English farms have generally shown significant negative relationships between debt and efficiency (Hadley, 2006, Barnes et al. 2011). Similarly the Defra Observatory publications on Cereals, Grazing Livestock and Dairy farms have all shown negative relationships, using a wider definition of economic efficiency. RBR's more qualitative study (Wilson et al. 2012) also suggested that low debt and high performance were associated, at least for dairy and cereals farms. By contrast results from other parts of the British Isles have sometimes shown positive relationships (Barnes, 2008 for Scottish Dairy and Sheep farms, and O'Neill et al., 2001 for Ireland).

Theoretical basis for relationship between debt and efficiency

A number of models are theoretically possible for the relationship between debt and economic performance of farms. These are summarised below, mainly using the terminology of Hadley et al (2001) and Davidova and Latruffe (2001), except in the case of 'historic correlation'.

Positive relationships between debt and efficiency

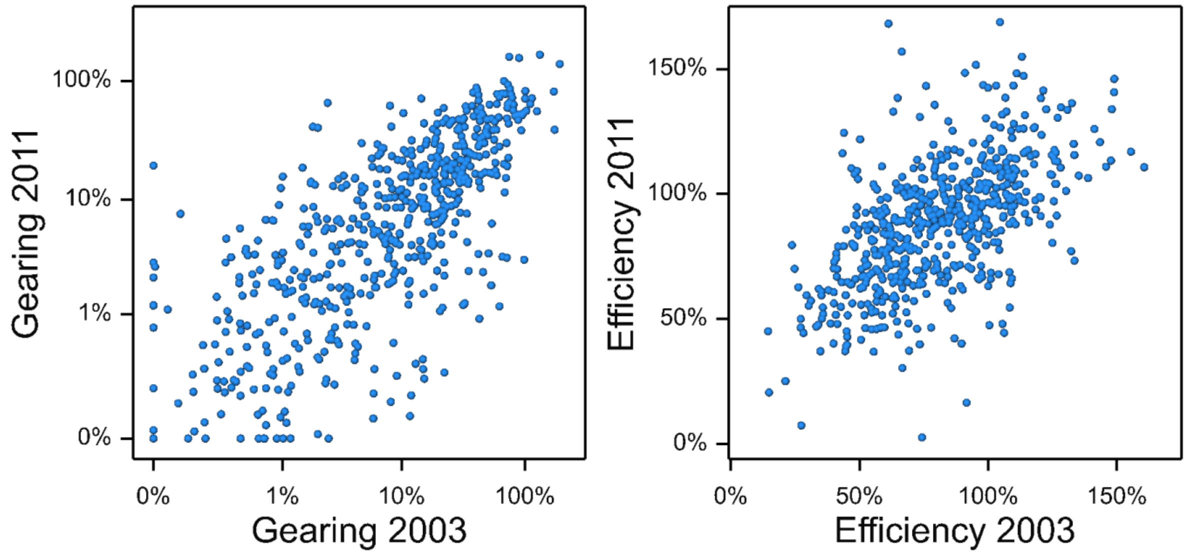
- Embodied capital: borrowing might allow farms to invest in improved machinery, buildings, etc. leading to improved efficiency.
- Free cash flow: indebted farms tend to be more efficient in order to service that debt, whereas large asset holdings may encourage managerial laxness. This is the 'free cash flow' model of Davidova and Latruffe (2001).
- Credit evaluation: lenders may prefer to lend to low risk farms, and their assessment of risk will tend to be based either on technical efficiency, or at least factors correlated with it. Note the reverse causation with the efficiency leading to the debt.

Negative relationships between debt and efficiency

- Agency theory: lender's costs of administering and monitoring are passed on to borrowers resulting in inefficiency.
- Adjustment: indebted farmers may not have access to further credit when it is needed, particularly in response to new economic conditions. Related to this, indebted farms may need to sell produce at sub-optimal times in order to generate funds, or adopt other inefficient processes for reasons of cash flow.
- Historic correlation: farms may tend to be indebted as a result of historic inefficiency. Both debt and efficiency show high levels of temporal correlation (Figure 2), and so it is possible that inefficient farms may gradually build up debt due to years of under-performance. Conversely, highly efficient farms may rapidly pay off debts and hence cease to be in debt. They may also be able to finance smaller investments directly from profits, without the need for external finance. As with credit evaluation, this is reverse causation with the inefficiency leading to the debt.

These different theories are not mutually exclusive and it is likely that all operate to some extent. This may explain why different relationships have been found in different studies of (mainly technical) efficiency around the world.

Figure 2: temporal correlations. Graphs show relationship between FBS data from 2003 and 2011 for debt (gearing ratio, correlation 0.73, left hand plot) and efficiency (agricultural output value/input costs, correlation 0.58 right hand plot).



Modelling approach

The empirical analyses presented here are based on data from the Farm Business Survey for England between 2003 and 2011 (years refer to harvest years, and so 2003 data is based on the financial year 2003-2004). The FBS is a panel survey with around 1,800 farms taking part each year, and most remaining in the survey for five or more years. The results below are based on 2,400 farms with almost 15,000 data points in total.

A broad definition of economic efficiency is used, with the log-tranformed output value being modelled as a quadratic function of log-transformed input costs. Efficient farms are those that produce a greater value of output from a given input cost. Separate analyses were conducted for the farm business as a whole, and just for the agricultural cost centre, excluding diversification, support payments (mainly Single Payment Scheme) and agri-environment payments. Imputed costs for family labour were included, but no imputed costs were added for rents on owner-occupied land; instead a term for tenancy type was included in the model. Similarly, no adjustments were made for inflation, but year was included as a fixed factor in the model, with interactions with the cost term, thus allowing for changes in the relationship arising from the very considerable fluctuations in input and output prices over the period studied.

The model was fitted as a mixed model by restricted maximum likelihood (REML) using the statistical package GenStat[3]. Initially a model was fitted to all farm types together, but there was evidence of differences in residual variance between types, and so the results presented below use separate models fitted to each farm type. Each model therefore had the form:

$$\text{Log(output value)} = y_j + b_1 x_{ij} + b_2 x^2_{ij} + b_3 x_{ij}.y_j + b_4 x^2_{ij}.y_j + t_{ij} + b_5 g_{ij} + f_i + e_{ij}$$

Where y_j is the effect for year j
x_{ij} is the log-transformed costs for farm i in year j
$x_{ij}.y_j$ is an interaction between the log costs and the year effect
t_{ij} is the tenancy status of farm i in year j
g_{ij} is the log-transformed gearing ratio for farm i in year j
f_i is the random effect for farm i (normally distributed)
e_{ij} is the normally distributed random error
b_1 to b_5 are regression coefficients

The e_{ij}s are assumed to be independently distributed, which will not be the case due to the inevitable temporal pattern of correlations, with residuals from the same farm in adjacent years being more strongly correlated. One solution would be to explicitly model this correlation (e.g. using an autoregressive error function), but instead a random coefficient term was added (see for example Galwey 2014), with the linear effect of years allowed to vary between farms. This allowed the trajectory of increasing or decreasing efficiency to be different for each farm, greatly reducing the temporal dependency in the residuals.

The model described above has clear similarities to a stochastic frontier model. The main difference lies in the characteristics of the error terms. On the one hand, the mixed model formulation allows for a more complex pattern of correlations amongst the residual term, but on the other, it is simpler than a stochastic frontier model in that these error terms must be normally distributed, rather than using a negatively skew (often half normal) distribution to represent inefficiencies relative to a frontier.

The error terms were therefore examined to check whether the assumption of normality was justified. The e_{ij} terms showed a fairly symmetrical distribution, but with a few extreme outliers for most farm types. This seems to be fairly typical of datasets of this type; the outliers are sometimes due to exceptional factors, such as a new enterprise occurring high costs, but in many cases the explanations are not clear. The f_i terms showed a good approximation to a normal distribution for most farm types, although with some negative skewness for grazing livestock farms; even in these cases the distribution was closer to a normal distribution than a half-normal.

[3] https://www.vsni.co.uk/software/genstat/

These checks suggest that the normality assumption is reasonable, but that significance tests should be treated with some caution as the extreme residuals may lead to the tests being somewhat non-conservative.

Results – simple mixed model

Table 1 shows the results of fitting the mixed model of equation 2, with gearing ratio fitted as both linear on the log scale and with the addition of a quadratic term. For simplicity only the sign of the coefficients and the nominal significance level is shown. The overwhelming majority of the models show a negative effect of debt, with lower outputs for given inputs when the gearing ratio is high, and these effects are significant in around 50% of models. The model for pig farms at the agricultural cost centre is the only one showing signs of a positive relationship, and even this is not quite significant at the conventional 5% level.

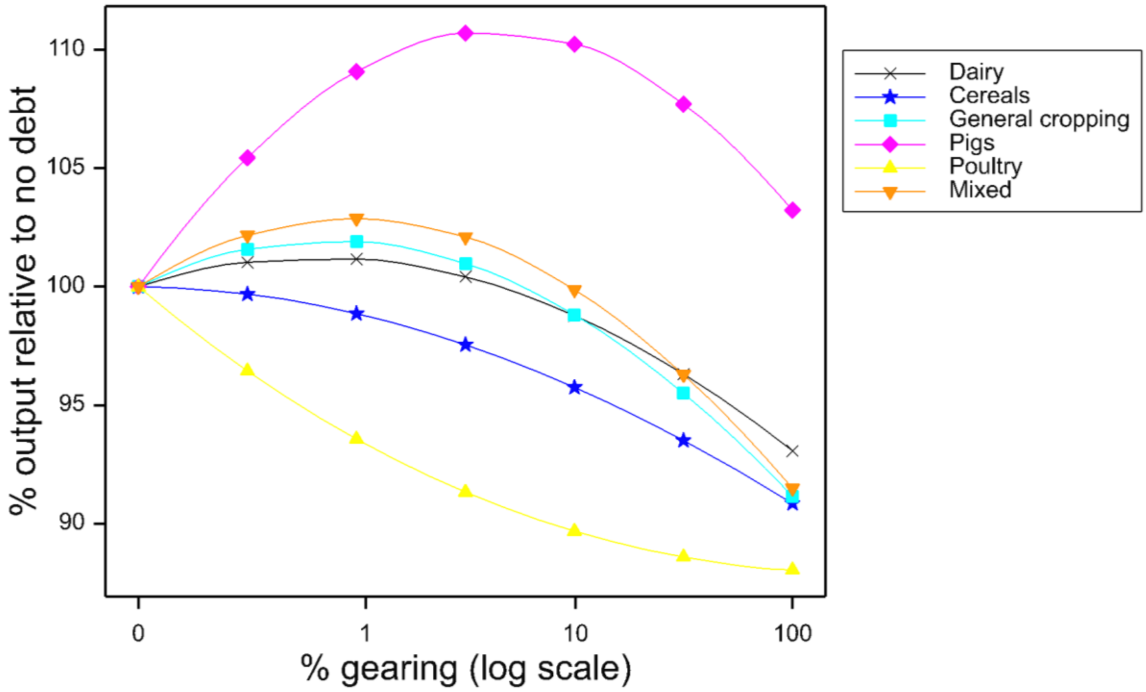
Table 1: significance of linear and quadratic effects of log gearing ratio.

	Farm business		Agriculture	
	Linear	**quadratic**	**Linear**	**quadratic**
Dairy	- -	- -	- -	- - -
LFA Grazing Livestock	NS	-	NS	- - -
Lowland Grazing Livestock	NS	NS	NS	-
Cereals	- - -	- -	- - -	- - -
General cropping	-	-	-	NS
Pigs	NS	- -	(+)	-
Poultry	-	NS	- -	NS
Mixed	NS	- -	NS	- -
Horticulture	NS	NS	NS	NS

Notes: Symbol indicates direction (+ positive relationship, - negative relationship), whilst the number indicates statistical significance (+++ = P<0.001, ++ = P<0.01, + = P=0.05, brackets indicate P<0.1, i.e. not quite statistically significant).
Agricultural cost centre excludes diversified enterprises, support payments and agri-environment schems.

Figure 1 illustrates the fitted quadratic curves for the whole farm business. For dairy, general cropping, mixed and cereals farms low levels of debt (gearing ratios below around 5%) seem to have little effect on output, with maybe a slight and non-significant positive slope. Above this, there is a marked negative slope with output falling off rapidly. Pig farms show the same pattern, but with a much stronger initial positive relationship. Poultry farms show a clear negative trend over the entire range of debt values.

Figure 1: fitted curves for the quadratic effect of debt for the whole farm business.



Between- and within-farm effects

In a conventional mixed model, the estimates for the fixed variables such as gearing ratio, combine information from the different strata (Galwey, 2014). Thus, if the level of debt is an explanatory variable the final coefficient uses the following sources of information:

- between farm correlations – Do better performing farms tend to have lower or higher debt levels on average?
- within farm correlations – do farms that take on additional debt tend to see increased performance?

These different sources of information were first identified in the context of incomplete block designs where they are described as 'inter-block' and 'intra-block' estimates (Yates, 1935). Normally these sources are combined into a single estimate but, in the case of debt, the estimates are calculated separately. This is achieved by including two debt variables in equation 5; one always taking the mean debt level for the farm and the other being the deviation of each value from this mean.

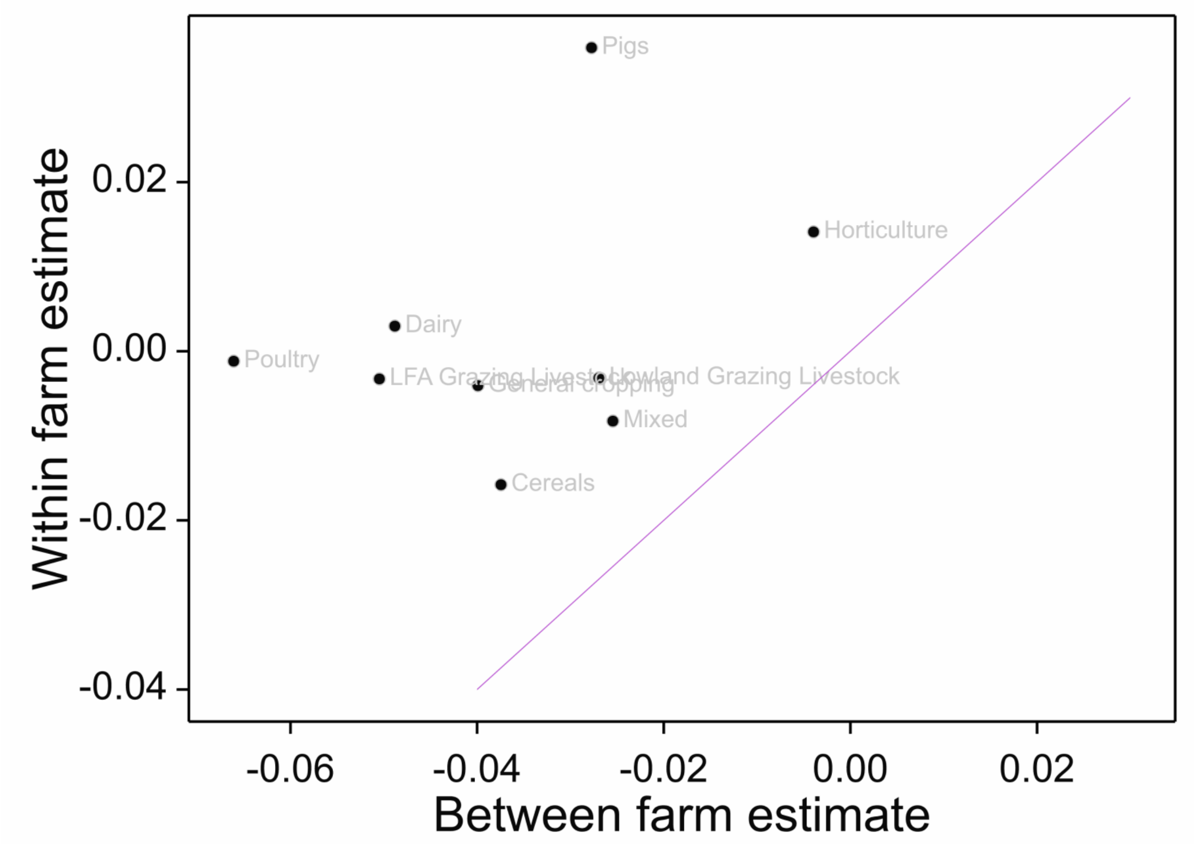
Results for the linear effects of debt are shown in Table 2, split into the two sources of information. Whilst the between-farm estimates are mainly negative, as with the results in Table 1, the within farm estimates are generally non-significant, with just a few negative slopes, especially for cereals farms, and a significant positive slope for the agriculture cost centre on pig farms. This is further illustrated by Figure 2, which plots the two sets of regression coefficients against each other; the within-farm estimates mainly cluster around zero, whereas the between-farm estimates are all negative apart from horticulture. If the two sets of coefficients were providing unbiased estimates of the same parameters, a positive correlation between the two would be expected, but there is no sign of this in Figure 2.

Table 2: significance of linear effects of log gearing ratio, using between and within farm information.

	Farm business		Agriculture	
	Between	**within**	**Between**	**within**
Dairy	- - -	NS	- - -	NS
LFA Grazing Livestock	- -	-	- - -	NS
Lowland Grazing Livestock	NS	NS	-	NS
Cereals	- -	- -	- - -	- -
General cropping	- -	NS	- - -	NS
Pigs	NS	NS	(-)	+
Poultry	- - -	NS	- - -	NS
Mixed	(-)	NS	-	NS
Horticulture	NS	NS	NS	NS

Notes: Symbol indicates direction (+ positive relationship, - negative relationship), whilst the number indicates statistical significance (+++ = P<0.001, ++ = P<0.01, + = P=0.05, brackets indicate P<0.1, i.e. not quite statistically significant).
Agricultural cost centre excludes diversified enterprises, support payments and agri-environment schems.

Figure 2: within farm estimates of the linear effect of log gearing ratio, plotted against the corresponding between farm estimates.



Discussion

The discrepancy between the between- and within-farm estimates is interesting and unexpected. It raises the possibility that different processes may be driving the relationships. Further work is needed to explore these differences, perhaps breaking down the overall debt into different lengths of loans (see Mugera and Nyambane, 2014), or different purposes.

In the meantime it is possible to speculate on the causes of the observed relationships between debt and economic performance in each stratum. The positive relationship within farms for pigs is interesting; the pig sector saw considerable structural change during this period, with the breeding herd decreasing by almost 20% over the period of this study. There was considerable financial pressure on farms, and those remaining in the industry may have needed to invest to remain competitive; hence this is a sector where the embodied capital theory might apply.

The negative within-farm relationship for cereals farms is also interesting. This sector needs investment in machinery, such as tractors and combine harvesters, but it is sometimes suggested that farms may tend to over-invest in this type of equipment, and surveys suggest that there is limited uptake of alternatives to purchase, such as sharing arrangements between farms or more formal machinery rings.

The lack of significant within-farm relationships for the other sectors may indicate that there are no strong effects. It could also indicate a high level of heterogeneity between farms, with some reaping the benefits of wise investment, whilst for others the benefits fail to cover the adverse effects of the agency cost and adjustment theories. Finally, it is possible that there is little information in this stratum, due to the high temporal correlations in the data.

The negative relationship between debt and economic efficiency shown in the between-farm stratum for most farm types is probably due to a combination of the agency costs, adjustment and historic correlation theories. The adjustment theory is compelling; successful farming is very dependent on getting the details right (Wilson et al, 2012) and high levels of debt will reduce the farmer's ability to do this, because decisions will tend to be driven by cash flow considerations, leading to sub-optimal financial and agronomic outcomes.

However, the adjustment theory would be expected to also have an impact at the within-farm level, and this is not apparent for most farm types; farms should struggle more in years when their debt levels are high. This suggests that the historic correlation theory may have some merit, since it is logical for this to have its primary impact in the between farm stratum.

The high temporal correlations for efficiency are not surprising. Farm level efficiencies will be partially determined by considerations such as soil fertility and topography, which are constant. Managerial competence will also be important and, in an industry dominated by family businesses where the same individual is often involved in the business for forty years or more, this will not change as rapidly as in an industry with greater mobility of managers. Similarly, debt levels will be at least partially determined by the farm's attitude to debt, and this will not change rapidly. These twin temporal correlations will reinforce any negative relationship between efficiency and debt; efficient farms will have less need to take on debt and, when they do seek external finance they will repay loans more quickly. Conversely, less efficient farms may need external finance for fairly modest projects, and may also need to extend their overdrafts to cover operating losses, especially if prices are lower than expected. Moreover, these farms will struggle to generate sufficient income to repay the loans, so that their gearing ratios remain high.

The other issue arising from this work is the approximate normality of both the farm level random effects and the residual error from the model. This allows models to be fitted using standard statistical software in a mixed model framework, rather than needing specialist software or bespoke programming. It is therefore worth considering why normally distributed farm terms might be possible, rather than the negatively skewed inefficiency terms commonly assumed below the frontier of best performing farms.

There are some situations where a skew distribution is entirely logical. Broiler production in England mainly takes place in indoor sheds each housing several thousand birds. These are bought in as day old chicks produced by relatively few hatcheries, using similar genetic strains. They are fed concentrated feed with uniform nutritional value. Many farms are part of larger businesses, which provide all their farmers with the same feed. As a result, most farms are using similar technology and should achieve an expected level of production, largely determined by maximum growth rate of the chicks. It would be expected that the best would cluster around frontiers of both production and financial performance, dictated by the constraints of their fairly uniform inputs. Inefficiencies will result from lack of attention to detail in terms of things like maintaining the correct temperature and identifying disease issues quickly, and are likely to lead to a skew distribution away from the frontier.

By contrast, when analysing data from a national farm survey, there is a huge range in production systems. This particularly applies to cropping farms, where a large number of different cropping patterns are possible. In addition there are different varieties of these crops, different choices of fertiliser and pesticide regimes, plus the vagaries of soil and weather. There is not a single optimal combination of these decisions; a highly successful strategy for one farmer in one year might prove to be much less successful for a different farmer, or even for the same farmer in a different year, perhaps due to a disease outbreak or weather damage.

The efficiency of each farm therefore depends on a very large number of different decisions made by the farm manager and these in turn interact with random variables such as climate, pests and diseases. Whilst the change in efficiency associated with any particular decision may well have the skew distribution implied by frontier models, the Central Limit Theorem (Bulmer, 1979) suggests that the distribution of overall farm efficiencies, representing the sum of all the efficiency terms associated with each decision, will be more symmetrical and closer to the normal distribution, particularly when averaged over a number of years. The degree to which a normal distribution is achieved will depend on the number of decisions, their relative magnitude and the degree of correlation. This is in accord with evidence from agricultural field trials, where normal distributions (or sometimes log-normal) are typical for variables such as yield, even for multi-site trials where crops are grown by different farmers.

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