Technical and Financial Sustainability in Scottish Agriculture

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Abstract:

This paper presents results of estimates of both the financial robustness and the technical efficiency of a representative sample of Scottish farms. Emphasis was placed on those factors that impact on long-term sustainability in order to identify those effects that may be characterised as having a high propensity to further increase the vulnerability of the sector. The aim was further one of providing focussed knowledge that might steer the policy decision making process towards potential targets of importance. Series of financial indicators were modelled to assess the financial health of each farm in the sample as well as predicting the future viability of each enterprise. Further, physical and financial data were employed to ascertain the technical efficiency of farms and possible sources of inefficiencies. On the strength of the findings, we concluded that farms that are characterised by being not being in Least Favoured Areas (LFA), specialised, large and with low indebtedness are those most likely to survive. However, although technical efficiency and financial distress indicators confirmed that while a significant proportion of farms were classed as being in financial distress, most of those being in LFA and mostly cattle or sheep farms, these same indicators effectively suggested that given the specialised nature of those farms, continued survival was possible, specifically where the debt ratio could be reduced to ideally zero while no significant attempt would be made at diversification of the agricultural enterprise. While some factors are rather fixed such as geographical location, in order to ensure continuity others can more easily be targeted for improvement, namely farm size, degree of specialisation, farmers' accumulated knowledge and financial health.

Keywords: technical efficiency, financial distress, risk measurement, diversification.

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1. Introduction.

Given the unrelentless move towards a gradual decrease in agricultural supports and the inevitable, eventual dismantling of the CAP as we have it today, the burning question that poses itself is as to whether Scottish agriculture can survive in its present state or whether certain sectors, if not all within the industry will have to undergo dramatic re-structuring. A major requisite in any business survival is the ability to operate at or near 100 percent technical efficiency while being financially healthy. A key objective for the agricultural industry will be to provide an economically sustainable system, integrated with the rural economy as a whole. In the light of such events as BSE, an overvalued currency and increasing globalisation, Scottish agriculture has been left in a perilous state. Many commentators are therefore anticipating major structural changes within the industry as farmers take voluntary decisions to leave the industry. Commentators also generally agree that an eventual sustainable farming system is likely to consist of three main types: hobby farmers, diversifiers in non-agricultural activities and very large-scale farms all with different, segmented, goals. Some will satisfy the market for food, some will integrate with the rural economy through diversification and some will engage in stewardship to preserve and enhance the rural environment. Some of these changes will occur due to factors that are independent of policy decisions e.g. many farmers are nearing retirement age. While others will be influenced to some extent by the availability of alternative employment or the opportunity to diversify into other enterprises while others will continue to rely on returns from agriculture.

The efficiency of farms will depend on major deterministic factors such as size, type of enterprise and geographical location (Hallam & Machado, 1996). It may be that the bulk of agricultural production will be produced from large farms located in fertile areas. Other areas, for example the urban fringes, may only allow part-time farming, as on the one hand employment is more readily obtainable whilst on the other hand, the legal constraints imposed on farming near population centres tighten. However, uplands areas may have no real alternatives resulting in the land being 'decommissioned'. This paper attempts at analysing the potential drivers of change with respect to technical and financial efficiency in order to identify the key indicators of long-run sustainability. It does this by applying a comprehensive analysis to farm account data with a view to determining the importance of location, economies of scale, enterprise structure, technical efficiency and financial health.

2. Technical Efficiency.

Turning first to the aspect of technical efficiency (TE), measurement methods of efficiency indicators are designed to identify a 'distance' from absolute technical efficiency. To date, numerous studies have investigates the issues of TE, starting with the seminal work of Farrell (1957). By definition, 'production is efficient if there is no way to produce more output with the same inputs or to produce the same output with less inputs' (Varian, 1992). In the context of a stochastic production possibility frontier, TE indicators will lie between zero and unity where unity indicates that a farm is perfectly economically efficient; that is, where both economic and technical efficiency are achieved at an optimal level (point A on Figure 1). Specifically, different levels of output will be determined by what is technologically feasible given specific types and amounts of inputs. A farm that achieves optimum output will be said to be technically efficient while one located at B or C will operate below maximum efficiency although still technically efficient. However, a farm that might be located at point D would be deemed inefficient. A measure of farm D's inefficiency, as proposed by Farrell, is given by the ration of the distances thus:

$$OR/OD = OC/OD.OR/OC$$

where essentially economic efficiency is the product of technical and allocative efficiencies while the magnitude of the inefficiency will be represented by the 'distance' between the two corresponding output levels.

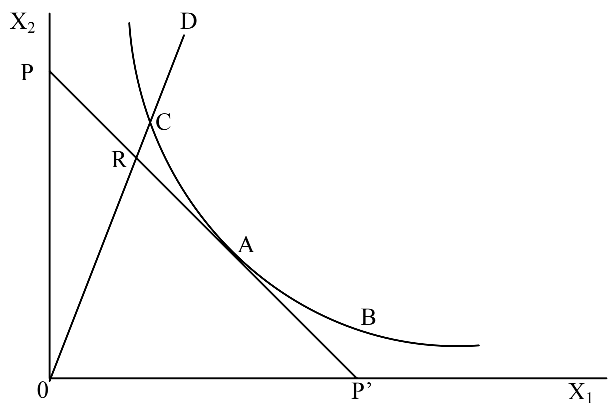


Figure 1. Farrell's efficiency indices (source: Colman & Young, 1989)

The estimation procedure consisted of applying Battese and Coelli's (1995) specification of an inefficiency model. The correct form of production function had to be identified by testing the adequacy of conventional production functions (Cobb Douglas and Constant Elasticity of Substitution) relative to the less restrictive Translog functional form. Thus, the frontier models estimated were defined as given in Equation A3 (See Appendix A for technical details and estimation results).

Data were drawn from the Farm Account Scheme (FAS) for Scotland and supplied by Scottish Executive Environment and Rural Affairs Department. They covered the production years from 1983 to 2000 and included a sample of 45 farms for which data are available for each year. Farms were selected so as to produce a representative sample and formed a balanced panel data set totalling 810 observations.

Output was defined as the sum of all revenues from agricultural enterprises. Aggregate inputs included as explanatory variables were feed costs, intermediate costs (fertiliser, fuel and seed costs), total utilised agricultural area in hectares, capital assets (buildings and machinery) and labour (the sum of hours worked by all classes of labour; family, hired and casual).

Predicted TE indicators range from 29% to an actual maximum of 100% for which the mean value was 63.2% and where 60% of sampled farms have an efficiency score of over 60%. The percentage distribution of farms by efficiency interval is represented in Figure 2 while Figure 3 gives the distribution by farm type. From the latter, one observes that the sector with the lowest efficiency rating is LFA Cattle & Sheep while that with the highest rating is dairy.

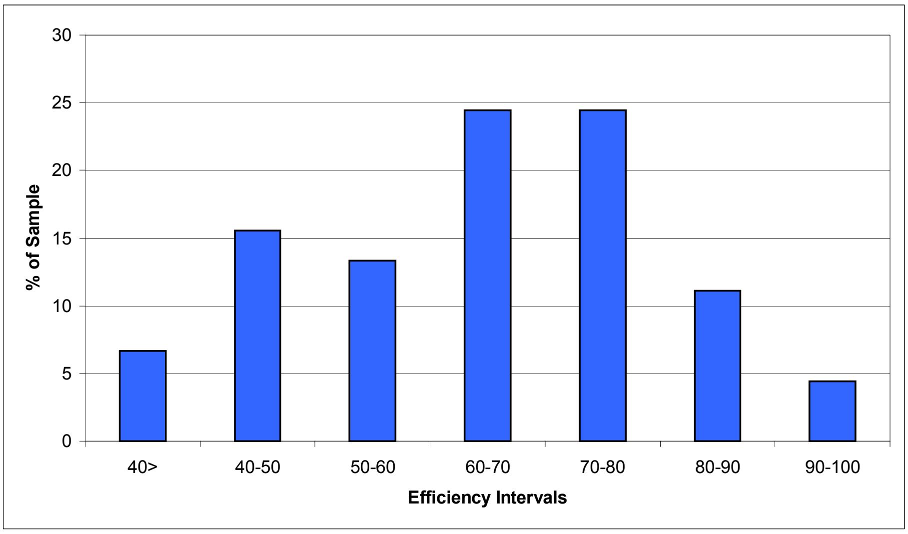


Figure 2. Efficiency Rating Distribution

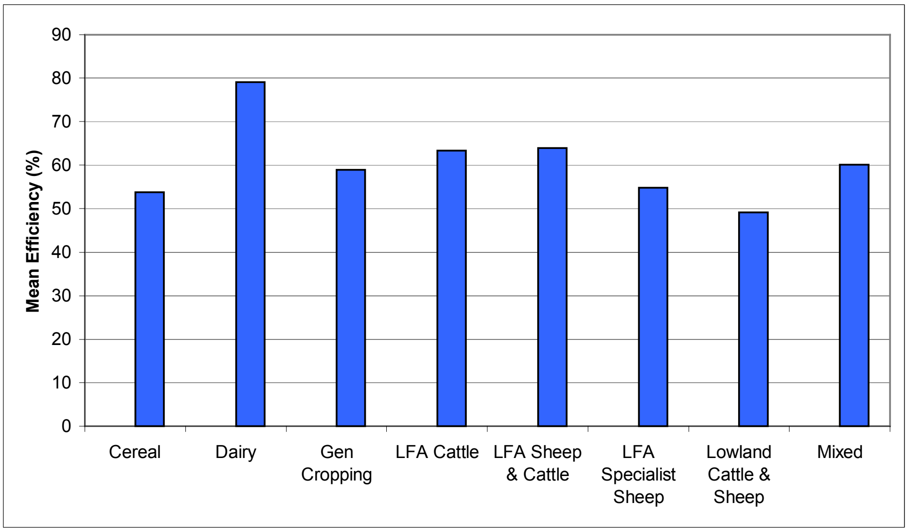


Figure 3. Efficiency distributed by Enterprise Type

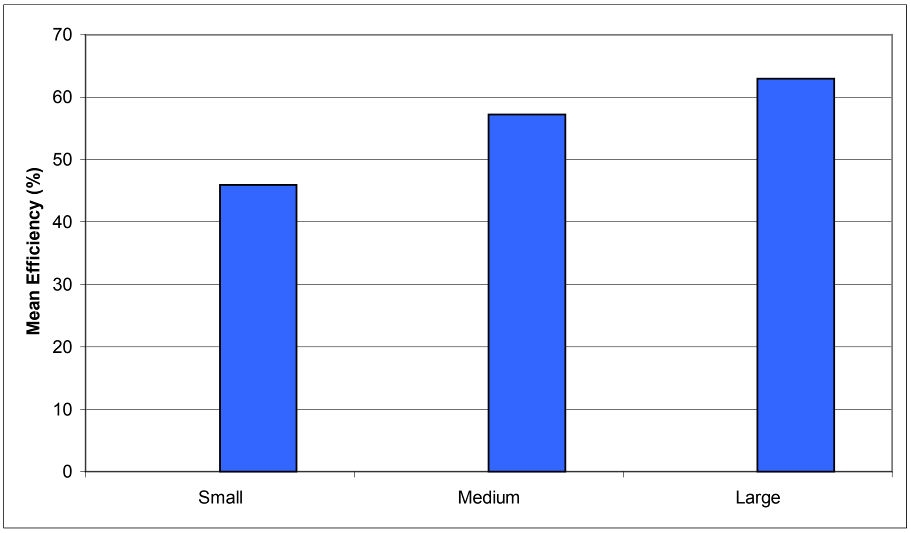


Figure 4. Efficiency Ratings Distributed by Enterprise Size

Further from the output of Equation A3, an attempt was made at explaining the differences in efficiencies between farms. Given the varied nature of farms in the sample, explanatory and dummy variables were constructed in order to explain possible sources of inefficiencies. The variables considered were farm size, whether the farm is in a Least Favoured Area (LFA), the degree of specialisation, farm type, a risk variable accounting for financial exposure calculated as the long term debt over total assets, region and an index of financial health (see Appendix A on how dummy variables were coded). Parameter estimates (where a positive coefficient means that the corresponding variable increases inefficiency) and marginal effects on efficiency expressed as percentages given in Table 1 indicate that all but one parameters were significant; the exception being that for farm size. While previous studies (notably that of Hallam and Machado, 1996) found that mixed farms appeared to be more efficient than specialised farms, our study suggests an opposite effect in that specialisation has a positive marginal effect of 3.27% increase in efficiency for a unitary increase in specialisation.

Table 1. *Sources of Inefficiencies*

	Coefficients	t-stat	Marginal Effects (%)
Time	-0.328	-3.486	6.45
Area	-0.004	-12.74	4.62
Size	0.372	0.599	-1.42
LFA	33.468	13.602	-35.39
Specialised	-2.54	-2.645	3.27
Type	3.376	5.829	-30.58
Debt ratio	78.036	24.452	-16.5
Region	-0.109	-5.906	6.83
Cit	-1.159	-3.043	0.98

The variable with the most powerful effect was the dummy for less favoured area which has a marginal effect of –36% and reflects the increased production risks present in hill farming; this decrease is markedly larger than that found by Hadley et al (2000) in their study for England and Wales who found an LFA marginal effect of around –2%. The second most influential variable was that describing farm type of which the marginal effect was calculated as having a negative effect on technical efficiency of 31%. A time trend was further included in the technical efficiency predictor expression; Battese and Coelli (1995) suggest that time in the inefficiency model captures the benefits of experience and learning by doing. As expected, our estimate of this effect is positive where experience makes up 6.5% of total efficiency.

The surprising marginal effect was that for size which was clearly expected to be positive although the coefficient itself is not statistically significant. From Figure 4, it can be clearly observed that larger farms display higher levels of efficiency in that they take advantage of economies of scale. However, one explanation for the size dummy not being as expected might be that due to market conditions (competition from imported products resulting in lower demand levels), and policies impacts (dairy quotas and livestock restrictions), larger farms may not be operating at full capacity.

A risk element was also introduced in the form of a long-run ratio of debts to assets. Results indicate that a 1 percent increase in the debt ratio decreases efficiency by 16.5% and it is therefore fair to conclude that levels of indebtedness can be significantly restrictive on a farm enterprise. With respect to the geographical location of farms, it was observed that farms located in the South of Scotland tended to be more efficient than their counterparts in the North. Similarly, an East-West divide was detected in that those on the Eastern side of the country were found to be only moderately efficient while those in the Southwest were the most efficient. Findings on the effects of geographical location were somewhat unexpected in that, among those most efficient farms were expected to be those on the Eastern side of the country. Closer investigation of the data revealed that farms classified as most efficient as in fact dairy farms which, from Figure 3, it is noted that these are the ones with the highest mean efficiency. Sampled farms in the operating area where one would have expected a high level of efficiency were mostly general cropping, LFA or mixed for which levels of efficiency are much lower. Thus, it can be fair to say that, in effect, the type of enterprise is a more important factor that geographical location when assessing efficiency.

Given the unstable environment in which Scottish agriculture has been operating, certainly since the first BSE crisis, an estimate of future financial stability was obtained. Thus, the Cit term, in Table 1, (see next section and Appendix B on how the index is derived), is an index reflecting whether a farm is in financial distress and with potentially worsening conditions or whether it is financially healthy. The marginal effect of that index is smaller than expected although, and more importantly, is of the correct sign in that one would expect that if farms were facing not only an uncertain financial future but a worsening one, efficiency should effectively decrease due to rationalisation. The effects of this index can be interpreted as where a 1 percent improvement in the future financial circumstances of a farm occur, efficiency increases by 0.98%. the low magnitude of this marginal effect may be caused by a number of reasons; on the one hand, many farms have a level of indebtedness which although does not qualify the farm as being in financial distress, it will nevertheless limit the long term possibilities of the farmer in making business decisions. On another front, the average age of the farming population being rather high, long term considerations might not have the same importance as for younger farmers. It was further noted that with respect to scale efficiency, most farms show increasing return to scale and therefore indicate spare capacity while three show decreasing return to scale two of which are in financial distress and one healthy. The causes as to why so many farms exhibits increasing return to scale may be attributed to market forces when agriculture's terms of trade have steadily decline in the face of severe competition from imports.

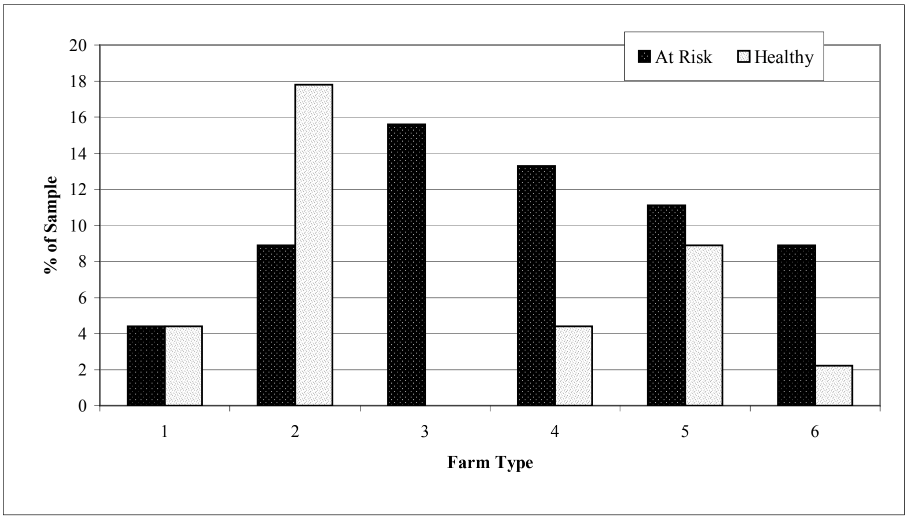
3. Financial Health.

With respect to the financial sustainability of Scottish agriculture, an analysis was carried out that looked at the 'financial health' of the industry. To do so involved the application of a financial distress model based on the cumulative sum (CUSUM) of the Z score and consists of assessing sequentially the financial condition of a firm incorporating current and past information about the firm. Equally important is the ability of the model, and therefore selected variables, to produce out-of-sample forecasts if one is to study the financial health of farms over a period of time in the future. The best stationary CUSUM model produced by a search procedure based on the Granger causality test, included six explanatory variable plus two deterministic dummies in the form of pre-estimation classification indices for healthy and failing farms. Farms were then pre-classified according to an index recording farms as either healthy or failing. The index for pre-classification was based on the deviation from the mean long term debt where if a farm was either consistently below the mean or gradually moving away from the mean, then it would be classified as failing while the opposite would result in a farm being classified as financially healthy. Of the 45 farms included in the sample, only two turned out to be mis-classified post estimation and a correcting mechanism (see appendix B) was employed in order to apply the correct classification according to the estimation procedure.

The final set of financial variables selected were:

Variables:	Proxy:
Current assets to Current liabilities	Liquidity
Current assets to Total assets	Liquidity
Working capital to Total assets	Liquidity
Long Term debt to Total assets	Financial leverage
Account receivable to Current assets	Management efficiency
Long term debt	Management efficiency

A number of other variables were initially constructed (specifically with respect to profitability) but were rejected as either not significant or of poor forecasting ability.



1-Cereals/general croping; 2-Dairy; 3-Cattle; 4-Sheep; 5-Cattle & Sheep; 6-Mixed

Figure 5. Distribution of Farms by Type

Table 2. Mean financial distress coefficients by farm type

Enterprise	Mean CUSUM Scores
Cereal & General Cropping	-0.77
Dairy	0.35
Cattle	-1.11
Cattle & Sheep	-0.98
Specialist Sheep	-0.72
Mixed	-0.78

From the results summarised in Figure 5 and Table 2, one can observe that from the farms sampled, 62% are, at the end of the sampling period, in financial distress. This does not however imply that these farms are on the brink of bankruptcy but rather that some remedial or preventative managerial input will be required if the farm is to survive. Figure 5 further shows that in all but two types of enterprises, the majority of farms are at risk; the exception being the dairy sector where most farms are financially healthy and cereals where half were classified as being at risk. Unsurprisingly, cattle enterprises were all found to be in financial distress where the export ban following the BSE crisis impacted severely on the financial sustainability of beef producers. Indeed, Table 2 shows that the latter is effectively the worst affected farm type where the CUSUM score is –1.11. For most sampled farms of that type, it was observed that the Z scores shows marginal decreases over the 1980s but then decreases quite rapidly over the 1990s. Overall, it can be noted that results from the prediction of financial distress support the findings from the TE analysis in that where farms are not financially healthy, they will tend to operate below capacity thereby reducing efficiency.

4. Risk and diversification measurement

In the study of economic choices and risky situations, it is sometimes convenient to have a quantitative measure of how the presence and magnitude of risk are likely to affect the outcome of a firm. The problem then is to devise a way of quantifying the risks of the various factors of production comprising a firm so as to gauge the response of firm owners. Perhaps the most well developed models of this process can be found in the study of capital asset pricing, where economists have extensively examined the relationship between the expected return an asset offers and the risks associated with that return. In order to do so, standard statistical measures of dispersion can be employed since if the distribution of returns can be described by a bell-shaped symmetrical curve with a finite variance; i.e. by a normal Gaussian probability distribution, two meaningful measures of their dispersion are available; namely the variance and the standard deviation. The standard deviation of a series of returns is the starting place for analysing the risk associated with assets since it is this variability of return that risk averse investors will seek to avoid.

Close inspection of the revenue figures for the sampled farms led us to select the revenue figures for Cattle, Sheep, Dairy and Other livestock based on the criteria that sufficient observations should be available so as to a) ensure that the assumption of a normal Gaussian distribution held and b) given the static nature of the analysis (e.g. no distinction between years), the mechanism described by the Central Limit Theorem would ensure that sufficient observations would identify a near-to population distribution height.

The calculation of the variance and standard deviation of returns for the probability distribution of annual returns are given in Appendix C while results are presented in Table 3.

Table 3. *Individual Analysis*

	Dairy	Cattle	Other	Sheep
Standard Deviation	0.147	0.161	0.004	0.102
Variance (Total risk)	0.022	0.026	0.001	0.01
Correlation	0.055	-0.205	-0.312	-0.089
Beta	0.094	-0.278	-0.011	-0.071
general risk (systematic)	0.006	0.001	0.0002	0.008
specific risk (unsystematic)	0.022	0.025	0.001	0.01
Ratio	0.003	0.042	0.098	0.008

As the above table makes clear, Cattle shows the highest standard deviation of return implying that the total risk of an undiversified investment in Cattle would be much more significant than would a similar investment in either Dairy, Other livestock or Sheep. It is therefore fair to say that of the enterprises included in the analysis, any farmer limiting his business to Cattle rearing would record returns with a higher variance from one year to the other.

The β coefficients of the four types of enterprises calculated by equation (2) indicate the respective volatilities. For example, on the average, a 10 percent increase in total revenue would be accompanied by a 0.94 percent increase in Dairy return, a 2.78

percent decrease in Cattle return, a 0.1 percent decrease in Other livestock return and a 0.7 percent decrease in sheep return. Intuitively, we suspect that this unexpected pattern may be explained by the fact that farmers will engage in other activities not listed in any of the four categories given in Table 3 and that therefore, through a re-distribution of resources, will scale down any of the three activities listed of which the β value is negative.

4.1. Partitioning Risks.

Because the variability of returns from investing in an enterprise is influenced by factors that are specific to that sector and others that are more general, it has become commonplace to regard total risk as being composed of two components; namely, a sector-specific component, known as unsystematic risk; and a more general component, known as systematic risk. For the purpose of this study, we defined systematic risks as that part of total variability that is correlated with the variability of total returns. Unsystematic risk, in turn, is the remaining portion of total variability, i.e., the part that, by definition, does not correlate with the variability of total return. The analysis requires the articulation of a model relating the variability of individual enterprises' return to that of total return (see equations 3,4, and 5 in Appendix C).

In all cases, we observe that unsystematic risks practically account for the entirety of total risks and consequently, none of the variability of returns from other enterprises seem to affect variability of individual enterprises. This would suggest a high level of separability between the various enterprises looked at with a high *unique* business or financial risk characteristics.

4.2. Diversification and Portfolio Analysis.

Unsystematic risk can be eliminated by diversification; that is to say that the holding of a diversified business can largely wipe out the unsystematic risk components of N individual enterprises within the business. In order to assess the possibilities of reducing such risk, we apply a portfolio management theory to enterprise and total return data. The question worth noting at this point is how large should N be to eliminate the unsystematic risk of individual enterprises within the business. The answer to that is “the entire agricultural sector”, i.e. a farmer should hold every possible enterprise that pertains to this industrial sector. Clearly, this is unrealistic and therefore, some level of risk will remain although much risk can be eliminated by holding an “efficient portfolio” of enterprises. Although perfectly theoretically valid, the above argument nevertheless breaks down when and where a firm, for one reason or another, attempts at combining enterprises where a large proportion of total risk is accounted for by unsystematic risk.

Hence, from Table 4, we observe that only some combinations of enterprises would lower levels of risk below that of single enterprises. For example, looking at a ‘Cattle/Dairy’ combination, as individual enterprises, both have extremely high unsystematic risk levels as a proportion of total risk while if combined, reduction in unsystematic risk is rather negligible (down to 0.021 from 0.025 and 0.022 for Cattle and Dairy respectively) while total risk in fact is found to increase due to a sharp increase in systematic risk. Thus, a farmer with a Cattle enterprise wishing to diversify by adding a Dairy enterprise to his business, although marginally reducing the risk specific to Cattle, would now face greater risk levels due to market conditions.

This can further be observed from the R^2 value. It is defined as that value which tells us the proportion of the movement in the portfolio value which is explained by overall market movement (total returns in this study).

Table 4. *Portfolio-Type Analysis*

	Total Risk	Unsystematic Risk	Systematic Risk	R^2
1,2	0.0431	0.0247	0.0183	0.6698
1,3	0.0303	0.0161	0.0142	0.7165
1,4	0.0346	0.021	0.0136	0.6318
2,3	0.0138	0.0104	0.0034	0.431
2,4	0.0246	0.0216	0.0031	0.2331
3,4	0.0102	0.0095	0.0007	0.1323
1,2,3	0.0303	0.0161	0.0142	0.7165
1,2,4	0.0345	0.021	0.0136	0.6318
1,3,4	0.0259	0.0145	0.0114	0.6856
2,3,4	0.0102	0.0095	0.0007	0.1324
ALL	0.0259	0.0145	0.0114	0.6856

1=Cattle, 2=Other, 3=Sheep, 4=Dairy
See Appendix C, Equations 6 to 9 for derivation of the above.

Hence, with an R^2 value of 0.6318, 63.2 percent of variations of returns from a combined 'Cattle/Dairy' business will be caused by market movements. Therefore, if markets display or indeed are prone to high volatility, this will be transmitted to the apparently diversified business. Note however that adding an 'Other livestock' enterprise to the above combination (row '1,2,4' in Table 4) would make no difference. Having said that, should a farmer hold the Dairy enterprise, one way of reducing unsystematic risk might be to combine it with Sheep since this would reduce all risk levels (row '3,4').

Lastly, a combination of all enterprises included in this study would only be advantageous if the farmer wished to eliminate risk levels from initially holding a Cattle enterprise. Given that risk levels in the 'All' combination are higher than either individual enterprises or certain of the combinations and as such, adoption of an all-encompassing business might not be the best option.

5. Conclusion

The objective was to obtain estimates of both the financial robustness and the technical efficiency of a representative sample of Scottish farms. Emphasis was placed on those factors that impact on long-term sustainability in order to identify those effects that may be characterised as having a high propensity to further increase the vulnerability of the sector. The aim was thus also one of providing focussed knowledge that might steer the policy decision making process towards potential targets of importance.

Two complementary steps were taken. The first consisted of constructing series of financial indicators that were employed to assess the financial health of each farm in the sample as well as predicting the future viability of each enterprise. In a second step, physical and financial data (including a financial health index constructed during the first phase) were employed to ascertain the technical efficiency of farms and possible sources of inefficiencies.

On the strength of the findings, we concluded that farms that are characterised by being non-LFA, specialised, large and with low indebtedness are those most likely to survive. However, although technical efficiency and financial distress indicators confirmed that while a significant proportion of farms were classed as being in financial distress, most of those being in LFA and mostly cattle or sheep farms, these same indicators effectively suggested that given the specialised nature of those farms, continued survival was possible, specifically where the debt ratio could be reduced to ideally zero while no significant attempt would be made at diversification of the agricultural enterprise. While some factors are rather fixed such as geographical location, in order to ensure continuity others can more easily be targeted for improvement, namely farm size, degree of specialisation, farmers' accumulated knowledge and financial health.

Applying financial economics theory to the data in order to estimate levels of financial risk as represented by each individual enterprise as well as combination of enterprises showed that at the individual level, enterprises provided most if not all of the risk. A high degree of separability between enterprises was found which in turn meant that combining enterprise with a view to diversifying might not always be appropriate, even if specific risk levels can be reduced, the combination of two or more enterprise might render the business as a whole more sensitive to market risks. Combining two or more enterprise with high specific risk as a proportion of total risk renders the theoretical argument that diversification eliminates risk practically null and void. Thus, should diversification become a necessary step for survivial, this should not come from the agricultural sector.

The empirical results might also be interpreted as indicating the vulnerability of the majority of farms to economic shocks. The potential benefits of such findings are that policy decisions targeted at maintaining the sustainability of the agricultural sector may be better directed. More specifically, having identified factors that can potentially ensure the continuity of the industry, results can be exploited with a view to improve advisory activities as well as assessing policy impacts such as the forthcoming application of CAP reforms.

Appendix A. Estimation of Technical Efficiency Model.

The derivation of technical efficiency coefficients specifically consists of measuring a distance that will represent a deviation from optimum. The optimum, located on the production possibility frontier as given in Figure 1, assumes a 100% efficiency level on the part of the firm. However, estimating a distance function from a deterministic approach does not allow the researcher to discriminate between random errors and differences in inefficiencies (since the inference is on the residuals of the model). Hence, more appropriate is the stochastic approach where a function f(.) of inputs against output is specified as

$$y_{it} = f(x_{it}, \beta) + \varepsilon_{it} \qquad \text{where } \varepsilon_i = V_{it} - U_{it}$$

$$\text{with } U_{it} \sim |N(m_{it}, \sigma_U^2)| \text{ and } V_{it} \sim N(0, \sigma_V^2)$$

where y_{it} is the output of firm i at time t, $x_{j,it}$ is the corresponding level of input j and β is a vector of parameters to be estimated. In the second part of the model, the inefficiency term, U_{it}, is made an explicit function of k explanatory variables, z_{kit} which are hypothesised as affecting levels of farm efficiency and is given as

$$U_{it} \sim N[\delta_0 + \sum_{k=1}^{M} \delta_k z_{k,it}, \sigma^2] \qquad \text{(A1)}$$

The technical efficiency of an individual farm is defined in terms of the ration of the observed output to the corresponding frontier output, conditional on the levels of inputs used by that firm. Thus, the technical efficiency of firm i at time t in the context of stochastic frontier production function is expressed in terms of the errors as

$$TE_{it} = E\left[\exp(-U_{it}) \mid (V_{it} - U_{it})\right] \qquad \text{(A2)}$$

the production function was specified as a translog function defined as

$$\ln y_{it} = \alpha_0 + \sum_{j=1}^{5} \alpha_j \ln x_{jit} + \sum_{j=1}^{5}\sum_{k=1}^{5} \alpha_{jk} \ln x_{kit} + V_{it} - [\delta_0 + \sum_{k=1}^{M} \delta_k z_{k,it}] \qquad \text{(A3)}$$

Maximum Likelihood estimators are reported in Table A1 where for the inefficiency model, variables were coded as follows:

- Time: 1 to 18 for each farm;
- Farm size: 1=small, 2=medium, 3=large;
- LFA: 0=non-LFA, 1=LFA;
- Specialised: where 70% or more of total revenue is from one single enterprise=1, else=0;
- Type: Cereal/cropping=1, Dairy=2, Cattle=3, Sheep=4, Cattle&Sheep=5, Mixed=6.

Table A1. *Maximum-Likelihood parameter estimates*

Variables	coefficient	standard-error	t-ratio
Stochastic frontier:			
Constant	317.935	1.08	294.326
X1 (Feed)	2.436	0.861	2.828
X2 (Intermediate)	11.261	1.372	8.207
X3 (Area utilised)	-0.592	0.917	-0.646
X4 (Capital)	3.577	1.035	3.457
X5 (Labour)	-367.834	1.466	-250.933
X1X1	0.009	0.005	1.824
X1X2	0.041	0.045	0.909
X1X3	-0.028	0.034	-0.824
X1X4	0.026	0.029	0.893
X1X5	-1.456	0.484	-3.009
X2X2	0.129	0.066	1.961
X2X3	0.051	0.051	0.998
X2X4	0.109	0.058	1.878
X2X5	-7.153	0.775	-9.227
X3X3	-0.034	0.019	-1.803
X3X4	-0.067	0.029	-2.282
X3X5	0.728	0.524	1.39
X4X4	0.052	0.025	2.049
X4X5	-2.532	0.591	-4.285
X5X5	110.651	1.148	96.414
Inefficiency model:			
Constant	-89.67	7.507	-11.944
Time	-0.328	0.094	-3.486
Area utilised	-0.004	0.000314	-12.74
Farm size	0.372	0.622	0.599
LFA	33.468	2.461	13.602
Specialised	-2.54	0.96	-2.645
Farm type	3.376	0.579	5.829
Debt ratio	78.036	3.191	24.452
Region	-0.109	0.019	-5.906
Cit	-1.159	0.381	-3.043
Variance parameters:			
sigma-squared	94.202	3.025	31.143
gamma	0.999	0.00011	9104.255

Appendix B. Estimation of Financial Health Model.

Based on the sequential probability and the theory of optimal stopping rules, Theodossiou (1993) shows that the time series CUSUM model will provide a signal of the firm's deteriorating conditions as soon as the cumulative sum of the estimated Z-score falls below a critical value. The latter measure the overall performance of a firm and takes the form of a weighted index in that serial correlation must be accounted for.

Following the work of Kahya and Theodossiou (1999), a Vector Autoregression is defined as:

$$X_{i,t} = A_h + A_f + X_{i,t-1}B_1 + e_{i,t} \tag{B1}$$

where X is the matrix of differenced variables, A_h and A_f are dummies for firms pre-classified as financially healthy or at risk respectively, B_1 is a matrix of coefficients to be estimated and e is the error term. The Z-score can then be computed as follows:

$$\begin{aligned} Z_{it} &= \beta_0 + (X_{i,t} - A_h - X_{i,t-1}B_1 - \cdots - X_{i,t-k}B_k)\beta_1 \\ &= \beta_0 + \left(A_f + \varepsilon_{i,t}\right)\beta_1 \end{aligned} \tag{B2}$$

$$\beta_0 = \left(\frac{1}{2}\right) A_f \Sigma^{-1} A_f^{'} \tag{B3}$$

$$\beta_1 = (-1/D)\Sigma^{-1} A_f^{'} \tag{B4}$$

and

$$D^2 = A_f \Sigma^{-1} A_f^{'} \tag{B5}$$

where β_0 and β_1 are the CUSUM parameters, D is the Mahalanopis generalised distance of the error term and Σ is the variance co-variance matrix of the residuals. CUSUM scores for each firm are calculated recursively using the formula:

$$C_{i,t} = \min\left(C_{i,t-1} + Z_{i,t} - k, 0\right) < -L \tag{6B}$$

where K and L are sensitivity parameters that operate as benchmarks; as long as Z_{it} are positive and greater than K, C_{it} is zero. When Z_{it} falls below K, the CUSUM accumulates negatively. A sign of failure is when C_{it} falls below $-L$ although the CUSUM would increase and go back to zero if and only if the Z_{it}-score becomes greater than K. In the context of this study, K was found to be 0.11136 and L 0.09861. Individual results are given in Table 2.

Appendix C

Given that if the distribution of returns can be described by a bell-shaped symmetrical curve with a finite variance, i.e. by a normal or Gaussian probability distribution, two measures of dispersion are available, namely the variance and the standard deviation. The variance, equal to the average of the squared deviation from the mean, is defined by:

$$\sigma^2\left(\widetilde{R}\right) = \sum\left[\widetilde{R}_i - E\left(\widetilde{R}_i\right)\right]^2 f\left(\widetilde{R}_i\right) \quad \text{(C1)}$$

where E is the expected value operator, $\widetilde{R}_i$ is the *i*th possible return and $f\left(\widetilde{R}_i\right)$ is the probability associated with the possible return. Note that equation 1 will also represent total risk.

Identification of an enterprise's systematic risk requires that the systematic volatility be derived. Commonly referred to a the beta value of a stream of returns, this index is obtained by:

$$\beta_i = \frac{\rho_{iR}\sigma\left(\widetilde{R}_i\right)}{\sigma\left(\widetilde{R}_R\right)} \quad \text{(C2)}$$

where ρ_{iR} is the correlation coefficient between the *i*th enterprise's return and total return and $\sigma(\widetilde{R}_R)$ is the standard deviation of total returns.

Hence:

Systematic risk: $\beta^2\sigma^2\left(\widetilde{R}_R\right)$ (C3)

Unsystematic risk: $\sigma^2\left(\widetilde{R}_i\right) - \beta_i^2\sigma^2\left(\widetilde{R}_R\right)$ (C4)

Systematic risk/total risk: $\dfrac{\beta^2\sigma^2\left(\widetilde{R}_R\right)}{\sigma^2\left(\widetilde{R}_i\right)}$ (C5)

Formal derivation of portfolio analysis:

Systematic risk: $\sum_{i=1}^{n}\left[\left(v_i / \sum_{i=1}^{n} v_i\right)\beta_i\right] * \sigma_R$ (C6)

Where v_i is the value of the return from the *i*th enterprise

Unsystematic risk: $$\sum_{i=1}^{n}\left[Ur_i\left(v_i / \sum_{i=1}^{n} v_i\right)\right]_i^2 \quad \text{(C7)}$$

Where Ur_i is the unsystematic risk of the ith enterprise

Total risk: $((Eq6)^2+(Eq7)^2)^{0.5}$ (C8)

R^2: $(Eq6)^2/(Eq8)^2$ (C9)

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