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**Autor:** Gerber, Jacques / Franks, Jeremy

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# Technical efficiency and benchmarking: An application on dairy enterprises in England and Wales

Jacques Gerber, Institut für Agrarwirtschaft, ETH Zürich
Jeremy Franks, University of Newcastle upon Tyne

**Farms are benchmarked by their technical efficiency. The inputs used by the most efficient farms are compared with those used by less efficient farms to show which were over-used, and to quantify the reduction needed to increase efficiency to that achieved by the most efficient farms. Using relative efficiency to benchmark performance allows farm managers to compare performance against best practice on real farms rather than against a notional average farm.**

**Keywords: DEA, dairy enterprises, technical efficiency, best practice, SSEMP, efficiency score**

## 1. Introduction

Benchmarking performance is a key management function. Current best practice recommends comparing performance against industry standards derived from average values obtained from pooling similar farms. One consequence of this is the need to ensure similar methodologies are used for the target and the average (comparator) farm (Cain and Venus, 2000). But in certain circumstances the average farm is little more than a notional farm that does not, or in some cases such as the average mushroom farm, could not exist. Moreover, it may not be clear from these comparisons how the required improvements should to be made.

Lund and ∅rum (1997) showed how data envelopment analysis (DEA) can be used to assess farm efficiency. DEA is a programming approach to ranking farms by their efficiency. A linear combination of the best practice farms replaces the pooled average as the comparator against which performance is measured.

Efficiency is an important concept for farm managers because it measures the ability of the business to convert inputs into outputs. Typically, efficiency is measured as a value of a ratio between a product (an output) and a resource (an input), but this has two practical problems. Firstly, deciding which inputs and outputs to use to construct the efficiency ratio, secondly how to interpret the value of the ratio.

Data Envelopment Analysis (DEA) can be used to help address both of these difficulties. DEA is a method of non-parametric analysis based on a series of linear-programmes, which together generates a pure technical efficiency score for each surveyed farm.[1] The efficiency score is derived from a ratio of the weighted sum of outputs and inputs used in the farm or in a specified farm enterprise. In the application of DEA to dairy enterprises,[2] each enterprise is scored between zero and 100: those assigned a value of 100 are described as being 100% efficient relative to other enterprises in the analysis. An inefficient unit's peer farms are those 100% efficient units with the most similar input/output orientation to itself. Therefore, the management of the peer farms should provide examples of 'best operation practice', and a comparison of input use will show the extent to which inputs are over-used.

There are several aspects of the efficiency approach to benchmarking that makes this approach particularly appealing:

- more than one output and input can be included in the ratio
- these outputs and inputs are summarised as a single index,
- this index allows dairy enterprises to be ranked, and
- the resources used by enterprises that are less than 100% efficient can be compared with the resource used by the 100% relative efficient farms, the so-called peer farms.

This approach has other advantages over the commonly used alternative of pooling survey data to generate an average farm from which industry norms and standards can be derived:

1 But the most efficient farms can be defined as either those that produce the most output from the same inputs or as those that produce a given output from the least inputs - and to measure efficiency one of these approaches needs to be selected. Because the data used here refers to milk production, which is limited by quota, efficiency will be measured using the second definition (i.e. it is input orientated).

2 Lund and ∅rum (1997) show how linear programmes are used to rank farm business by their relative efficiency.

- the 100% efficient farms are real, they do exist,
- much less data needs to be collected to analyse performance
- therefore, results are more timely, and
- although less data is collected, because the most efficient farms exist they can be visited (or surveyed in more depth) to reveal the basis of the success of the farming system thereby spreading best practice.

The last point should be emphasised. Even extremely comprehensive enterprise and whole farm surveys rarely gather all the management information required to allow farmers to identify what changes are needed to improve performance. However, after the most efficient farm has been identified, because it exists in reality, this problem can be overcome by organised farm visits allowing farmers to see for themselves the appropriate changes needed, thereby directly spreading best practice.

The ranking of farms by relative efficiency has become more feasible, and can now produce more useful feedback to farm managers, because of recent improvements in DEA software. In particular, a software package called Frontier Analysis *Professional* (FAP) (a windows based, largely menu driven package) has been designed specifically to cater for the needs of a non-academic audience (Hollingsworth, 1997). It has been described as being designed 'for a managerial user who accepts without question the concepts of DEA' (Hollingsworth, 1999). Importantly, reports produced by FAP are readily interpretable and the package is accompanied by a comprehensive user-manual (Banxia, 1998). Although FAP can calculate the effect of scale on efficiency, at the moment this part of the analysis is not menu driven. Scale efficiency is discussed later, and this paper shows how the FAP software can be used to estimate the effect of scale on efficiency.

This paper is designed to show the benefits of benchmarking using relative efficiency. The next section discusses the database used and discusses DEA further. This is followed by an estimation of the economies of scale in milk production. Section four summarises for the whole sample the saving of inputs if all farms were 100% efficient, and this is followed by a review of the reports produced by FAP for individual farms. The last section summaries the potential of the DEA approach to benchmarking the management of farms.

# 2. Data used and Methodology

The data used in this paper to demonstrate DEA is taken from the Special Studies into the Economics of Milk Production 1996/97 (SSEMP). This is one of an ongoing series of enterprise studies that form part of MAFF's commissioned work, and was undertaken by nine farm business and rural studies units in England and Wales. Full details are available in Farrar and Franks (1998).

DEA is a mathematical programming approach to estimating relative efficiency. The programme identifies weights to apply to each element in the ratio of outputs to inputs, and these weights are used to locate each farm in relation to each other. Those that perform best represent the leading edge of a production frontier. More comprehensive discussions of DEA and of efficiency in general can be found in Charnes et al. (1994) and Ganley and Cubbin (1992).

This paper will show the potential benefits to farm managers from using DEA to identify the most efficient farms; some of these benefits have been referred to above and are discussed in Lund and ∅rum (1997). Although DEA has been applied widely (Emrouznejad (1995-1998)), the methodology needs careful application, particularly with respect to:

- the importance of clean data with no errors or 'outliers',
- the inputs and outputs used in the efficiency ratio can be selected from a large number of alternatives (the specification problem, Gerber (1998)) and
- pure technical efficiency ignores any inefficiency caused by the difference in the price of inputs between farms.[3]

Similar problems also occur in alternative approaches to estimating relative efficiency (i.e. the parametric approach or simple ratios). This paper argues that the potential problems with DEA can largely be addressed because the identify of the peer farms, those used to quantify excessive input use on inefficient farms, can be determined.

The outputs and inputs used in the DEA model specified here are set out and defined in Table 1. They include the major outputs and inputs used in dairy enterprises.

[3] DEA can be used to allow for this potential source of inefficiency (called cost or allocative inefficiency), but this makes higher demands on the survey data and the interpretation of DEA becomes more complex.

Table 1. Variables used in the data envelopment analysis.

| |
|---|
| Litres of milk produced adjusted to average butterfat of 4%. |
| Number of living calves. |
| Tonnes of concentrate used. |
| Total hours of dairy specific direct labour. |
| Forage area used by the dairy herd. |
| Number of replacement cows introduced into the herd in the year. |

Economies of scale

Economies of scale are obtained by estimating two formulations of the DEA model, one assuming constant returns to scale, the other variable return to scale. Returns to scale concerns what happens to units' outputs when they change the amount of inputs used to produce those outputs. If a doubling of all inputs leads to a doubling of all outputs then the units exhibit 'constant returns to scale'. This means that no matter at what scale the units operate their efficiency will remain unchanged. If, however, a doubling of all inputs leads to a greater than or a less than a doubling of all outputs produced then the units exhibit 'variable returns to scale'. This would mean that as the unit changed its scale of operations its efficiency would either increase or decrease.

Evidence from studies of dairy enterprises suggests that they are subject to variable returns to scale (Farrar and Franks, 1998: Franks, 1999: MAFF, 1992). Therefore, by removing the effect of scale on inefficiency the resource savings each farm manager can make in the short term, i.e. without changing herd size, can be revealed.[4, 5]

[4] In FAP, the inefficiency due to scale is calculated by subtracting the constant returns to scale score from the variable returns to scale score by cutting and pasting the results from both models into a spreadsheet.

[5] An alternative approach to removing the scale effect was used by Lund and ∅rum (1997). They limited the farms included in the DEA analysis to only those smaller than the target farm.

# 3. Results: Efficiency scores

Figure 1 shows the inefficiency caused by incorrect scale. Smaller herds incur an average 14% loss in efficiency because of their scale (potential economies of scale). Herds between 70 and 160 cows show constant returns to scale but units with more than 160 cows incur diseconomies of scale.

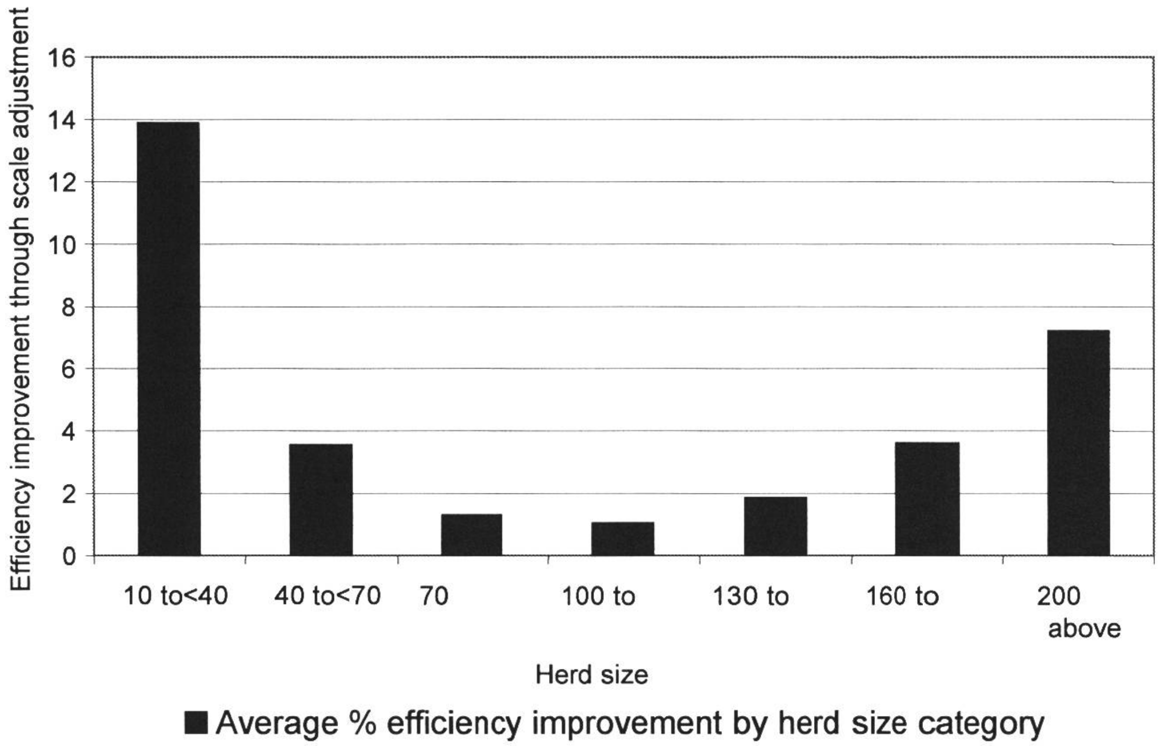


Figure 1: Inefficiency and herd size (scale effect).

The efficiency score ranks farms by their relative efficiency. The distribution of the efficiency scores for the 377 dairy enterprises is shown in Figure 2. This model identified 44 enterprises as 100% relative efficient, with the average relative efficiency for all enterprises estimated at 80.9%.

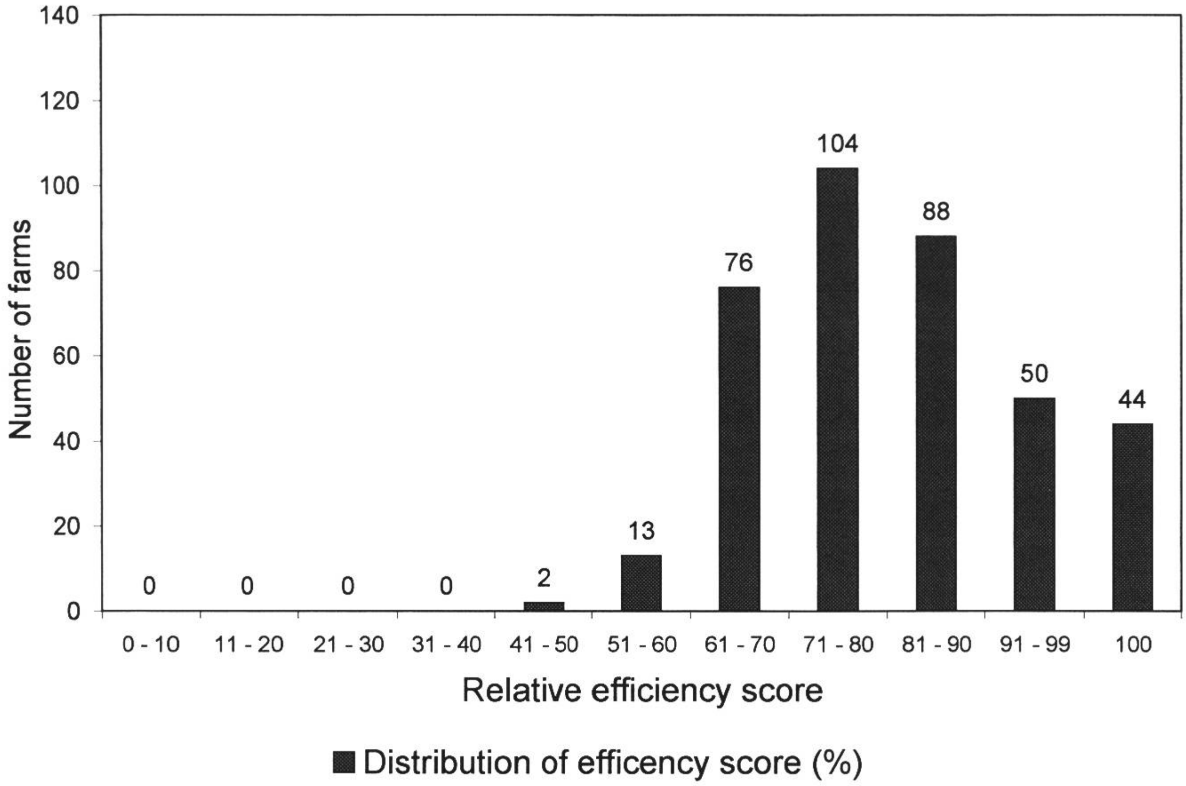


Figure 2: Summary of efficiency scores (variable returns to scale)

# 4. Output for the sample

A key advantage of using DEA is its ability to compare an individual farm's performance with the performance of its peer farms. This allows the actual inputs used to be compared with those used on the most efficient farms, so that over-use can be identified and quantified. Figure 3 shows the resource saving that would be made over the full sample of 377 enterprises if each enterprise produced at 100% efficiency without changing herd size (i.e. over the short-term).

Figure 3 shows that it should be possible to produce 2.4% more milk and 5.4% more calves whilst using 25.4% less dairy specific labour, 22.0% less concentrate, a 22.5% reduction in the annual number of replacement cows and 22.2% less forage area.

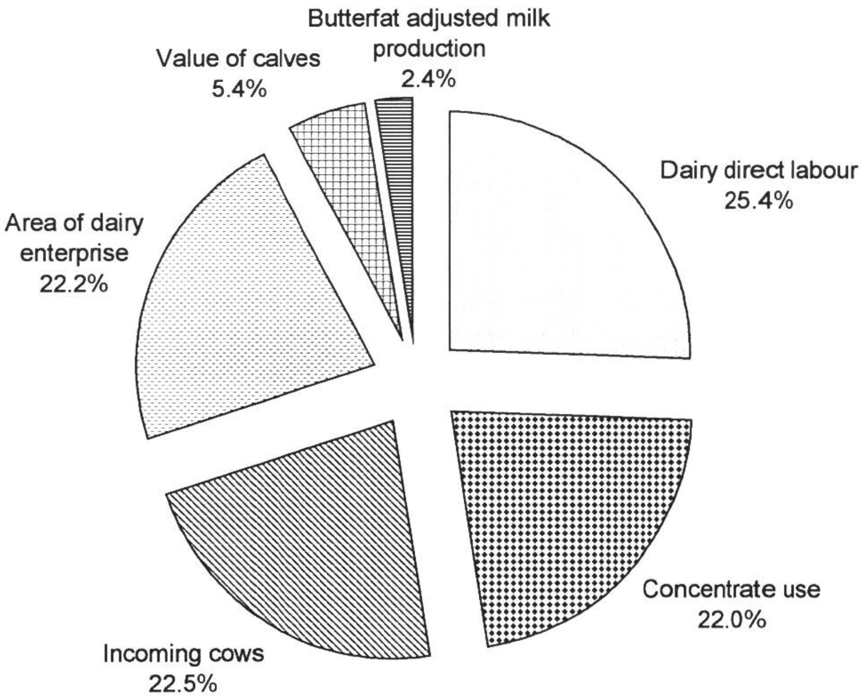


Figure 3: Total potential short-run improvements for the entire sample.

Figure 3 and Figures 4 to 7 summarise resource use for the entire sample and therefore may be of particular interest to policy makers. Figures 4 to 7 summarise the potential savings in the inputs used if each farm achieved 100% efficiency. For example, Figure 4 shows that 71 farms would have to reduce dairy specific direct labour by between 11 and 20% to become 100% efficient; Figure 5 shows that 75 farmers would have to reduce concentrate use by between 31 and 40% to become 100% efficient.

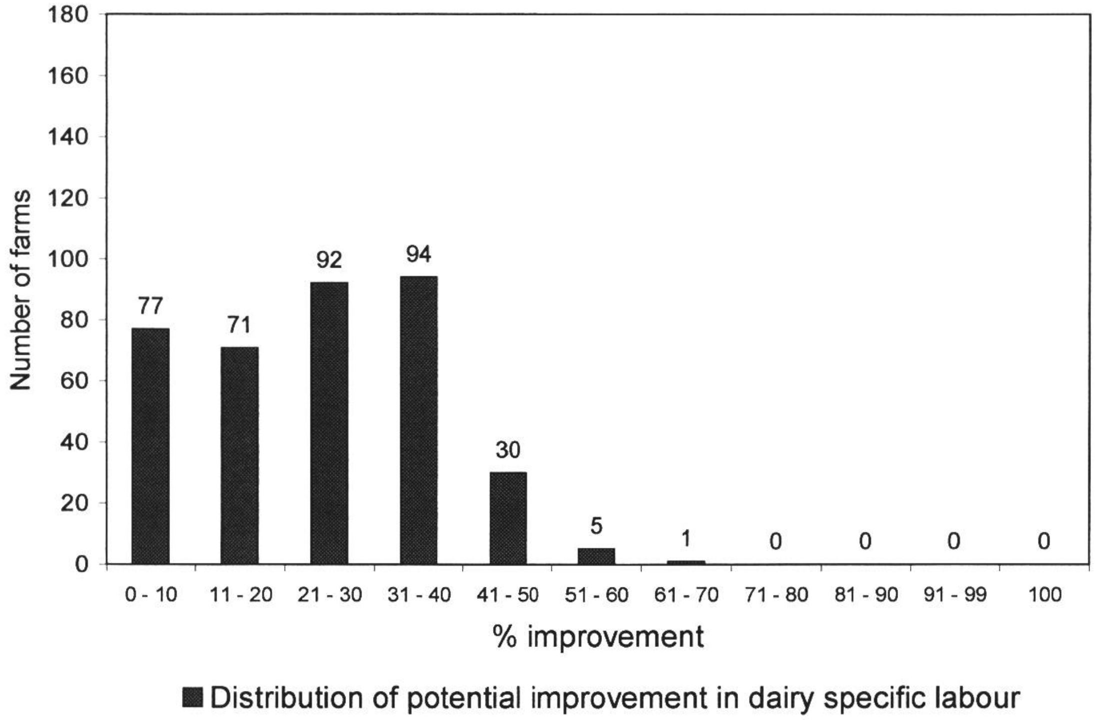


Figure 4: Distribution of potential improvements in dairy specific direct labour

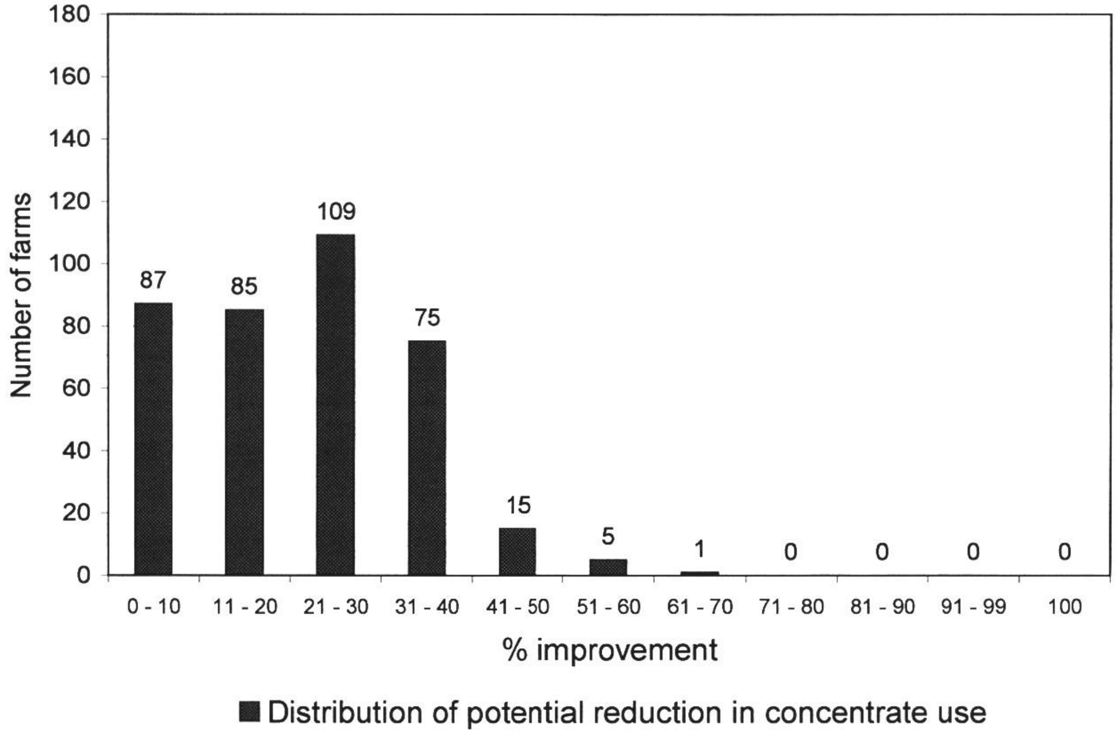


Figure 5: Distribution in potential improvements in concentrate use

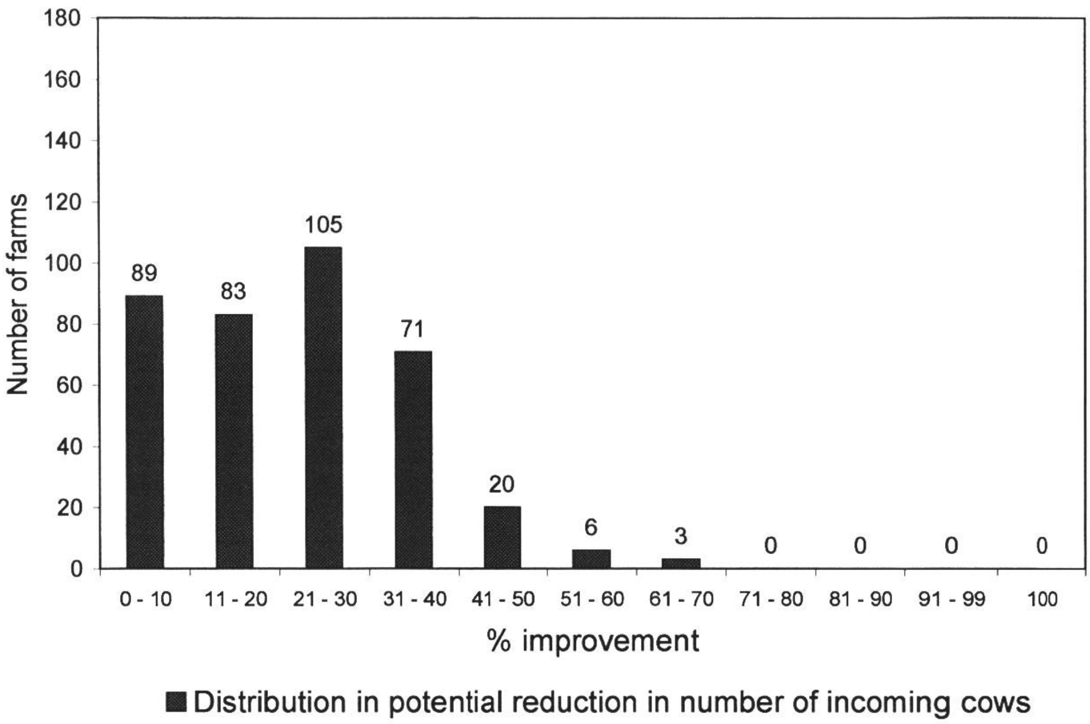


Figure 6: Distribution of potential improvements in the number of incoming cows.

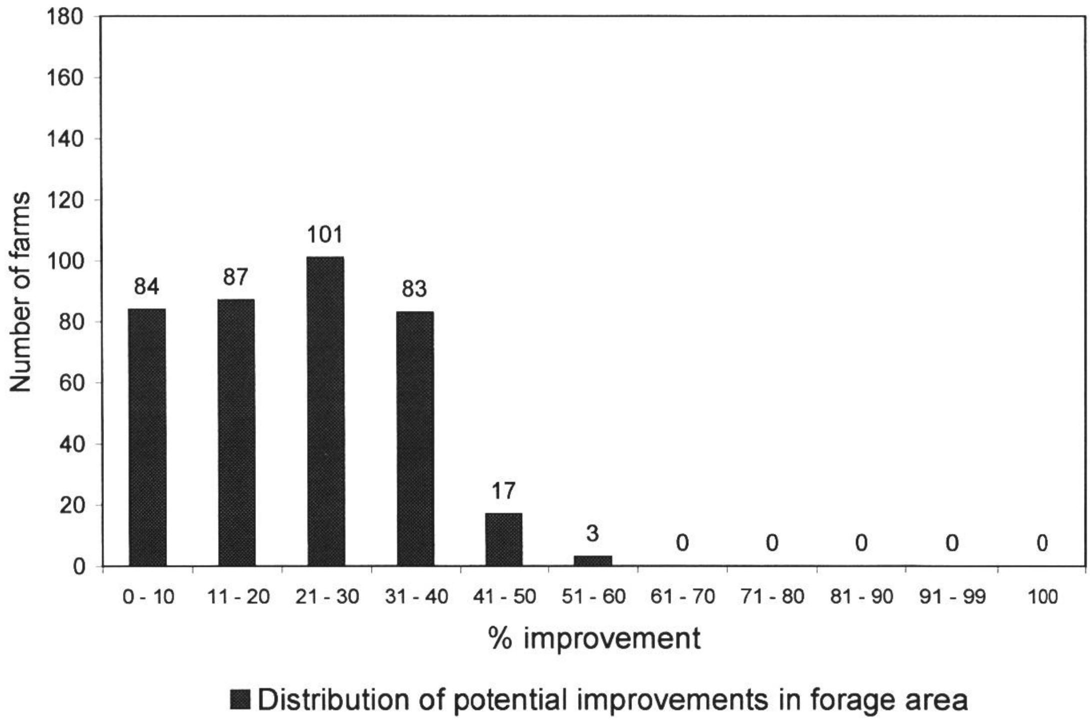


Figure 7: Distribution of potential improvements in forage area.

# 5. Output generated for individual farms

Whilst the summaries of the sample presented in Figures 3 to 7 are likely to be of interest to policy makers, farmers are likely to be more interested in the results as they relate to their own farm. FAP presents estimates of the changes in input use needed to raise an inefficient farm to 100% relative efficiency. Figure 8 illustrates this output for a hypothetical farm. The potential improvement graph shows the percentage decrease in inputs (or increase its outputs) needed to become 100% relative efficient. For example, this hypothetical farm must reduce labour by 38%, concentrate use by 37%, the number of incoming cows by 40% and forage area by 32% whilst leaving production unchanged to become 100% efficient.

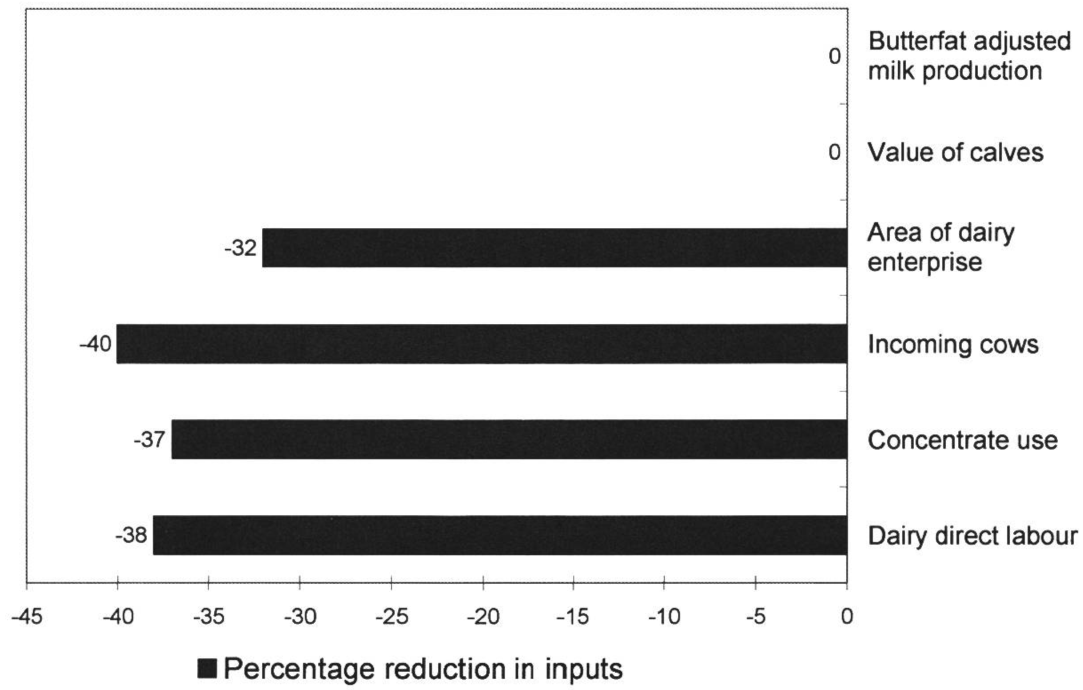


Figure 8: Typical results for a 'specimen' farm: percentage reduction in inputs compared to the farms in the sample.

In addition to this, FAP identifies the farms used as peer farms for each inefficient farm. An example of an efficiency report, again for a hypothetical farm, is shown in Table 2.

Table 2: An Efficiency report for a hypothetical farm (sample of output available for each farm)

| {Farm name/number} | | | Date: ............... |
|---|---|---|---|
| **Efficiency score** | **95.70 %** | Number of peers | 4 |
| | | Number of times used as a reference | 0 |
| **Potential Improvements** | | | |
| **Variable** | **Actual** | **Target** | **Improvement** |
| Milk (lts) | 232942.0 | 232942.0 | 00.0% |
| Calves (nos.) | 46.0 | 46.0 | 00.0% |
| Concentrate use (t) | 3300.0 | 1946.9 | -41.0% |
| Direct Labour (hrs) | 37.0 | 35.4 | -4.3% |
| Forage area (ha) | 8.0 | 7.7 | -4.3% |
| Replacement cows (nos.) | 31.7 | 27.5 | -13.2% |

**Peer Contributions**

| Farm Number/name | Variables | Contribution (%) |
|---|---|---|
| 88 | Milk (lts) | 12.07 |
| 88 | Calves (nos.) | 19.20 |
| 88 | Concentrate use (t) | 35.99 |
| 88 | Direct Labour (hrs) | 12.96 |
| 88 | Forage area (ha) | 28.84 |
| 88 | Replacement cows (nos.) | 24.69 |
| 268 | Milk (lts) | 25.35 |
| 268 | Calves (nos.) | 31.33 |
| 268 | Concentrate use (t) | 15.28 |
| 268 | Direct Labour (hrs) | 21.29 |
| 268 | Forage area (ha) | 38.21 |
| 268 | Replacement cows (nos.) | 22.18 |
| 286 | Milk (lts) | 55.92 |
| 286 | Calves (nos.) | 43.43 |
| 286 | Concentrate use (t) | 45.62 |
| 286 | Direct Labour (hrs) | 61.63 |
| 286 | Forage area (ha) | 21.39 |
| 286 | Replacement cows (nos.) | 47.98 |
| 354 | Milk (lts) | 6.66 |
| 354 | Calves (nos.) | 7.04 |
| 354 | Concentrate use (t) | 3.11 |
| 354 | Direct Labour (hrs) | 4.13 |
| 354 | Forage area (ha) | 11.56 |
| 354 | Replacement cows (nos.) | 5.16 |

| Input/output contributions | | |
|---|---|---|
| Variable | Contribution: | Input/Output: |
| Milk (lts) | 92.1 | |
| Calves (nos.) | 7.8 | |
| Concentrate use (t) | 1.67 | |
| Direct Labour (hrs) | 76.2 | |
| Forage area (ha) | 23.8 | |
| Replacement cows (nos.) | 1.16 | |
| **Peer references units** | | **88, 268, 286, 354** |

The efficiency score is presented on the top line, in this example the score is 95.7%. The number of peer farms is 4 and the number of time the farm has itself been used as a peer farm is also shown (here as zero). The potential improvements required to become 100% relative efficient are shown, with the actual inputs used by the farm and by the 100% efficient peer farms (the 'target' input use). The farms used as peers are clearly identified, together with the contributions each peer farm made to the 'target'. This tells the farmer which peer farm is the most important in setting targets for each input or output. For example, farm 286 is most important in setting the target for concentrate use.

Because of the restrictions imposed on use of this data set, the peer farms presented in Table 2 must remain identified only by a number. But a key contributions of the FAP software is its ability to identify real farms that are similar in total output terms to the inefficient farm, but which are more efficient. This is different from many studies of enterprise profitability which present profitability averaged over a group of farms - so that the average farm rarely if ever exists in reality.[6]

From an industry point of view, knowing the identity of surveyed farms would greatly assist with the dissemination of best practice. Poorer performers would then benefit from visiting their peer farms.

6 This is a particular problem when a commodity is produced from different production systems. In this case industry standards drawn from the 'average' farm are of less value because the average farm could not exist in practice. This is the case, for instance, with mushroom production (Franks and Farrar, 1999).

Figure 9 shows another result produced by FAP. It is a graph showing the number of times a farm was used as a peer farm. The farms most often used as reference farms are of particular interest, as they represent "best practice" (comparator) farms used to set targets for many other farms. Visits to or presentations about the most used peer farms would be of most use to the sector as a whole.

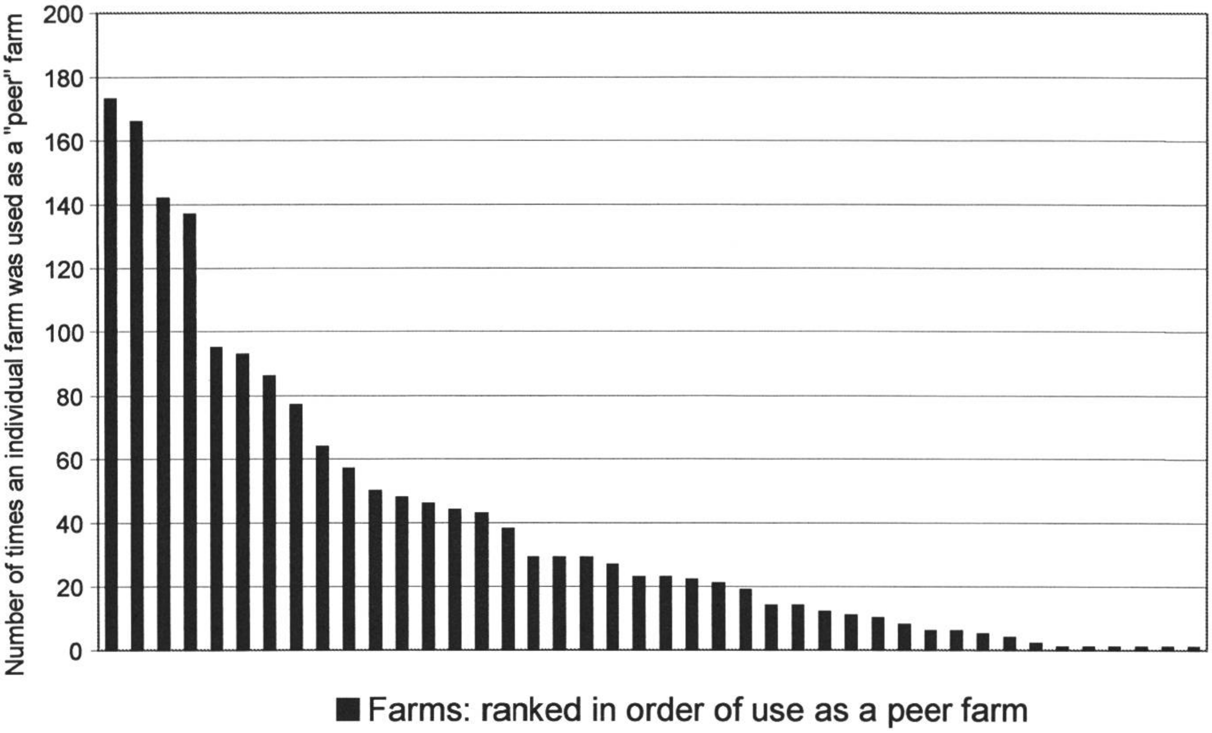


Figure 9: Number of times a farm was used as a "peer" farm.

# 6. Discussion and summary

The onus has always been on managers to achieve better results from their available resources: in the current financial circumstances these pressures on managers have intensified. Benchmarking performance by comparing enterprise performance with industry standards derived from an average farm is a popular and relatively successful means of improving performance. But this paper has introduced an alternative approach to using an average farm, using data envelopment analysis to identify real farms which are 100% relative efficient. These farms can then be used as comparator farms that represent best practice.

It is argued that data envelopment analysis takes benchmarking a stage further by identifying each surveyed farm's peer farms, and using the input used on these farms to calculate the potential input savings for the inefficient farms. Importantly, DEA software identifies real farms rather than an average farm to be used in the benchmarking exercise.

Some of the benefits of ranking by relative efficiency include:

- summarising all major outputs from and inputs to an enterprise as a single value i.e. its efficiency score,
- ranking enterprises and / or farms by this efficiency score to identify "best" and "poor practice",
- identifying resources that are over-used,
- quantifying the resource over-use,
- setting targets based on peer farms,
- revealing 'best practice' for less efficient farms to emulate,
- although not discussed here, it allows efficiency changes over time to be estimated (by repeating DEA on the same sample of farms in the following year), and
- surveys need to collect less data, reducing survey costs and improving timeliness.

Recent improvements in DEA software now make it feasible to include in any analysis of survey material an efficiency score for each participating farm. The benefits of knowing their relative efficiency would be greater if peer farms allowed themselves to be named and agreed to host farmer-visits to disseminate "best practice".

The management information produced by DEA could be a key tool in improving performance. But care should be taken to validate the output generated by the analysis. Some of the problems of DEA have been referred to previously, and to help overcome these the characteristics of peer farms must be scrutinised to confirm their suitability as peers, for example check they are in the same region. However, the potential problems should not be allowed to dominate the useful information that DEA can generate, and awareness of the methodology is more likely to lead to the analysis being conducted with some consideration and care.

To some extent the importance of these potential problems will only be known after further applications of DEA to farm enterprise data. Indeed, DEA can be used to generate even more useful information if it is used to study how the efficiency of the same farms or enterprises changes over time (Parkin and Hollingsworth, 1997). It is hoped that the output generated by the DEA analysis will, at the very least, generate discussion points and be a catalyst for change. And the potential benefits of knowing the identity of peer farms and visiting these farms to the dissemination of 'best practice' throughout the sector are transparently clear.

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## Biographic details

At the time of this research Jacques Gerber was a Research Associate working with Professor Bernard Lehmann, at the Department of Agriculture at the Swiss Federal Institute of Technology, Zurich. This study is a development of the Thesis submitted for his Masters degree in Economics at the University of Manchester. Jacques is currently working at the Institute of Agricultural Economics, Zurich, researching aspects of the adoption of dairy related technologies in Tanzania with Professor Awudu Abdulai.

Jeremy Franks is a lecturer in Farm Management in the Department of Agriculture at the University of Newcastle upon Tyne. His research interests include analysing whole farm and farm enterprise survey data, the financial structure of UK agriculture and the potential impacts of new technologies on farming systems and profitability.

Anschriften der Verfasser:

Jacques Gerber
Institut für Agrarwirtschaft
ETH-Zentrum (SOL)
CH-8092 Zürich

E-Mail: jacques.gerber@iaw.agrl.ethz.ch

Jeremy Franks
Department of Agriculture
King George VI Building
University of Newcastle
Newcastle upon Tyne, NE1 7RU
Great Britain

E-Mail: j.r.franks@ncl.ac.uk