Using technical efficiency to classify Austrian dairy farms

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Anwendung der technischen Effizienz zur Unterscheidung von Milchviehbetrieben in Österreich

1 Introduction

The beef and milk sectors contribute almost 30 per cent to the production value of agriculture in Austria where a third of all farms are producing and selling milk. 70 per cent of these enterprises were mountain farms and 15 per cent were organic farms in 2004. Since the average size of the milk quota per farm is one of the lowest in the EU (48 t in 2003/04), income from milk production alone is insufficient for many farmers. Thus dairy farming is experiencing structural change, exemplified by the fact that the number of dairy farms declined by 33 per cent from 1995 to 2003 (KIRNER, 2005).

Direct payments for Austrian farms are designed to compensate natural disadvantages and higher environmental standards. However, in a globalizing world where markets are integrating and price support is replaced with payments independent of production, competitiveness in the market is increasingly important for the viability of farms. As a result, and exemplified by the ongoing discussions about the continuation of the present level of farm support, efficiency is becoming the key determinant of long-term dairy farm survival.

The aim of this study is to estimate technical efficiency (TE) of dairy farms in Austria, and to determine whether efficiency scores correlate with farm income, farm size, the degree of natural disadvantage and other farm characteristics. We investigate whether efficiency is a unique dimension of the variation between farms which is not directly accessible through farm accounting data. If so, efficiency scores can be used in combination with other variables to define clusters of farms which differ in their ability to remain economical-

Zusammenfassung

Milchviehbetriebe in Österreich sind klein strukturiert und 70 % von ihnen liegen im Berggebiet. Ihr wirtschaftliches Überleben hängt zunehmend von ihrer Wettbewerbsfähigkeit ab. In der vorliegenden Studie wird die Technische Effizienz von 222 spezialisierten Milchviehbetrieben mit Hilfe der Data Envelopment Analyse (DEA) berechnet. Nur 16 % der Betriebe in der Stichprobe erreichten eine 100%ige Effizienz. Die Technische Effizienz repräsentiert einen eigenen Faktor neben der Betriebsgröße, der natürlichen Erschwernis und dem Alter bzw. der Ausbildung des/der Betriebsleiter(in)s. Eine auf Basis von Faktorwerten durchgeführte Clusteranalyse zeigt auf, dass die wirtschaftliche Lebensfähigkeit von bis zu 60 % der untersuchten Milchbetriebe in der Stichprobe wegen kleiner Betriebsgrößen und/oder ineffizienter Produktion gefährdet ist.

Schlagworte: DEA, Technische Effizienz, Milchviehbetriebe, Cluster Analyse, landw. Einkommen.

Summary

Dairy farms in Austria are small, and 70 per cent of them are located in mountain areas. Their ability to stay in business increasingly depends on their competitiveness. We estimate technical efficiencies (TE) of 222 specialised dairy farms using Data Envelopment Analysis (DEA). As a result, only 16 per cent of the farms in the sample were fully efficient. TE represents a unique dimension to characterise these farms, along with size, natural disadvantage and the age of the farm manager. A cluster analysis based on factor scores reveals that up to 60 per cent of the sample dairy farms are either too inefficient or too small to ensure their economic viability in the future.

Key words: DEA, technical efficiency, dairy farms, cluster analysis, farm income.

ly viable in the future. Efficiency may more or less depend on natural conditions of where a farm is located. If the relationship is strong, efforts to improve efficiency on the farm are futile and direct payments by disadvantage are decisive. However, as it turns out, this is not the case.

2 Data

The data for the present analyses were provided by approximately 2,400 Austrian farms who participated in the voluntary farm accounting data network in 2001, 2002 and 2003. This sample farms represent about 54 per cent of farms and 95 per cent of dairy cows in Austria (BMLFUW, 2004, 298). Their data are used to prepare the report on the income of Austrian farms.

Some 550 of the nearly 2,400 farms in the above-mentioned network specialize in dairy farming, i.e. more than 75 per cent of gross margin originates from forage cropping, and the standard gross margin from milk production exceeds that from cattle fattening (BMLFUW, 2004, 280). Since production structure among these farms varies considerably, we introduced additional selection criteria to ensure a more homogeneous sample:

- revenues from diversification (e.g. direct marketing) must be less than 10 per cent
- revenues from cash crops in all revenues must be less than 10 per cent, and
- more than 95 per cent of livestock must be cattle.

222 dairy farms fulfilled conditions mentioned above for each year from 2001 to 2003. In order to eliminate outliers, average data of each farm over three years were used for the analysis. In Table 1 we compare some key figures between the sample farms and the average of all dairy farms in Austria. The sample contains larger enterprises in terms of milk quota (215 per cent) and area (129 per cent), farms with a higher share of grassland in farmland, and a higher share of mountain farms and organic farms than the population of dairy farms in Austria.

Table 1: Comparison of dairy farms in the sample and all dairy farms in Austria (average of 2001–2003)

Tabelle 1: Vergleich der Milchviehbetriebe in der Stichprobe mit allen Milchviehbetrieben in Österreich (Durchschnitt von 2001–2003)

Characteristic	Sample	All dairy farms
Dairy farms (number)	222	58,107
Milk quota per farm (t)	100.4	46.5
Utilized agricultural area (UAA, ha)	22.0	17.1
Proportion of grassland in UAA (%)	75.3	57.9
Proportion of mountain farms (%)	76.1	70.1
Proportion of organic farms (%)	26.1	15.5

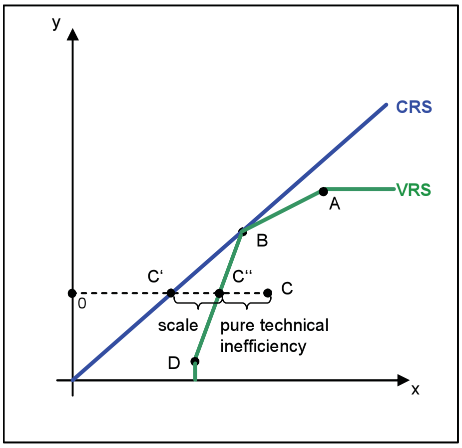
Source: Invekos Data 2001–2003 and LBG 2001–2003

3 Methodology

3.1 Data Envelopment Analysis

Efficiency analysis is by now a well-known concept which has been applied in numerous fields, including dairy farms (ASMILD et. al., 1999). One of the most popular tools for efficiency measurements is Data Envelopment Analysis (DEA) (e.g. CHARNES et al., 1978; COOPER et al., 2004). This is a non-parametric approach which does not impose a functional form on the relationship between inputs and outputs. DEA is a data oriented and deterministic method for evaluating the performance of a set of peer entities called Decision Making Units (DMUs) which convert multiple inputs into multiple outputs (COOPER et al., 2004). Unlike other methods (e.g. regression methods) DEA constructs a frontier by comparing the data of each DMU with data of benchmark DMUs that perform better. Observations lying on the production frontier are defined as technically efficient (TE), and those lying below the frontier are considered inefficient. The frontier is a hyperplane that depicts the maximum attainable set of outputs for a given set of inputs. It is determined by solving a linear programming model for each DMU with data from all DMUs used to constrain the transformation space.

In our model we allow for both variable and constant returns to scale (VRS and CRS). CRS implies that the efficiency of a farm is measured relative to scale efficient farms; i.e. for a farm to become efficient it may have to change its size to the optimal scale. Given the distribution of dairy farms in Austria, that is a heroic assumption whose realisation would only be possible in the long run. However, scale contributes to technical efficiency and thus should not be neglected as a source of inefficiency. Its contribution, scale efficiency (SE), is given by the following definition: TE = SE * PTE where PTE is pure technical efficiency. PTE is obtained from the efficiency calculation under the assumption of VRS. This assumption implies that the maximum ratio between outputs and inputs that can be attained depends on the scale at which a farm operates. More farms are efficient under this assumption, and PTE scores match or exceed TE scores for every farm (see Figure 1).



$$Technical\ Efficiency\ (TE) = \frac{0C'}{0C}$$

$$Pure\ Technical\ Efficiency\ (PTE) = \frac{0C''}{0C}$$

$$Scale\ Efficiency = \frac{TE}{PTE} = \frac{0C'}{0C''}$$

$$TE = PTE \times SE$$

$$A, B, C, D \ldots\ldots\ldots\ldots Farms$$

Figure 1: Production frontiers to measure technical, pure technical and scale efficiency
Abbildung 1: Produktionsfunktionen zur Bestimmung der technischen bzw. der puren technischen Effizienz sowie der Skaleneffizienz

Taking into account the quota regulated character of the Austrian milk market the input-oriented linear programming model, as originally presented in CHARNES et al. (1978), was chosen for the efficiency calculations.

$$\theta^* = \min \theta$$
$$subject\ to$$
$$\sum_{i=1}^{n} x_{ki}\lambda_i \leq \theta x_{k0} \quad k = 1,\ldots,p$$
$$\sum_{i=1}^{n} y_{ji}\lambda_i \geq y_{j0} \quad j = 1,\ldots,q$$
$$\lambda_i \geq 0 \quad i = 1,\ldots,n$$

$$\max \sum_{k=1}^{r} s_k^- + \sum_{j=1}^{s} s_j^+$$
$$subject\ to$$
$$\sum_{i=1}^{n} x_{ki}\lambda_i + s_k^- = \theta^* x_{k0} \quad k = 1,\ldots,p$$
$$\sum_{i=1}^{n} y_{ji}\lambda_i - s_j^+ = y_{j0} \quad j = 1,\ldots,q$$
$$\lambda_i, s_k^-, s_j^+ \geq 0 \ \forall k,i,j \quad i = 1,\ldots,n$$

where θ is a scalar, x and y are input and output quantities respectively, s- and s+ are slacks (input reduction) and surpluses (output increase) used to convert inequalities to equivalent equations. λ is a vector describing the contribution of the benchmark DMUs to the virtual DMU on the frontier. Imposing the additional convexity constraint $\Sigma\lambda_i = 1$ into the first calculation allows the solution of VRS-models. The value of θ* represents the efficiency score of the j-th DMU, where a value of less than one indicates an inefficient DMU which could improve its efficiency by a proportional reduction of all inputs and adoption of the best available technology. θ* can then be used to detect input slacks or output surpluses in a second step.

Limitations of efficiency measurement through DEA concern the implicit assumption that differences in the performance of farms are due to an inefficient transformation of inputs into outputs. In reality the efficiency scores of DMUs may also vary due to

a) outputs and inputs that are not accounted for in the analysis, f.i. leisure
b) measurement errors in the variables (f.i. unaccounted-for quality differences), and
c) the presence of production techniques that may not be applicable in all DMUs.

Only a comparison of DMUs with similar production technologies can generate reasonable results on their relative efficiencies. Thus the sample has to be adequate. For the study in hand, the selection process applied secures a high level of homogeneity within the sample.

In general the number of efficient farms increases the more inputs and outputs are distinguished and the fewer farms are compared within the sample. DYSON et al. (2001) suggest that in order to achieve a reasonable level of discrimination, the number of DMUs should at least be twice the product of the number of inputs and outputs. We selected two outputs and six inputs as summarised in Table 2.

Thus all production inputs of the farm and all outputs which generate revenue were taken into account. If other variables, such as agro-climatic conditions or production techniques etc., affect the ratio between inputs and outputs, their effect will bear on the efficiency scores. Other authors selected similar inputs and outputs, for example CLOUTIER and ROWLEY (1993) used total quantity of milk, revenue from milk sale and other revenue as outputs and herd size, labour, cultivated land, animal feed and other inputs as inputs. The mathematical analysis was performed in MATLAB (CINATL, 2004).

Table 2: Statistics of the used in- and outputs for DEA
Tabelle 2: Statistik zu den verwendeten In- und Outputs für DEA

Variables	Unit	Input/Output	Mean	Min.	Max.	Std. Dev.
Total quantity of milk-produced during the year minus milk for feeding	kg	0	104.7	9.8	329.7	61.1
Other revenue, accruing to the individual farm, excluding revenue for milk and direct payments	€	0	26.7	3.7	62.7	12.1
Expenses for animal husbandry, e.g. feed, vet	€	I	13.0	1.5	440.4	8.6
Expenses for machinery & energy, e.g. fuel, repair, depreciation	€	I	13.4	2.4	34.4	6.0
Other expenses, e.g. insurance, taxes	€	I	17.8	3.8	63.6	9.8
Cultivated land, adjusted for quality differences	ha	I	22.0	4.1	66.4	10.1
Heavy Livestock Units	LU	I	30.7	6.0	76.0	13.8
Labour, unpaid family work units	FWU	I	1.9	0.6	3.8	0.5

3.2 Factor analysis

Factor analysis is used to extract much of the information of original farm characteristics and represents it with a significantly smaller number of so-called factors to characterise the farm sample in hand. Principal component (PC) analysis extracts sequentially linear combinations of these variables with maximum variance on the condition that they are uncorrelated with the previously found combinations of variables. The question of how many factors to extract from the data set is usually answered by the Kaiser criterion, according to which the number of factors is equal to the number of eigenvalues of the correlation matrix whose value exceeds 1. This ensures that the factors capture more variation each than any of the original variables in the data set. (Since the sum of the eigenvalues in a data set is equal to the number of variables, a variable corresponds to an eigenvalue of 1).

Factors are designed to capture a significant share of the variation in the original data set and to correlate ("load") with particular variables of the original data set as much as possible. The latter goal can be achieved by an appropriate rotation of the axes of a subset of the PCs. Whether factor analysis is going to be useful on a particular data set can be determined on the basis of the MSA-criterion, a measure of sampling adequacy developed by KAISER, MEYER and OLKIN. Its range is from 0 to 1, with values above 0.7 indicating that this is indeed ("rather well") the case. The MSA-criterion is applicable both to the correlation matrix and individual variables. Another quality indicator of a factor analysis is the vector of communalities, i.e. the shares of the variance of each variable that is captured by the selected number of factors (see BACKHAUS et al., 2003, 276f).

3.3 Cluster analysis

Cluster analysis tries to find a natural grouping of the units under consideration, the 222 dairy farms, into a number of clusters on the basis of the factor scores (see STERN et al., 2004). A slight drawback of using factor scores is that not all of the available information is used for clustering. It is more than compensated by a substantial simplification of the interpretation of the clusters. There are various cluster analysis techniques: Hierarchical clustering results in a classification which has an increasing number of nested classes. With non-hierarchical methods such as, for example, k-means clustering, the number of clusters to be formed has to be given exogenously or determined on the basis of certain criteria. We intend to distinguish farms on the basis of criteria which are related to their viability in the future. This may depend on some but not all of the factors extracted from the variables in the data set. The decision of how many clusters to form will eventually depend on the characteristics of the clusters formed and whether they have an economically plausible interpretation.

4 Empirical results and discussion

4.1 Efficiency scores

The number of efficient farms under constant returns to scale (CRS) technology in the sample is 35 (16 per cent); their milk quota varies between 20 and 321 t. The majority of farms in the sample is not efficient (see Table 3 und Figure 2).

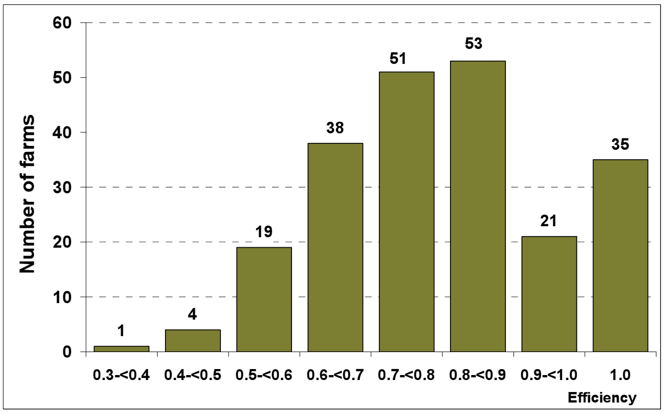


Figure 2: Distribution of farms by technical efficiency scores
Abbildung 2: Verteilung der Betriebe nach technischer Effizienz

The technical efficiency of 5 farms is less than 50 per cent, and 51 per cent of the farms operate at an efficiency level of less than 80 per cent. Technical inefficiency is partly due to the fact that these farms operate at an inefficient scale. If it were possible to move all inefficient farms to the CRS production frontier, 21 per cent of the inputs into dairy farming could be saved without compromising output.

Similar distributions of efficiency have been obtained in other studies using DEA. In a Danish case study with 1,810 dairy farms the median efficiency was 0.805 under the assumption of constant return to scale (ASMILD et al., 1999). The study of CLOUTIER and ROWLEY (1993) compared the distribution of efficiency scores across Canadian dairy farms in 1988 and 1989 and found mean scores of efficiency between 0.761 and 0.952 across different samples. JAFORULLAH and WHITEMAN (1998) calculated a mean of 0.890 for technical efficiency for a sample of 264 dairy farms in New Zealand. GRAHAM and FRASER (2002) employed DEA to measure technical efficiency and scale efficiency for a sample of 1,742 Australian dairy farms. Their results showed an average technical efficiency of 59 per cent. REINHARD (1999) and REINHARD et al. (2000) indicated a mean technical efficiency score of 78 per cent for Dutch dairy farms. A study by GERBER and FRANKS (2001) and FRANKS and GERBER (2002) estimated average relative efficiency of 87 per cent for dairy farms in England and Wales.

Ordering farms by their technical efficiency scores and comparing their characteristics gives first indications of whether technical efficiency and other descriptive variables are correlated. Table 4 shows how the characteristics of farms and farmers change with technical efficiency.

It appears that there is a correlation between the number of milk cows, the amount of milk quota and milk production on the one hand and technical efficiency on the other. The more milk cows are held and the more milk is produced on average, the higher the technical efficiency. F. e. farms with an average efficiency of 0.981 (4^{th} quarter) produced 143 t of milk, farms with an average efficiency of 0.596 (1^{st} quarter) 82 t of milk. Other characteristics of the size of the enterprise, like the standard gross margin or the utilised agricultural area, do not correlate unequivocally with efficiency scores. Income from farming was clearly higher in efficient operations. More efficient farms farmed on average less land but produced definitely more milk on their land: some 6,900 kg/ha in the 4^{th} quarter and only some 4.000 kg/ha in the 1^{st}. The gap in milk production per cow and year was not as high: it ranged from 5,500 kg to 6,600 kg between the 1^{st} and the 4^{th} quarter. Direct payments decreased slightly with increasing technical efficiency; this may be due to the higher share of mountain farms in the less efficient quarters.

Many other authors also found at least a slightly positive relationship between efficiency and farm size (e.g. CLOUTIER and ROWLEY, 1993; HESHMATI and KUMBHAKAR, 1997; WILSON et al., 1998; HELFAND and LEVINE, 2004). On the other hand, in a study by BRAVO-URETA and RIEGER (1991) efficiency levels were not markedly affected by socioeconomic variables.

Table 3: Efficiency of specialised dairy farms in Austria, 2001–2003 average
Tabelle 3: Effizienz von spezialisierten Milchviehbetrieben in Österreich, Durchschnitt von 2001–2003

	Unit	TE	PTE	SE
Average efficiency	per cent	78.9	84.0	93.8
Median efficiency	per cent	79.4	83.7	97.0
Share of 100 per cent efficient farms	per cent	15.8	24.3	15.8

Abbr.: TE = technical efficiency = PTE*SE, PTE = pure technical efficiency, SE = scale efficiency.

Table 4: Variation of farm and farmer's characteristics by technical efficiency
Tabelle 4: Merkmale der Betriebe bzw. Betriebsleiter nach technischer Effizienz

	Unit	25 per cent least efficient	25 per cent below average efficiency	25 per cent above average efficiency	25 per cent most efficient
Technical efficiency	score	0.596	0.734	0.843	0.981
Standard gross margin	€/farm	22,014	27,945	26,322	27,233
Utilized agricultural area (UAA)	ha	20.4	25.5	22.1	20.6
Share of grassland in UAA	%	76.0	71.2	79.8	73.0
Heavy livestock units	no.	27.2	33.9	31.7	30.7
Dairy cows	head	14.9	19.3	19.9	21.6
Milk quota	t/farm	64.6	102.2	109.6	128.7
Milk production	t/farm	82.4	120.1	126.1	142.7
Agricultural income	€/farm	9,104	13,829	16,392	18,680
Direct payments	€/ha	848	759	752	738
Capital costs[1]	€/ha	469	530	500	619
Age of the farm manager	years	46.6	45.9	46.9	46.1
Agricultural education[2]	score	2.20	2.56	2.51	2.49
Sea level	m	684	624	614	607
Share of mountain farms	%	83.6	82.1	66.1	72.7
Share of organic farms	%	36.4	23.2	19.6	25.5

[1] Imputed interest on assets (4 per cent)
[2] 1 = none, 2 = vocational or apprentice school, 3 = master craftsman, 4 = high school or university

4.2 Factors

The factor analysis is based on the following 14 characteristics of farms and their managers: technical efficiency score, standard gross margin (€), proportion of grassland in utilised agricultural area (per cent), milk cows (head), milk quota (t), income from farming per unpaid family work unit (€/FWU), direct payments (€/ha), age of the farm manager (years), agricultural education (points), sea level (m), location (points), mountain farm cadastre points, capital costs per ha (€) and value of the soil per ha (€). Variables which have been used to calculate efficiency scores have been excluded. On the basis of the anti-image-correlation matrix, the overall MSA-value was 0.752. Since the MSA-criterion of the variable "location" was less than 0.5 and the variable "proportion of grassland" loads lower than 0.5 on all factors, they had to be excluded. All other 12 variables fulfilled the requirements of this analysis; they are the basis for the following results.

Table 5 shows the eigenvalues of the correlation matrix of the variables and the shares of variance explained by subsequent principal components. The eigenvalue of four principal components exceeds 1. Due to normalisation, the overall variance of 12 variables is 12. An eigenvalue of 3.544 for the first principal component relative to 12 amounts to an explanatory share of some 30 per cent for the first factor, for example.

Table 5: Extracted factors, eigenvalues, and proportion of total variance explained
Tabelle 5: Extrahierte Faktoren, Eigenwerte und Anteil an erklärter Varianz

Factor	Eigenvalue	Share of total variance of factors	Share of total variance cummulated
1	3.54	29.54	29.54
2	2.68	22.29	51.83
3	1.47	12.24	64.07
4	1.15	9.57	73.64

The four factors whose eigenvalue exceeds 1 capture 74 per cent of the variance in the original data set. Considering the ratio between the number of cases (farms) and the number of variables, 74 per cent of explained variance is a good result as it becomes more difficult to obtain a high share of explained variance with an increasing number of cases. Table 6 shows the matrix of factor loadings after rotation according to the varimax criterion.

In order to interpret the factors properly it is necessary to find names which allude to the highly loading variables per factor (in absolute terms). In the present result, no variable loads higher than 0.5 with more than one factor. In this case every variable is to be consulted for the interpretation of only one factor (BACKHAUS et al., 2003, 299). Given the factor loadings in Table 6, the following names characterize the dimensions represented by the four factors:

Factor 1: farm size
Factor 2: degree of natural disadvantage
Factor 3: competitiveness
Factor 4: farm manager's youth and education

Note that factor 3 which corresponds to technical efficiency is indeed a unique dimension in the data set (although agricultural income per family work unit is correlated with it but also with farm size). If only accounting data had been available we could have replaced it with six partial productivity and input use indicators (milk yield, non-milk revenue, expenditures on livestock, machinery and energy, buildings, other). Doing so in an alternative factor analysis leads to five factors: Four as above but factor 3 would be less well defined (direct payments per ha 0.61, agricultural income per FWU 0.51), plus a factor 5 featuring all six new variables with factor loadings between 0.71 (milk yield) and 0.86 (other expenditures per ha). While factor 5 suggests a positive relationship between outputs per ha and inputs per ha, technical efficiency represents something else, namely the ratio between total outputs and total inputs, which is new. Note also that technical efficiency is quite independent of factor 2, i.e. a higher degree of natural disadvantage affects TE only slightly. The following cluster analysis is performed with the factor scores resulting from the factors in Table 6.

4.3 Clusters

Cluster analysis yielded four clusters of dairy farms of somewhat similar size whose characteristics are shown in Table 7. The first cluster, A, contains farms with substantially above average endowments of farmland, livestock units and milk quota. With an average production of 194 t of milk these farms produced about twice as much on average as those in the other clusters. Although they operated with average technical efficiency, income from farming was highest in this cluster.

The other clusters contain farms of about equal size; there were no statistically significant differences between the farms in clusters B, C and D in terms of their utilised agricultural area, livestock numbers and milk quotas. However, these clusters differ significantly in their technical efficiency.

Farms in cluster C are the technically most efficient (0.919). They achieved the highest agricultural income per unpaid family work unit – about twice as much as those in clusters B and D and higher than in the large farms (cluster A). 89 per cent of the farms in cluster C are located in mountain areas, and 44 per cent of them are organic farms. Accordingly these farms were eligible to receive almost the same amount of direct payments as the large farms in cluster A. Farm managers in cluster C had higher levels of agricultural education (62 per cent with vocational schooling) than their colleagues in clusters B and D, and they earned less off-farm income.

Cluster D contains farms which were technically most inefficient on average. They produced significantly less milk per ha of utilised agricultural area than those in the other clusters, and they hardly generated any income from farming. Almost all of them farmed in mountain areas (94 per cent), but their share of organic enterprises was not significantly different from cluster C. Although they relied more heavily on off-farm income, their earnings from these sources were not significantly different from the farms in

Table 6: Factor loadings by varimax rotation
Tabelle 6: Faktorladungen nach der Varimax Rotation

Variable	Factor 1	Factor 2	Factor 3	Factor 4
Standard gross margin	**.955**	-.109	.074	.097
Milk cows	**.946**	-.132	.176	.048
Milk quota	**.886**	-.121	.233	.098
Capital costs per ha	**.827**	.114	.069	.137
Mountain farm cadastre points	-.054	**.891**	-.075	.020
Sea level	-.107	**.819**	.013	-.096
Value of the soil per ha	-.041	**-.753**	.165	.062
Direct payments per ha	-.042	**.718**	.061	.062
Technical efficiency	.120	-.212	**.835**	-.002
Agricultural income/FWU*	.455	.151	**.687**	.023
Age of the farmer	-.105	.020	.211	**-.824**
Agricultural education	.134	-.033	.351	**.645**

The highest correlations between a variable and the corresponding factor are marked.
* Unpaid family work unit

cluster C. The farm managers in this cluster were significantly younger than those of clusters B and C.

In cluster B the share of mountain farms and organic farms was the lowest (52 and 14 per cent, respectively). Accordingly, and due to their slightly less than average size, they received significantly less direct payments than farms in the other clusters. Although they operated in an environment with little natural disadvantages, their technical efficiency scores were at the average level of all farms in the sample. Farmers in this group had a significantly lower level of agricultural education and were older. Although they achieved a much higher level of technical efficiency than farms in cluster D, their income per unpaid working unit was not remarkably higher.

The differences between clusters become more obvious if we look at the distribution of factor scores in Figure 3. The left panel ("farm size") shows that cluster A comprises the largest farms; the median size of farms in cluster A (horizontal line) is significantly above the sample mean (0); 25 per cent of the farms in cluster A score higher than 2 on the factor "farm size", and another 50 per cent score between 1 and 2 (coloured box). Farms in other clusters are clearly smaller although some 25 per cent of them are bigger than the average farm in the sample.

The most obvious differences between clusters are found on factor 3 ("competitiveness") where the median factor scores are +1.23 in cluster C and -0.71 in cluster D. Striking differences also appear on factor 2 ("natural disadvantage"), with a median value of -0.78 (favourable conditions) in cluster B and +0.58 (unfavourable conditions) in cluster C. From the right hand panel in Figure 3 we conclude that farmers in cluster B are relatively older and/or have received less agricultural education.

The analysis above allows us to characterize the four clusters of specialised Austrian dairy farms as follows:

Cluster A (19 per cent): "large farms"

Farms which are well endowed with farmland and milk quota, operating under favourable natural conditions, with a low share of organic farms.

Cluster B (28 per cent): "conventional farms"

Farms whose size is below average, operating under favourable natural conditions at an average level of technical efficiency, with an older or less educated manager.

Cluster C (20 per cent): "efficient farms"

Farms whose size is slightly below average, operating at a

Table 7: Characteristics of farms in the four clusters
Tabelle 7: Merkmale der Betriebe in Abhängigkeit der vier Cluster

	Unit	Cluster			
		A	**B**	**C**	**D**
Farms	number	42	63	45	72
Utilized agricultural area (UAA)	ha	33.8 [B,C,D]	17.4 [A]	21.1 [A]	19.8 [A]
Proportion of grassland	per cent	61.5 [B,C,D]	74.2 [A,C]	86.0 [A,B]	77.7 [A]
Unpaid family work units (FWU)	FWU/100 ha	7.0 [B,D]	11.3 [A]	9.2	10.7 [A]
Heavy livestock units	head	51.3 [B,C,D]	25.5 [A]	26.6 [A]	25.7 [A]
Milk cows	head	31.7 [B,C,D]	15.8 [A]	17.3 [A]	14.7 [A]
Milk production	tons	194.4 [B,C,D]	83.5 [A]	94.8 [A]	76.0 [A]
Milk production per UAA	tons/ha	6.1 [B,C,D]	5.1 [A,D]	4.6 [A]	4.0 [A,B]
Technical efficiency	score	0.826 [C,D]	0.792 [C,D]	0.919 [A,B,D]	0.682 [A,B,C]
Income from agriculture per FWU	€/FWU	19.813 [B,D]	11.106 [A,C]	21.285 [B,D]	9.825 [A,C]
Income from agriculture	€/farm	41.391 [B,D]	18.833 [A,C]	35.766 [B,D]	18.839 [A,C]
Direct payments (DP)	€/farm	22.974 [B,D]	10.740 [A,C,D]	20.370 [B]	17.081 [A,B]
Income from agriculture excl. DP	€/farm	18.417 [B,D]	8.093 [A,C,D]	15.396 [B,D]	1.758 [A,B,C]
Off-farm income	€/farm	3.449 [D]	6.802	4.327	8.221 [A]
Age of farmer	years	42.6 [B,D]	53.5 [A,C,D]	48.9 [A,B,D]	41.3 [B,C]
Agricultural education level*	per cent	78.6 [B,D]	25.4 [A,B,D]	62.2 [B]	48.7 [A,B]
Share of mountain farms	per cent	66.7 [C,D]	52.4 [C,D]	88.9 [A,B]	94.4 [A,B]
Share of organic farms	per cent	16.7 [C,D]	14.3 [C,D]	44.4 [A,B]	30.6 [A,B]

* Share of agriculturally skilled worker and above.
The high ranked letters indicate differences between the clusters at a significance level of 5 per cent.

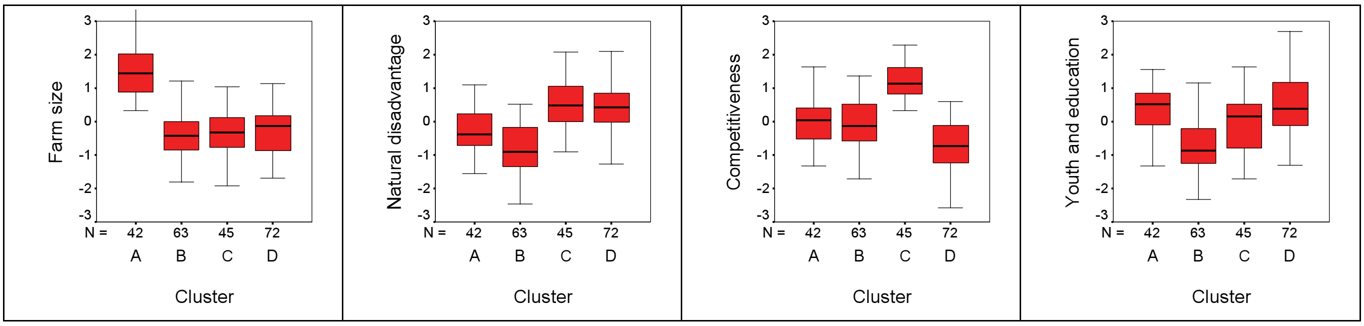


Figure 3: Distribution of factor scores on farm size, natural disadvantage, competitiveness and farmer's youth and education by clusters
Abbildung 3: Verteilung der Faktorwerte für die Faktoren Betriebsgröße, natürliche Erschwernis, Wettbewerbsfähigkeit und Alter bzw. Ausbildung des Betriebsleiters nach Clustern

high level of natural disadvantage at a high level of technical efficiency, partly employing organic practices.

Cluster D (33 per cent): "low input farms"
Farms whose size is slightly below average, operating at a high level of natural disadvantage at a very low level of technical efficiency, where direct payments are decisive for agricultural income.

5 Conclusion

The bulk of Austrian dairy farms seem to operate below capacity as only 16 per cent of the sample examined achieves an efficiency level of 100 per cent, further 10 per cent achieve more than 90 per cent. A similar range can be observed in the panel of approximately 600 Austrian dairy farms who participate in a network on milk enterprise accounting where the best quarter obtains a gross margin per cow about twice as high as that of the lowest quarter (BMLFUW, 2005).

Technical efficiency is not highly correlated with any of the variables available on the farms in the sample. There is no unambiguous relationship between the share of organic farms or mountain farms and efficiency, and neither with the size of the agricultural area. Only the milk quota per farm and per ha of farmland correlate clearly positively with efficiency. Thus we conclude that there may be other variables which affect efficiency strongly, besides the structural characteristics considered in the analysis. F.i. the skill of the farm manager could actually be an important cause for differences in efficiency but there is only data on age (experience) and level of education which do not clearly support this hypothesis.

The variables available can be compressed into the following four factors: Farm size, natural disadvantage, competitiveness and farmer's youth and education. The variation in the data captured by these factors is 74 per cent. In addition, the correlation between the variables and the corresponding factors is also very high. This indicates that dairy farms in the sample can be well described with just a few factors. The fact that agricultural income correlates well only with technical efficiency and farm size is a clear indication that income depends on both: efficiency and the size of the business.

Using factor scores, the sample of farms can be split into four relatively well defined and distinct clusters which we call "large", "conventional", "efficient" and "low input" farms. The presence of a cluster of "efficient" and another of "large" farms shows that business size is only one route to generate income from agriculture. An alternative route is the efficient use of factors of production. Farms in which these alternatives are not or cannot be pursued (clusters B and D) may run into difficulties in the future since they produce little income from farming. For the low input farms, technical efficiency is very low; they strongly depend on agricultural policies and are at risk by modifications of them; in the years 2001 to 2003 their viability relied almost exclusively on direct payments and likely off-farm income. The so-called conventional farms operate at an average level of efficiency although they face favourable natural conditions; their low income from farming comes along with low direct payments. These two types of enterprises make up some 60 per cent of the sample. Since the sample is biased towards the bigger and more specialized dairy farms in Austria, the share of farms whose viability is questionable or depends on off-farm income is likely even higher in the population of some 54,000 enterprises (in 2004).

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