Technical efficiency of organic milk-farms in Germany
- the role of subsidies and of regional factors

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Technical efficiency of organic milk-farms in Germany – the role of subsidies and of regional factors

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This paper investigates the efficiency of organic milk farms in Germany based on data from 1994/95 to 2005/06. Five inputs and one output are analyzed by means of a stochastic frontier production function, allowing for heteroscedasticity and technical effects. The selection of determinants of technical efficiency includes 5 groups of indicators. The analysis is focused on the impacts of farm support of organic farms and of regional factors, that can influence technical efficiency. The results show, that the agri-environmental payments show a negative effect on efficiency. Farms, which receive investment aid, show lower efficiency scores. Finally, the implication for agricultural policy are discussed.

Keywords: Efficiency Analysis, Organic Farming, Agglomerations Effects, Subsidies

1. Introduction

Organic farming system rely on an efficient use of inputs and natural resources. Gubi (2006) could show, that farm success coincides with high efficiency scores. Besides the need for technical efficient farming, there is a different structure of incentives in organic farming systems, since other inputs (as animal fodder or nitrogen in the crop rotation) are scarce. The stronger dependence of the production system on the availability of natural resources could, however, in some cases lead to a wider spread of technical efficiency scores in organic farming (as e.g. in Kumbhakar et al., 2008). Therefore organic farming might be an interesting subject to apply efficiency models.

In particular the role of innovations is especially interesting, since organic farming starts with the conversion period. During this period yields in grain production in Germany are 40% lower than with conventional production (Nieberg, 2001). Furthermore, farmers in conversion have to build up knowledge and management capacity in a new technology, which might suppress technical efficiency during the conversion period. The same is true for investments in new technologies, which in the long run can lead to a higher productivity and efficiency but in the short run can cause inefficiency due to the learning process with the new technology.

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As other farming systems organic farming is subject to different policy measures of the 'EU Common Agricultural Policy (CAP)'. With respect to efficiency analysis of policy measures two types of programs might be especially interesting: agri-environmental programs and farm investment-programs. Since 1992 the EU provides different agri-environmental programs to promote organic farming as a environmental friendly farming system (Stolze et al., 2000; Nieberg and Kuhnert, 2006). Recent analysis could show, that before 2005 organic farms in Germany profit on average more from the CAP agri-environmental-payments than comparable conventional farms and less in from the EU direct payments (Nieberg and Offermann, 2006). Due to the last CAP-reform after 2005, some of the specific organic payments in Germany were cut. Nevertheless, the impact of farm payments on the efficiency of organic farms is hardly analyzed.

Besides that organic farmer can participate at general agricultural investment-programs, which support investments in new technologies as animal friendly production systems or efficient production technique. The goal of these programs is not very precise, there might be some windfall gain and empirical data show, that this kind of payments are not very often used by organic farms (Dirksmeyer et al., 2006, 53). Nevertheless these programs might be an appropriate aid to overcome e.g. the conversion period.

The following paper will discuss the technical efficiency of organic milk farms in Germany with a focus regional determinants of technical efficiency and on the two policy measures.

2. Literature Survey

A very extensive literature deals with the determinants of technical efficiency in farming in general (Brümmer and Loy, 2000; Balmann and Czasch, 2001; Curtiss, 2002; Davidova and Latruffe, 2007; Abdulai and Tietje, 2007; Kumbhakar et al., 2008) and have identified

- farm structure and location factors,
- management capacities and human capital,
- institutional choice and
- market orientation and subsidies

as important determinants for technical efficiency.

In the recent past there have been some studies, that investigate the technical efficiency of organic farms. Oude Lansink et al. (2002) find that organic farms in Finland are closer to their frontier but use a less productive technology. However, the selection method for this kind of farm comparison is not discussed in the paper. According to (Offermann and Nieberg, 2001) the selection of 'comparable conventional farms' requires a proper selection. Another study of organic farms in Finland investigates dairy farms in conversion (Sipiläinen and Lansink, 2005). Results show that the learning process after conversion period takes 6-7 years. Tzouvelekas et al. (2001) analyze organic olive production in Greece and find that organic olive farms are more technically efficient than conventional olive farms. Another study on organic Greece olive producer could show, that farms with more innovative techniques on their farms show better efficiency results. By means of an innovation-index, the study could show, that there is scope for improvement even for farms, that haven't used new technologies yet (Karafillis and Papanagiotou, 2008).

Gubi (2006) investigates the efficiency of organic farms in Germany. Farm profitability measures for organic farms and efficiency scores are found to be strongly correlated. The results for dairy farms indicate that family labor, stocking density and area under legal production limitations affect technical efficiency. Low stocking densities and high shares of family labor increase, while high shares of area under limitations decrease technical efficiency.

A related study (Francksen et al., 2007) investigates the impact of farm specialization. (Lohr and Park, 2006) analyze the technical efficiency of organic farms in USA based on a sample split according to experience with organic farming (more or less than 5 years). Farmers in conversion are found to be less efficient than experienced farmers. The question of system comparisons has recently been discussed by (Kumbhakar et al., 2008).

They used a SFA-technique combining a Cobb-Douglas production function with an inclination to convert, which depends on efficiency. Adoption of organic farming techniques is mainly influenced by efficiency and subsidies. Although some authors find that East German farms on locations with low soil quality (which might show up as lower technical efficiency) are more likely to convert to organic farming (Schulze Pals, 1994; Köhne and Köhn, 1998), there exist other drivers for the decision to convert. Many studies investigate the attitude of farmers towards organic farming. Economic reasons to convert are quoted very often and efficiency might be one of the economic reasons, but not all of them. Some of the reasons to convert to organic farming are political attitudes or ecological concerns (Rahmann et al., 2004). Hollenberg (2001) argues that the decision for organic farming is determined by the personal attitude of the farm manager towards the new farming system. The personal willingness to learn and risk-behavior of farmers as drivers for or against a conversion to organic farming might be added here (Musshoff and Hirschauer, 2008; Serra et al., 2008).

From the rather heterogeneous results in the literature, we summarize the determinants of technical efficiency in organic farming into five categories:

1. **Management capacity:** Farmers with **lack of specific agricultural education** are expected be less efficient. High **expenses for advisory services** should exert a positive influence on efficiency, farms **in conversion to organic farming** might be less efficient since farmers are learning to apply a new technology (Lohr and Park, 2006).
2. **Farm structure:** Soil quality (measured in EMZ/ha[1]) has a positive impact on efficiency (Gubi, 2006). The **share of grassland area** in total agricultural area could lead to a lower efficiency in a single output framework because of higher production of cash crops. This variable might on the other point at a highly specialized and therefore efficient milk-production. From a high **milk quota** we would expect a similar effect. The **share of equity** could affect technical efficiency in both directions (Davidova and Latruffe, 2007), depending on wether agency theory (monitoring) or credit evaluation issues (lender aversion against risky credits) dominates.
3. **Institutional choices:** Farms in **legal forms other than individual ownership** might face higher internal transaction costs but might also economize on inputs in the production process. Opting for a **regular sales taxation** (thus forfeiting the privilege for simplified sales taxes[2]) makes only sense for farms which had major investments in the recent past, which in turn should lead to higher technical efficiency.
4. **Policy support:** The volume of **environmental payments**[3] received for the organic farming scheme might indicate stronger reliance on policy which, in turn, might be the preferred choice for technically less efficient farms. On the other hand, most

[1]*Ertragsmesszahl (EMZ)* is a measure of soil quality based on various characteristics of each plot.

[2]According to the German 'Value-Added-Tax Act' (Umsatzsteuergesetz) farms can use a simplified value-added-tax system, where sold agricultural products are taxed with 9% (instead of the regular tax of 7%). This taxation mode is made without compensation for paid tax for inputs, which are taxed with 7%/16%.

[3]Organic farms receive per hectare premia according to the agri-environmental programs, which were offered by the EU (see EU-VO 2078/92 and EU VO 1257/99

of the subsidies are paid for direct environmental services which might be most attractive for farms which are technically efficient in the provision of these ecosystem services. **Investment aid** is used by farms, who invest in a new and potentially more efficient technology. We can expect a lower efficiency due to an adjustment to the new technology as a short term effect. However farms which receive investment aid should theoretically be in the long run more efficient.

5. **Regional variables:** Information on farm location at the district (Landkreis) level was matched with various regional variables. We distinguish primary agglomeration (**regional share of organic farmers**) and secondary agglomeration effects (**distance to the closest organic dairy**), where both effects are expected to have a positive effect on technical efficiency. A regional dummy for districts in North, Central and East Germany captures competitive advantages in organic farming. Hemme et al. (2004) by using the IFCN-framework[4] identify east German farms as being competitive even in an international comparison. The local election results of the green party might show a socio-economic environment, that potentially supports organic farming and that might lead to a higher efficiency.

3. Methods and Data

3.1. The Frontier Model

The framework of Stochastic Frontier Analysis (SFA), defines the frontier of output given inputs as ´best practice'. Dating back to Aigner et al. (1977) and Meeusen and Broek (1977), SFA allows estimating firm-specific technical efficiency conditional on the specification of a production function and distributional assumptions for the composed error term. A model with one output and five inputs might be compactly written as:

$$y_{it} = f(x_{jit}; \beta_j) * \exp\{w_{it}\} \qquad \text{with} \quad w_{it} = v_{it} - u_{it} \tag{1}$$

$$y_{it} = f(x_{jit}; \beta_j) * \exp\{v_{it} - u_{it}\} \tag{2}$$

with the output y_{it} as the sum of agricultural turn over on $i = 305$ farms in $t = 11$ time periods and with $j = 5$ inputs of

x1: agricultural material costs,

x2: other expenses,

x3: depreciation as a proxy for services from capital stock,

x4: agricultural working units per year,

x5: utilised agricultural area in hectares.

The translog functional form is used as a starting point. The composed error w_{it} has two components: The first error term captures stochastic effects (white noise), which are not under the control of the farmer such as weather, luck or unforseen events. It is assumed as identically and independently normal distributed: $v_{it} \sim iidN(0, \sigma_v^2)$.

The second error term, u_{it} depicts the effects of farm-specific inefficiency. There are several alternative distributional assumptions for this error-term (half normal, truncated normal, exponential, gamma are all found in the literature). Although the efficiency estimates depend on the distributional assumption, the ranking of the estimates seems to be rather robust to the choice of the distribution (Kumbhakar and Lovell, 2000, 90). The truncated normal distribution provides a few advantages for modelling, since it allows for a

[4]IFCN: International Farm-Comparison Network, http://www.ifcnnetwork.org/

straightforward incorporation of determinants of technical efficiency via the mode of the distribution, μ, and for heteroscedasticity by using the scaling parameter σ_u. Therefore we used a truncated normal distribution such as $u_{it} \sim iidN^+(\mu, \sigma_u^2)$. It is worth mentioning, that σ_u^2 is in this case not equal to the variance of the one-sided error.

Technical efficiency is then defined as the ratio of empirically observed output $\hat{y_{it}}$ and the maximum feasible output $y_{max} = f(x_{jit}; \beta_j) * \exp(v_{it})$

$$TE_{it} = \frac{\hat{y_{it}}}{f(x_{jit}; \beta_j) * \exp\{v_{it}\}} \tag{3}$$

$$TE_{it} = \frac{f(x_{jit}; \beta_j) * \exp\{v_{it} - u_{it}\}}{f(x_{jit}; \beta_j) * \exp\{v_{it}\}} \tag{4}$$

$$TE_{it} = \exp\{-u_{it}\} \qquad \in [0, 1] \tag{5}$$

3.2. Heteroscedasticity

One of the main assumptions of the stochastic model building is constant variance of both error components, homoscedasticity (Kumbhakar and Lovell, 2000, 116). It might occur, however, that the inefficiency error-term varies according to the size of a farm, since a farm with a high input and output capacity has some scope for variations and therefore more scope for inefficiency (Caudill et al., 1995). This results in a greater variance in the inefficiency term with increasing farm size.

Since the sample of organic farms shows quite a lot of variation, we allowed for the heteroscedastic model specification of (Caudill et al., 1995, 107), where heteroscedasticity is modeled as

$$\sigma_{u_{it}} = \exp\{x_{it}; \rho\}, \tag{6}$$

with x_{jit} as the vector of inputs of i observation in t time-periods.

3.3. Technical Effects Model

The influence of potential determinants of technical efficiency can be estimated in terms of the location parameter μ in the truncated normal distribution (Battese and Coelli, 1995). The location parameter becomes farm-specific according to the following relation:

$$\mu_{u_{it}} = \delta + \sum_{j=1}^{N} \delta_{it} z_{jit} + e_{it} \tag{7}$$

where z_{jit} is a matrix of explanatory variables, (i.e., potential determinants of technical efficiency), δ_j a parameter vector to be estimated that captures the influence of $j = 18$ determinants on the level of inefficiency and $\gamma = \sigma_u^2 / \sigma^2$.

4. Data

We use accounting data for organic milk farms from 1994/1995 to 2004/2005[5]. Table1 describes the input and output variables.

Table 1: Description of the variables

Variable description		Unit	Min	Mean	Max	Std.dev.
Sum of agric. turnover	y	€	8,835.0	157,640.0	2,001,400.0	138,320.0
Materialcosts	x1	€	3,466.0	58,818.0	1,031,200.0	78,051.0
Other expenses	x2	€	3,116.0	31,656.0	365,840.0	27,400.0
Depreciation	x3	€	575.0	35,326.0	383,740.0	30,631.0
Labor	x4	WU/year[1]	0.46	1.86	15.2	1.13
Area	x5	hectares	11.6	63.32	1041.8	81.47

Source: own calculation
1: WU standardized agricultural working units

The selection of farms specialized in milk farming was based on the revenue share: Only farms with more than two thirds of total revenue from grassland farming and more than 50% revenue share in milk production remain in the sample. Monetary variables were deflated using the official price index for agricultural products and for agricultural inputs which are provided annually by the 'German Federal Office for Statistics' (Statistisches Bundesamt, 2006). The candidate variables which were considered as determinants for technical efficiency are described in table 5 (see appendix A). All of them were included in the initial specification of the technical efficiency model.

All input variables were normalized by dividing them by their sample mean except for the linear trend which enters in deviation from the sample mean.

[5]The data were collected according to the standard of the Federal Ministry for Nutrition, Agriculture, and Consumer Protection, and provided by LAND DATA. The data consist of an unbalanced panel with 1,348 Observation from 305 farms in 11 years.

5. Results and discussion

Table 2 shows the results of the basic model:

Table 2: Coefficient estimates

Parameter	Coefficient	T-value	Parameter	Coefficient	T-value
β_0	0.5230	8.02	β_{14}	0.0294	0.62
β_1	0.4621	18.80	β_{15}	- 0.0572	- 1.20
β_2	0.1530	7.85	β_{1t}	0.0166	2.24
β_3	0.1611	8.79	β_{23}	0.0432	1.34
β_4	0.2082	9.42	β_{24}	- 0.0017	- 0.04
β_5	0.0419	1.78	β_{25}	0.1034	2.42
β_{t1}	0.0008	0.23	β_{2t}	- 0.0132	- 2.20
β_{11}	0.2932	5.58	β_{34}	- 0.1299	- 3.47
β_{22}	0.0311	0.61	β_{35}	- 0.0666	- 1.98
β_{33}	0.1325	4.22	β_{3t}	0.0124	2.50
β_{44}	0.0024	0.04	β_{45}	0.0296	0.56
β_{55}	- 0.0648	- 1.03	β_{4t}	- 0.0143	- 1.83
β_{t2}	- 0.0065	- 4.30	β_{5t}	0.0075	1.04
β_{12}	- 0.1152	- 2.88	$\ln v$	- 2.4662	- 13.50
β_{13}	- 0.0413	- 1.21			

Source: own calculation

Most of the estimated coefficients are significantly different from zero at the 5% level, indicating an acceptable fit of the model. The first order estimates β_j in a translog model can be interpreted as elasticities at the the sample mean. The costs for material have the largest impact. If intermediate materials increase by 1%, output grows by 0.46 %. The estimated elasticity of labor (0.22) is larger than has been found for conventional dairy farms (Brümmer and Loy, 2000, estimate a value of 0.03). This is plausible since the labor share on organic farms is higher than on conventional farms, even in labor intensive animal breeding. The other inputs play a less important role.

The parameter $\gamma = 0.86$ leads to a variance composition of 0.70 indicating that a great part of the variation in the error term w_{it} can be explained by inefficiency u_{it}. The mean technical efficiency score is 0.64. Figure 1 shows the distribution of the TE-scores in the whole sample.

The rate of technical change is slightly negative but not significantly different from zero. Other studies report negative technical change for organic grassland-farms (Gubi, 2006). The study of Brümmer and Loy (2000) reports a positive rate of technical change of conventional dairy farms in Northern Germany.

Before discussing the results of the heteroscedasticity- and the technical effects model, some tests for the quality of the model are considered (table 3):

Table 3: Results for different tests for model-quality

Null-hypothesis	Test value	Critical value	Result
$H_1 : \gamma = 0, \rho = 0, \delta = 0$	465.34	29.55[1]	rejected
$H_2 : \beta_{tt} = \beta_{jt} = \beta_{jk} = 0$	164.19	31.41[2]	rejected
$H_3 : \sum \beta_j = 1 \quad \sum \sum \beta_{jk} = 0$	26.52	12.59[2]	rejected
$H_4 : \sum_{j=1}^{5} \beta_j = 1;$	1.32	3.84[2]	not rejected
$H_5 : \delta_0 = \delta_0 \ldots \delta_{22} = 0$	553.35	30.14[2]	rejected
$H_6 : \rho_j = \rho_{t1} = \rho_{t2} = 0$	51.45	14.07[2]	rejected
$H_7 : \delta_{13} = \delta_{14} = 0$	10.54	7.81[2]	rejected
Source: own calculation			

All tests are rejected at the 5% level of significance, only the linear homogeneity-test at sample mean (H_4) can not be rejected. H_1 tests the hypothesis that every farm in the sample is fully efficient and the inefficiency term is not justified. The hypothesis could be rejected, which indicates that some inefficiency on the farms can be found[6] H_2 tests the Cobb-Douglas model-specification, which has to be rejected too. H_3 tests for the linear homogeneity is rejected, but the test for linear homogeneity at the sample mean (H_4) can not be rejected. This result indicates that there is almost constant returns to scale. The mean scale elasticity is 1.0201, 50% of the observed elasticities are between 0.97784 and 1.0687. H_5, and H_6 justify the model-specification with either the heteroscedasticity and the technical effects-model. And the choice of the "subsidy-variables" can be justified by rejecting H_7.

Table 4 show the estimated coefficients of the technical effects model, which will be discussed in the next paragraph.

Farms in conversion show lower TE-scores than regular organic farms. This result meets the expectation, since converting farms run threw a learning period with an expected lower technical efficiency. The agricultural education of the farmer does not seem to have an influence on the efficiency (which surprises a little bit), the same holds for the expenses for advisory services. Both were expected to play a role. Farms with higher soil quality show better performance. Obviously a good soil quality provides better options to increase on farm efficiency. A high greenland-share and a high milk quota have a positive impact on efficiency. Farms who have opted for a simplified taxation show better TE-performance.

The estimated results in the technical effects-model provide many insights into the determinants of efficiency of organic milk farms, the following discussion focuses on two questions:

1. Do regional factors influence technical efficiency? and
2. Which is the influence of subsidies on efficiency of organic farming?

The most coefficients of the regional variables are significant at the 5% level except the election results of the green party. There are regional differences in the technical efficiency. The reference region is Southern Germany. In comparison, the milk-farms in West- and Northern Germany are more efficient. The difference between farms in Eastern and Southern Germany are not significant. This is somewhat surprising, as it contradicts the

[6]Since $\gamma = 0$, the test statistic has a mixed chi-square distribution, therefore we have to take the critical value from Kodde and Palm (1986).

Table 4: Estimated coefficients for the technical effects model

Variable	Parameter	Coefficient	T-value
Constant	δ_0	0.5653**	7.88
No eduction	δ_1	- 0.0380	- 0.16
Advisory costs	δ_2	- 0.0006	- 0.07
Status (organic or in conversion)	δ_3	0.0450**	2.45
Soil quality	δ_4	- 0.0555**	- 4.23
Greenland share	δ_5	- 0.0470**	- 4.31
Milk quota	δ_6	- 0.0161**	- 2.85
Equity share	δ_7	- 0.0040	- 1.04
Institutional choice	δ_8	- 0.0462**	- 2.66
Option for sales taxation	δ_9	- 0.1677**	- 10.70
Agri-env. premia	δ_{10}	0.0071**	2.93
Dummy agri-investment payments	δ_{11}	0.0274*	1.84
regional variables			
Regional share organic farming	δ_{12}	- 0.0313**	- 2.84
Dummy east Germany	δ_{13}	0.1363**	2.53
Dummy northern Germany	δ_{14}	- 0.0622**	- 2.06
Dummy west Germany	δ_{15}	- 0.0801**	- 2.57
Share of green voters	δ_{16}	- 0.0311	- 1.21
Distance to the next dairy	δ_{17}	0.0301**	3.29
Source: own calculation			

findings of (Hemme et al., 2004)), who found East-German organic milk-producers to be more competitive.

The results for the variables 'regional share of organic farms' and 'distance to the next dairy' confirm the impacts of primary and secondary agglomeration: Farms in regions with a high share of organic farms show a higher efficiency. With an increasing distance to the next dairy the efficiency scores become lower. This result supports the theory of an agglomeration effect in regions with a high share of organic milk farms. This might as well occur because farms that are far from the next organic dairy have to sell milk to conventional dairies, which often do not pay organic premium prices.

The results for the agri-environmental payments are significant but show parameters that are close to zero. This indicates first of all that farms with high agri-environmental payments show lower efficiency scores. Since the goal of the agri-environmental programs is not the promotion of efficient or inefficient farms but the provision of environmental goods and services, this result shows that some market distortions (i.e. promotion of inefficient farms) from this type of payment cannot be excluded in the organic milk sector.

16% of the organic farms in the sample participate at farm-investment programs. The average support for these farms is 22,894 €, which shows that organic farms rather use the investment scheme for the 'large investments'. Farms in years after an investment-aid show a lower efficiency performance. In the sample we can only observe 11 years per farm, therefore the mid-term and long-term effects of an investment cannot be analyzed. Therefore the result can only be interpreted as a short-term effect of an investment. Nevertheless farms, who have used the investment-aid seem to perform less efficient after the investment in a new technology. It should be a necessary condition for continuing this type of programs, that at least a positive long-run-effect of these policy measures can be demonstrated, which could not be done by this study. The study of Brümmer and Loy (2000) showed a negative impact of the participation in farm credit programmes on conventional milk farms in Northern Germany. Dirksmeyer et al. (2006) are rather sceptical on the dynamic effect of the programs. According to the authors farm credit programmes have a lack in a precise target description. The authors suppose some windfall gains for farmers, who in any case would have invested. An adjustment of the farm investment programs seems to be adequate in order to avoid market distortion and windfall gains. Since farm-investment programs during the last years were expanded (at least in some of the federal states in Germany) and milk-farms are the biggest group, that use this kind of aid, further efficiency analysis on the long-term effect of these payments should be carried out.

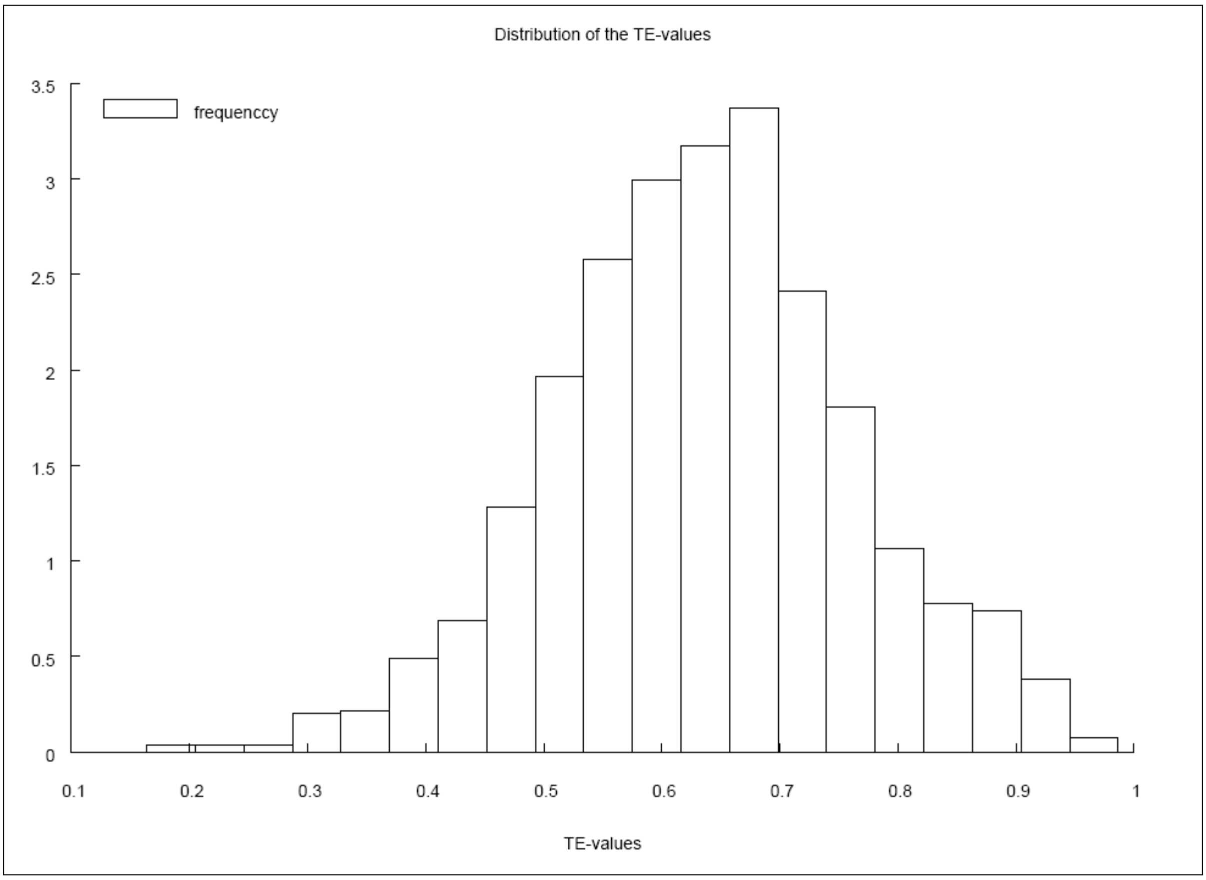

Figure 1: Distribution of the efficiency scores

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A. Description of the used determinants of technical efficiency

Table 5: Variables used as determinants for technical efficiency

Variable	unit	Min.	mean	Max.	Std.dev.
1. Human capital variables					
no education	0/1	0.0	0.08	1.0	0.27
advisory costs	€	0.0	- 3,032.17	- 21,773.1	2,422.46
status (organic / in conversion)	0/1	0.0	0.11	1.0	0.32
2. Farm structure					
Soil quality	EMZ/ha	57.0	3,451.72	9,877.0	1,283.10
Greenland share	%	2.3	61.41	100.0	28.40
Milk quota	kg/year	0.0	14,548.41	335,093.3	31,606.91
Share of equity	%	0.0	78.51	100.0	23.16
3. Institutional choice					
Legal status of the farm	0/1	0.0	0.14	1.0	0.35
simplified sales tax	0/1	0.0	0.81	1.0	0.40
4. Policy support					
Agri-environmental payments	€	0.0	17,186.89	320,738.5	16,943.44
Dummy for agri-investments	0/1	0.0	0.19	1.0	0.39
5. Regional variables					
Share of organic farming	%	0.3	4.33	16.4	2.87
South German farms	0/1	0.0	0.85	1.0	0.36
East German farms	0/1	0.0	0.03	1.0	0.18
Northern German farms	0/1	0.0	0.04	1.0	0.20
West-German farms	0/1	0.0	0.07	1.0	0.26
Regional green voters	%	2.44	6.66	18.3	2.22
Distance to the next dairy	km	4.85	36.12	152.4	23.88

Source: own calculation, n=1348