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DAIRY FARMS EFFICIENCY ANALYSIS BEFORE THE QUOTA SYSTEM ABOLISHMENT

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Abstract: The abolishment of the dairy quota system in the EU is expected to increase competition across dairy farms in Europe. Assuming a common price for milk in the EU, only the most efficient farms will survive in the new environment. The main objective of the research is to compare dairy farms in Germany, The Netherlands and Hungary about their technical efficiency. In the first part of the research, the efficiency is measured by partial efficiency indexes using one dimensional efficiency measuring. In the second part, the Stochastic Frontier Analysis (SFA) have to be used to measure efficiency in a multidimensional space, using six inputs and two outputs.
It appears from the results that the highest efficiency farms are in the Netherlands, and then Germany and Hungary follow thus, we get that the most efficient farms are in the Netherlands with 84% efficient. The German farms are 76% efficient. The Hungarian farms are 68% efficient. With respect the abolishment of the dairy quota system, our results suggest that the Dutch farms are the most efficient, thus probably they will increase their production after the quota system. But because the size of the country we cannot expect dramatic changes in the European Dairy market. The Germans farms efficiency is lower, but their efficiency is also lower, so we won't expect high increase about the dairy supply. The Hungarian dairy sector is not so efficient like the Dutch, and the size of the sector has also small among the European countries, thus if they want to survive the quota system demolishing, they have to increase their technical efficiency.

Keywords: efficiency, dairy sector, data envelopment analysis (DEA), stochastic frontier analysis (SFA)

Background and research problem

The world milk production shows a continuous rising trend since 1961. In 2005 the world total fresh milk production was 541 million tonnes (FAOSTAT 2010). Since the introduction of milk quotas in 1984 the European Union (EU) production has stagnated around 149 million tonnes (EUROSTAT 2010). The milk quota system was introduced to stop over-production in Europe.

The biggest milk producer in the world is Europe (37.08%) including the European Union (26.22%). The second largest milk producer is the American continent (North-, Central-, South America and the Caribbean) which represents 28.65% of the total milk production in the world (FAOSTAT 2010). The biggest milk producer in the EU is Germany (18.98%), the second is France (16.13%), and the third is the United Kingdom (9.83%). The Netherlands and Hungary account for 7.31% and 1.22% of total EU production, respectively (FAOSTAT 2010). Currently, dairy farms in a given EU country are expected to be more or less competitive when compared to dairy farms in other countries. A reason for that is the quota system, which does not allow trading between countries, may protect farmers from international competition. Given that the quota system will be abolished in 2015, this will put pressure on less competitive farms in different countries. The issue of optimal use of resources becomes important.

As noted by Bauer et al. (1998), policy makers are particularly interested in the potential impact of their decisions on performance of firms. A firm that is inefficient is wasting inputs because it does not produce the maximum attainable output, given the quantity of inputs used, and hence the possibility of reducing average costs. Irrespective of whether a developed or developing economy is under consideration, findings from the study of technical efficiency have far-reaching policy implications.

Studying farm efficiency and the potential sources of inefficiency are therefore important from a practical and a policy point of view. On the one hand, farmers could use this information to improve their performance. On the other hand, policymakers could use this knowledge to identify and target public interventions to improve farm productivity and farm income (Solís et al. 2009).

This research focuses on estimating and comparing the levels of technical efficiency (TE) among Dutch, German and Hungarian dairy farms. The estimation of technical efficiency is carried using Stochastic Frontier Analysis (SFA).

The first objective of the research is to measure dairy farms efficiency in Hungary, Germany and The Netherlands. Based on the results, we can assess the potential of dairy farms in the three countries to survive of the abolishment of the dairy quota system. The research questions of this paper are: What are the differences and the similarities in the Dutch, German and Hungarian dairy sectors? The dairy farms in which coun-

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try (the Netherlands, Hungary or Germany) are more efficient compared to their national frontier?

A literature study is performed in two directions. Firstly, literature on the overviews of the world, EU, Dutch, German and Hungarian dairy farming is studied. Secondly, the efficiency measurement techniques in the dairy sector are reviewed.

The next step is the determination of the three countries dairy farm criteria to define what a dairy farm is. Because in most cases dairy farms produce more than one product, we need to define a rule to decide what constitutes a dairy farm. In other words, we need to decide what type of farms will be studied, i.e., specialised, diversified etc. For the analysis we select those farms which has 75% of the revenues coming from the milk producing activity and build up our panel database from 2001 to 2005. These data are available at different sources but mainly the FADN database. For the country overview following database are used: FAOSTAT, EUROSTAT.

To study the determinants of technical efficiency we use the **stochastic** (production, cost, or profit**) frontier analysis (SFA)** (e.g., Heshmati and Kumbhakar 1994; Bravo-Ureta et al. 2008) which is an alternative parametric approach for the estimation of frontier functions using econometric techniques. Kumbhakar and Lovell (2000) argue that a stochastic frontier model seems to be the most appropriate approach in studies related to the agricultural sector because of its ability to deal with stochastic noise, accommodate traditional hypothesis testing, and allow for single-step estimation of the inefficiency effects (Cabrera 2010).

Literature review

The entire cattle population in the world in 2005 was approximately 1372 million heads (FAOSTAT 2010). The biggest cattle livestock raising region was the American continent (503 million cattle; 37%), but most of the cattle was for beef production and not for dairy cows.

The world milk production shows a continuous rising trend since 1961. In 2005 the world total fresh milk production was 541 million tonnes. Since the introduction of milk quotas in 1984 the EU production stagnated at around 149 million tonnes. The milk quota system was introduced to stop overproduction in Europe. Since 1984 there have been further reductions in quota of around 9%. The world milk production in 2005 is 541.34 million tonnes, of which the EU 25 was 149.26 million tonnes (FAOSTAT 2010).

The biggest milk producer in the world is the European continent (38.74%), including the European Union (27.57%), the second largest milk producer is the American continent (North-, Central-, South America and the Caribbean) which represents 28.52% of the total milk production in the world. The differences could be attributed to the size of the continent, but this may not be the only reason. The most prominent factors are: how many resources are available for milk production and how efficiently are these resources used. Another factor that is really important is the government policies in the different continents. We already mentioned the European milk quota, which restricts production or the subsidies connected to milk production.

The total EU dairy cow population is 22.92 million heads. The biggest dairy livestock placed in Germany, 4.16 million dairy cows (Figure 1), which presents 21.15% of the whole European dairy livestock. Other big dairy raising countries are France (17.00%) and Poland (12.02%). The Netherlands and Hungary present 6.48% and 1.24% respectively.

As we can see in the previous Figures the biggest dairy livestock, keeping countries are Germany, France and the Poland, but if we see the ratio of these countries' livestock and milk production, we can be surprised. The biggest milk producer in the EU is Germany (19.06%), the second is France (16.67%), but in the third place is the United Kingdom, and not Poland. The reason for this is that some countries use livestock-intensive technologies rather the livestock extensive technologies, which refer perhaps better production efficiency. For example, the generally accepted productivity index is the average milk production per cow in the UK is 7261 kg/dairy cow, contrast with the polish 4336 kg/dairy cow. The Netherlands and Hungary milk production presents 7.27% and 1.29% respectively of the whole European fresh milk production.

Introducing the Dutch, German and the Hungarian dairy sector

The European Union is the largest milk producer in the world and the EU dairy sector is one of Europe's most important farming sectors. To compare the three countries dairy farms efficiency, it is essencial to examine the structural differences between the countries. Figure 2. presents the distribution of dairy farm livestock according their size in terms of agricultural area (ha) in percentage, which means how much land the dairy farms have in the different countries. The hungarian dairy farms are mainly large in terms of land. 70 percent of the farms use more than 100 hectares of land for their business.

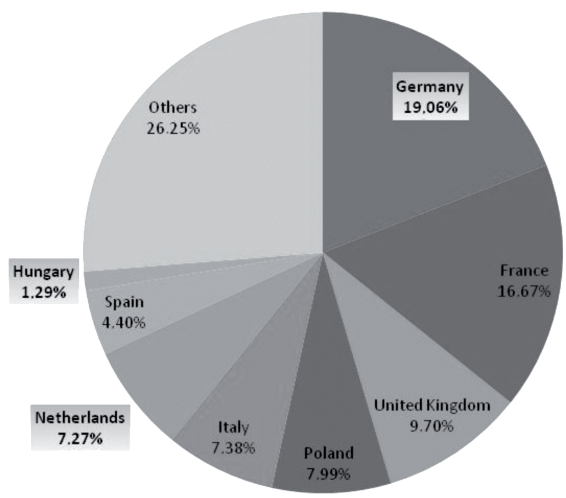

Figure 1. The European Union dairy milk production share in 2005.

Source: EUROSTAT 2010

The German farm's represent a mix of small (less than 50 hectares land), medium (between 50 and 100 hectares land) and big (more than 100 hectares) farms. The Dutch dairy sector consists of many small and middle-sized farms, with the big dairy farms accounting for only 8 percent of the whole land. The Hungarian dairy sector is land extensive in contrast to the Dutch dairy sector which is land intensive. This intensive farming practices can involve very large numbers of animals raised on limited land which require large amounts of food, water and medical inputs. The German dairy sector about the land use is somewhere in the middle of the other two examined countries. This specialisation will be discussed in later sections.

Another way to compare the dairy farms size examines the distribution of dairy farms according their size in terms of dairy cows (DC) in percentage (Figure 3). This figure presents the farms size regarding to the number of dairy cows instead of the agricultural land that the dairy farm use. Figure 3, shows that 73 percent of the Hungarian dairy livestock which means 0.19 million dairy cows live in big farms where there are more 100 dairy cows are kept. The average herd size is 22 dairy cows per holding (EUROSTAT 2010b).

The German farms characteristics are still the same as the previous comparison, so there are several types of farm working in Germany. 55% of the cows, which means 2.25 million dairy cows, live in big farms, where there are more than 100 dairy cows. The average size of the herd is 40.7 dairy cows per holding (EUROSTAT 2010c).

The Dutch farms are more specialised about dairy cows, so they own less land, but they keep the dairy cows in a big (more that 100 DC per farm) farms. 64 percent of the Dutch dairy cows, which means 0.946 million dairy cows live in dairy farms, with more than 100 cows. The average size of the herd is 59.9 dairy cows per holding (EUROSTAT 2010a).

The EU-25 produced around 146 million tones of whole fresh cow milk in 2005 (EUROSTAT 2010), which was 27.5 percent of the world production. The countries studied in this paper, namely Germany, Hungary and the Netherlands together represented around 27.74 percent of the total EU-25 production and 7.65 percent of the total world production (FAO-

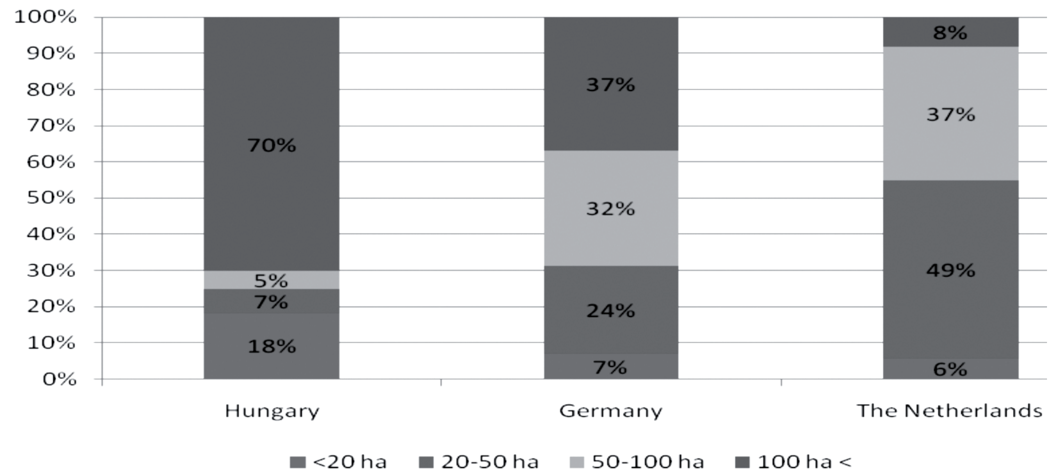

Figure 2. Distribution of dairy farms according their size in terms of agricultural area (ha) in percentage

Source: EUROSTAT 2010.

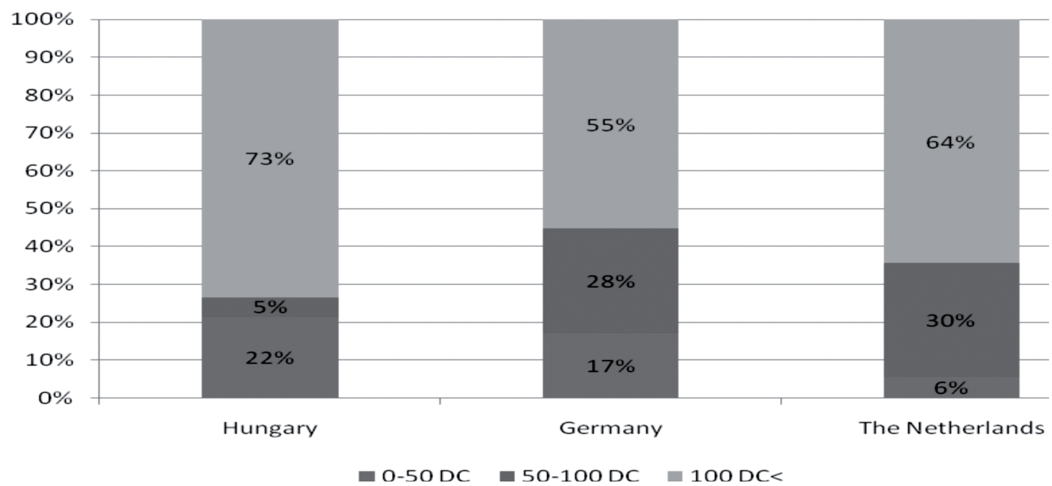

Figure 3. Distribution of dairy farms according their size in terms of dairy cows (DC) in percentage

Source: EUROSTAT 2010.

STAT 2010). According to Figure 4, which represents the milk production in the examined countries over the period of 2001 to 2005, the three countries milk production was relatively stable, as was the EU-25 production in this period. Among the three countries Germany is the largest milk-producing country with 28.49 million tonnes. The Netherlands and Hungary produced 10.98 million and 1.94 million tonnes respectively.

The milk production was stable, but a small reduction was observed on the number of dairy cows (Figure 5) during the examined period. The country with the biggest cow population was Germany (4164 million heads in 2005) and the reduction was approximately 7 percent from 2001 to 2005. The Dutch dairy cows' number was 1486 million heads in 2005, which was quiet stable during the examined period. However a 4.2 percentage decrease occurred from 2001 to 2005. The Hungarian dairy cows' number was 285 thousand heads in 2005, which decreased 17.4 percent from 2001. Hence this was the highest decrease among the three countries.

An interesting observation is that during the examined period the number of cows decreased in all chosen countries, but the milk production was quite stable. This was caused by the increasing performance of the cows. The average milk production per year per cow (Table 1) is the highest in The Netherlands (7615 kg); and lower in Germany (6984 kg) and Hungary (6850 kg).

The milk production per operating cost indicator calculated by the average milk production per farm divided by the livestock-specific operating cost (feeding cost, herd renewal purchases, milk levy and other specific costs) and the non-specific cost (machinery and building upkeep, energy cost, contract work, taxes and other dues, other direct inputs cost). This indicator represents the partial operating technical productivity, which is the highest in the Netherlands and lowest in Germany.

The next indicator is the milk production per total labour index, which shows the labour productivity among the three countries. This indicator is also the highest in the Netherlands, but the lowest in Hungary. About the labour use Hungary is use their labour extensively; on the other hand the Netherlands and Germany use intensively (Table 1).

The milk production per forage area index presents the land intensity of the dairy farms, which is the highest in the Netherlands and lower in Germany and Hungary. The Hungarian result is really low, 46% of the Dutch index, which shows that the Netherlands use extremely high land intensive technology.

The milk production per total input index shows the milk production related with the input costs (operating cost and fixed cost), where the highest result came from Hungary and the lowest from Germany. That index presents the ratio of the

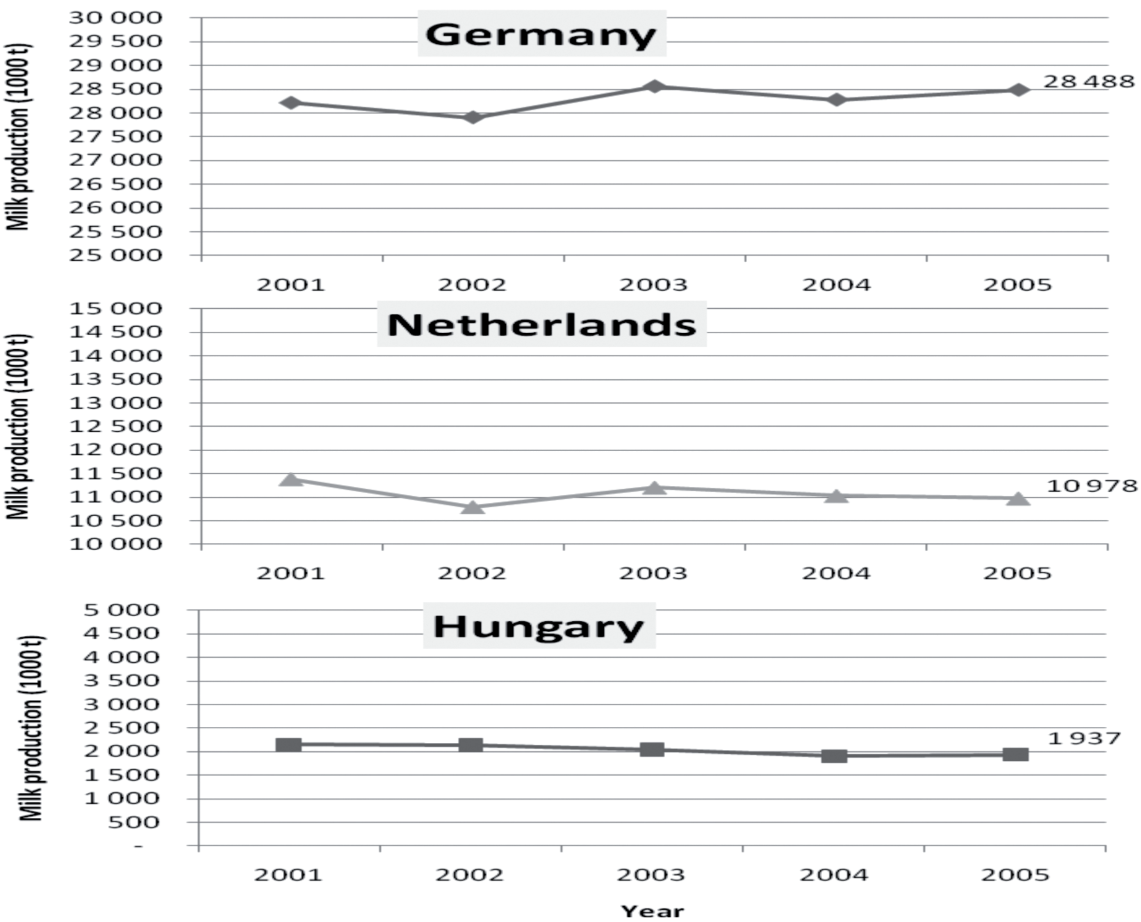

Figure 4. Milk production in the examined countries from 2001 to 2005

Source: EUROSTAT 2010.

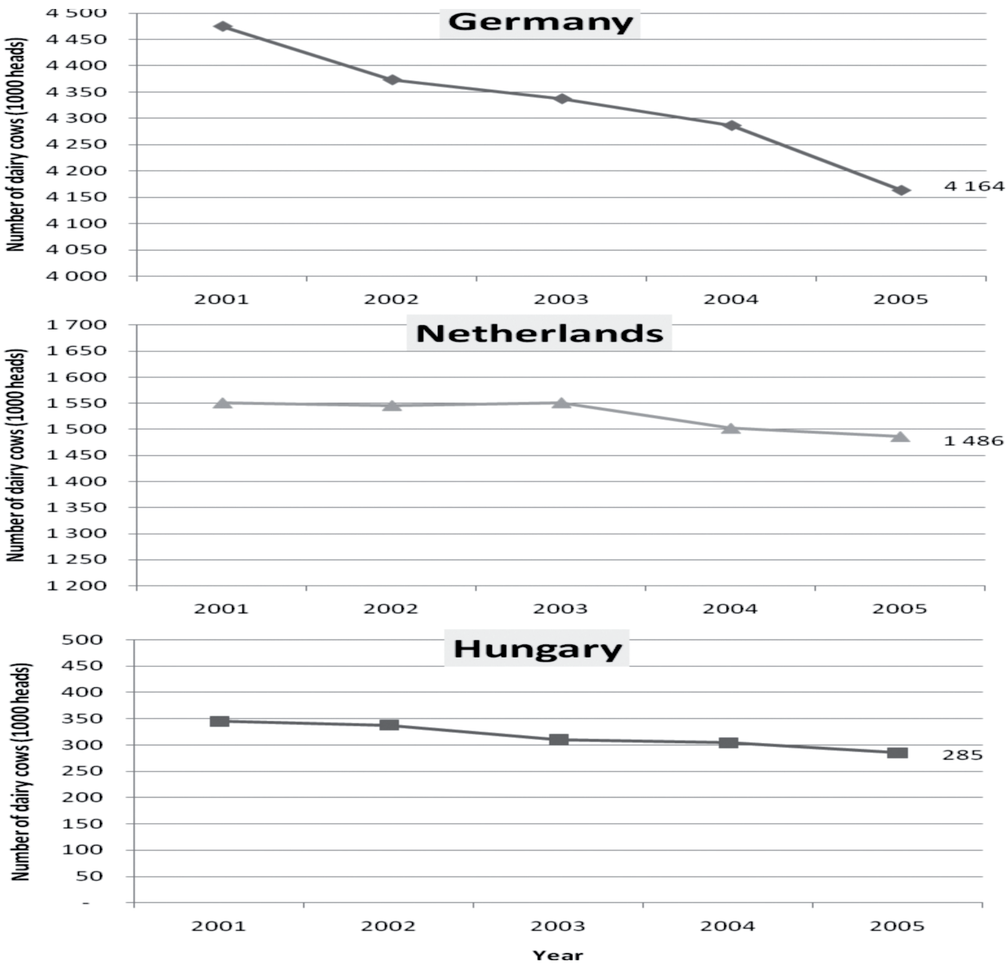

Figure 5. Number of dairy cows in the examined countries from 2001 to 2005

Source: EUROSTAT 2010.

milk production and the total inputs. The last index called milk production per farm shows that the Hungarian farms use less input and produce more output in the farm level, because of the size effect, thus we conclude that the Hungarian farms are larger than the Dutch or the Germans.

Based on Table 1 the Dutch farms are more efficient regarding the technical partial productivity indexes. It seems that after the dairy quota system abolishment the Dutch farmers will increase their production potential and they will reach the best efficiency results among the three countries. After the quota system abolishment the Hungarian farms should have to increase their technical efficiency, otherwise they will decrease their production potential, now it seems that they are producing extensively, but in a big volume per farm. The German farms are lied in between of the other two countries.

So far we measured the efficiency only through partial productivity indicators. Although it is impossible to decide which counties technical efficiency is the highest. So far the different countries measuring was limited by measuring one input and

Table 1. Partial productivity indicators in the examined countries in 2005

	Germany	Hungary	The Netherlands
Milk production per cow (kg/DC)	6984	6850	*7615
Milk production per total operating cost (kg/€)	1828	2900	*3369
Milk production per total labor (kg/AWU)	172464	85374	*333553
Milk production per forage area (kg/ha)	7324	5849	*12572
Milk production per total input (kg/€)	939	*1928	1603
Milk production per farm (kg/farm)	332856	*584814	540356

AWU: annual working unit; DC: dairy cow; *the best result among the three countries

Source: FADN REPORT 2010.

one output performance of the farms. Thus the measuring of the inputs and the outputs was separately, during the following chapters the efficiency performance measuring regard with respect to all inputs and all output as many authors called (Farrel 1957; Begum el. al. 2009; Coelli et. all 2005.; Tauer 1998; Jaforullah and Whiteman 1999; Stokes et al. 2007; Kumbhakar and Lovell 2000; Emvalomatis, 2010) in the literature the *"multiple input and output measurement"*.

1. Measuring efficiency

Measuring the productive efficiency of the dairy sector is important to both the practical experts and the economic policy makers. *"If economic planning is to concern itself with practical industries, it is important to know how far a given industry can be expected to increase its output by simply increasing its efficiency, without absorbing further resources."* (Farrel 1957)

Measuring efficiency is a widely used concept in economics. Economic (or overall) efficiency expressed as a combination of technical and allocative (or price) efficiencies. Technical efficiency is the ability of the farmer to obtain maximal output from a given set of inputs while allocative efficiency measures the ability of the farmer to use inputs in optimal proportions, given their input prices and technology (Begum el. al. 2009; Coelli et. all 2005). There have been several methods to measuring efficiency; the generally used methods are data envelopment analysis (DEA) and stochastic frontier analysis (SFA), which involve mathematical programming and econometric methods, respectively.

Farell (1957) distinguishes input and output orientated measures depending on which factor we assume altering. So in the input orientated measure the input quantities changing without changing the output quantities. The assumed objective is to reduce the input quantities as much as possible, without changing the output quantities.

2. Materials and methods

This chapter firstly introduces the FADN database which has been used for this article. It includes yearly data from 2001 to 2005 for different dairy farms in Germany, the Netherlands and from 2001 to 2008 for Hungary.

In this research we use a database from the European Farm Accountancy Data Network (FADN). The concept of the FADN was launched in 1965, when Council Regulation 79/65 established the legal basis for the organisation of the network. It consists of an annual survey carried out by the Member States of the European Union (EU). The agencies responsible in the Union for the operation of the FADN collect every year accountancy data from a sample of the agricultural holdings in the European Union. Derived from national surveys, the FADN is the only source of micro-economic data that is harmonised; because the bookkeeping principles are the same in all countries. Holdings are selected to take part in the survey on the basis of sampling plans established at the level of each region in the EU. The survey does not cover all the agricultural holdings in the EU, but only those which due to their size could be considered commercial. The methodology applied aims to provide representative data along three dimensions: region, economic size and type of farming (FADN 2010a).

Currently, the annual sample covers approximately 80.000 holdings. They represent a population of about 5.000.000 farms in the 25 Member States, which cover approximately 90% of the total utilized agricultural area (UAA) and account for about 90% of the total agricultural production of the EU. It is expected that for the EU-27, that is including Bulgaria and Romania, the FADN would represent about 6.400.000 farms. The information collected, for each sample farm, concerns approximately 1000 variables (FADN 2010b).

To ensure that this sample reflects the heterogeneity of farming before the sample of farms, Liaison Agencies stratify the field of observation is defined according to 3 criteria: region, economic size and type of farming. Farms are selected in the sample according to a selection plan that guarantees its representativity. An individual weight is applied to each farm in the sample, this corresponding to the number of farms in the 3-way stratification cell of the field of observations divided by the number of farms in the corresponding cell in the sample. This weighting system is used in the calculation of standard results. The database contains farm level data, where the input and output data express with monetary units (€). The dataset organised by yearly for every farm, so this makes the panel dataset (FADN 2010c).

In this research we selected the dairy farms from Germany, Hungary and the Netherlands from 2001 to 2005. We focussed mainly on those dairy farms, whose revenues from cow's milk production are at least 75% of their total revenues for every year.

We use two outputs in our model, the revenues from cow's milk production and the revenues from other outputs. This other output revenues includes revenues from beef and veal and other output production that a dairy farm can produce. For the better estimation to account for the dependence of revenues on inflation, the output revenues and the input costs are deflated with country-wide price indices for each category of products, with prices obtained from EUROSTAT.

The analysis uses six deflated (base year is 2000) inputs categories, which cover the whole input side of the dairy business. These categories are the following:

1. Capital (K) consists of the buildings and fixed equipment like: tractors, lorries, milking machines, cleaning machines, feeding automats.
2. Labour (L) is measured in working hours and includes both family and hired labours.
3. Land (A) is measured in hectares, and includes the total utilized agricultural area (UAA) of the holding. Does not include areas used for woodland, roads, non-farmed areas.
4. Total material inputs (M) includes all deflated farm specific costs, that arise in the dairy business like: seeds and plants, fertilizers, crop protection, crop and livestock-specific cost

(storage cost, marketing cost, veterinary cost) and energy (fuel, electricity, heating) costs.

5. Livestock (S) is measured in standardized livestock unit (LSU) which is the total number of livestock heads on the farm aggregated with European standard weight coefficients. In our case the LSU includes female bovine animals, which have calved and are held principally for milk production for human consumption and other cattle. The weights for dairy cows are 1, while the younger than two years cattle weights are 0.4 to 0.6.
6. Purchased feed (F) is measured in deflated monetary value, and includes purchased feed and concentrates for grazing and home-grown livestock, but excludes the value of feed produced within the farm.

The following table contains the descriptive statistic from the used dataset:

Table 2 prove the same results, as we have seen in the section where the three countries dairy sectors have been introduced. Here the selected farms represent their countries quiet well. In the Netherlands, we can see the highest milk revenue per farm, Hungary is in the second place, but the standard deviation value is three times higher than the other countries, so this average doesn't make a good representation of the whole sample.

The input side of the dataset prove the previous sections statement, which is for instance the Hungarian dairy farms are labor-extensive; on the other hand the Netherlands and Germany use intensively or an other statement wes that the Hungarian dairy sector is land extensive in contrast to the Dutch dairy sector which is land intensive.

In our model the dairy farms produce two outputs, milk and other output, which includes beef and veal, manure and other outputs. This multiple output technology better represented by a distance function rather, than a single production function. This model uses output distance function; because we assume that the farmers try to increase the quantity of outputs from the given quantity of inputs. In the stochastic frontier analysis (SFA), which is a parametric method, this distance function is specified as translog function in inputs (x), outputs (y) and time (t):

$$
\begin{aligned}
\log D_0(x_i, y_i, t) &= \alpha + \sum_k \beta_k \log(x_{ki}) + \sum_k \gamma_k \log(y_{ki}) \\
&+ \frac{1}{2}\sum_k \sum_l \delta_{kl} \log(x_{ki}) \log(x_{li}) \\
&+ \frac{1}{2}\sum_k \sum_l \zeta_{kl} \log(y_{ki}) \log(y_{li}) \\
&+ \frac{1}{2}\sum_k \sum_l \eta_{kl} \log(x_{ki}) \log(y_{li}) \\
&+ \theta_1 t + \theta_2 t^2 \\
&+ \sum_k \varepsilon_k t \log(x_{ki}) + \sum_k \psi_k t \log(y_{ki})
\end{aligned}
\tag{8}
$$

This output distance function (8) has different curvature in the input and output dimensions as well. To capture the effect of technological changes, we introduce the interaction terms as well. So finally the translog function makes every combination of the variables what we have in our models, which are the two outputs, the six inputs and the time.

Finally we have to normalise the model with one output, for instance we can choose the cow milk production as the normalizing output to get the following equation:

$$
-\log y_{cmilk} = \log D_0(x_i, y_i/y_{cmilk}, t) - \log TE_i + v_i \tag{9}
$$

where y_{cmilk} is the cow milk output as a dependent variable; x_i the inputs which are constants, y_i/y_{cmilk} is the function of (log y_{others} – log y_{cmilk}) the outputs, t is the time variables, TE_i is the technical efficiency and v_i is the noise.

The data for all inputs and all outputs are normalized by their appropriate geometric means prior to estimation. That procedure makes the model's parameter estimates directly interpretable as distance elasticises evaluated at the geometric mean of the data.

In this article we use the Barttese and Coelli (1992) time-varying panel model to predict the technical efficiency on an individual firm at the particular time period. Our empirical example is the Dutch and German dairy farms data from 2001 to 2005 and for the Hungarian dairy farms from 2001 to 2008.

Table 2. Variable averages and standard deviations (SD) in the examined countries

	Germany		The Netherlands		Hungary*	
	Average	SD	Average	SD	Average	SD
Milk revenues (€)	104 587	122 106	186 221	105 997	154 573	364 781
Other revenues (€)	32 553	39 187	32 807	25 902	52 265	140 798
Capital (€)	167 258	162 329	196 327	145 140	89 124	144 576
Labor (AWU)	4 085	4 245	4 251	1 753	16 038	32 601
Land (UAA)	63	73	50	29	164	339
Material inputs (€)	44 699	52 518	52 230	26 455	81 718	223 520
Livestock (DC)	92	91	113	61	159	326
Purchased feed (€)	20 448	33 505	33 099	22 308	58 596	148 720

AWU: annual working unit; UAA: utilized agricultural area; *time interval is 2001 to 2008 for Hungary

Source: Own calculation based of the FADN database 2001–2005.

Barttese and Coelli (1992) considered a stochastic frontier production function with simple exponential specification of time-varying firm effects which incorporates unbalanced panel data associated with observations on a sample on N farms over T time periods. The model is the following:

$$Y_{it}=f(x_{it};\beta)\exp(V_{it}=U_{it}) \qquad (10)$$

and

$$U_{it}=U_i^*\{\exp[-\eta(t-T)]\}, \qquad i=1,2,....,N; \qquad (11)$$

where Y_{it} represents the production for the i-th firm at the t-th period, $f(x_{it};\beta)$ the suitable function of a vector x_{it}, of factor inputs associated with the production of the i-th firm in the period t, vector β is an unknown parameter; V_{it} is assumed to be independent and identically distributed random errors; U_i is assumed to be independent and identically distributed non-negative truncations of the normal distribution; η is an unknown scalar parameter, T the set of the time periods, t is the time between the time period T.

Results

We know from SFA model specification section that the technical efficiency of the examined farm is defined by $TE_i=\exp(-u_i)$. This equation provides a basis for the prediction of the farm and the industrial (sectorial) technical efficiency. The industry efficiency is the average of the predicted efficiencies of the farms in the sample.

Table 3 reports the final results of the 3 countries parameter estimates of the first-order terms of the distance function. The full results table is in the Appendix section table A.4. All the estimated elasticties are statistically significant, except the labor parameter in the Netherlands and Hungary. It caused perhaps the lower sample size of these two countries.

The log_oth row results present the distance elasticties considering to outputs as measures of the curvature of the production possibilities frontier. That elasticity values mean, if the other output (which is the beef and veal and manure and other in our model) will increase 1 percent than cause 0.19% increase in the distance function, thus these farms will get closer to the production possibilities frontier in Germany. This elasticity value is 0.10% for the Netherlands and 0.33% for Hungary. The Hungarian elasticity value is the highest if we compare the three countries results respect to the other output, which means that the increase of the other parameter by 1 percent cause the highest increase in the distance function, thus this is the most sensitive countries for this parameter, which represents the beef and weal and other outputs of the dairy farming.

Considering the Hungarian other parameter's elasticity value, the elasticies implied by the linear homogeneity restrictions with respect to the cow milk output (log_*cmilk*) are about 0.67% for Hungary, which is the lowest marginal transformation rate of other output to milk. This number is 0.81% for Germany and 0.9% for the Netherlands.

The negative sign of the first-order terms in the Table 3 means that the increases in inputs push the production possibilities frontier outwards. Every input of the three countries has a negative elasticity of the distance function except the Hungarian labor parameter, but that parameter estimate is not significant statistically. For every countries the largest effect caused by the livestock input (log_*S*) for the outputs. The second important input for the outputs is the total material inputs (log_*M*) for Germany and for Hungary, but for the Netherlands the feed input (log_*F*) is that. The most interesting part

Table 3. Estimates of the Time-varying SFA model's parameters

	Germany			The Netherlands			Hungary*		
log_cmilk	Coef.	Std. Err.	p-value	Coef.	Std. Err.	p-value	Coef.	Std. Err.	p-value
log_*oth*	0.189	0.003	0.000	0.099	0.010	0.000	0.327	0.021	0.000
log_*K*	–0.054	0.006	0.000	–0.043	0.010	0.000	–0.139	0.033	0.000
log_*L*	–0.060	0.011	0.000	–0.022	0.017	0.195	0.083	0.060	0.167
log_*A*	–0.047	0.013	0.000	–0.158	0.025	0.000	–0.115	0.050	0.021
log_*M*	–0.210	0.011	0.000	–0.092	0.021	0.000	–0.228	0.066	0.001
log_*S*	–0.445	0.015	0.000	–0.520	0.030	0.000	–0.527	0.080	0.000
log_*F*	–0.156	0.006	0.000	–0.193	0.015	0.000	–0.122	0.030	0.000
trend	–0.016	0.002	0.000	–0.020	0.003	0.000	–0.004	0.010	0.693
μ	0.207	0.033	0.000	–0.070	0.223	0.753	0.389	0.635	0.540
η	0.001	0.006	0.850	–0.044	0.015	0.003	–0.019	0.077	0.808
$\sigma2=\sigma u^2+\sigma v^2$	0.064	0.008	0.000	0.079	0.040	0.000	0.056	0.006	0.000
$\gamma=\sigma u^2/\sigma^2$	0.882	0.015	0.000	0.953	0.023	0.000	0.154	0.204	0.000
σ_u^2	0.057	0.008	0.000	0.076	0.040	0.000	0.009	0.012	0.000
σ_v^2	0.008	0.000	0.000	0.004	0.000	0.000	0.047	0.011	0.000

Note: * The Hungarian data are unbalanced from 2001–2008

Source: Own calculation based of the FADN database 2001–2005.

is the third dominant input, which is the feed (log_*F*) for Germany; the land or area (log_*A*) for the Netherlands, and the capital (log_*K*) for Hungary. These third dominant inputs can give the varying characteristics of the three different countries dairy efficiency.

The negative trend parameter input means that every county has technological improvement over the years, which push the production possibility sets outwards over the years. Although the Hungarian technological improvement effect statically is not significant.

The scale elasticity of the distance function, which is calculated by adding the distance elastictes with respect to the six inputs are: –0.971 ($p=0.02$) for Germany; –1,027 ($p=0.20$) for the Netherlands and –1,047 ($p=0.08$) for Hungary thus we can assume that the examined countries dairies are operation in the increasing returns to scale part of the technology; except Germany, which dairies are operating the decreasing returns to scale part of the technology. That means for instance 1 percent increases for input side; generate 1.047% increase for the output side for Hungary; 1.027% for the Netherlands and 0.971% for Germany.

The estimate of η is positive for Germany, not suggesting improvements in technical efficiency over time. However, this effect is not statistically significant. For the Netherlands the η is negative, which is suggesting significant increasing in technical efficiency over these five years. For Hungary the η is negative, but not statistically significant.

STATA software parameterises the log-likelihood in terms of $\gamma=\sigma u^2/\sigma^2$. This estimate (0.953) is the highest for the Netherlands, meaning that much of the variation in the composite error term is due to the inefficiency component. The lowest γ is in Hungary (0.154) meaning that much of the variation in the composite error term is due to the statistical noise component and the less observation.

Table 4 presents the final results of the three countries technical efficiency score. The most efficient country comparing with their national production possibilities frontier is the Netherlands with 84%, the second is Germany with 76% and the third is Hungary with 68%. That means that the Hungarian dairy farms can improve their performance the most to reach their maximal reachable production level. The dairy farming technology is different for the three countries, that's why this comparison is more reliable than to assume a common production possibilities frontier for the three countries.

Figure 6 presents histograms of the efficiency estimates for the examined countries. The shape of these graphs suggests a higher variability of efficiency score for Germany. The Hungarian graphs suggest less variability, but it caused the less number of observations. The Dutch left skewed distribution represents more efficient dairy farm comparing to the central skewed Hungarian distribution.

Discussion

The methods in this research were suitable and the most widely used methods to compare dairy farms efficiency for farm and national level. The SFA methods that have been used in this research help to measure technical efficiency with using multiple outputs and multiple inputs. From the literature review we saw that it is hard to compare countries using just the partial productivity indexes, where we can examine the farms efficiency in just one dimension. Using SFA methods, we can examine the farm's technical efficiency in a multidimensional level.

The database of the research has been collected by the European Union's FADN system from 2001 to 2005 and from 2001 to 2008 for Hungary. The small number of observations per year is the reason why the Hungarian database continues more years in the sample. Thus the time horizon of the data is 5 or 8 years, but it can be longer like 10 or 20 years to get more valid results for the comparison. The number of dairy farms in the sample per year is 982 for Germany, 178 for the Netherlands and 23 for Hungary. In the future research it is desirable to increase the numbers of Hungarian dairy farms in the sample as high as the other countries farms number to get more clear view about their management for the comparison. But in the present FADN database for Hungary is not that wide about the specialised dairy farmers. On the other hand it is also possible that the Hungarian farms are not as specialised only for milk production as the Dutch or the German farms.

We can see in our database, that there are only few specialised big farms comparable to the Dutch and German farms, that's one reason for the small Hungarian sample. Although we can see that the farms are relatively efficient in the Hungarian sample comparing their national frontier. Nevertheless to get a better view about the break points of the different countries dairy efficiency, we need to make a SWOT (strength, weakness, opportunity, threats) analysis or examine allocative efficiency for their dairy sector, which require more time, capital and more experts opinions. Thus this can be a good topic for future research.

The usability of these methods for other country, region sector is possible, if they have proper data for the analysis.

Table 4. Comparing technical efficiency for the examined countries

Country	# of Obs.	Mean	Std. Dev.	Min	Max
Germany	4910	0.76	0.12	0.16	0.99
The Netherlands	890	0.84	0.10	0.33	0.99
Hungary*	187	0.68	0.03	0.57	0.81

Note: * The Hungarian data's are unbalanced from 2001–2008

Source: Own calculation based of the FADN database 2001–2005.

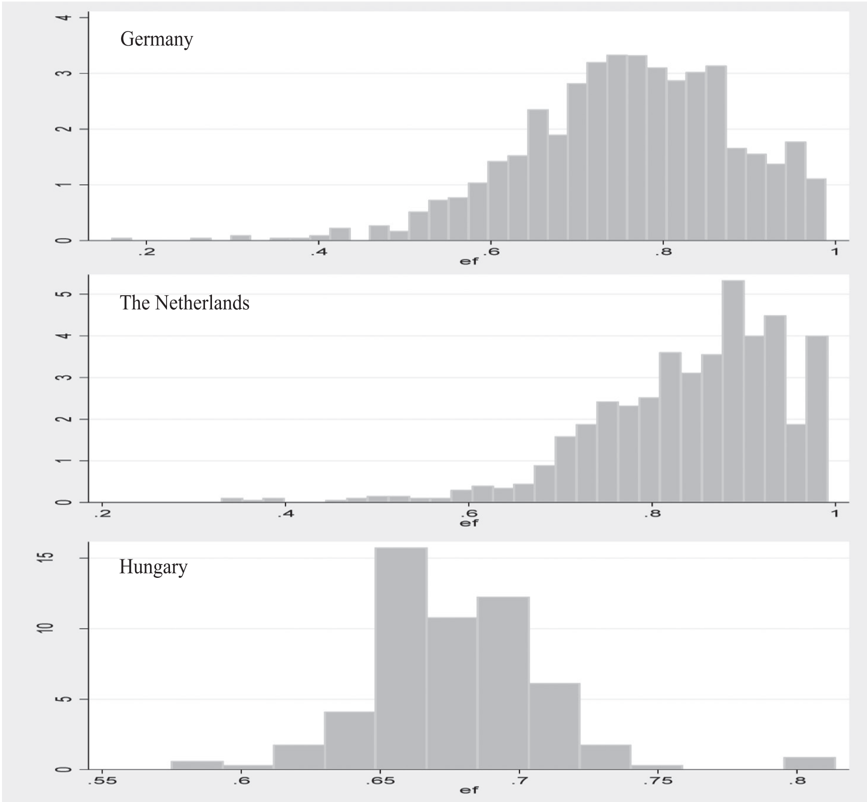

Figure 6. Histograms of Efficiency Score Estimates (using SFA) for Germany, the Netherlands and Hungary

Note: * The Hungarian data are unbalanced from 2001–2008

Source: Own calculation based of the FADN database 2001–2005.

The method is available to compare not just countries but regions inside the counties. The adaptability of this model is wide so we can analyse different sectors in the agriculture and different industrial sectors as well.

Conclusions

The first objective of the research is to measure dairy farms efficiency in Hungary, Germany and The Netherlands.

First we compare the three countries partial efficiency indexes, which mainly comparing ratio of one input and one output. According to the results we can establish the dairy sector characteristic of the three countries. The biggest milk producer is Germany; the smallest is Hungary among the three countries. About the applied technology, the Hungarian dairy sector are land and labor extensive in contrast to the Dutch dairy sector which are land and labor intensive. This intensive farming practices can involve very large numbers of animals raised on limited land which require large amounts of feed, water and medical inputs. The German dairy sector about the land and labor are somewhere in the middle of the other two examined countries.

So far the measuring of the inputs and the outputs was carried separately, the next step was measuring the efficiency performance with respect to all inputs and all output called *“multiple inputs and output measuring”*. The parametric SFA methods that have been used in this research help to measure technical efficiency with using multiple outputs and multiple inputs.

We used two outputs in our models, the revenues from cow’s milk production and the revenues from other outputs. For the better estimation to account for the dependence of revenues on inflation, the output revenues and the inputs are deflated with country-wide price indices for each category of products. The analysis used six deflated inputs categories, which cover the whole input side of the dairy business. These categories were the following: capital, labor, land, total material inputs, livestock and purchased feed.

The European Union’s FADN database has been used for this research which contains data from 2001 to 2005 and from 2001 to 2008 for Hungary, because of the small sample size. The number of dairy farms in the sample per year was 982 for Germany, 178 for the Netherlands and 23 for Hungary. We define specialised dairy farm like those dairy farms, whose revenues from cow’s milk production are at least 75% of their total revenues for every year.

It appears form the results that the Netherlands has highest technical efficiency; the second is Germany and Hungary. But the Hungarian results are less trustable than the others, because of the low sample size. Eliminating the low sample size effect with assuming a common frontier, which decrease the efficiency scores a bit, and it makes the Hungarian results more reliable.

We can assume that if the quota system abolished and assuming a common price for milk in EU, only the efficient farms will survive the higher competition among the countries. In our case the Dutch farms are the most efficient, thus probably they will increase their production after the quota system. But because the size of the country we cannot expect dramatic changes in the European Dairy market. The Germans farms efficiency is lower, although their dairy sector size is bigger than the other two countries, so we won't expect high increase about the dairy supply. The Hungarian dairy sector is not as efficient as the Dutch, and the size of the sector is also small among the European countries, thus if they want to survive the quota system demolishing, they have to increase their efficiency.

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