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The impact of herd health on the efficiency of dairy farms

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Abstract. Maximization of profit is one of the main interests of any farmer. Profit depends on managerial decisions and many economic factors, but also on the health of the herd. Thus, it is important to study how different factors related to herd health impact farms' economic performance. The objective of this paper is to determine how herd health influences farm technical efficiency by comparing Estonian farm data from two periods, the years 2012 and 2017. Typically, the major herd health issues are related to udder problems, followed by reproduction issues and limb disorders. We used the FADN (Farm Accounting Data Network) database and data from Estonian Livestock Performance Recording Ltd. The two-stage mathematical approach was chosen as the research method. In the first stage the DEA (Data Envelopment Analysis) was used to estimate farms' technical efficiency. The output-oriented VRS (Variable Returns to Scale) approach was applied to the data of 64 farms. In the second stage, we used the FRM (Fractional Regression Model) to define which the technical efficiency drivers were among herd health and economic factors. The study revealed that major changes have occurred between the two periods analysed. The main herd health factors influencing farms' technical efficiency are the somatic cell count (SCC) and age at first calving.

Key words: dairy farms technical efficiency, herd health, DEA, FRM.

INTRODUCTION

Impact of diseases on milk production

The success of modern dairy farming lies in the production of high-quality milk. To produce and supply safe and valuable products to consumers, dairy farmers have to ensure a healthy herd, balanced feeding, appropriate housing conditions, qualified labour, as well as successful management, which is a key tool for increasing the efficiency and profitability of a dairy farm (Noordhuizen & Cannas da Silva, 2009). Cow health has a major impact on the quantity and quality of milk. Diseases constitute an important economic issue. They result in a decline in milk production, which in turn causes loss of income and dairy products, increased costs for farmers and loss of food value as estimated by consumers (Fig. 1).

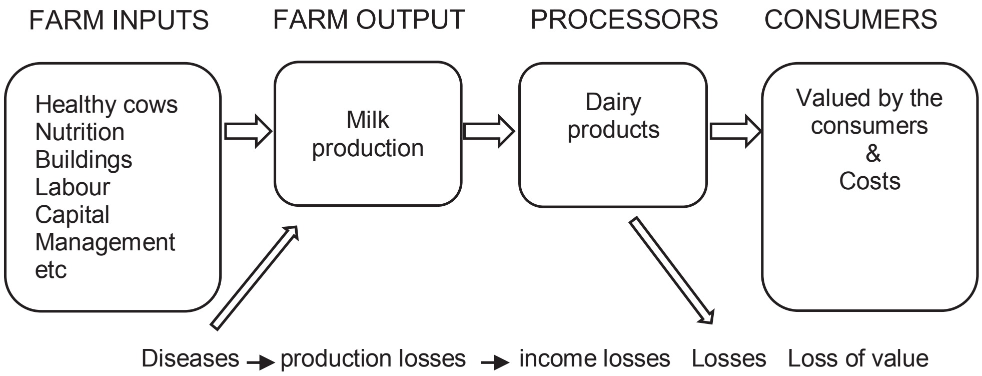

Figure 1. An illustration referring to the impact of diseases as an economic issue at farm and consumer level (adapted from Noordhuizen & Cannas da Silva, 2009).

Changes in dairy farming

The dairy sector has undergone major changes, caused by economic pressures, technological innovation, customer expectations and different regulations for the organisation of production (Barkema et al., 2015). Improvements in breeding, feeding, housing and management have supported the increase in milk production per cow (Kimura & Sauer, 2015). It is found that improved cow comfort and welfare is associated with increased herd productivity and profitability on free-stall farms (Villettaz Robichaud et al., 2019). Cattle housing conditions and housing type play an important role in ensuring the longevity of cows and preventing udder diseases (Ruud et al., 2010; Leso et al., 2019). Due to the shortage of qualified labour, modern technology is the most important helping tool for the farmer. Increasingly advanced technologies and machines help dairy farmers to monitor and enhance the welfare of farm animals and prevent diseases in dairy herds in ways that is difficult to achieve by human effort alone (Barkema et al., 2015; Gargiulo et al., 2017).

The EU accession in 2004 brought a significant change to the dairy sector in Estonia. Estonian dairy cattle are mostly kept in large intensive production farms which use innovative technological solutions and achieve high average milk production per cow. The dairy sector was modernised, switched to a free-stall barn system, new innovative feeding and milking technologies were introduced. (Luik & Viira, 2016; Gaworski et al., 2018; Luik-Lindsaar et al., 2019) Studies show that investments into modern dairy technologies can assure the increased milk yield and therefore sustainability of businesses (Kiiman et al., 2013; Luik & Viira, 2016; Cielava et al., 2017).

Herd health problems

Several researchers have studied dairy herd health problems from different aspects. High milk production means high incomes, but it can contribute to poorer cow health and fertility, resulting in a higher culling rate, most often caused by udder diseases (especially mastitis) and limb diseases (Horvath et al., 2017; Gussmann et al., 2019; Krpálková et al., 2019).

One of the most important characteristics of udder health, milk quality and composition is the number of somatic cells (SCC) in raw milk (Cinar et al., 2015). High levels of somatic cells are associated with mastitis (Özkan Gülzari et al., 2018). Mastitis is a disease that causes economic loss in the form of lost milk, loss of milk quality, premature culling of dairy cows, and treatment costs (Horvath et al., 2017). Özkan Gülzari et al. (2018) found that milk loss increased with an increase in SCC, indicating the effect of disease on production. Geary et al. (2013) pointed out that higher SCC has a considerable negative impact on farm, dairy processor and whole industry profitability. The acquisition of new milking technologies and better milking hygiene ensure higher milk quality, which results in a lower somatic cell count in milk (Sant'Anna & Paranhos da Costa, 2011). The high quality milk with low SCC is crucial in the dairy industry to produce high-quality products (e.g. cheese production), the raw milk quality affects the products shelf-life and better organoleptic properties for the consumer. As a result, producers, processors and consumers have lower food losses and food waste (Østerås & Sánchez Mainar, 2019).

Study conducted by Archer et al. (2013) showed that SCC is negatively associated with lifetime milk production. The key factor to increase revenue is to improving udder health early in the first lactation. Eastham et al. (2018) found that lower calving age is associated with a lower SCC, increased lifetime daily milk yield, improved reproductive performance, and improved udder health.

The number of somatic cells is one component of the price of milk to be sold. Therefore, determining somatic cell counts is important for farm management as the quality of milk is directly linked to the income of the cattle owner (Hadrich et al., 2018). Having healthy cows with healthy udders is a prerequisite for producing quality milk.

Cow health is a complex issue because it is difficult to draw a line between udder, fertility and limb diseases. Furthermore, these diseases are frequently interrelated (Koeck et al., 2014). One disease can easily lead to another, e.g. lameness might cause problems with standing and walking, because the cow lies down more. The desire to lie down frequently may in turn cause udder diseases, including milk fever (higher SCC), and decreased food intake, which can lead to a decreased milk yield (Potter et al., 2018). On the other hand, milk fever is also the biggest source of milk losses (Hadrich et al., 2018).

Increased milk production has a direct impact on cow health. Average milk yield in Estonia has increased from 3,968 kg in 1991 to 9,326 kg in 2018 (Statistics Estonia, 2020). Nor et al. (2014) confirm in their study that the culling rate of cows has grown, which is affirmed by Estonian data. While in 2002, the average herd life of cows in Estonia was 3.0 lactations, it had fallen to 2.4 by 2017 (Annual report 2002, 2017). In 2012, which was the first year of the analysed period, the main culling reasons of cows were udder diseases (21.1%), fertility issues (20.2%), and limb diseases (15.5%) (Results…, 2013). In 2017, the largest number of cows were culled due to udder diseases (20.4%), fertility issues (19.0%), and limb diseases (17.9%) according to Estonian Livestock Performance Recording Ltd. (Results…, 2018).

In the 1990s, herd health and production management programmes (HHMP) were developed in the Netherlands. The aim of HHMP programmes is to improve herd health through routine monitoring, problem analysis and preventive actions (Noordhuizen & Wentink, 2001; Duval et al., 2018; Svensson et al., 2018). The results of HHMP programmes are expected to improve herd health significantly, it has been recommended by veterinarians to Estonian dairy farmers.

The aim of this study is to determine the impact that animal health and economic indicators have on technical efficiency in the sample of 64 Estonian dairy farms in 2012 and 2017.

MATERIALS AND METHODS

The Estonian National level FADN dataset and data from Estonian Livestock Performance Recording Ltd. was used for analysing the same 64 dairy farms in 2012 and 2017. Data from both years was analysed using DEA and FRM, and then compared.

The output and input variables for the DEA analysis were chosen to characterise dairy production (Table 1). In the DEA model, there is one output and five inputs. The output variable is the sales revenue, and inputs are the number of cows, the amount of land, labour, capital, and production costs. These variables are common in technical efficiency analyses (Sipiläinen et al., 2009; Latruffe et al., 2012; Allendorf & Wettemann, 2015). The output and input variables are from FADN. The total sales revenue includes sales revenue from milk and other sales revenue from agricultural products. Sales revenue from animals is not taken into account as it can be considered as sales revenue from assets. The number of cows represents the annual average number of cows in the farm. The land variable is measured in hectares and includes all arable land. The labour variable is measured in hours and includes all working hours, both paid and unpaid. The capital expenditure is equalized to the annual depreciation. Intermediate consumption has been included in this work as production costs.

Output and input variables are in different units to represent the actual use of resources, e.g. labour is measured in hours to reflect the real labour input instead of labour costs, which are sometimes underestimated; the land variable is measured in hectares, which allows to compare farms more fairly than using the value of land or rent taxes.

Comparing the variables in 2012 and 2017 from the first stage analysis, it can be noted that some changes have occurred at farm level. The production output and input variables on average have grown from 2012 to 2017, except the agricultural area, which has decreased slightly (Table 1).

On average, milk yield increased by 1.13 times and sales revenue increased by 1.41 times in the sample farms during the analysed period. The increased sales revenue is a result of increased production volume rather than an increased milk price. The increase of milk price was 9% in 2017 compared to 2012 (Statistics Estonia, 2020). Some authors have found that higher milk yield influences technical efficiency positively (Sipiläinen et al., 2009). Therefore, it is crucial to consider milk yield as the factor of determining technical efficiency.

Capital and intermediate consumption increased by 1.26 and 1.22 times respectively. Prices of goods and services currently consumed in agriculture decreased by 1.45% and prices of agricultural investments increased by 3.63% from the year 2012 to 2017 (Statistics Estonia, 2020). The fact that input variables increased more than input prices suggests that the actual use of inputs has grown from the year 2012 to 2017.

In our sample the average number of cows per farm has increased from 302 to 348 from the year 2012 to 2017. In comparison, in 2017the national average herd size was 150 cows (Results…, 2018). The total number of cows was 19,308 in 2012 and 22,295 in 2017 in our sample. According to the total number of dairy cows in Estonia, approximately 25% cows are represented in our analysis.

Table 1. Descriptive statistics of the variables for Data Envelopment Analysis and fractional regression model

Variables		2012					2017				
	Unit	Min	Max	Mean	St. Dev	Median	Min	Max	Mean	St. Dev.	Median
Output and inputs in DEA											
total sales revenue	thousand euros	25.9	9,970.3	935.7	1,500.0	380.9	32.8	12,607.1	1,322.6	2,060.4	422.8
dairy cows	number	19	1,638	302	366	154	16	1,840	348	438	140
agricultural area	ha	37	5,729	922	1,156	447	39	5,612	912	1,143	366
labour	h	2,150	254,376	38,424	48,902	14,078	2,100	368,925	38,789	57,096	13,150
capital expenditure	thousand euros	3.0	735.4	133.7	159.1	63.3	3.1	792.7	168.1	200.6	64.5
intermediate consumption	thousand euros	29.3	9,510.8	969.8	1,477.0	376.9	40.2	11,317.4	1,185.3	1,783.4	437.4
Variables in FRM											
technical efficiency	score	0.394	1.000	0.803	0.154	0.806	0.514	1.000	0.835	0.135	0.837
milk yield per year	kg cow^{-1}	4,987	9,953	7,667	1,346	7,653	5,426	12,814	8,682	1,728	8,801
milk fat content	%	3.32	4.77	4.11	0.25	4.10	3.42	4.73	4.06	0.26	4.02
milk protein content	%	3.08	3.62	3.36	0.09	3.36	3.19	3.58	3.35	0.08	3.35
somatic cell count	10^3 ml^{-1}	129	609	343	121	325	67	1,070	266	139	267
age at first calving	days	735	1,305	875	124	843	704	1,249	835	107	814
productive period	days	844	2,247	1,317	340	1,210	881	2,817	1,212	315	1,130
age at culling	days	1,613	3,233	2,193	381	2,131	1,644	3,807	2,076	368	1,980
culling rate (udder)	%	0.0	57.1	27.8	15.1	28.6	0.0	50.0	24.0	11.2	22.8
share of EHF	%	0.6	100.0	76.5	32.6	93.4	0.0	100.0	78.4	33.9	99.8
share of own feed	%	18.4	100.0	59.7	19.7	57.8	4.7	95.0	56.3	17.3	54.8
feed costs per milk kg	euro kg^{-1}	0.075	0.292	0.174	0.049	0.171	0.085	0.310	0.171	0.042	0.164

Comparing the variables from the second stage analysis, some important changes can be observed between 2012 and 2017 (Table 1). The technical efficiency score which is a dependent variable in fractional regression increased. The increase in technical efficiency is in line with the economic theory, the farms must be efficient and become more efficient in order to be competitive (Cooper et al., 2007). The SCC decreased by 22.45% from 2012 to 2017. The change is significant and is presumably reflected in decreased treatment costs and increased revenue. The rate of culling due to udder diseases also decreased by 3.8 percentage points, and together with a decreased SCC it indicates improved udder health. Due to the increased milk yield, milk fat and protein content decreased slightly.

The age at first calving decreased by 40 days on average, from 875 to 835 days between 2012 and 2017. Earlier age at first calving should increase the productive period, but due to intensive production, the productive period decreased as well as the age at culling (longevity).

The share of Estonian Holstein breed (EHF) increased, which has been a trend for years. The share of EHF increased by 1.9 percentage points between 2012 and 2017. The EHF has a higher milk yield and lower milk fat and protein content compared to the Estonian Red (Results…, 2019). The above-mentioned decreased milk fat and protein content could be associated with the increased share of EHF.

The share of own feed describes the share of home-grown feed cost out of total feed costs. The share of home-grown own feed decreased by 3.4 percentage points, which means that the share of purchased feed increased. The latter is mainly concentrated feed, which enables to produce a higher milk yield.

Intermediate consumption, which includes feed cost also increased, at the same time feed costs per milk kg decreased slightly. The reason for decreased unit costs could be associated with increased milk yield, which grew more prosperously than feed costs.

We used the two-stage approach to analyse herd health and economic indicators that are potentially connected with farm technical efficiency. Farm performance was evaluated in the first stage using the Data Envelopment Analysis and the result of the analysis is considered as a variable that describes management capabilities. In the second stage, we looked for variables that could affect farm performance.

The output-oriented variable returns to scale model (VRS) was used in the Data Envelopment Analysis to calculate the technical efficiency of dairy farms. The DEA refers to dairy farms as decision making units (DMUs). Production outputs (sales revenue) and inputs (cows, land, labour, capital, production costs) are variables in the DEA model. The DEA compares the output-input ratios of different DMUs on a relative scale and constructs a best practice frontier comparing the best DMUs to others. Farms that determine the best practice frontier were defined as technically efficient, whilst others as technically inefficient, and their efficiency was calculated in comparison to the most efficient farms on the relative scale. Technical efficiency scores were calculated for each farm.

We used the output-oriented model where outputs were maximised and inputs were kept at their current levels (Eq. 1):

$$\theta^* = \max \theta$$

subject to $\sum_{j=1}^{n} \lambda_j x_{ij} \leq \theta x_{i0} \quad i = 1, 2, \dots, m;$

$$\sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{r0} \quad r = 1, 2, \dots, s; \tag{1}$$

$\sum_{j=1}^{n} \lambda_j = 1$; $\lambda_j \geq 0$; $j = 1, 2, \dots, n$.

where *DMUo* represents one of the *n* DMUs under evaluation, and x_{io} and y_{ro} are the i^{th} input and r^{th} output for *DMUo*, respectively. If $\theta^* = 1$, the current input levels cannot be reduced (proportionally), indicating that *DMUo* is on the frontier. Otherwise, if $\theta^* < 1$, *DMUo* is dominated by the frontier (Zhu, 2009).

In the second stage the fractional regression model (FRM) was used. The technical efficiency score from the DEA was the dependent variable and factors that potentially affect technical efficiency are independent variables. The technical efficiency score is within the range of 0 to 1. A model that is suitable for analysing the dependent variable in the DEA framework is the fractional regression model (Ramalho et al., 2010; Ramalho & Ramalho, 2011). We used the one-part cauchit model. The one-part cauchit model was chosen as the proportion of efficient farms is small. The advantage of the second part of the two-part model appears when there is a considerable amount of efficient farms.

The technical efficiency score from the first stage of the analysis was regressed in the second stage fractional regression model to find out the variables that affect technical efficiency.

RESULTS AND DISCUSSION

Results of the DEA analysis

The average technical efficiency has grown between the years 2012 and 2017. The average technical efficiency was 0.803 (80.3%) in 2012 and 0.835 (83.5%) in 2017. The technical efficiency score shows the actual amount of production compared to the potential level of outputs. The results suggest that farmers could have produced 19.7% more outputs in 2012 and 16.5% more outputs in 2017, whilst keeping the inputs at the same level. The number of technical efficient farms was 13 (20.3%) in 2012 and 16 (25%) in 2017.

On average, technical efficiency has increased, but this is not the case for all farmers. We divided the farms into three groups according to their technical efficiency change from 2012 to 2017 (Table 2). Farms whose technical efficiency change was above 0.05 points are in the group with positive change in technical efficiency (PosCh). Farms whose technical efficiency change was in the range of -0.05–0.05 points are in the group with neutral change in technical efficiency (NeutCh). If the farm's technical efficiency decreased by more than 0.05 points, the farm is in the group with a negative change in technical efficiency (NegCh).

Some significant differences emerged from group comparisons. Above all, the group of farmers with positive technical efficiency change had the lowest average technical efficiency score (0.699) in 2012, and the highest (0.882) in 2017. This group hence had the highest positive change and they are the new frontrunners in 2017.

Vasiliev et al. (2011) reached a similar result analysing Estonian dairy producers between 2000–2006. They found that innovators had the lowest initial technical efficiency score and the highest score in 2006.

Table 2. Changes in variables in three technical efficiency change groups between 2012 and 2017

Variables	Unit	Variables increase/decrease (%)		
		PosCh	NeutCh	NegCh
total sales revenue	thousand euros	+621 (+72.9)	+341 (+31.8)	+168 (+20.2)
dairy cows	number	+94 (+29.0)	+32 (+10.9)	+12 (+4.0)
agricultural area	ha	-61 (-5.9)	-27 (-2.8)	+80 (+10.9)
Labour	h	-78 (-0.2)	+3,931 (+11.4)	-4,541 (-10.7)
capital expenditure	thousand euros	+36 (+23.7)	+43 (+37.1)	+20 (+14.3)
intermediate consumption	thousand euros	+276 (+28.6)	+205 (+19.2)	+156 (+19.0)
milk yield per year	kg cow^{-1}	+1,110 (+14.8)	+1,159 (+15.4)	+679 (+8.3)
milk fat content	%	-0.017 (-0.41)	-0.072 (-1.75)	-0.045 (-1.09)
milk protein content	%	+0.018 (+0.53)	-0.024 (-0.71)	-0.009 (-0.26)
somatic cell count	10^3 ml^{-1}	-112.0 (-31.2)	-75.5 (-24.9)	-35.1 (-9.2)
age at first calving	days	-54.7 (-6.3)	-33.3 (-3.8)	-29.3 (-3.4)
productive period	days	-181.3 (-12.5)	-79.0 (-6.2)	-48.4 (-4.0)
age at culling	days	-211.1 (-9.0)	-60.4 (-2.8)	-86.6 (-4.1)
culling rate (udder)	%	+5.4 (+27.1)	-12.0 (-36.2)	-2.6 (-8.7)
share of EHF	%	+2.0 (+2.6)	-0.7 (-0.9)	+5.8 (+8.0)
share of own feed	%	-6.6 (-10.9)	-3.9 (-6.7)	+1.3 (+2.1)
feed costs per milk kg	euro kg^{-1}	-0.022 (-11.8)	+0.011 (+6.9)	+0.002 (+0.9)
number of farms	number	21	26	17

The group with positive technical efficiency change had the biggest growth in sales revenue (+72.9%) and in the number of dairy cows (+29%), whilst their agricultural area decreased, which refers to the intensification of production.

The growth of intermediate consumption and capital expenditure was the fastest in positive and neutral change technical efficiency groups. The changes in intermediate consumption and capital expenditures are associated with better feeding (e.g. total mixed feed ratios) and better housing conditions (new or renovated barns). As a result, milk yield has increased and SCC has decreased by +14.8% and -31.2% respectively, in the group with positive technical efficiency change.

In the farms where the technical efficiency change was negative, milk yield increased by 8.3% and SCC decreased by 9.2%. Additionally, they had smaller agricultural areas (814 ha) and fewer dairy cows (306 cows) compared to the farms with positive technical efficiency change (982 ha and 416 cows).

Farms with negative technical efficiency change had the highest labour use per cow – 144 hours in 2012 and 124 hours in 2017 – which could lead to the lower technical efficiency. At the same time, farmers in the group with positive technical efficiency change had the lowest labour use per cow – 124 hours in 2012 and 96 hours in 2017. Stokes et al. (2007) found similar results analysing labour use. They found that too much labour with too little milk and butterfat production characterize inefficient dairy producers.

The results indicate that high technical efficiency and intensive production led to some negative aspects: the productive period and longevity decreased the most in the group with positive technical efficiency change. Nevertheless, these farms had the highest productive period (1,272 days) and age at culling (2,128 days), as opposed to the farms with negative technical efficiency change where the productive period was 1,169 days and age at culling 2007 days in 2017.

The decrease in the share of home-grown feed was the most pronounced in the group with positive technical efficiency change, yet those farmers' feed costs per kg milk decreased the most (-11.8%). Additionally, in 2012 they had the highest feed cost per milk kg (0.186 eur kg^{-1}), but the lowest in 2017 (0.164 eur kg^{-1}), which can be linked to the scale effect.

Results of the fractional regression analysis

The SCC had a statistically significant negative impact on technical efficiency in 2012. The average partial effect shows that if the SCC increased by 100 x 10^3 mL^{-1}, the technical efficiency would decrease by 0.02 points (Table 3). SCC is an indicator of potential mastitis, and is associated with reduced animal health (Telldahl et al., 2019). Mastitis is one of the most frequent diseases and causes of loss of income and milk, and increased costs (Horvath et al., 2017; Hogeveen et al., 2019). Cinar et al. (2015) found that high SCC has a negative effect not only on milk yield but also on milk composition and quality. Halasa et al. (2009) found that fat and protein production were also affected negatively by a new case of subclinical mastitis. Technical efficiency studies have found that higher SCC predicts inefficiency or has a negative impact on technical efficiency (Allendorf & Wettemann, 2015; Luik-Lindsaar et al., 2018; Luik-Lindsaar et al., 2019). Thus, all kind of preventions of mastitis (Barkema et al., 2015; Gargiulo et al., 2017) together with better housing conditions (Ruud et al., 2010; Villettaz Robichaud et al., 2019) are important factors to increase income and reduce costs, which in turn leads to increased technical efficiency. The SCC had no significant impact on technical efficiency in 2017.

Feed costs per kg milk (FeedEuroKg) had a significant negative impact on technical efficiency in 2012. According to the average partial effect, if the feed costs increased by 0.01 euro per kg milk, the technical efficiency would decrease by 0.0123 points (Table 3). The value of feed costs per kg milk contains information on both the cost and milk production: the higher the milk production, the lower the cost per unit of milk. A healthier herd has a better dry matter and nutrient intake therefore every euro spent on feed produces more milk and revenue in healthier herds. Feed cost per kg milk decreased slightly (-1.72%), but average milk yield increased markedly (+13.2%) in 2017 compared to the year 2012. Considering the increase in milk yield, it would have been reasonable to expect a greater decline in feed costs per kg milk. One of the reasons why the latter was not the case was the increased share of purchased feed, which is mainly concentrated feed at a higher price. The share of home-grown feed (ShoOFeed) had a significant negative impact on technical efficiency in 2012 and 2017, which means that a higher share of purchased feed (concentrated feed) helps to achieve higher technical efficiency through higher milk yield. Therefore, it is important to achieve lower production costs through focusing more on having a healthier herd with better food intake and higher milk yield.

Table 3. Factors affecting technical efficiency of dairy farms according to the results of the one-part cauchit model in 2012 and 2017

Variables	2012					2017				
	estimate	Std. Err	*t*-value	Pr(>|*t*|)	Average partial effect	estimate	Std. Err	*t*-value	Pr(>|*t*|)	Average partial effect
Intercept	-6.451	6.827	-0.945	0.345		7.947	6.007	1.323	0.186	
Milk	0.000	0.000	0.955	0.340	0.0000	0.000	0.000	0.179	0.858	0.0000
Fat	1.313	0.964	1.362	0.173	0.1412	0.981	0.745	1.317	0.188	0.0820
Protein	2.128	1.258	1.692	0.091 *	0.2288	-1.255	1.894	-0.662	0.508	-0.1049
SCC	-0.002	0.001	-1.830	0.067 *	-0.0002	0.000	0.001	-0.038	0.969	0.0000
AgeFirstCalv	-0.001	0.001	-1.199	0.231	-0.0001	-0.005	0.002	-2.298	0.022 **	-0.0004
ProdPer	0.000	0.002	-0.119	0.906	0.0000	0.001	0.002	0.573	0.567	0.0001
AgeCull	-0.001	0.002	-0.402	0.688	-0.0001	-0.001	0.002	-0.383	0.702	-0.0001
ShoCullUdd	0.005	0.008	0.674	0.500	0.0006	-0.030	0.019	-1.612	0.107	-0.0025
EHF	0.008	0.003	2.323	0.020 **	0.0008	0.010	0.005	2.221	0.026 **	0.0008
ShoOFeed	-0.017	0.007	-2.370	0.018 **	-0.0018	-0.028	0.011	-2.629	0.009 ***	-0.0023
FeedEuroKg	-11.479	2.707	-4.240	0.000 ***	-1.2342	-3.004	2.800	-1.073	0.283	-0.2510
Number of observations				64					64	
R^2				0.534					0.476	

***; ** and * denote coefficients which are significant at 1, 5 or 10%, respectively-

The share of EHF had a significant positive effect on technical efficiency in 2012 and 2017. The average partial effect showed that if the share of EHF increased by 1%, the technical efficiency would increase by 0.0008 points.

One of the factors that determines a dairy herd profitability is the productive period, which depends on the age at first calving. The age at first calving (AgeFirstCalv) had a significant negative impact on technical efficiency in 2017. The age at first calving decreased by 40 days from 2012 to 2017. The average age at first calving was 27.4 months in 2017 in our sample, which is slightly higher than the Estonian average (25.8 months) (Results…, 2018). According to Froidmont et al. (2013), the optimal age at first calving is in the range of 22–26 months. Reducing the age at first calving can lead to an increase in technical efficiency. The decrease in age at first calving by 1 month increases technical efficiency by 0.0122 points.

The decreased SCC and age at first calving are positive changes in Estonian dairy herds according to our sample farms, whereas the productive period (ProdPer) and longevity (AgeCull) are factors that need to improve. The share of culling caused by udder problems (ShoCullUdd) has no significant impact on technical efficiency.

The dairy cattle information system Vissuke is a good tool for recording and analysing herd health at farm level for Estonian dairy farmers (Lillik, 2015). The NGO Piimaklaster, in cooperation with the Estonian University of Life Sciences, has carried out an HHMP project (2017–2019) whose results show that systematic work on livestock health improves animal health and productivity, as well as economic profitability of production through this (Mõtus et al., 2019). Dairy farmers have to pay attention to cow health in order to remain competitive and ensure profitability.

CONCLUSIONS

Herd health is an important issue for any farmer as it influences the farm's revenue, costs and technical efficiency. Increased consumer awareness of healthy food and animal welfare requires farmers to produce high quality raw milk. Therefore, today it is not only crucial to focus on quantities but to also have an increased focus on the high quality of raw milk.

One indicator of udder health is the number of somatic cells in raw milk. High level of SCC characterizes herd health and is associated with losses in both the quantity and quality of milk. The present study showed that a high SCC has a negative impact on farm technical efficiency. High SCC increases costs and decreases revenue, therefore it directly influences farms' economic performance. It emerged that decreasing the age at first calving increases technical efficiency. Therefore, reducing the SCC and age at first calving are the key factors to increasing technical efficiency.

To ensure healthier herds, farms' technical efficiency, sustainability of production and catering to consumers' expectations, it is essential to manage farms consciously and include herd health programmes into the farm management process.

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