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Measuring Technical Efficiency and Returns to Scale in Finnish Food Processing Industry

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Abstract

This research aims to understand the major reasons causing efficiency losses in the Finnish food industry from 1999 to 2012. The paper identifies the sectors with the lowest level of technical and scale efficiency. Technical efficiency and return to scale are measured using the Data Envelopment Analysis approach. The sectors technical efficiency and scaling possibility are described using the VRT, CRT, IRT, DRT models. The relationship between input costs and the output was analyzed by Pearson's correlation coefficients. This study contributes with a scientific assessment of the productivity and efficiency of food processing sectors. Four underperforming sectors were identified. The correlation analysis shows differences in the impact of various input costs among the sectors efficiency performance. The research results are valuable for policy makers, managers and processing company owners.

Keywords: Data Envelop Analysis (DEA); Variable Return to Scale (VRS); Constant Return to Scale (CRS); Technical Efficiency (TE); Food Processing Industry.

1. Introduction

The Finnish food processing industry (FPI) makes significant contributions to the national economy. It has the third rank among others manufacturing industries in Finland [1].

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Its turnover is about 10 billion euros, which is 7% of the whole manufacturing industry. It employs 37 200 persons, which corresponds to 11% of the entire Finnish manufacturing labor [2]. As described by Marttila, J. (1996), the Finnish FPI is specialized on producing intermediate and edible products, which are sold to both trading sectors and households [3]. There are a total of nine sectors of the Finnish FPI, listed in table 1. According to the value added results from 1999 to 2012 the average share of the meat sector is 23% of the Finnish FPI. The second largest food processing sector is manufacturing of bakery and farinaceous products with an average share of 19%. In terms value added, the manufacturing of dairy products takes the third rank with an average share of 15% [2].

The overall Finnish FPI has faced a number of challenges related to competition and efficiency. Strong competition from foreign companies has affected the Finnish FPI after Finland became EU member [4, 5]. In Viitaharju, L. (2008) study about challenges of the Finnish food SMEs is stated that the largest issue is urbanization and centralization of trading, which increases transportation costs. The urbanization tendency reduces the supply of skilled workers available in rural areas, in which Finnish food enterprises are mainly located [6]. After 1995 the income of food processors has been decreasing [7], along with the amount of labor and the number of enterprises. These changes are highly significant in the manufacture of dairy, grain mill products and meat processing sectors. The higher cost of raw materials is a key factor contributing to these reductions [8].

This study mainly addresses two research questions: Firstly, what are the losses through technical inefficiency in the Finnish FPI. Secondly, what is the optimal scale size of each Finnish FPI sector in order to reach the best economical performance? Both questions apply to the study period from the year 1999 to the year 2012. Measuring return to scale (RTS) and technical efficiency (TE) contributes to the production analysis of the Finnish FPI.

The paper consists of five sections. The first section reviews literature related to the topic. The methodology section describes the methods applied to the research and data collection. The results and discussion section presents the results of measuring RTS and TE in the nine FPI sectors, and it discusses the factors affecting their optimal level. The conclusions section summarizes the results. The last section provides recommendations.

1.1. Limitation of the Study

In this study the DEA method is utilized for analyzing RTS and TE. Other approaches, such as Stochastic frontier analysis (SFA), are out of the scope of this paper. There is no certainty about unexpected noise from the data collected. The data for user cost of capital is not publicly available at the sector level (table 1). Consequently, this study excludes the measurement of allocative efficiency, which could be useful for understanding the competitiveness issue in the food domestic market. Lastly, the data for the input and output variables were only available for the years from 1999 to 2012 (table 3).

1.2. Background of the Study

There is extensive literature concerning the measurement of efficiency in food industries with the DEA approach. According to Bogetoft, P. (2012), the DEA technique has been introduced since the late 1970's, and from that time it has been actively used for measuring economic performance [9]. However, the DEA models have not been extensively applied for measuring scale and technical efficiency in the Finnish FPI.

A comparative analysis was curried out by Oude Lansink, A., et al. (2002) using the DEA approach to analyze the differences between organic and conventional Finnish farms. It was found that the constant return to scale (CRS) score of organic crop farms is greater than the same score for conventional farms (0.91 for organic and 0.67 for conventional). It was concluded that organic crop farms could reach an optimal CRS level through reducing their input use by 9%. Conversely, conventional crop farms needed to reduce its input use by 33% to achieve the same goal. These results indicate that organic crop farms could increase their efficiency by 5% and conventional ones by 8%. Their comparative analysis of CRS efficiency of the Finnish livestock sector produced similar results. From 1994 to 1997, organic farms were more efficient than conventional ones, despite their lower productivity level. However, their lower productivity score was compensated by a higher score of technical efficiency [10].

The technical efficiency and return to scale measurements have been used for proposing improvements to the FPI of different countries, in terms of structure, financing and processing plan [11, 12]. The proposed recommendations are relevant for agricultural policy makers, managers and owners. Ali et al. (2009) analyzed the Indian FPI using the DEA approach. The scale efficiency of the Indian FPI had a yearly average of 0.870 from 1980 to 2002. From this result, Ali et al. (2009) concluded that the technical efficiency of the industry could increase by 10% through improving scale efficiency. Furthermore, their results highlighted the changing score in return to scale from increasing (IRS) to constant (CRT), and to decreasing (DRS). The authors made multiple recommendations to Indian policy makers, processors and managers. These include increasing the investments in sectors with optimal score of IRS and CRT, in order to help processors to reach higher profits. Additionally, modernization and reorientation of the production performance was suggested for food processing sectors with DRS production plan. Furthermore, the factors affecting the Indian FPI efficiency during the period were analyzed according to the input slacks estimation. High expenses related to materials, energy and capital were highlighted as the main cause of low scale efficiency levels. Based on the results of this factor analysis Ali et al. (2009) proposed an increase in capacity utilization, particularly with regard to materials, energy and input capital [13].

In the case of Finland, input costs have been an influential factor in the efficiency of its FPI [6]. In addition, policy makers realized the importance of input cost reduction for the growth of the Finnish agricultural market [14]. Despite of high relevance, the TE and RTS of Finnish FPI is not thoroughly studied in the literature.

2. Materials and Methods

This paper studies the efficiency of the nine Finnish FPI sectors. Each sector has a corresponding Standard Industrial Classification, as presented in table 1.

Table 1: Classification and description of the Finnish FPI sectors

Standard Industrial Classification codes and Finnish FPI sectors description	
101	Processing and preserving of meat and production of meat products
102	Processing and preserving of fish, crustaceans and mollusks
103	Processing and preserving of fruits and vegetables
104	Manufacture of vegetable and animal oils and fats
105	Manufacture of dairy products
106	Manufacture of grain mill products, starches and starch products
107	Manufacture of bakery and farinaceous products
108	Manufacture of other food products
109	Manufacture of prepared animal feeds

The models of this paper includes five variables describing the input costs and an output variable (value added). Table 2 summarizes the descriptive statistics of the variables.

Table 2: Finnish food processing industry data description

Output and input, thousand euro	Min.	Mean	Max.	Std. Dev.
Value added	33437	231088	471041	202826
Salaries and employee benefits	15203	155871	337108	142808
Total asset	123555	1271583	3210983	981428
The use of materials and supplies	95797	627747	1788475	620110
Transport and storage services expenses	1309	48219	160478	54849
Electricity, fuel, heat cost	3160	22094	51872	17112

This paper utilizes Data Envelop Analysis as a general methodology for analyzing the Finnish FPI efficiency. The DEA approach was introduced by Charnes, A., et al. (1978) for estimating the efficiency of decision making units (DMUs) [15]. The approach was applied by Banker, R.D., (1984) for understanding the relationship between most productive scale size (mpss) and returns to scale [17]. Furthermore, the DEA approach was extended for estimating technical efficiency, scale efficiency and the optimal scale size [16, 17]. This methodology is also known as the mathematical programming model approach. A relevant concept for DEA is *return to scale*, which is the ratio between the change in inputs and the change in outputs. There are different DEA models depending on the rescaling possibility assumptions. These include: Constant return to scale (CRS), which assumes a constant rescaling; Decrease return to scale (DRS), which assumes that only downscaling is possible; Increase return to scale (IRS), which assumes no upscaling is possible; Variable return to scale (VRS), which assumes no rescaling is possible [9]. The rest of this section presents descriptions and formal definitions of these models.

A CRS model for measuring efficiency of DMUs was presented by Charnes, A., et al. (1978). It is also known as CCR [15]. There are two alternatives for applying this model according on the dependent variables: input orientation and output orientation. This study utilizes input orientation models. Similar to the notation of Bogetoft, P., Otto, L., (2011) [18], the inputs and outputs are identified as sets of vectors $\boldsymbol{x}$ and $\boldsymbol{y}$. Additionally, according to Charnes, A., Cooper, W.W., Rhodes, E., (1978) the *s* inputs and *m* outputs for the *j*-th DMU are identified by $\boldsymbol{x_{rj}}$ and $\boldsymbol{y_{ij}}$, such that $r = 1..s$ and $i = 1..m$ respectively. The DEA model defines weight vectors for input $\boldsymbol{u_r}$ and for output $\boldsymbol{v_i}$. Each component of the weight vectors should be grater or equal to 0, and their values are determined by an optimization solution. Efficiency is defined by the CRS model as the optimal solution $max\, h_0$, subject to be less or equal to *1*. The CCR model is [15]:

$$max\, h_0 = \sum_{r=1}^{s} u_r\, y_{r0} / \sum_{i=1}^{m} v_i\, x_{i0}$$

subject to:

(1)

$$max\, h_0 = \sum_{r=1}^{s} u_r y_{rj} / \sum_{i=1}^{m} v_i x_{ij} \leq 1;$$

$$j = 1, \dots, n, \quad u_r, v_i \geq 0;\ r = 1, \dots, s; \quad i = 1, \dots, m\,,$$

where:

$$efficiency = max\, h_0 = uy_0 / vx_0$$

Another two relevant concepts for the definition of TE are *production plan* and *production possibility* set. A production plan is a combination of input *x* and output *y*, such that *x* can produce *y*. The production possibility set, also known as *technology* set, is a set of *n* production plans. Formally, the technology set is defined as [17]:

$$T = \{(\boldsymbol{x}, \boldsymbol{y}) :\ \boldsymbol{y}\ can\ be\ produced\ from\ \boldsymbol{x}\} \quad such\ that\ \boldsymbol{y} \geq 0\ and\ \boldsymbol{x} \geq 0$$

(2)

Technical efficiency and scale efficiency derive from these concepts, and they are utilized as benchmarking metrics for identifying best practices of industries performance [18]. Based on the explanations of Bogetoft, P., Otto, L., (2011), TE for a DEA model is defined as the coefficient vector of the optimal technology set T* [18]:

$$T^*(\gamma) = \left\{(\mathrm{x,y}) \in \mathbb{R}_+^m \times \mathbb{R}_+^s \mid \exists\, \lambda \in \Lambda^n(\gamma) : x \geq \sum_{j=1}^{n} \lambda^j x^j, y \leq \sum_{j=1}^{n} \lambda^j y^j \right\}$$

(3)

such that:

$$\Lambda^n(\mathrm{CRS}) = \{ \lambda \in \mathbb{R}_+^n \} = \mathbb{R}_+^n$$

$$\Lambda^n(\mathrm{DRS}) = \left\{ \lambda \in \mathbb{R}_+^n \mid \sum_{j=1}^{n} \lambda^j \leq 1 \right\}$$

$$\Lambda^n(\mathrm{IRS}) = \left\{ \lambda \in \mathbb{R}_+^n \mid \sum_{j=1}^{n} \lambda^j \geq 1 \right\}$$

$$\Lambda^n(\mathrm{VRS}) = \left\{ \lambda \in \mathbb{R}_+^n \mid \sum_{j=1}^{n} \lambda^j = 1 \right\}$$

Technical efficiency is obtained by solving the following linear programing problem for each DMU j:

$$\max_{F,\lambda^1,\dots,\lambda^n} F \tag{4}$$

subject to:

$$x^0 \geq \sum_{j=1}^{N} \lambda^j x^j,$$

$$Fy^0 \leq \sum_{j=1}^{N} \lambda^j y^j, \;\; \lambda \geq \Lambda^j(\gamma)$$

SE is an estimation of the efficiency gain by moving from the current scale to the optimal scale. It is the ratio between the efficiency at CRS (i.e. according to CCR model) and the efficiency at VRS [18].

2.1. Data Sources

This paper utilized data publicly available in Finnish statistics databases. The data from two exclusive date ranges was combined from various data sets corresponding to the model variables. Table 3 summarizes the data sources.

Table 3: Data collection description

Output:	Source: Statistics Finland
Value added	Industrial subsectors financial statements 2006-2012 (TOL 2008) and 1999-2005 (TOL 2002)
Input cost:	Source: Statistics Finland
Salaries and employee benefits	Industrial subsectors financial statements 2006-2012 (TOL 2008) and 1999-2005 (TOL 2002)
Total asset	Industrial subsectors financial statements 2006-2012 (TOL 2008) and 1999-2005 (TOL 2002)
The use of materials and supplies	Industrial subsectors financial statements 2006-2012 (TOL 2008) and 1999-2005 (TOL 2002)
Transport and storage services expenses	The industry's revenue and expenses, 2008-2012 (TOL 2008). Industrial statistics on manufacturing, whole country 1995-2008, Classification TOL 2002
Electricity, Fuel, heat cost	The industry's revenue and expenses, 2008-2012 (TOL 2008). Industrial statistics on manufacturing, whole country 1995-2008, Classification TOL 2002

3. Results and Discussion

The TE of the Finnish FPI sectors is estimated for the years between 1999 and 2012. The period is split in three intervals for the purpose of simplifying the analysis. The average CRS and VRS scores are calculated based on equations 3 and 4 [18] for each interval. The average score over the nine sectors is obtained in terms of CRS and VRS. The SE is obtained as the ratio between the average CRS and VRS scores [18]. The results are summarized in table 4. Two derived metrics are obtained for the analysis of this paper, namely the average scores over the nine sectors and the percentage of inefficient sectors for each interval. During the interval 1999-2003, the average VRS and CRS for the entire Finnish FPI are 0.984 and 0.967 respectively. In this interval 66%

of the sectors operated with TE in terms of VRS, as opposed to only 44% in terms of CRS. During 2004-2007 the average VRS score is 0.987, and the average CRS score is 0.968. In this time period the TE level in terms VRS is optimal in 90% of the sectors. However, the VRS model shows that the TE score of the dairy products manufacturing is only 0.887. The optimal TE level for this sector in terms of VRS could be reached by decreasing the input cost by 11.3%. Similarly, during 2004-2007 only 44% of the sectors operated with TE in terms of CRS. In contrast, the period 2008-2012 had larger challenges for the Finnish FPI. In this time period the average VRS score is 0.955, and the average TE in terms CRS is reduced to 0.900. These correspond to 44% of the sectors with technical inefficiency in terms of VRS, and 66% in terms of CRS.

Table 4: Technical efficiency and scale efficiency of the Finnish FPI sectors, 1999-2012

Sectors	Average , 1999-2003			Average , 2004-2007			Average , 2008-2012		
	VRS	CRS	SE	VRS	CRS	SE	VRS	CRS	SE
SIC 101	1.000	0.982	0.982	1.000	0.943	0.943	1.000	0.747	0.747
SIC 102	1.000	1.000	1.000	1.000	0.988	0.988	1.000	1.000	1.000
SIC 103	1.000	0.992	0.992	1.000	1.000	1.000	0.926	0.874	0.939
SIC 104	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.985	0.985
SIC 105	0.928	0.840	0.907	0.887	0.847	0.957	0.896	0.826	0.923
SIC 106	0.997	0.978	0.980	1.000	0.957	0.957	0.931	0.903	0.966
SIC 107	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
SIC 108	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
SIC 109	0.929	0.912	0.980	1.000	0.976	0.976	0.841	0.760	0.894
Total	0.984	0.967	0.982	0.987	0.968	0.980	0.955	0.900	0.939

Source: calculated based on data from Statistics Finland

The Finnish FPI has faced different challenges related to input costs and market structure. The transportation costs are larger for the Finnish FPI compared to foreign ones due to its geographical location. Consequently, Finnish processors have focused their sales on domestic markets. However, both in the domestic and international markets, Finnish processors face competition from different foreign companies, which sell their products at comparatively lower prices. Moreover, Finnish food processors are exposed to changing prices of fuel, heat, electricity and chemical products imported from foreign markets [19]. These challenges contribute to the decreased TE in the Finnish FPI. As a consequence, some sectors had losses related to scale inefficiency during the period 1999-2012. The following is an analysis of the scale efficiency and rescaling possibility for the overall Finnish FPI.

Scale efficiency is estimated as the ratio between CRS and VRS scores for each sector. According to Bogetoft's, P. and Otto, L. (2011), a SE ratio equal to one corresponds to the optimal scale size, without scale efficiency losses [18]. The table 4 presents the SE score for each sector and the average score in the Finnish FPI. During 1999-2003 the average SE score was 0.982 or about 2% of losses. In this period 44% of the sectors had optimal SE level. From 2004 to 2007 the industry had a similar SE. However, the industry SE had significant changes in the period 2008-2012. The average SE score in this time period is 0.939 or 6% of losses, corresponding to 67% of the sectors operating at inefficient scale size.

This paper further considers the IRS and DRS assumptions for analyzing returns to scale. The results of this analysis are indicators of rescaling possibility, which according to Myyrä, S., et al. (2009) is a condition for increasing productivity and profitability [20]. The analysis follows a similar approach than the previous one, splitting the time range in three intervals and obtaining average IRS and DRS scores over the nine sectors. The results are summarized in table 5. During 1999-2003, around 66% of the sectors could operate more efficiently by decreasing their return to scale, and 44% by increasing their return to scale. From 2004 to 2007, nearly 78% of the sectors had an IRS possibility. The manufacture of prepared animal feeds, grain mill products and processing of fish sectors could operate more efficiently by increasing their return to scale. On the contrary, in this time interval the meat processing sector could improve its operations by rather decreasing its production scale. In the period 2008-2012, about 44% of the sectors had optimal score of DRS and IRS. However, the manufacture of vegetable and animal oils and fats had the possibility to increase their processing plan in order to operate at optimal levels. Lastly, the meat processing sector could improve its performance by rather decreasing its return to scale across all the three intervals.

Table 5: Possibility downscaling and upscaling production for Finnish FPIs, 1999-2012

Sectors	Average , 1999-2003		Average , 2004-2007		Average , 2008-2012	
	DRS	IRS	DRS	IRS	DRS	IRS
SIC 101	1.000	0.982	1.000	0.943	1.000	0.747
SIC 102	1.000	1.000	0.988	1.000	1.000	1.000
SIC 103	1.000	0.992	1.000	1.000	0.904	0.897
SIC 104	1.000	1.000	1.000	1.000	0.985	1.000
SIC 105	0.928	0.840	0.887	0.847	0.896	0.826
SIC 106	0.978	0.997	0.957	1.000	0.931	0.903
SIC 107	1.000	1.000	1.000	1.000	1.000	1.000
SIC 108	1.000	1.000	1.000	1.000	1.000	1.000
SIC 109	0.920	0.921	0.976	1.000	0.834	0.767
Total	0.981	0.970	0.979	0.977	0.950	0.904

Source: calculated based on data from Statistics Finland

The sectors have performed differently in terms of SE. Four sectors had lower TE performance than the rest of them. As a result, the overall Finnish FPI had losses due to scale inefficiency during observation time. The underperforming sectors include manufacture of dairy, grain mill products, prepared animal feeds, and meat processing sectors. They are the main contributors to the decreasing performance of the overall food industry. In particular, the SE score of the meat processing sector has a negative linear trend. By the year 2005 the SE losses in this sector have reached 13.1%. After 2005 the losses have a steeper trend than the previous years. The years 2007, 2008 and 2010 have the largest challenges for the sector, with losses of 23%, 28.4%, and 34.9% respectively (figure 1).

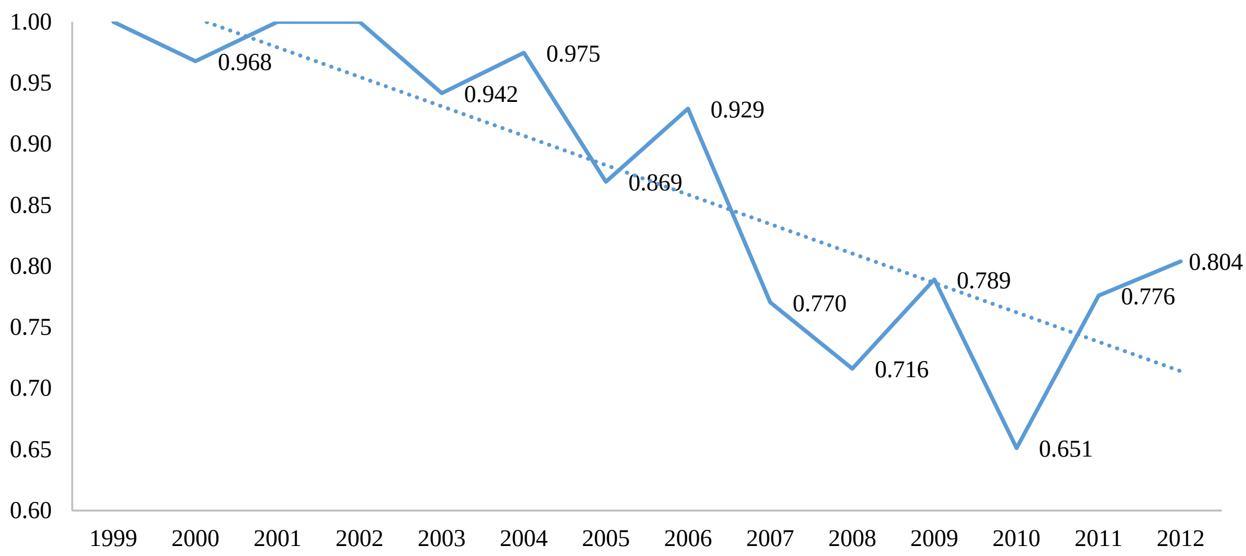

Figure 1. Processing and preserving of meat and production of meat products SE trend, 1999-2012.

Furthermore, a correlation analysis between input and output variables was carried out for the underperforming sectors. The results suggest that two input costs are a crucial factor for the value added of the meat sector. Among the six input cost variables, labor and materials related costs have a strong positive correlation of with value added, respectively R=0.829 and R=720. Contrarily, logistic, capital and energy related costs have no strong correlation with the output variable in this sector (table 6).

Table 6: Correlation coefficients between input costs with value added in four Finnish FPI sectors, 1999-2012

Input cost	Correlation with value added (R)			
	SIC101	SIC105	SIC106	SIC109
Labor	0.829	0.887	0.976	0.684
Capital	-0.404	0.949	0.841	-0.312
Materials	0.720	0.814	0.774	0.369
Transport and storage	0.171	0.892	0.084	0.851
Energy (fuel, electricity, heat)	-0.153	0.905	0.376	0.388

Source: calculated based on data from Statistics Finland

The most challenging years for the manufacture of dairy products in terms of SE were 2000 and 2010, with losses of 16.7%, and 15.6% from the optimal level respectively (figure 2). The analysis shows that there is a strong correlation between value added and all five categories of inputs costs from 1999 to 2012 (table 6). According to this analysis, the dairy sector value added has a larger dependency on capital, compared to the other underperforming sectors.

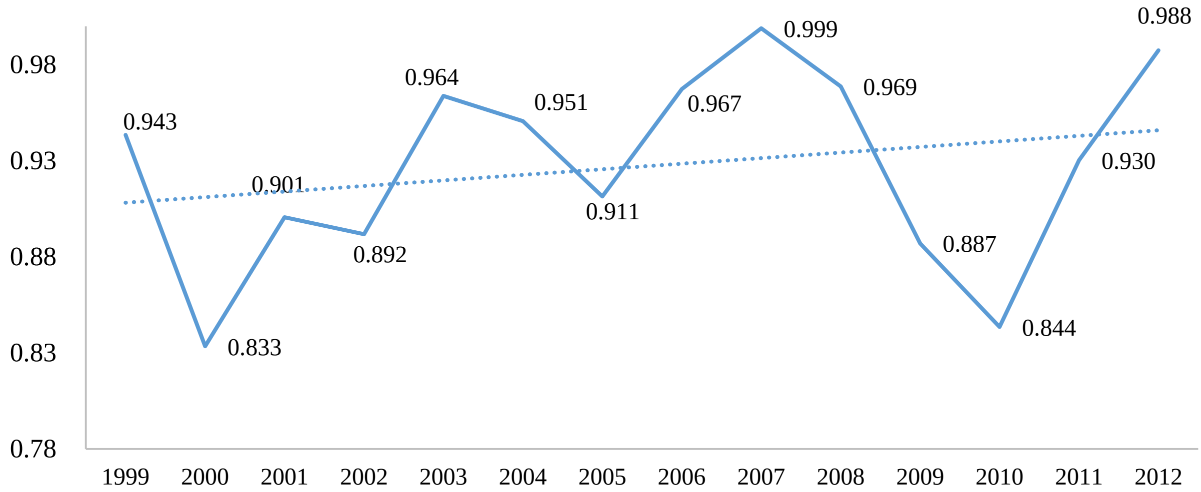

Figure 2. Manufacture of dairy products SE trend, 1999-2012

The grain mill sector has a declining trend in its SE score (figure 3). It had large losses in 2007 and 2010, corresponding to 8.4% and 12.2% of the optimal SE respectively. As a result of the correlation analysis, labor costs have the strongest impact on the value added of this sector, with correlation coefficient R=0.976. In addition, capital and materials related costs have strong correlation coefficients, R=0. 841 and R=0.774 respectively (table 6).

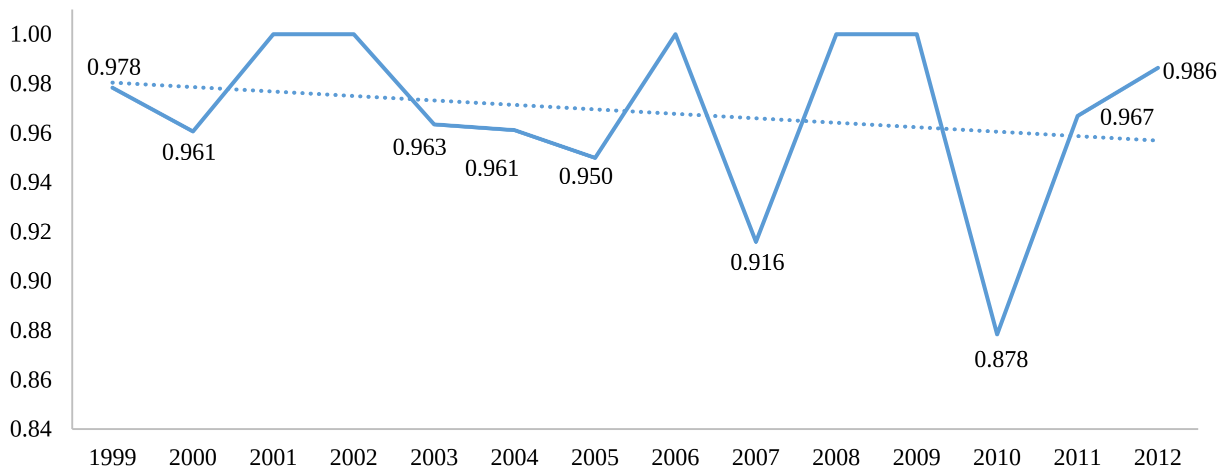

Figure 3. Manufacture of grain mill products, starches and starch products SE trend, 1999-2012.

From 1999 to 2012, the manufacture of prepared animal feeds has a negative trend in SE. The years 2007 and 2010 are highly challenging for the SE of this sector, with SE scores of 0.903 and 0.802. These loses correspond to 9.7% and 19.8% of the optimal levels respectively (figure 4). Logistics related costs have the strongest correlation with the value added for this sector. In particular, transportation and storage costs have the largest correlation coefficient, namely R=0.851. Lastly, the results of the analysis show that labor costs have a strong correlation with animal feed value added, with coefficient R=0.684.

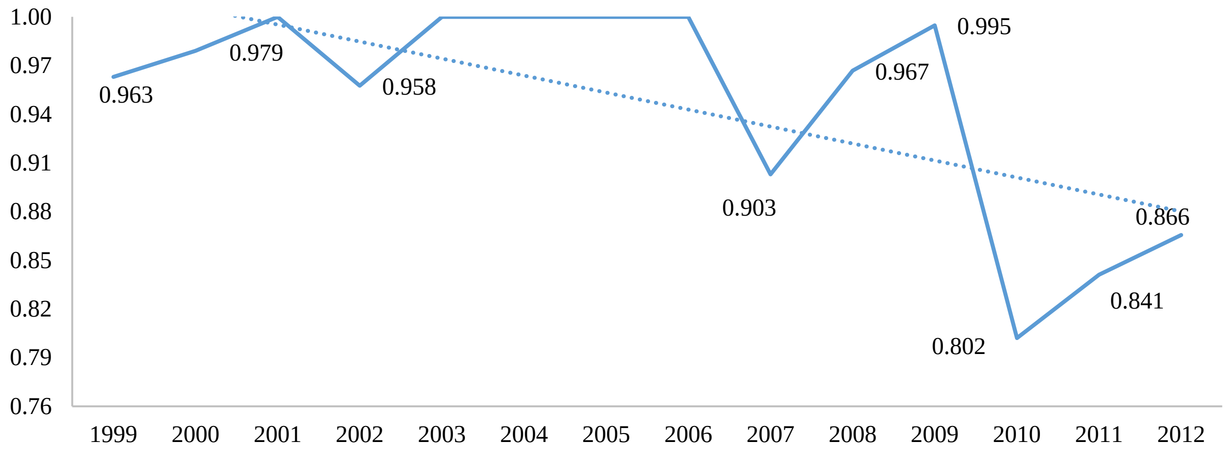

Figure 4 Manufacture of prepared animal feeds**.** SE trend, 1999-2012.

In addition to the TE and SE performance issue, the Finnish FPI face strong competition in the domestic and foreign markets [5]. Deeper competition analyses are interesting for further research. Open questions include, what is the relationship between TE and SE across the animal feed, dairy and meat sectors? To what extent does the government support help to improve the SE and TE of the Finnish FPI sectors? Do government subsidies facilitate or hinder the Finnish FPI best practices?

4. Conclusion

In this paper the technical and scale efficiency of the Finnish FPI sectors is analyzed using DEA models. The results identify the sectors with inefficient scale and technical score from 1999 to 2012. The Finnish FPI could operate at optimal scale size with higher TE, by improving the efficiency of the dairy, grain mill products, animal feeds and meat sectors. The rescaling possibility analysis shows that the manufacturing of grain mill products and animal feeds could increase their production scale from 2004 to 2007. Contrarily, during the entire observation time the meat processing sector could be more efficient and profitable by decreasing its return to scale. The underperforming TE score and RTS of these sectors are caused by different factors. In general, the major reasons of efficiency losses are the high costs of materials and labor. In particular, logistics related expenses are a significant factor for the dairy and animal feed sectors. Additionally, the efficiency of the dairy sector is affected by capital and energy input costs. Lastly, market share and competition issues impact the optimal levels of technical and scale efficiency in the FPI.

5. Recommendation

Among the four underperforming Finnish FPI sectors, the grain mill products and animal feed sectors have the largest opportunity to increase their production scale plan. A recommendation for government policy makers is to consider programs and subsidies for increasing the scale size of these sectors. The same recommendation is not applicable to the meat and dairy sectors. The scale of the meat sector production plan could rather decrease. Any rescaling of the dairy sector would cause efficiency losses. For the dairy sector, an increase in investments on logistics could bring larger benefits than investments on rescaling its production plan. Similarly, the investments on research and development of export marketing could improve the performance of meat and dairy sectors. Lastly, the efficiency of these two sectors could benefit from a non-price competitiveness strategy.

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