8. ESTIMATING THE EFFICIENCY OF ESTONIAN INDUSTRIAL FISHING BY DATA ENVELOPMENT ANALYSIS

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Introduction

In connection with joining the European Union (EU), comparison of the efficiency of Estonian and the EU countries' production activities and units has become relevant. One topic of interest here is industrial fishing.

In the Baltic Sea countries, the contribution of fishing industry to the GDP is regularly under 1% (OECD Statistics: Agriculture and Fisheries, 2003). Nevertheless, from the viewpoint of employment, fishing has great relevance in the regions where there are few other employment possibilities, especially in the coastal regions.

One of the main activities involved here is industrial fishing, including fish catches and delivery from fishing regions to ports, aimed at supplying primary goods for the fishing industry. Major problems related to contemporary industrial fishing include (Field 2001, p. 243):

- overfishing which results in substantially diminished stocks of some species;
- overcapitalisation, i.e. unreasonably excessive investments in national fishing fleets;
- water pollution, which threatens spawning areas vital to the health of many marine species;

- conflicts over fishing rights and international agreements about limits for fishery.

All these issues are closely intertwined. The overcapitalization is an important reason for overfishing, while the decrease in fish resources is a reason for the overcapitalization of the industry. The decrease of fish resources is dangerous also from a wider perspective and needs intervention and regulation on the level of states and international agencies (Ströbele 1978, p. 156).

Three main methods for regulation of fishing are (Dichtl, Issing 1987, p. 612):

- direct intervention (constraints on the time, volume and technology of fishing);
- assessment of fish catches (calculated on the basis of the value of catches);
- delivery of licences.

In the EU, mainly constraints on time and volume are used for regulating fishing. Every year the EU council determines the total allowable catch (TAC) for quota species in the Exclusive Economic Zones of the EU member states. These TACs are divided between the member states into national quotas. The distribution of the national quota is then decided by each member state itself (Kirkley et al. 1999, p. 7). In Estonia the regulation of fishing is coordinated with the EU activities and has the objective to contribute to the recovery of fish stocks in the whole Baltic Sea (Vetemaa 2001, p. 5).

After joining the EU, the Estonian fishing industry can apply for quotas in the Economic Zones of the other EU member states and for subsidies from various EU funds to compensate for the unfavourable geographical conditions, enacted restrictions and technological backwardness. For example, the Development Fund for the Fisheries of the EU is intended primarily for modernization of vessels and the technology of catching, processing and preserving fish and fish products. Also, support can be applied for in order to overcome the economic difficulties associated with the disadvantageous weather conditions on the Baltic Sea, such as in the winter of 2002/2003.

The discussions about the quotas and subsidies are dependent on the relative efficiency of fishing in Estonia by comparison with the other EU states and with the other economic activities. In this chapter, an attempt is made to use the Data Envelopment Analysis (DEA) approach to estimate the relative efficiency of Estonian industrial fishing on the example of the Baltic Sea area trawl fleet. The landings of this fleet form about 87% of the volume and about 82% of the overall value of the Estonian industrial fishing. Herein, due to lack of comparable data, only three trawl fleets of the Baltic Sea area (those of Denmark, Finland and Sweden) can be used as the reference group units.

The chapter will continue as follows. In the first section, a short overview of DEA is given. We consider the setting of DEA in terms of the volume and refer to some possible shortcomings of the method. In the second section, the data set used for the computations is presented, characterized and analyzed. The main problems here are related to the small size of the data set, the representativeness and comparability of the data, the correspondence of the data to the meaning of the indicators and occasional deviations from characteristic annual values. In the third section, the efficiency index for different sets of input-output indicators and with different reference groups are computed and compared. Finally, the efficiency of Estonian industrial fishing in the Baltic Sea is calculated for the conditions of a hypothetical increase in the quotas for more valuable fish. The quotas are found so that the efficiency index for the value of landings will become equal to the efficiency index for the volume of landings, with the total of landings unchanged.

8.1. Data Envelopment Analysis (DEA)

The efficiency of a production unit or economic activity is supposed to characterize how successful this unit or activity is in utilizing its inputs for producing its outputs. The difficulty here lies in the fact that in most cases it is not determined, in a natural way or uniquely, how to aggregate all the unit's different inputs into a single indicator, say s, and all its different outputs into another single indicator, say v, so that the ratio v/s could be considered as the measure of efficiency. The DEA approach is one of those which do not require such an aggregation for calculating the relative efficiency index of the given examined unit in comparison with similar units of some reference group.

Calculating the efficiency of a unit by DEA can be interpreted in two different but dual ways (see, e.g., Charnes et al. 1978, Charnes et al. 1994, Lozano et al. 2002, Roland, Vassdal 2001, Seiford 1996):

- in monetary terms: as the maximum of the ratio p_v/p_s of the price p_v of all the considered outputs and the price p_s of all the considered inputs for the examined unit, when assigning to the inputs and outputs fictitious prices so that for all the units of the reference group the ratio p_v/p_s is less than or equal to 1, i.e. assigning to inputs and outputs relatively the most favourable prices for the examined unit,
- in volume terms: as the minimum of the number $E=a/b$ so that some virtual composite unit (formal linear mixture of the units of the reference group) can produce each output at least b times as much as the examined unit when utilizing each input at most a times as much as the examined unit.

We will follow the interpretation in terms of volume and find the efficiency index for the examined unit as a solution to the following problem:

(1) $\min E=a/b$ (or $\max 1/E=b/a$)

s.t.

$$\sum_k w_k \cdot s_{ik} \le a \cdot s_{ie} \quad \forall i,$$
$$\sum_k w_k \cdot v_{jk} \ge b \cdot v_{je} \quad \forall j,$$
$$w_k \ge 0 \; \forall k, \quad a,b > 0,$$

with the optimum considered over variables a, b and all the w_k, where

- i, j, and k are the indices of inputs, outputs and units of the reference group, respectively, and index e refers to the examined unit,
- $v_{jk}\ge 0$ and $v_{je}>0$ are the values of the jth output of the kth unit of the reference group and of the examined unit, respectively (we assume that for every j, $v_{jk}>0$ at least for some k),
- $s_{ik}\ge 0$ and $s_{ie}>0$ are the values of the ith input of the kth unit of the reference group and of the examined unit, respectively (we assume that for every i, $s_{ik}>0$ at least for some k),
- w_k are nonnegative numbers, which can be interpreted as the loadings of the units of the reference group in the composite unit, or as the fractions of the units of the reference group, which are used to compose the composite unit.

The composed unit with the weights w_k from the solution of (1) is called the target unit. It is the virtual unit relative to which the efficiency of the examined unit is actually estimated.

The efficiency index is input oriented if b=1 and output oriented if a=1. In the first case, a indicates that the composite unit could produce at least as many of all the outputs as the examined unit with only a times of the input of the examined unit. In the second case, b indicates that exploiting all the inputs at most in the same amount as the examined unit, the composite unit could produce at least b times the output of the examined unit. The solutions $E^*=a^*/b^*$, $\{w_k^*\}$ and $E_a^*=a^*$, $\{w_{ka}^*\}$ and $E_b^*=b^*$, $\{w_{kb}^*\}$ of the problems (1), (1) with b=1 and (1) with a=1, respectively, are closely connected: $E^*=a^*/b^*=a^*=1/b^*$, $\{w_{ka}^*\}=\{w_k^*/b^*\}$, $\{w_{kb}^*\}=\{w_k^*/a^*\}=\{w_{ka}^* \cdot b^*/a^*\}$. (These equalities must not hold, if additional restrictions are introduced, e.g., if the sum of w_k must be equal to 1.)

Problem (1) can be set in a different but equivalent form as problem (2) or (3):[1]

(2) $\min E$ (or $\max 1/E$)

s.t.

$$\frac{v_{je}/s_{ie}}{(\sum_k w_k \cdot v_{jk})/(\sum_k w_k \cdot s_{ik})} \le E \quad \forall i, j$$

(or $((\sum_k w_k \cdot v_{jk})/(\sum_k w_k \cdot s_{ik}))/(v_{je}/s_{ie}) \ge 1/E \quad \forall i, j$),

$$w_k \ge 0 \quad \forall k,$$

(3) $\min E$

$$\text{s.t.} \quad \frac{v_{je}/(\sum_k w_k \cdot v_{jk})}{s_{ie}/(\sum_k w_k \cdot s_{ik})} \ge E \quad \forall i, j,$$

$$w_k \ge 0 \quad \forall k.$$

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[1] Let E' and E'' be the solutions of problems (1) and (2), correspondingly. It is clear that $E'' \le E'$ whereas every choice of $\{w_k\}$, a, $b \neq 0$ and $E=a/b$ feasible for (1) is feasible for (2), also. In order to prove that $E' \le E''$, we shall define a and b so that $E''=a/b$ and all the inequalities in (1) hold. Let $\sum_k w''_k \cdot s_{ik}/s_{ie} \le \sum_k w''_k \cdot s_{rk}/s_{re} \;\; \forall i$ hold for w''_k from the solution of (2) and some r. Choose $a=\sum_k w''_k \cdot s_{rk}/s_{re}$. Then from the inequality conditions in (2) follows that for any j, $\sum_k w''_k \cdot v_{jk}/v_{je} \ge (\sum_k w''_k \cdot s_{rk}/s_{re})/E''=a/E''$ and we can choose $b=a/E''$.

From (2) we get another interpretation for the DEA efficiency index: if E^* is the solution of (1) then

1) there exists a virtual composite unit so that for all output-input pairs the efficiency of the examined unit, measured as the output/input ratio, is at most E^* times the same ratio for this composite unit; such a composite unit is called a target unit,
2) there exists no virtual composite unit so that for all output-input pairs the efficiency of the examined unit, measured as the output/input ratio, is less than E^* times the same ratio for this composite unit.

To put it in another way, for the examined unit there exists a composite unit which is in terms of any output/input ratio at least $1/E^*$ times more efficient than the examined unit, and no such composite units exists which are for all output/input ratios more than $1/E^*$ times as efficient as the examined unit.

On the basis of (3), we can also say that if E^* is the solution of (1) then:

1) there exists a virtual composite unit so that for all output-input pairs its output exceeds the output of the examined unit at least $1/E^*$ times more than its input exceeds the input of the examined unit,
2) there exists no virtual composite unit so that for all output-input pairs its output exceeds the output of the examined unit at least $\alpha > 1/E^*$ times more than its input exceeds the input of the examined unit.

The approach in terms of the volume seems to be more easily interpretable intuitively. Another advantage of this approach is that the relative differences of the left and right hand sides of the inequalities in (1) give some hint about which inputs could be used and which outputs could be produced better by the units of the reference group than it is done by the examined unit. Thus, maybe the examined unit itself could do better there, also. If the relative differences of the left and right hand sides are large for some few inequalities in (1), then it can (but need not) refer to any special conditions with respect to utilizing these inputs or producing these outputs by the examined unit (e.g. the examined unit must use at least some given quantity of these inputs, or it cannot use enough other inputs).

An important moment in interpreting and using the efficiency index by DEA is that when comparing the examined unit with the composite units, only the most favourable of the examined unit's output-input pairs is decisive and inefficiency in the sense of the other output-input pairs does not matter. Therefore, the calculated efficiency index is in fact some upper estimate of the efficiency in the model. There is a reason to suspect that the examined unit is not working efficiently if the efficiency index is small, but in general it cannot be asserted that it is working efficiently if the efficiency index is large. Thus in general the efficiency index by DEA is useful only for discovering the inefficiency (in the model) of the examined unit.

The examined unit itself can belong to the reference group, too. In this case, it is obvious that the minimum of E is not greater than 1. (It is feasible to choose w_k=1 for the examined unit and w_k=0 for all the other units of the reference group, and $a=b=E=1$.) Moreover, in this case, if $E^* = a^*/b^*$ is less than 1, then in any optimal choice of variables the loading w^*_e of the examined unit in the composite unit equals 0.[2]

As the minimum value E^* of E in (1) does not change if b is set equal to 1, we have taken b=1 in the calculations, i.e. we have formally considered the input oriented efficiency index.[3] It is quite

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[2] Otherwise we do not have the optimal choice, whereas for $a=a^*-w^*_e$, $b=b^*-w^*_e$ we have $a/b<a^*/b^*$.

[3] If there are more restrictions for w_k, e.g., that their sum equals 1, then the minimum value of E can depend on the choice of the model and problems (1) and (2) are not equivalent. Moreover, under additional restrictions the input or output oriented problems may have no solutions at all. To avoid this, if the sum of w_k must equal to 1, it is sufficient to include also the examined

natural when discussing the efficiency of fishing, because in the case of fishing, the resources being limited, the outputs are restricted due to quotas.

There are also some problems concerning the efficiency index calculated by DEA.

- In reality different production units are working in different conditions (different prices, opportunities, regulations, etc.) and there is always the problem whether the chosen reference group is appropriate for assessing the efficiency of the given examined unit. Also, no composite unit can be really composed. Therefore the importance of the efficiency index calculated by DEA must not be overestimated. Nevertheless, this index and the differences of the values of the inputs-outputs of the examined unit and the target unit give some useful information in many cases.

- The composite unit in DEA is composed as a linear mixture of the real input-output profiles, i.e. the constant returns to scale are proposed. In order to reduce the influence of this proposition, the restriction that the sum of w_k must equal 1 is frequently added — in this case, the units of the reference group, which are of the same scale as the examined unit, are more preferably used for composing the target unit.

- In (1) and (2), all the inputs and outputs are treated as equally important, so that all the inequalities must hold. Thus, the relatively best input and output of the examined unit will be decisive. Therefore, if the examined unit uses some inputs (or produces some outputs) relatively efficiently, then the value of the efficiency index will be high despite the inefficiency in utilizing other inputs (or producing other outputs).[4] This situation is characterized by the

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unit itself into the reference group. For problem (1) the solution always exists.

[4] We illustrate the possible pseudo-efficiency with the following example. For the examined unit and the reference unit only two inputs and one output are considered, with s_{1e}=0.1, s_{2e}=300, s_{1r}=1, s_{2r}=3 and v_e=v_r=100. In this case,

large relative differences of the left and right hand sides of most of the inequalities in (1) and can hint to the specific character of the examined unit in comparison with the reference group. In terms of (2), this situation is characterized by the fact that most of the one-output-one-input efficiency indices relative to the target unit are considerably smaller than E^*. In this case it is quite questionable to interpret E^* as a good (upper) estimation of the efficiency. Thus the magnitudes of the relative differences of the left and right hand sides of the inequalities in (1) characterize, to some extent, the appropriateness of E as the efficiency index. In order to reduce the influence of the individual indicators, the reference group must be sufficiently representative.

- As the consequence of treating in (1) and (2) all the inputs and all the outputs as equally important, the solution of (1) and (2) can be very sensitive to adding or removing constraints and to accidental deviations in the data. Thus the use of the inputs-outputs which are not essential or whose values are not reliable can distort the result and give a higher value for the efficiency index and wrong signals about the efficiency of producing outputs and utilizing inputs. Increasing the reference group can reduce the influence of occasional deviations in the data (of the small reference group).

8.2. Data

The data used in the analysis originate from the annual reports of *Economic Assessment of European Fisheries (EAEF)* (EAEF 2002) and cover the years 1998–2001. Due to lack of comparable data, only the trawl fleets of Denmark, Finland and Sweden were used as

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for (1) the optimal value of E is 10. Nevertheless, based only on this information (i.e. if nothing more is known about the inputs), it does not seem reasonable to assert that the examined unit is 10 times as efficient as the reference unit, or even that it is at least as efficient as the reference unit.

the reference group units. (For example, the German and Lithuanian data are with gaps and no data are given for Russia.)

The following aggregated indicators are used (as defined in EAEF 2002, pp. 241–242; 2003, pp. 252–253):

- *Employment on board (Emp)* — the number of crew members counted as full time equivalents;
- *Invested capital in millions of euros (Inv)* — the amount of capital invested in the vessels and buildings at a certain moment of time (the book value based on the replacement value is a measure for the invested capital; in some cases, the insured value of the vessels has been reported instead);
- *Capacity, total kW in thousands of kW (Cpc)* — the capacity of trawlers fleet (the maximum level that a national trawl fleet could reasonably expect to attain under normal operating conditions);
- *Value of landings in millions of euros (Val)* — the value of landed fish in actual market prices;
- *Gross cash-flow in millions of euros (GCF)* — value of landings minus all expenses, except depreciation and interest (GCF gives the amount available for interest payments, loan repayments, and also for depreciation and dividends);
- *Volume of landings in thousands of tonnes (Vol)* — the actual volume of landed fish.

The concrete values of these indicators are presented in Table 1 and illustrated in Figure 1. Here and further by Est, Den, Fin and Swe we refer to the Baltic Sea area trawl fleets of Estonia, Denmark, Finland and Sweden, respectively, whereas Den/10 stands for 1/10 of Den.

For Sweden we used only the data about the trawl fleet and left aside the fleet of large Pelagic vessels catching mainly herring and sprat in the coastal regions. Thus Est, Den, Fin and Swe all have vessels of comparable type.

Table 1. Selected data about the Baltic Sea area trawl fleets.

1998	Est	Den	Fin	Swe	1999	Est	Den	Fin	Swe
Emp	932.0	2463.8	282.0	273.0		780.00	2591.5	244.0	266.0
Inv	20.3	372.6	18.3	40.9		15.98	397.1	16.3	48.2
Cpc	34.9	228.3	41.2	28.3		29.91	231.2	37.1	34.7
Val	9.2	330.5	22.5	21.2		5.67	302.0	13.4	26.7
GCF	1.7	84.3	4.5	4.3		0.03	46.8	1.7	6.9
Vol	69.5	1261.2	99.5	13.7		62.34	1199.9	92.2	14.6
2000	**Est**	**Den**	**Fin**	**Swe**	**2001**	**Est**	**Den**	**Fin**	**Swe**
Emp	667.0	2582.4	216.0	282.0		635.00	2456.3	214.0	315.0
Inv	12.9	387.9	18.5	47.1		11.42	408.2	17.3	41.4
Cpc	26.0	232.2	34.7	32.9		25.00	226.0	34.3	33.5
Val	10.0	280.9	13.7	32.0		12.84	293.4	16.3	25.2
GCF	2.9	29.5	1.4	5.9		4.86	49.1	2.6	7.3
Vol	70.1	1247.8	96.1	13.5		67.40	1219.5	97.6	13.7

Source: EAEF, composed by the authors.

For Est the data expose a rather considerable monotonous decrease in using all the inputs (employment, investments and capacity). At the same time, with the exception of the year 1999, the volume of landings has decreased marginally and the value of landings has even increased. (Presumably the data of the year 1999 were influenced by the Russian 1998 crisis, as the eastern market was very important for Estonian fish export.) Thus, considering these inputs and outputs, the absolute efficiency of Est must have increased.

Comparing Est with the other fleets, we see that 7–9 times less capital was invested per unit of employment than in Den and Swe, and 3–4.5 times less than in Fin. Est had about 2–4 times less capacity (in kW) per unit of employment than Den (2 times), Fin (4 times) or Swe (2.5–3 times). Thus, regarding capacity, the Est ships appear to be old, depreciated and technically backward.

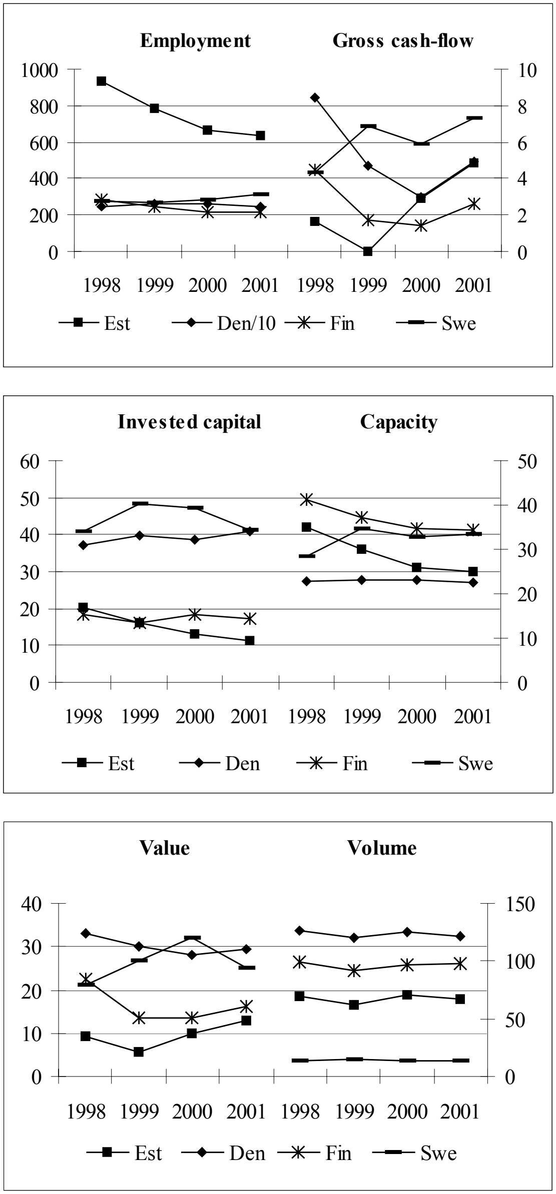


Figure 1. Graphs of data by fleets.

At the same time, for Est the volume of landings per unit of capacity in 2000 and 2001 was about half of Den, but almost equal to Fin and almost 6–7 times that of Swe. The volume of landings per unit of employment in Est was about 4 times smaller than in Den and Fin, and about 3 times larger than in Swe.

From these data it seems that Est is using too much labour on board, and that Swe is overcapitalized and overemployed by comparison with its volume of landings.

The value and volume of landings change differently across the fleets — Fin and Est have much less value and much more volume than Swe. This is explained by the fact that most of the catches of Est and Fin are made up by herring and sprat whose market prices are about ten times lower than the market prices of plaice, flounder and cod forming the majority of the catches of Swe and Den (see Tables 2 and 3). The reason here is geographical — every country has its own Economic Zone for fishing near its location and in the zones of Estonia and Finland the water is too cold for more valuable fish.

Table 2. Valuable species in total landings of trawl fleets by countries.

	Valuable species (10^3 t)				**% of valuable species in total landings**			
	1998	**1999**	**2000**	**2001**	**1998**	**1999**	**2000**	**2001**
Est	–	–	–	–	–	–	–	–
Den	45	51	42	34	3.57	4.25	3.37	2.79
Fin	–	–	–	–	–	–	–	–
Swe	9.9	10.8	10.3	10.2	72.26	73.97	76.30	74.45

Source: EAEF, composed by the authors.

Table 3. Average market prices of landings of valuable and cheap fish 1998–2001,[5] in EUR/kg

Year	**1998**	**1999**	**2000**	**2001**
Valuable species	1.59	1.69	1.66	1.84
Cheap species	0.15	0.14	0.13	0.20
Price ratio	10.68	12.12	12.60	9.17

Source: EAEF, composed by the authors.

Comparing the data of different fleets, we see that the values of most of the indicators are of the same magnitude for Est, Fin and Swe but they are much smaller than the corresponding values for Den. With approximately ten times more labour and seven times more capacity, the volume of landings of Den is more than ten times higher. Thus the effect of increasing returns to scale is possible in the case of Den.

Hereby we note that the data of Table 1 are quite inaccurate and partially incomparable across the different fleets and different years for many reasons, e.g.:

- employment on board does not reflect the worker's qualification and the real working time, which depends on the weather conditions, labour legislation, etc.;
- gross cash flow is influenced by the investments in fixed assets (new buildings, fishing nets, etc.), by the national price level, wage rates, etc. and can be very volatile over the years; also, in order to decrease the tax burden, it is often useful for fishing enterprises to distort the actual data;
- invested capital is, in different cases, calculated differently (based on the replacement value or on the insurance value);

[5] Average market prices of landings are calculated by the data from *EAEF* (EAEF 2002, pp. 124–133, 183–189) as the ratios (sum of values of landings)/(sum of volumes of landings), where the sums are taken over the countries and species.

- capacity does not reflect the age of the vessels and their distribution between different capacity classes; also, trawl fleets may be restricted in actual use of their potential capacity due to different constraints on operating hours, etc.;
- value of landings depends on national prices and is influenced by the national quotas imposed by the EU, both of which vary from year to year (whereby quotas may be bought, sold and exchanged);
- volume of landings does not reflect the differences by species and constraints due to the quotas.

The concrete data show that the invested capital and capacity change differently across the fleets. The investments for Swe and Den/10 are twice as large as the investments of Fin, but the capacity of Fin is greater than the capacity of Swe and equals almost twice the capacity of Den. Since different calculation principles may be used in different cases for investments, capacity seems to be a more reliable indicator than investments here. On the other hand, capacity in kW considers the capacity of the old and modern vessels on the same grounds, and this is in favour of modern vessels, when speaking about efficiency.

Considering the output indicators, we see that the value of landings and gross cash flow change analogically over the years, although gross cash flow is more volatile. At the same time, the value and volume of landings change differently across the countries. As explained earlier, the reason is geographical. Thus the efficiency index of Estonia can substantially depend on the output indicators that are taken into account.

8.3. Results

Discarding temporarily the problems related to the data, let us consider the efficiency indices calculated by DEA. In Table 4 the results are presented for different sets of input-output indicators.

(The indicators marked by + are used to compute the data of the corresponding row.) Figure 2 illustrates the data of Table 4. To have more data for comparing the behaviour of the efficiency index in different cases, the efficiency indices were calculated for Den, Fin and Swe also. Thereby, when calculating the efficiency index for any of these fleets, this fleet itself was replaced by Est in the reference group.

Table 4. Efficiency coefficients of the fleets in 1998–2001.

	Inputs			Outputs						
Years	**Emp.**	**Inv.**	**Cpc**	**Val.**	**GCF**	**Vol.**	**Est**	**Den**	**Fin**	**Swe**
	+	+	+	+	+	+	0.72	3.02	1.60	0.58
	+	+	+	+	–	+	0.72	2.54	1.60	0.58
	+	–	+	+	+	+	0.36	3.02	0.69	0.58
1998	+	–	+	+	–	+	0.36	2.54	0.69	0.58
	+	+	+	+	+	+	0.78	2.74	1.77	1.44
	+	+	+	+	–	+	0.78	2.74	1.77	0.86
	+	–	+	+	+	+	0.40	2.74	0.82	1.44
1999	+	–	+	+	–	+	0.40	2.74	0.82	0.86
	+	+	+	+	+	+	2.18	2.35	1.50	1.83
	+	+	+	+	–	+	1.04	2.35	1.50	1.04
	+	–	+	+	+	+	0.76	2.35	0.92	1.83
2000	+	–	+	+	–	+	0.50	2.35	0.92	1.04
	+	+	+	+	+	+	2.56	2.17	1.68	1.36
	+	+	+	+	–	+	1.19	2.17	1.68	0.80
	+	–	+	+	+	+	0.89	2.15	0.92	1.16
2001	+	–	+	+	–	+	0.50	2.15	0.92	0.67

Source: composed by the authors.

The data of Table 4 and Figure 2 confirm that when investments (see Est) or GCF (see Swe) are included, then the efficiency index in some cases has large changes, which are presumably caused by the occasional events that we want to exclude when speaking about efficiency. Also, including investments and GCF causes overestimation of the efficiency. Therefore, based on Table 4 and taking into account the discussions in Section 2, it seems to be justified to leave out investments and GCF when computing the efficiency by DEA.

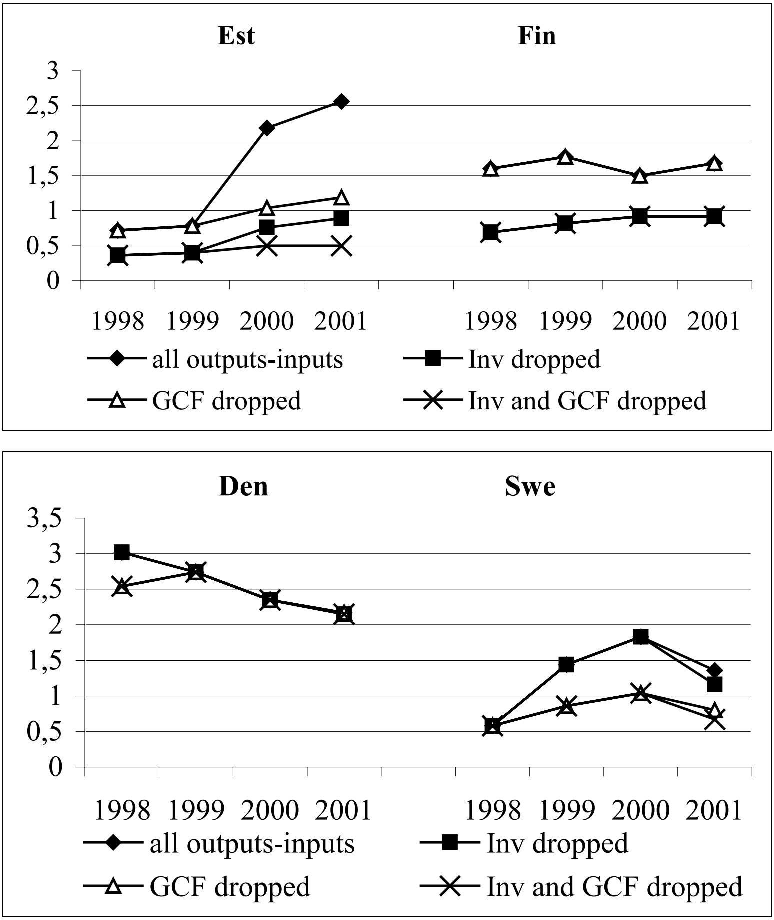


Figure 2. Efficiency index of fleets for different combinations of outputs-inputs.

As a by-product of these calculations, we make two observations. First, the efficiency indices of Den are much higher than those for Fin and Swe. This can be a result of the increasing returns to scale effect or of some other factors (e.g., different operating conditions). It does not seem realistic that in Denmark fishing is organized so much better than in Finland or Sweden. Therefore, when estimating the relative efficiency of Est by DEA, we use also the reference group which consists only of Fin and Swe.

Second, for most of the sets of input-output variables the computed relative efficiency index is increasing for Est, Fin and Swe (except the year 2001 for Swe), and decreasing for Den. So the difference in the relative efficiency of Den and other fleets (and particularity of Den) is decreasing.

There is another problem associated with the data. With such a small reference group, the effect of accidental deviations in the data can be noticeable. Therefore, in order to increase the reference group, we consider the data of the same fleet in different years as the data of different units, say Swe99, Fin01, etc. — we presume that there has not been any considerable qualitative technological progress in industrial fishing in the Baltic Sea area over the last years. The efficiency of Est, calculated relative to this bigger reference group, presumably reflects the changes in the efficiency over years even better.

In Table 5 the efficiency index of Est for the years 1998–2001 is calculated on the basis of employment, capacity, value of landings and volume of landings. The ratio of the inputs and outputs of the target unit and Est is also calculated for all the inputs and outputs. Herein the following different reference groups are used:

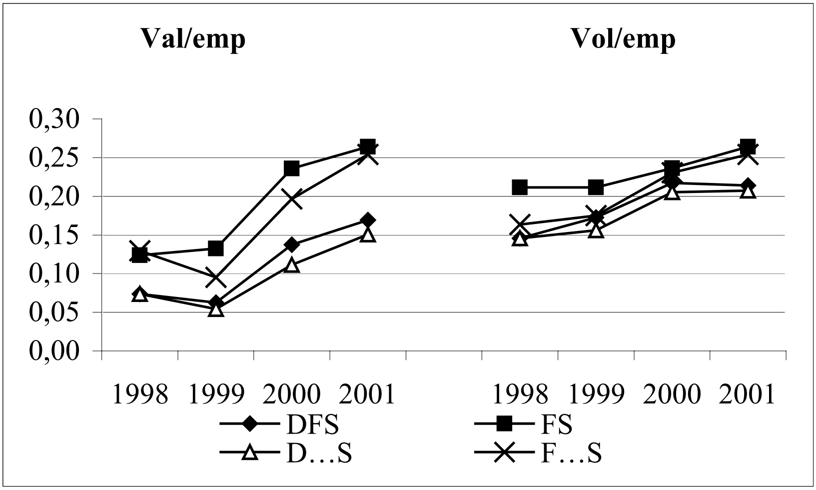
1. Den, Fin and Swe of the same year (DFS),
2. Fin and Swe of the same year (FS),
3. Den, Fin and Swe of all the years (D...S),
4. Fin and Swe of all the years (F...S).

Table 5. Efficiency index of Est in the case of different reference groups

Year	Reference group	Efficiency	Emp	Cpc	Val	Vol
1998	**DFS**	0.36	0.15	0.36	1.98	1.00
	D…S	0.36	0.15	0.36	1.98	1.00
	FS	0.83	0.21	0.83	1.71	1.00
	F…S	0.70	0.16	0.70	1.26	1.00
1999	**DFS**	0.40	0.17	0.40	2.77	1.00
	D…S	0.38	0.16	0.38	2.88	1.00
	FS	0.84	0.21	0.84	1.60	1.00
	F…S	0.73	0.18	0.73	1.84	1.00
2000	**DFS**	0.50	0.22	0.50	1.58	1.00
	D…S	0.49	0.21	0.49	1.84	1.00
	FS	0.97	0.24	0.97	1.00	1.00
	F…S	0.95	0.23	0.95	1.17	1.00
2001	**DFS**	0.50	0.21	0.50	1.26	1.00
	D…S	0.49	0.21	0.49	1.38	1.00
	FS	1.03	0.26	1.03	1.00	1.00
	F…S	1.01	0.25	1.01	1.00	1.00

Source: composed by the authors.

The efficiency index by DEA can also be calculated as the solution of the problem (2) and the efficiency index equals the maximum of the one-output-one-input efficiency indices of the examined unit relatively to the target unit. Therefore, in order to observe the differences of the cases of the different reference groups in more detail, the fractions $(v_{jt}/s_{it})/(v_{je}/s_{ie})$ for every output-input pair are calculated and depicted in Figures 3 and 4.



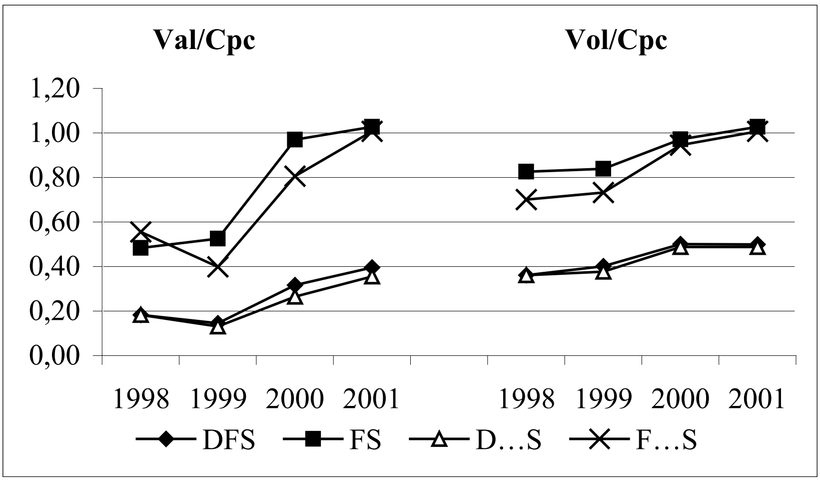


Figure 3. Dynamics of Est one-output-one-input efficiencies relative to target unit for different reference groups.

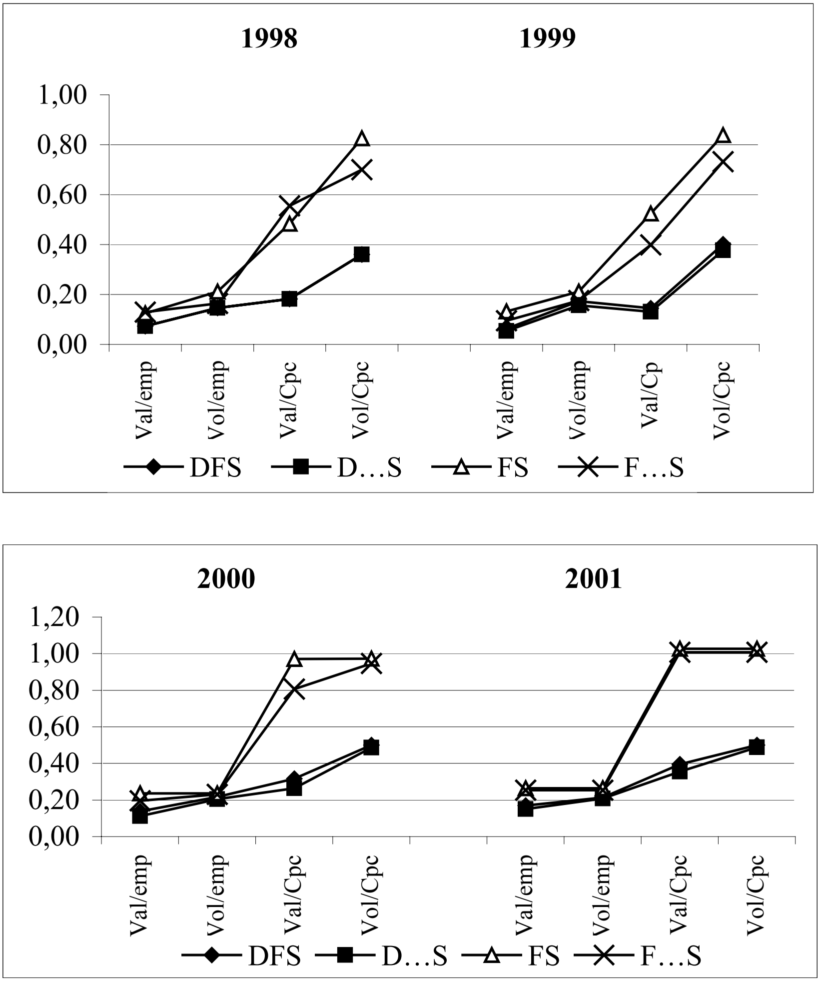


Figure 4. Output-input fractions in different years.

From Table 5 and Figure 4 we see that the efficiency indices, the differences of the input-output values of the examined unit and the target unit, and the one-output-one-input efficiency indices relative to the target unit

- depend substantially on including Den into the reference group,
- depend, although noticeably less than on including Den, on whether the data of all the years or only of the same year are considered in the reference group.

All the further calculations are done for the reference groups D...S and F...S only.

In Table 5 the high value of the efficiency index of Est against the reference group F...S may be somewhat surprising. This high value is a result of the comparatively (compared with Fin and Swe) efficient use of its capacity (Cpc) to produce volume by Est. The inefficiency in using labour and in producing value is not reflected in the efficiency index. (Thus Table 5 and Figure 4 are good illustrations that the efficiency index by DEA is in some sense the upper estimate of the efficiency in the model, because it is determined by the best one-output-one-input efficiency index relative to the target unit and is not dependent on how inefficiently the other inputs are used and the other outputs produced.) Table 5 and Figure 4 indicate that the efficiency index of Est by DEA is considerably higher than the actual efficiency of Est if all the inputs-outputs are considered.

We recall that the differences of the input-output values of the examined unit and the target unit give some hint as to which inputs could be used and which outputs could be produced more efficiently by the examined unit. (Also the one-output-one-input efficiency indices relative to the target unit can be used for this.) In our case, Est may have had the potential to use significantly less labour and to produce more value of landings. (Reducing the employment on board and increasing the value of landings had also resulted in real efficiency being closer to the efficiency index by DEA.) Similar conclusions were reached by the provisional analysis of data.

The ineffective use of labour compared to the use of the capacity of the fleet is likely connected with the historic grounds and technical backwardness — in Est the amount of the invested capital per unit of employment is about 7–8 times smaller than in Den or Swe and 3–4.5 times smaller than in Fin, and the capacity (Cpc) per unit of employment is 2–4 times lower. Presumably, the technology is used which demands more labour and the technical backwardness is partly compensated for by the more extensive use of labour (employment on board). Hence the technical progress (and EU subsidies for this) can cause serious social problems here, while the quotas restrict the volume of landings.

The inefficiency in producing the value of landings compared with the volume of landings, especially noticeable with the reference group D...S, is caused, as explained earlier, by the structure of catches. Here the solution can be the subsidies and/or the quotas to catch more valuable fish in the economic zones of the other countries.

It is clear from Table 5 (and Figure 4) that the relative inefficiency of Est in producing the value of landings is mostly ignored when estimating the efficiency by DEA. At the same time, from the economic viewpoint the value of landings is of utmost importance. Therefore we also calculated the efficiency indices for Est separately in the cases if only the volume of landings or the value of landings is considered as the output.

In Table 6 and Figure 5 the results are presented for the reference groups D...S and F...S. Here we calculated also the efficiency indices for Est2002.[6] As could be expected, the efficiency indices based on value are about half of the indices based on volume. (All the indices expose a small increasing trend in time and the diffe-

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[6] We have data for Est2002 in *Economic Performance of Selected European Fishing Fleets: Annual Report 2003*. By these data Emp=606, Cpc=24.04, Val=10.7, Vol=67.7 for Est2002. But we have no data about other fleets in 2002.

rence between the efficiency indices based on value and volume tends to decrease slightly.)

Table 6. Efficiency index by one output (Val or Vol) for the different reference groups.

Year	D…S		F…S	
	Val	**Vol**	**Val**	**Vol**
1998	0.18	0.36	0.27	0.70
1999	0.13	0.38	0.19	0.73
2000	0.26	0.49	0.39	0.95
2001	0.35	0.49	0.53	0.95
2002	0.31	0.51	0.46	0.99

Source: composed by the authors.

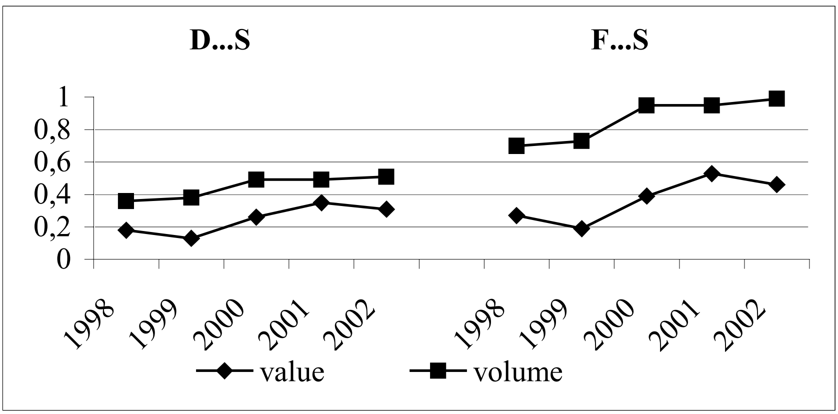

Figure 5. Efficiency index by one output for the different reference groups.

As explained earlier, the main reason for such a large difference in efficiency coefficients is in the operating conditions of Est, resulting in a comparatively bad structure of landings. In order to compensate for this, Estonia can apply for and the EU can deliver to Est some quota for more valuable species in the economic zones of the other EU countries.

When applying for the quota from the EU, it is of great importance to give reasons for the amount of this quota. One possible argument here can be that the quota must equalize the efficiencies by value and by volume. (In this case the amount of work and the value of the result of this work were in equal ratio for all the parties.) Therefore we calculated, for the years 2001 and 2002, with the total of landings unchanged, the percentage and volume of more valuable species in the landings of Est, under which the efficiencies by value and by volume were equal for Est. We used average prices (calculated on the basis of EAEF 2003) of more valuable and cheaper species for all landings (not only landings from the Baltic Sea fleet) in Estonia in 2002.

As the result obviously depends on the presence of Den in the reference group, the results are calculated for both reference groups, D...S and F...S. The results of the calculations are presented in Table 7.

Table 7. Efficiency coefficients of Est by the value of landings with a hypothetical % of valuable species in the total catch.

2001				**2002**			
% of valuable species	**Vol of valuable species**	**Ef. index D…S**	**Ef. index F…S**	**% of valuable species**	**Vol of valuable species**	**Ef. index D…S**	**Ef. index F…S**
0%	0	0.35	0.53	0%	0	0.31	0.46
2.5%	1,685	0.39	0.58	5%	3,383	0.37	0.55
5%	3,370	0.44	0.66	10%	6,765	0.43	0.64
7.5%	5,055	0.49	0.74	15%	10,148	0.49	0.72
10%	6,740	0.55	0.81	20%	13,530	0.54	0.81
12.5%	8,425	0.60	0.89	25%	16,913	0.60	0.90
15%	9,770	0.64	0.95	30%	20,600	0.67	0.99

Source: composed by the authors.

Comparing the data of Tables 6 and 7 we get for the years 2001 and 2002 the quota for more valuable species, which would have equalized the efficiency of producing the value of landings with the efficiency of producing the volume of landings, assuming the actual total of landings. For the reference group D...S, the necessary quota was 5,055 t in 2001 and 11,500 t in 2002, while for the reference group F...S it was 9,770 t in 2001 and 20,600 t in 2002.

As a matter of fact, the quotas for more valuable species were already delivered to Estonia as 1,353 t of cod for the year 2002, 1,135 t of cod for the year 2003 and 1,097 t of cod for the year 2004 (EMA 2003). Thus the quota actually imposed by the EU on Estonia is much smaller than the one that would have equalized the efficiency indices of Est by value and volume of landings.

There is also another problem with these actually delivered quota — they were delivered for Estonia (and not for Estonia's Baltic Sea area trawl fleet) and were used by other Estonian fleets. Thus to decide about the sufficiency of these quota, we would actually need to analyze the efficiency of the whole Estonian fishing fleet.

Conclusions

In this chapter an attempt was made to use the DEA approach to estimate the relative efficiency of the Estonian Baltic Sea trawl fleet. The data for the analysis were taken from the publication *EAEF Economic Performance of Selected European Fishing Fleets: Annual Reports 1999–2002.* Due to a lack of comparable data, only the trawl fleets of Denmark, Finland and Sweden in the Baltic Sea area between 1998 and 2001 were used in the reference group. For DEA analysis, the employment on board and the capacity of fleet (in kW) were chosen as the inputs, and the value and volume of landings as the outputs. Even with these data, problems like the representativeness and comparability of the data, the correspondence of the data to the meaning of the indicators and the occasional deviations of the data from their typical values arose. It is quite questionable to apply the DEA approach with such a data set. Nevertheless, the obtained results accord with common sense based on prior information.

The efficiency index was calculated for two reference groups, for the group F...S including only the trawl fleets of Finland and Sweden, and for the group D...S including also the trawl fleet of Denmark. The reason for this was that the data of Denmark looked quite different from the data of the other countries.

For the years 2000 and 2001, the efficiency index for Est by DEA was about 0.5 relative to D...S and about 1 relative to F...S. The high value of efficiency index relative to F...S is a result of the comparatively (compared with Fin and Swe) efficient use of capacity by Est for producing volume. The inefficiency in using labour and in producing value is not reflected by the efficiency index. Thus, for example, the efficiency of Est was actually much lower than its efficiency index by DEA.

The results of the calculations indicate that the Estonian fleet has been quite inefficient in using labour compared to the use of capacity. This is in accordance with the technical backwardness of the Estonian trawl fleet, which presumably has led to more extensive use of the labour force. Thus the quick technical progress supported by EU subsidies may cause serious social problems here.

The calculations also show that the relative inefficiency of Est in producing the value of landings is mostly ignored when estimating the efficiency by DEA. At the same time, from the economic viewpoint, the value of landings is of utmost importance. Therefore we also calculated the efficiency indices of producing the value and the volume of landings for Est separately. The efficiency of producing the value of landings was approximately half of the efficiency of producing the volume of landings. This is explained by the structure of catch, which is determined by the geographical factors — in the economic zone of Estonia only relatively cheap fish species are found.

To compensate for the worse conditions, Estonia can apply to the EU for some quota of catching more valuable fish in the economic zones of the EU countries. We calculated the amount of the quota, which was necessary for equalizing the efficiency of producing the value of landings and the efficiency of producing the volume of landings, assuming that the total of landings remains unchanged. For the reference group F...S it was 9,770 t in 2001 and 20,600 t in 2002, and for the reference group D...S it was 5,055 t in 2001 and 11,500 t in 2002.

As a matter of fact, the EU has, starting with the year 2002, already delivered to Estonia a quota of 1,353 t cod in 2002, 1,135 t cod in 2003 and 1,097 t cod in 2004. We see that the quota delivered by the EU to Estonia was much smaller than the quota which would have equalized the efficiency indices of Est by value and volume of landings. There is also another problem with this actually delivered quota — it was delivered for Estonia (and not for Estonia's Baltic Sea area trawl fleet) and was used by the other Estonian fleets. Thus to decide about the sufficiency of the quotas, we would actually need to analyze the efficiency of the whole Estonian fishing fleet.

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