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N° D-21-2007

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Working Papers Series

www.gdr-amure.fr

ISSN 1951-641X
AMURE Publications. Working Papers Series.
Online publications : www.gdr-amure.fr

Excess capacity and fuel consumption – The case of the fishing fleet in Brittany (France)

- Excess capacity in fisheries (France) -

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Abstract : This paper addresses the question on the origins of excess capacity situations in fisheries. DEA model is applied to the trawling fleet in Brittany (France) and provides performance scores, in term of unbiased capacity utilization on a monthly period (from January 1994 to December 2003). However, DEA method does not inform on the origins of scores. Consequently, fishermen's behavior is analyzed according to fluctuations in costs of variable inputs. Amongst them, fuel cost appears as the main preoccupation of crew members. Finally; relationship between capacity and inputs framework does not appear so trivial to support the assumption that excess capacity is, for instance, driven through an increase in fuel price.

Key-words: Data Envelopment Analysis - Excess capacity – Efficiency – Fisheries

1. Introduction

The measure of capacity utilisation is more and more derived from DEA (Data Envelopment Analysis) method. The implementation of this mathematical tool requires individual data on outputs and inputs. Usually, results are defined in terms of capacity utilization (CU) and technical efficiency (TE) in the level of individual fishing vessels (defined as Decision Making Units – DMU) and fleet level. The former score (CU) takes into account only fixed costs whereas the latter (TE) includes fixed and variable costs. An unbiased measure of capacity utilisation can be suggested as a weighted result by technical efficiency measure.

In these conditions, excess capacity is easily interpreted as the non-fully used part of the unbiased capacity utilisation. However, DEA method does not inform on the origins of scores. Typically, how can we explain the worst situation in terms of capacity utilisation and excess capacity at the fleet level given by the model ? This paper addresses this question, drawing on the performance of the trawling fleet in Brittany (France) from January 1994 to December 2003. The method consists of a post-analysis of fixed and variable inputs used by the fleet on a monthly basis following a discussion of capacity utilisation scores and excess capacity. Particularly, fishermen's behaviour can be analysed according to fluctuations in costs of variable inputs. Amongst them, fuel cost appears as the main preoccupation of crew members. Traditionally, fuel expenses are paid commonly by skip-owner and crew members. Hence, every time this input price is soaring, labour remuneration is dropping. In these conditions, it appears pertinent to focus our attention on a potential effect of inputs prices on excess capacity levels.

Section 2 briefly presents DEA method, applied to technical efficiency and capacity utilisation. Materials required in the estimation of capacity are described in section 3. The trawlers fleet, located in Southern Brittany, is divided into three segments. Individual data are available on a monthly basis from 1994 to 2003. As most fishing vessels using active gear, these units are characterised by multi-production, including a set of target species and by-catch. Results from the DEA analysis are shown in section 4 in terms of excess capacity. These scores are relative measures and are constrained through the size of samples. Section 5 is a first attempt to provide explanations of excess capacity levels from inputs framework. A discussion is suggested in a final section.

2. Methods

The origins for the current measurement of efficiency of production is typically regarded to be the work of Farrell (1957). Since, several techniques for measurement have been developed. One such technique is that of data envelopment analysis (DEA) which can be used to estimate technical, allocative and economic efficiencies (Charnes et al, 1978; Banker et al, 1984). DEA is deterministic and as a result does not require pre-specification of the frontier technology. It provides a relative measure for those firms[i] being compared, hence at least one firm will lie on the frontier in a DEA analysis.

In this report, DEA is applied to data for French fishing vessels operating in Southern Brittany. DEA has been used considerably in recent years in fisheries economics for the measurement of vessel technical efficiency and capacity utilisation (e.g. Tingley et al, 2003; Kirkley and Squires, 1999). In fact, DEA has been promoted as the preferred technique for such analysis since 2000 by the Food and Agriculture Organisation of the United Nations (FAO, 2000).

Here, not only do we consider technical efficiency, as well as capacity utilisation, but we also use individual vessel accounts in order to compare these results to the actual economic performance of the vessels. It is rarely possible in fisheries to have access to such data, and as such provides for an innovative analysis.

The technical efficiency (TE) measure can by obtained by solving the following DEA model:[ii]

$$Max\ \theta_i$$

Subject to

$$\begin{aligned} &\theta_i y_{im} \le \sum_j \lambda_j y_{jm} && \forall m \\ &\sum_j \lambda_j x_{jn} \le x_{in} && \forall n \\ &\lambda_j \ge 0 \end{aligned} \tag{1}$$

Where θ_i is a scalar outcome denoting how much the production or outputs, y_m, of each firm, *i*, can increase by using inputs, x_n, (both fixed and variable) in a technically efficient configuration. In this case, both variable and fixed inputs are constrained to their current level. In this case, θ_i represents the extent to which output can increase through using all inputs efficiently, and is therefore output-based. The technically efficient level of output (y^*_{TE}) is defined as θ_i multiplied by observed output (*y*). As defined, this model represents a constant return to scale (CRS) assumption. In order to model variable returns to scale (VRS) or non-increasing returns to scale (NIRS), the constraints $\sum_j z_j = 1$ or $\sum_j z_j \le 1$ respectively are required.[iii] The level of technical efficiency is estimated as:

$$TE_i = 1/\theta_i \ . \tag{2}$$

Following Färe *et al.* (1989, 1994), a measure of capacity output can be found using:

$$Max\ \theta_i^{'}$$

Subject to

$$\begin{aligned} &\theta_i^{'} y_{im} \le \sum_j \lambda_j y_{jm} && \forall m \\ &\sum_j \lambda_j x_{jn} \le x_{in} && \forall n \in \alpha \\ &\lambda_j \ge 0 \end{aligned} \tag{3}$$

Where $\theta_i^{'}$ is a scalar denoting the multiplier that describes by how much the output of firm *i* can be expanded. In the estimation of capacity, only fixed factors are considered where inputs are separated into fixed factors (i.e. set α) and variable factors (i.e. set $\hat{\alpha}$). Capacity utilization (CU) for firm *i* is defined as:

$$CU_i = 1/\theta_i^{'} \ . \tag{4}$$

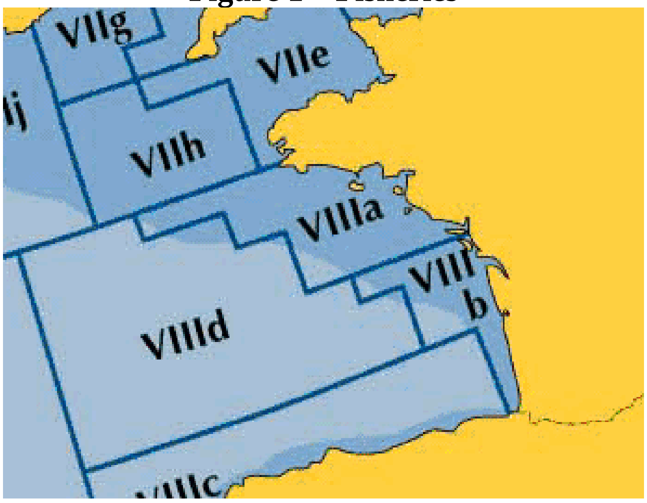
An unbiased estimate of capacity utilization (*CU**) for firm *i* is estimated by removing the effects of technical efficiency from the capacity utilization measure (i.e. equation 7 divided by equation 2), and is achieved by the following equation:

$$CU_i^* = \frac{CU_i}{TE_i} = \frac{\frac{1}{\theta_i^{'}}}{\frac{1}{\theta_i}} = \frac{\theta_i}{\theta_i^{'}} \qquad (5)$$

3. Materials

Data used for DEA analysis come from the Regional Economic Observatory in Brittany, a NGO created by a professional fishers organisztion. Three segments of trawlers are defined in terms of length. The smallest group is composed of vessels of 12-16 meters exploiting resources mainly in inshore fisheries (VIIIa area). The second segment characterizes trawlers of 16 to 20 meters. Most of the time, vessels belonging to this segment produce fish in offshore fisheries (WIIIa, VIIh areas), but a few of them spend fishing time in the same grounds as the first segment units. The biggest trawlers compose the third segment, with a length of 20-25 meters. These largest fishing units produce fish essentially in offshore fisheries (VIIh-g areas).

Figure 1 – Fisheries



Individual observations by boat are available over 120 months, from January 1994 to December 2003, and include information on price and quantities by species, technical parameters (length, engine power) and fuel consumption (liters). Months during which boats had no fishing activity have been removed from the analysis (13 observations for 12-16 meters boats, 12 for 16-20 meters boats, and 26 for 20-25 meters boats). If the model is specified on a monthly basis, scores are averaged from individual data based on monthly production by boat and by year. Hence, number of data is 1560 for the 12-16 meters sample (less 13 months with no production), 600 for the 16-20 meters sample (less 12 months with no production), 1320 for the 20-25 meters sample (less 26 with no production).

DEA model had to be specified as follows, respectively for the three segments:

$$Max\ \theta_i$$

Subject to

$$
\begin{aligned}
\theta_i y_{ilm} &\le \sum_{j=1}^{i}\sum_{t=1}^{12}\lambda_{jt} y_{jtm} \qquad \forall l = 1...12, m \\
\sum_{j=1}^{i}\sum_{t=1}^{12}\lambda_{jt} x_{jtn} &\le x_{il\,n} \qquad \forall l = 1...12, n \\
\sum_{j=1}^{i}\sum_{t=1}^{12}\lambda_{jt} &= 1 \\
\lambda_{jt} &\ge 0
\end{aligned}
\tag{6}
$$

Table 1 – Fleet characteristics

	12-16 m	16-20 m	20-25 m
No of boats	13	5	11
Average engine power (kw)	214.8	305.4	410.9
Average overall length (meters)	14.8	18.0	21.4
Observations with DEA (boat x month)	156	60	132

Fixed inputs are represented by length and engine power. As abundance index is not available on a monthly basis, a proxy has been built as a catch per unit of fuel consumption from landings by selected species (kg) divided by fuel consumption (litres) at the level of each sample. In empirical applications of DEA, abundance index is considered as fixed input or more precisely "…DEA model also included biomass levels…as additional fixed environmental parameters…"(Dupont et al., 2002). Variable input is included through fuel consumption. The set of target species varies considerably according to the segment fleet observed. The smallest units, so called 12-16 meters, exploit simultaneously and mainly five stocks (nephrops, anglerfish, megrim, hake and sole). Cod and whiting stocks have to be added to the above list in the case of the intermediate segment, 16-20 meters. The biggest trawlers produce a larger panel of fish in offshore fisheries, including those cited previously. Eventually, three species have been selected in DEA analysis (nephrops, anglerfish, megrim) because they are considered as the main valuable products for all three segments. Others species, targeted fishes and by-products, are gathered in a fourth category.

Table 2 – Inputs and outputs used in the DEA analysis

Fixed inputs	Input variable	Outputs*
- Lenght (meters) - Engine power (kW) - Catch per unit of fuel (kg/l)	- Fuel consumption (litres)	- Nephrops - Anglerfish - Megrim - Other species

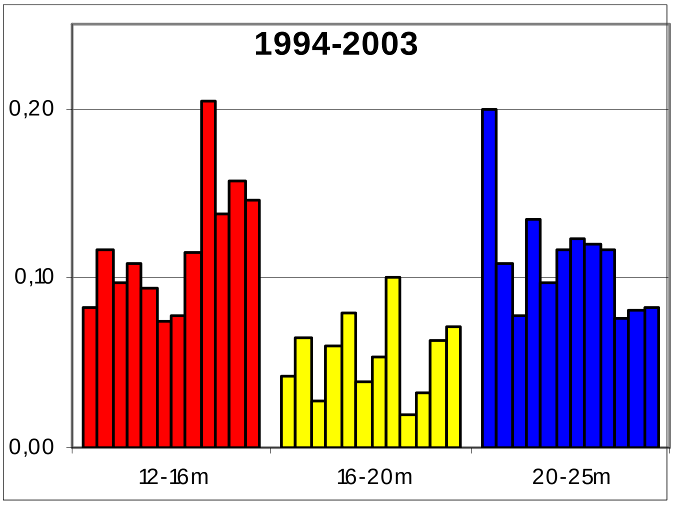
*Landing values have been inflated to 2003 values using a Fisher price index.

4. Capacity utilization and excess capacity

In this work, excess capacity is used as a dual measure of unbiased capacity utilization (CU*). Precisely, the difference between CU* and the number 1, meaning a totally efficient score for the fleet, reveals the scope of excess capacity. As the overcapacity concept, excess capacity means an economic waste of inputs. If the former reveals a long run problem, requiring management measures by a public agency (FAO, 2003a, 2003b), the latter could be, in theory, managed by market forces. Indeed, excess capacity can be defined as "the inability of capital inputs to adjust instantaneously to changes in prices and variable costs and is considered to be a short-run, self correcting phenomenon" (Ward, Mace and Thunberg, 2005).

Average measures of excess capacity are given for all three segments by month for the period 1994 to 2003 (figure 2). The highest scores are devoted to the smallest units in September (20%) and the biggest trawlers in January (20%). The intermediate segment, only described from 5 vessels, has recorded excess capacity of less than 10%. These measures have been produced during different historical contexts. Consequently, it appears more interesting to analyze how fleet segments behaved year by year (figure 3). This approach, based on relative measures of excess capacity within a segment, can be related to input usage modifications. Permanently, fishermen have to respond to input variations, in terms of prices or abundance, and can change their fishing strategy as an adjustment to market forces or biomass variability.

Figure 2 – Average measures of excess capacity on the period 1994-2003

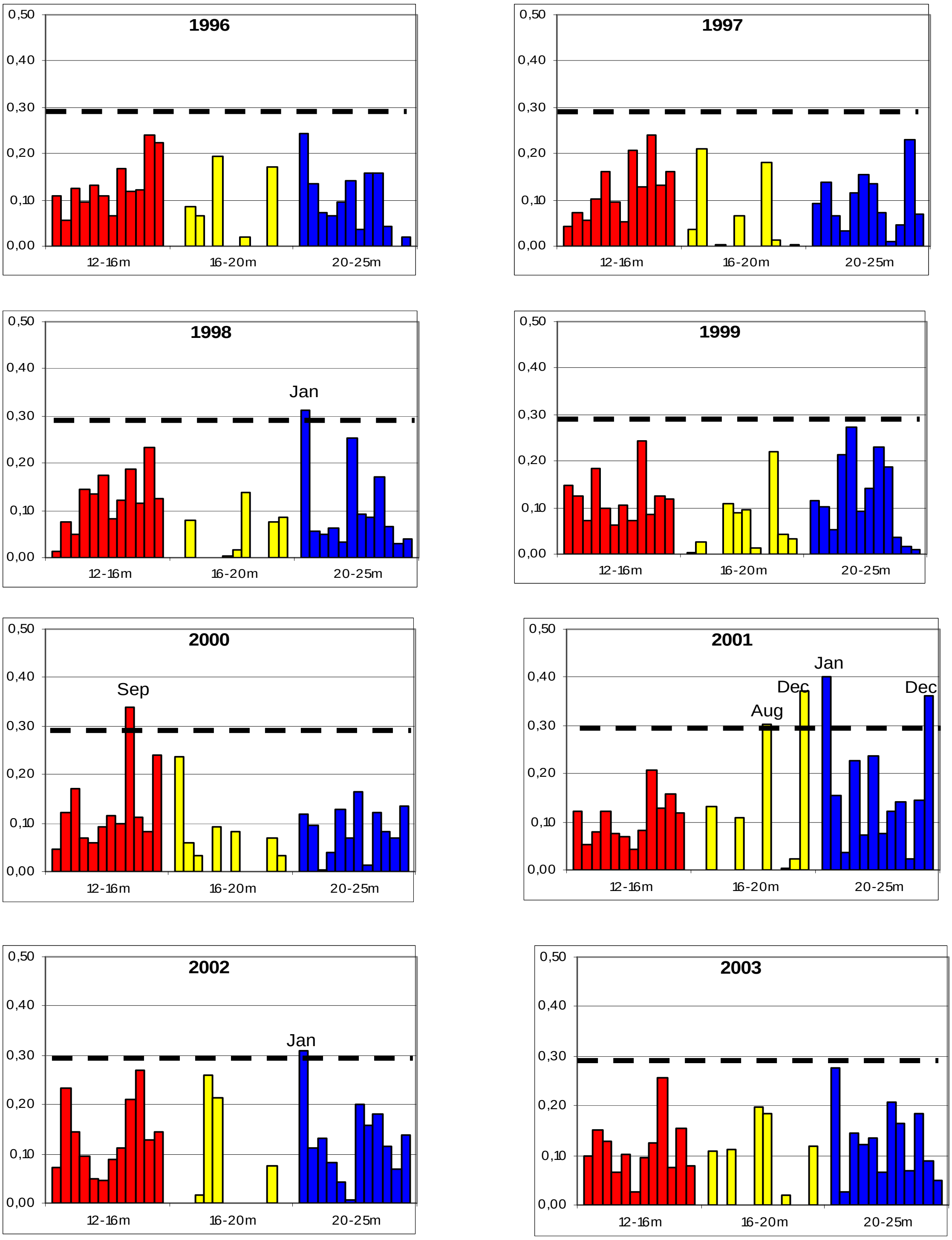


If we consider all scores of excess capacity up to 30%, different historical paths are defined from the figure 3. The 12-16 meters class had an average excess capacity of 34% in September 2000. 8 out of 13 boats had an excess capacity up to 30%, and five of which displayed a level as high as 45%. Usually, they have used fully their capacity utilization in May and June, which means no economic waste of their inputs.

If average measures of excess capacity are low for the 16-20 meters segment for the overall period, these boats had monthly scores up or equal to 30% in August 1994 (30%), August 2001 (30%), and December 2001 (37%). The worse result (December 2001) is explained by the fact that 3 out of 5 vessels have recorded an excess capacity up to 45%.

The biggest units exceeded their capacity by 30%, in January 1998 (31%), in January 2001 (40%), in January 2002 (31%), in April 1994 (36%), and in December 2001 (36%). 8 out of 11 units were in excess up to 30% in January 2001, and 7 of them have scored an excess up to 45%.

Figure 3 – Average scores of unbiased CU



Occurrence of excess capacity situations is explained by short run variations in input and output prices. Other considerations can influence fishermen's behavior, such as biological seasons for target species and weather conditions. When short run variations occur, we can expect an adaptation in fishing strategy, meaning a change in the capacity utilization of vessels. Of course, this is a relative measure of capacity and excess capacity compared with all scores during the study period. In the following section, we make an attempt to explain the highest levels of excess capacity mentioned above with inputs framework, particularly fuel price (as the variable input) and the proxy for abundance (catch per unit of fuel).

5. Excess capacity levels and inputs framework

According to the definition given by Johansen (1968), capacity utilization is : "the maximum amount that can be produced per unit of time with the existing plant and equipment, provided that the availability of variable factors of production is not restricted" (p. 57, cited in Färe et al 1994). Consequently, excess capacity can be interpreted as a result of a non-maximized production in the short term due to fluctuations in fuel price. In a first sub-section, analysis is focused on fuel price evolution and total revenue of landings. The second sub-section suggests an explanation of the highest levels of excess capacity from fuel consumption and catch per unit of fuel consumption. These two analyses are implemented on a monthly basis.

51. Fuel price

Usually, fuel cost appears as the more important variable cost for fishing units, specifically for vessels using active gear (trawling and dredging). For this reason, fishermen's behavior can be influenced in a context of strong variations of fuel price. During the study period, from January 1994 to December 2003, fuel price increased by 0.24% per month (average monthly growth rate). Monthly average price for fuel, providing by the Fishermen Association in Southern Brittany, reached 0.17 € / liter in January 1994[iv], the fuel price index being 0.75 compared to December 2003 as the reference period. In December 2003, fuel price was around 0.23 € / liter. In a retrospective analysis, fuel crisis can be precisely dated for trawlers fleets in Southern Brittany, beginning in February 1999 (the lowest level during the overall period, 0.12 € / liter) and ending twenty one months later in November 2000 (the peak of the curve), with a level of 0.37 € / liter. During this time-span, price fuel was soared every month at an average growth rate of 6 %.

In these conditions, we can expect modifications in fishing strategies through a weaker utilization of potential capacity. Mechanically, labour and capital remuneration decrease with a constant rise in fuel price.

For instance, a permanent increase on fuel price might change fishermen's behavior by a reduction in fishing time, thereby developing an excess capacity phenomenon. This assumption has been made in a clear and concise explanation of excess capacity concept (Ward, Mace and Thunberg, 2005). Indeed, a few fishing companies, managing 30-35 meters trawlers in South Brittany, decided to stop their activity for a short period in August 2000 (Le Monde, 22 August 2000). Table 3 shows measures of excess capacity for the three segments during the period of highest prices for fuel. Only the smallest units had a low score in term of unbiased capacity utilization, 66% of their potential capacity was used in September 2000. This represents an excess capacity of 34%. In other cases, it does not seem that fuel price could be considered as a driving force in fishing behavior modification. On the contrary, the remuneration's share system is often used as a shock absorber in the fishing industry to compensate for the rise of other variable costs such as fuel expenses.

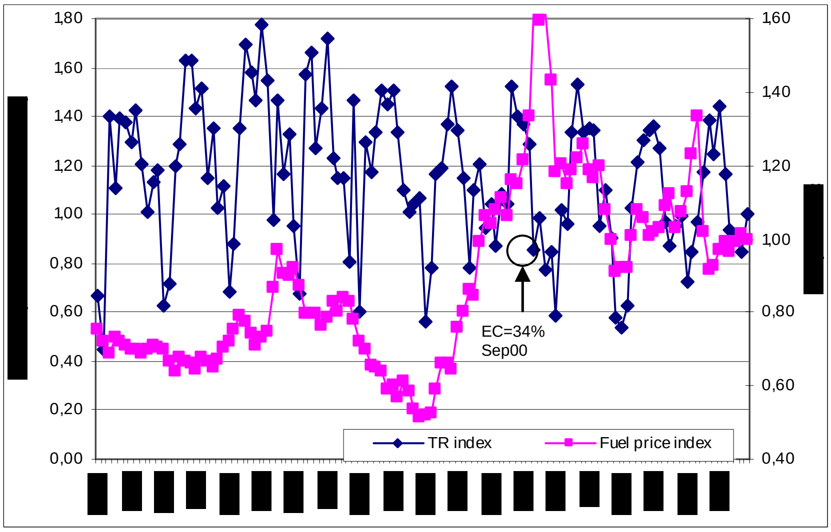
In 8 out of the 9 cases listed in table 3, excess capacity was reached maximum 12%. This means that most of units used almost fully their fishing capacity in a context of high level for fuel price. This apparent paradox can be explained in term of low opportunity cost for labour and capital in fisheries.

Table 3 – Measure of excess capacity during the peak of fuel crisis

	12-16m	16-20m	20-25m
Sept. 2000	34%	0%	12%
Oct. 2000	11%	0%	8%
Nov. 2000	8%	7%	7%

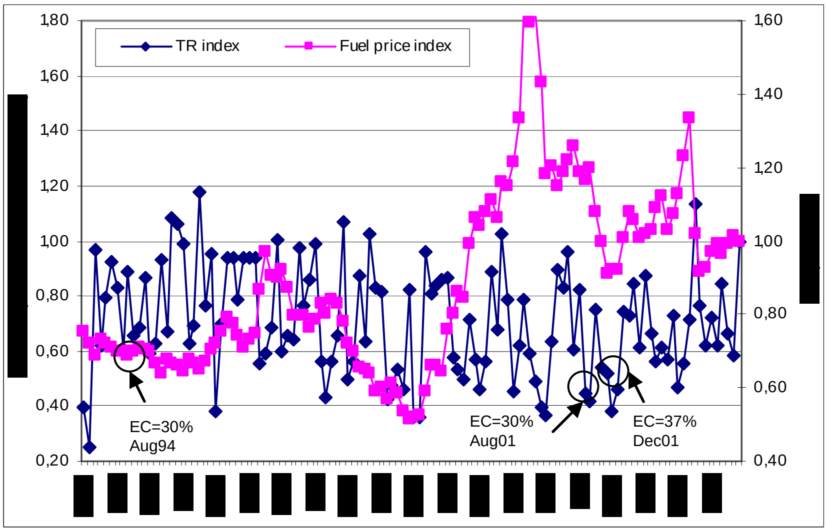
Total revenue index, inflated with a Fisher price (FP) index, and fuel price index are depicted on the following figures. Levels of excess capacity up or equal to 30% are indicated on the total revenue index curve. The 12-16 meters fleet has registered an excess capacity superior to 30% in September 2000, corresponding to a peak in fuel price. However, no boat stopped its activity during the second semester of the year 2000. Moreover, unbiased capacity utilization reaches respectively 89% and 92% in October and November 2000, whereas fuel price is maintained at its highest levels.

Figure 4 – Evolution of Total Revenue (TR) index and Fuel Price index – 12-16 meters



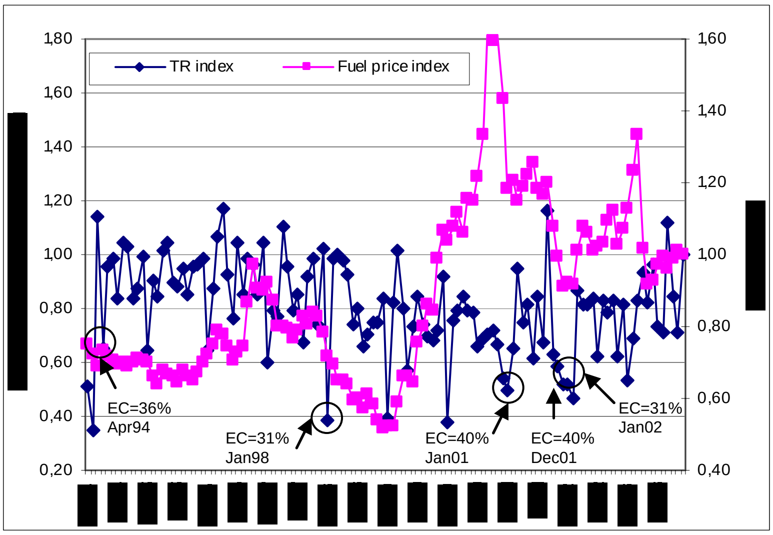
The three excess capacity situations are clearly not related to fuel price for the 16-20 meters trawlers (figure 5), none occurring during the "fuel crisis". They appeared when monthly total revenue was 39% (August 1994) to 55% (August 2001) less than in December 2003 (the reference period). But if we compare total revenue index to similar months (August and December) during the decade, revenues generated in August 1994, August 2001 and December 2001 were not the lowest landings values. For instance, total revenue in August 1998 was 57% inferior to revenue in December 2003, but excess capacity was only estimated to be 14%. Consequently, high levels of excess capacity (up to 30%) do not mean automatically the worst performance in term of gross revenues.

Figure 5 – Evolution of Total Revenue (TR) index and Fuel Price index – 16-20 meters



Like the first two samples of trawlers, the last one rejects the assumption of a relationship between fuel price and excess capacity (figure 6). Average capacity utilization has been estimated to be a minimum of 80% during the “fuel crisis”. Conversely, DEA analysis has shown that capacity utilization reached the lowest levels before and after this high fuel price period. In only two out of five excess capacity up to 30%, total revenue was the lowest compared to other scores for identical months (total revenue indices are 0.65 and 0.52 respectively for April 1994 and December 2001). The lowest landing values registered in January occurred in 2000, with total revenue of 62% less than in December 2003 (index being 0.38). In spite of this poor result, capacity utilization was slightly in excess of 12%. On the other hand, excess capacity was up to 30% in January 1998, 2001 and 2002. Total revenue indexes were respectively 0.39, 0.49 and 0.52.

Figure 6 – Evolution of Total Revenue (TR) index and Fuel Price index – 20-25 meters



Finally, no clear relationship exists between fuel cost variations and fishermen’s behavior at the fleet level. If the excess capacity phenomenon is supposed to be driven by market forces in the short run, fishermen can use a set of options as a response to market signals. Particularly, multiple-output fisheries are characterized by different target species and by-catch products. Consequently, skip-owners have the possibility to adapt their fishing strategy in the short-run. In DEA analysis, three target species were selected (anglerfish, megrim, nephrops). In the next sub-section, these biological factors associated with fuel consumption are used to analyze fishing behavior specifically for the 9 monthly periods displaying the highest excess capacity levels.

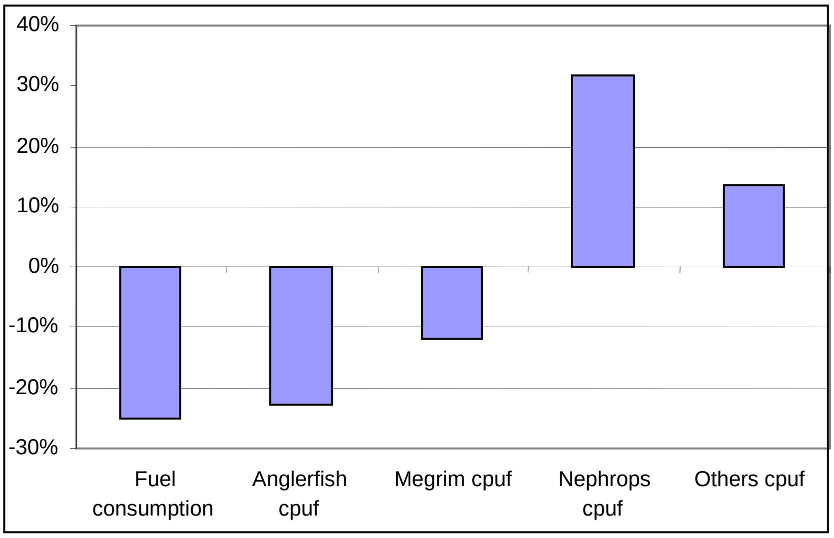
52. Fuel consumption and catch per unit of fuel

Variable cost, expressed through fuel consumption in DEA analysis, and catch per unit of fuel (cpuf), designed as a fixed asset[v], are used in terms of monthly variations. If we can logically accept the assumption of expanding excess capacity when fuel price is rising, it is much more problematic to guess variations of CU face to modifications in proxy for biomass, catch per unit of fuel (estimated at the sample level). According to the law of diminishing returns, we can assume that marginal product of capital decreases (increases) when effort increases (decreases). This expectation has been frequently discussed in fisheries literature (Cunnimgham and al. 1985).

As the law holds only in the short run and is fitted to physical returns (Doll, 1988), total catch (kg) per unit of fuel (liter) should soar (drop) when fuel consumption drops (soars). However, fishermen adapt their fishing effort in a multi-production process, in relation to several target stocks. As catch per unit of fuel were estimated according to target species and by-catches, we can study fishing strategies in the short run (on a monthly basis) for the three segments of trawlers. Analyses are driven during the key periods of excess capacity situations up to 30%.

The 12-16 meters fleet has decreased its fuel consumption by 25% in September 2000 compared with the average level during the same month over the period 1994-2003 (figure 7). As a result, cpuf for nephrops was considerably higher in September 2000 (+32%). Fishing effort is mainly allocated on nephrop stock, so that as this specie represents around 50% of annual total revenue for this segment of trawlers. So, we can assert that nephrops have been primarily exploited and were treated as a target species during this month, as cpuf for other species for which variation was positive (+13%). A possible explanation is a verification of diminishing returns because nephrops production was a decreasing function of fuel consumption in September 2000. On the other hand, anglerfish and megrim landings (kg / litre of fuel) were 23% lower for the first specie and 12% lower for the second in comparison to average values in September from 1994 to 2003.

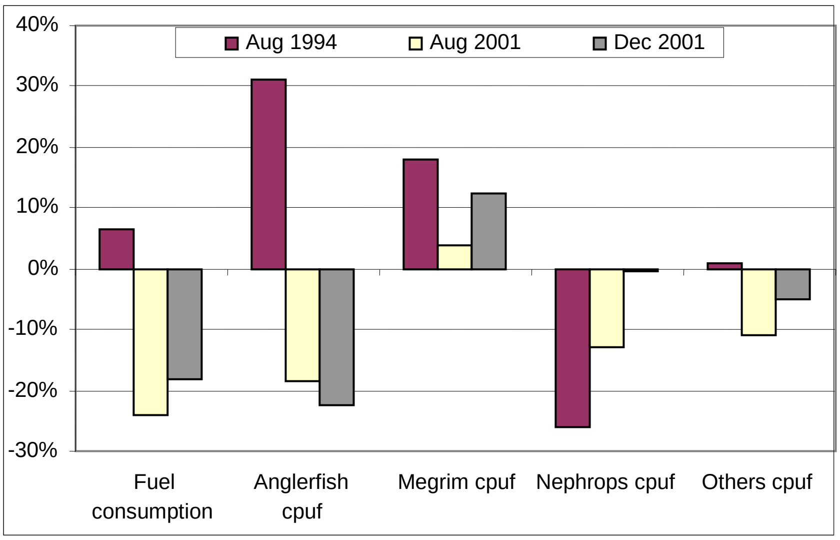
Figure 7 – Average fuel consumption and catch per unit of effort (%) in September 2000 compared to average values in September from 1994 to 2003, 12-16 meters



In August 1994, fuel consumption was superior to average level for the same month during the overall period for the intermediate segment (figure 8). Scores for anglerfish and megrim are positively correlated to fuel utilization. Cpuf for these two species were respectively higher by 31% and 18%. By rank, nephrops and anglerfish are the main outputs in weight and value. If variations are opposite for these two main valuable species in August 1994, they are both negative in August 2001 and December 2001.

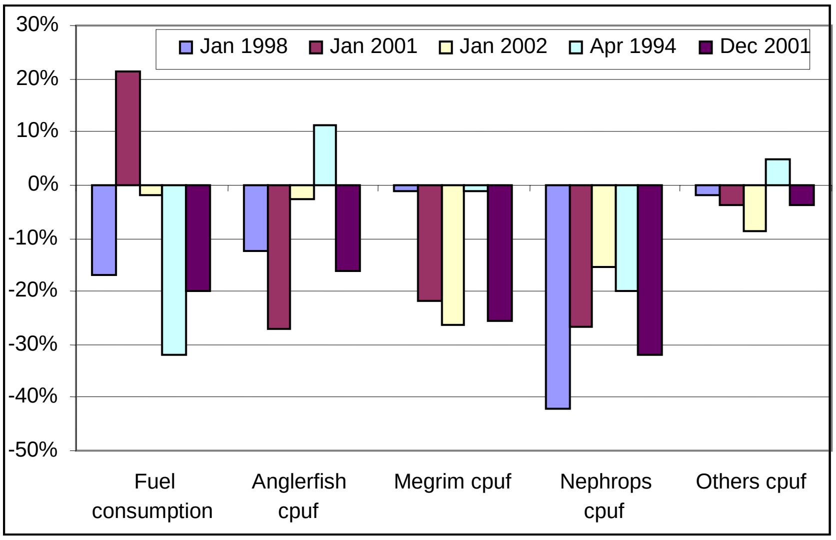
Fishermen reduced fuel consumption in August and December 2001, when excess capacity situations reached respectively 30 and 37%. However, anglerfish, nephrops and by-products landings were lower. Positive variations for megrim appear essentially as a spillover effect, this specie being less valuable for these units and can considered as a by-catch compared to nephrops and anglerfish.

Figure 8. Average fuel consumption and catch per unit of effort (%) in August 1994/2001 and December 2001 compared respectively to average values in August and December from 1994 to 2003 (%), 16-20 meters



On the five cases of excess capacity as great as 30% (figure 9), fuel consumption was higher than the average result on only one occasion, in January 2001 (21%). If we could expect a rise (a drop) in cpuf for target species when fuel consumption decreases (increases), as explained through the law of diminishing returns, this assumption is only verified in 2 cases out of 5. In January 2001, variations are negative for all species (-28% for Anglerfish and Nephrops). In April 1994, only anglerfish production is higher (11%) compared to averages landings in April during the decade, as fuel utilization was lower (-31%).

Figure 9. Average fuel consumption and catch per unit of effort (%) in January 1998/2001/2002, April 1994 and December 2001 compared respectively to average values in January, April and December from 1994 to 2003, 20-25 meters



6. Discussion

An excess capacity phenomenon up or equal to 30% of unbiased capacity utilisation was identified in nine cases for the trawlers fleet located in Southern Brittany (table 4). Smallest units, 12-16 meters segment, were in this situation one single time, in September 2000. At first glance, it could be argued that the highest level of fuel price reached in the same period caused an excess capacity situation. This is a logical assumption, which can be suggested in the short run. Although fuel consumption was reduced by –25% in September, excess capacity dropped 11% and 8%, in October and November 2000. Consequently, no evidence appears between fuel cost variation and capacity utilisation for this first segment. However, the 12-16 meters class was the only one to record an excess capacity up to 30% during the "fuel crisis" (February 1999 to November 2000). The intermediate class, composed of 16-20 meters units, was in strong excess three times, in August 1994, August 2001, and December 2001. None of them was occurred during the "fuel crisis". Our findings show that fuel consumption was higher than the average level in August 1994 (+6%), which is a surprising result to explain excess capacity. In more, cpuf for anglerfish, megrim and slightly for other species were higher than average monthly scores. Finally, the biggest vessels were in excess capacity up to 30% at five occasions. In one case, occurring in January 2001, fuel consumption was greater than the average consumption on the overall period (+21%).

Excess capacity is explained by negative variations of fuel consumption 7 out of the 9 cases. Fixed biological inputs, defined through a proxy for biomass abundance as catch per unit of fuel consumption, showed negative (positive) variations of target species when fuel utilization was decreasing (increasing) in 5 cases. On the other hand, cpuf for target species (mainly anglerfish and nephrops) was dropping (rising) when fuel consumption was rising (dropping), as theoretically expected.

Table 4 - Characterisation of excess capacity situations

Excess Capacity ≥ 30%		Fuel Crisis Feb 99-Nov 00	TR index min	TR index score	TR index max	Monthly variations Fuel	Anglerfish cpuf	Megrim cpuf	Nephrops cpuf	Others Cpuf
12-16m	Sep 2000	Yes	0.78	0.86	1.2	-25%	-23%	-12%	+32%	+13%
16-20m	Aug 1994	No	0.43	0.61	0.94	+6%	+31%	+18%	-26%	+1%
	Aug 2001	No	0.43	0.45	0.94	-24%	-18%	+4%	-13%	-11%
	Dec 2001	No	0.39	0.52	1.07	-18%	-22%	+12%	0%	-5%
20-25m	Jan 1998	No	0.38	0.39	0.64	-17%	-12%	-1%	-42%	-2%
	Jan 2001	No	0.38	0.49	0.64	+21%	-27%	-22%	-27%	-4%
	Jan 2002	No	0.38	0.52	0.64	-2%	-3%	-26%	-15%	-9%
	Apr 1994	No	0.65	0.65	1.17	-32%	+11%	-10%	-20%	+5%
	Dec 2001	No	0.52	0.52	1.04	-20%	-16%	-25%	-32%	-4%

Relationship between capacity and inputs framework does not appear so trivial to support the assumption that excess capacity is, for instance, driven through an increase in fuel price. On the contrary, empirical applications have proved that capacity utilization could be optimal (equal or near to one and consequently on the production frontier) whereas fuel price reached a maximum peak. In fact, this research could be oriented toward a behavioral analysis of fishermen. Indeed, two topics deserve a special attention. Firstly, crossed effects can be expected amongst variable inputs, particularly between fuel expenses and labor cost. Labor remuneration, traditionally based on a share process, is often used as a shock absorber to compensate an increase in fuel price (Gaspart, Seki, 2003). Secondly, fishermen are usually said to have low opportunity costs. Consequently, they have no economic incentives to cut back their level of activity in a context of rocketing fuel price. Furthermore, they can expect to receive subsidies from public agencies, as it is the case in the French fisheries.

References

Banker R.D., Charnes A., Cooper W.W., 1984. Some models for estimating technical and scale efficiencies in data envelopment analysis. *Management Science*, 30, pp1078-1092

Charnes A., Cooper W.W., Rhodes E., 1978. Measuring the efficiency of decision making units. *European Journal of Operational Research*, 2, pp429-444

Coelli, T., Rao D.S.P., Battese G.E., 1998. *An introduction to efficiency and productivity analysis*, Kluwer Academic Publishers, USA

Cunningham S., Dunn M.R., Whitmarsh D, 1985. Fisheries Economics: An Introduction. Mansell Publishing, London

Doll, J.P., 1988, Traditional economic models of fishing vessels: A review with discussion, *Marine Resource Economics*, vol.5, pp99-123

Dupont D.P., Grafton R.Q., Kirkley J., Squires D., 2002. Capacity utilization measures and excess capacity in multi-product privatized fisheries, *Resource and Energy Economics*, 24, pp193-210

FAO, 2000. *Report of the Technical Consultation on the Measurement of Fishing Capacity*. FAO Fisheries Report No.615. FAO, Rome.

FAO, 2003a. Measuring and assessing capacity in fisheries. 2. Issues and methods. Fisheries Technical Paper No 433/2. FAO, Rome.

FAO, 2003b. *Report of the Expert Consultation on Catalysing the Transition Away from Overcapacity in Marine Capture Fisheries* - Rome, 15-18 October 2002, FAO Fisheries Report No. 691

Färe R., Grosskopf S., Kokkelenberg E.E., 1989. Measuring plant capacity, utilization and technical change: a non-parametric approach. International Economic Review, 30 (3), pp655-666

Färe R., Grosskopf S., Lovell C.A.K., 1994. *Production frontiers*. Cambridge University Press, UK

Farrell M.J., 1957. The measurement of productive efficiency. *Journal of the Royal Statistical Society Series* A 120 (3), pp253-281

Gaspart F., Seki E., 2003. Cooperation, status seeking and competitive behaviour: theory and evidence. Journal of Economic Behavior and Organization, vol51, pp51-77

Johansen L., 1968. *Production functions and the concept of capacity*. Recherches récentes sur la fonction de production. Centre d'Etudes et de la Recherche Universitaire de Namur

Kirkley J.E., Squires D.E., 1999. *Measuring capacity and capacity utilization in fisheries*. In Greboval D. (ed.), Managing fishing capacity: Selected papers on underlying concepts and issues. FAO Fisheries Technical Paper 386, FAO, Rome

Tingley D., Pascoe S., Mardle S., 2003. Estimating capacity utilisation in multi-purpose, multi-metiers fisheries, *Fisheries Research*, 63, pp121-134.

Vestergaard N., Squires D.E., Kirkley J.E., 1999. *Measuring capacity and capacity utilization in fisheries: the case of the Danish gillnet fleet*. FAO Technical Consultation on the Management of Fishing Capacity, Mexico City, Mexico, November 29-December 3, 1999. FAO, Rome

Ward J., Mace P., Thunberg E., 2005. The relationship of fish harvesting capacity to excess capacity and overcapacity, *Marine Resource Economics*, 19, pp525-529

[i] In the original DEA literature, the generalised term decision making unit (DMU) is used. However, in economic application, the firm is the common concept.

[ii] This model is in fact a linear programming model, and in this case for ease of solution is denoted in the dual-form (see for example Färe et al (1994), Charnes et al (1978) and Coelli (1998) for a complete derivation).

[iii] This is the case for all DEA models presented in this paper.

[iv] Prices were deflated by the price index in 2003.

[v] Catch per unit of fuel is computed separately for target species (anglerfish, megrim and nephrops) and others products.

ISSN 1951-641X

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Excess capacity and fuel consumption – The case of the fishing fleet in Brittany (France)

- Excess capacity in fisheries (France) -

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Abstract : This paper addresses the question on the origins of excess capacity situations in fisheries. DEA model is applied to the trawling fleet in Brittany (France) and provides performance scores, in term of unbiased capacity utilization on a monthly period (from January 1994 to December 2003). However, DEA method does not inform on the origins of scores. Consequently, fishermen's behavior is analyzed according to fluctuations in costs of variable inputs. Amongst them, fuel cost appears as the main preoccupation of crew members. Finally; relationship between capacity and inputs framework does not appear so trivial to support the assumption that excess capacity is, for instance, driven through an increase in fuel price.

Key-words: Data Envelopment Analysis - Excess capacity – Efficiency – Fisheries

1. Introduction

The measure of capacity utilisation is more and more derived from DEA (Data Envelopment Analysis) method. The implementation of this mathematical tool requires individual data on outputs and inputs. Usually, results are defined in terms of capacity utilization (CU) and technical efficiency (TE) in the level of individual fishing vessels (defined as Decision Making Units – DMU) and fleet level. The former score (CU) takes into account only fixed costs whereas the latter (TE) includes fixed and variable costs. An unbiased measure of capacity utilisation can be suggested as a weighted result by technical efficiency measure.

In these conditions, excess capacity is easily interpreted as the non-fully used part of the unbiased capacity utilisation. However, DEA method does not inform on the origins of scores. Typically, how can we explain the worst situation in terms of capacity utilisation and excess capacity at the fleet level given by the model ? This paper addresses this question, drawing on the performance of the trawling fleet in Brittany (France) from January 1994 to December 2003. The method consists of a post-analysis of fixed and variable inputs used by the fleet on a monthly basis following a discussion of capacity utilisation scores and excess capacity. Particularly, fishermen’s behaviour can be analysed according to fluctuations in costs of variable inputs. Amongst them, fuel cost appears as the main preoccupation of crew members. Traditionally, fuel expenses are paid commonly by skip-owner and crew members. Hence, every time this input price is soaring, labour remuneration is dropping. In these conditions, it appears pertinent to focus our attention on a potential effect of inputs prices on excess capacity levels.

Section 2 briefly presents DEA method, applied to technical efficiency and capacity utilisation. Materials required in the estimation of capacity are described in section 3. The trawlers fleet, located in Southern Brittany, is divided into three segments. Individual data are available on a monthly basis from 1994 to 2003. As most fishing vessels using active gear, these units are characterised by multi-production, including a set of target species and by-catch. Results from the DEA analysis are shown in section 4 in terms of excess capacity. These scores are relative measures and are constrained through the size of samples. Section 5 is a first attempt to provide explanations of excess capacity levels from inputs framework. A discussion is suggested in a final section.

2. Methods

The origins for the current measurement of efficiency of production is typically regarded to be the work of Farrell (1957). Since, several techniques for measurement have been developed. One such technique is that of data envelopment analysis (DEA) which can be used to estimate technical, allocative and economic efficiencies (Charnes et al, 1978; Banker et al, 1984). DEA is deterministic and as a result does not require pre-specification of the frontier technology. It provides a relative measure for those firms[i] being compared, hence at least one firm will lie on the frontier in a DEA analysis.

In this report, DEA is applied to data for French fishing vessels operating in Southern Brittany. DEA has been used considerably in recent years in fisheries economics for the measurement of vessel technical efficiency and capacity utilisation (e.g. Tingley et al, 2003; Kirkley and Squires, 1999). In fact, DEA has been promoted as the preferred technique for such analysis since 2000 by the Food and Agriculture Organisation of the United Nations (FAO, 2000).

Here, not only do we consider technical efficiency, as well as capacity utilisation, but we also use individual vessel accounts in order to compare these results to the actual economic performance of the vessels. It is rarely possible in fisheries to have access to such data, and as such provides for an innovative analysis.

The technical efficiency (TE) measure can by obtained by solving the following DEA model:[ii]

$$Max\ \theta_i$$

Subject to

$$\theta_i y_{im} \leq \sum_j \lambda_j y_{jm} \qquad \forall m$$

$$\sum_j \lambda_j x_{jn} \leq x_{in} \qquad \forall n \tag{1}$$

$$\lambda_j \geq 0$$

Where θ_i is a scalar outcome denoting how much the production or outputs, y_m, of each firm, i, can increase by using inputs, x_n, (both fixed and variable) in a technically efficient configuration. In this case, both variable and fixed inputs are constrained to their current level. In this case, θ_i represents the extent to which output can increase through using all inputs efficiently, and is therefore output-based. The technically efficient level of output (y^*_{TE}) is defined as θ_i multiplied by observed output (y). As defined, this model represents a constant return to scale (CRS) assumption. In order to model variable returns to scale (VRS) or non-increasing returns to scale (NIRS), the constraints $\sum_j z_j = 1$ or $\sum_j z_j \leq 1$ respectively are required.[iii] The level of technical efficiency is estimated as:

$$TE_i = 1/\theta_i\ . \tag{2}$$

Following Färe *et al.* (1989, 1994), a measure of capacity output can be found using:

$$Max\ \theta_i^{'}$$

Subject to

$$\theta_i^{'} y_{im} \leq \sum_j \lambda_j y_{jm} \qquad \forall m$$

$$\sum_j \lambda_j x_{jn} \leq x_{in} \qquad \forall n \in \alpha \tag{3}$$

$$\lambda_j \geq 0$$

Where $\theta_i^{'}$ is a scalar denoting the multiplier that describes by how much the output of firm i can be expanded. In the estimation of capacity, only fixed factors are considered where inputs are separated into fixed factors (i.e. set α) and variable factors (i.e. set $\hat{\alpha}$). Capacity utilization (CU) for firm i is defined as:

$$CU_i = 1/\theta_i^{'}\ . \tag{4}$$

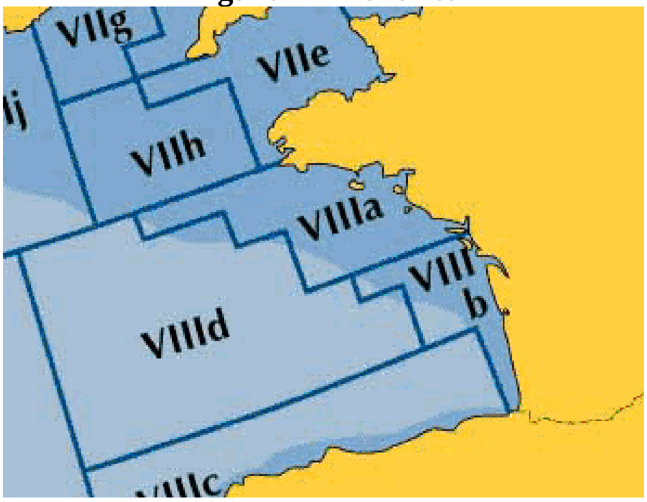
An unbiased estimate of capacity utilization (CU^*) for firm i is estimated by removing the effects of technical efficiency from the capacity utilization measure (i.e. equation 7 divided by equation 2), and is achieved by the following equation:

$$CU_i^* = \frac{CU_i}{TE_i} = \frac{1}{\theta_i'} \Big/ \frac{1}{\theta_i} = \frac{\theta_i}{\theta_i'} \quad (5)$$

3. Materials

Data used for DEA analysis come from the Regional Economic Observatory in Brittany, a NGO created by a professional fishers organisztion. Three segments of trawlers are defined in terms of length. The smallest group is composed of vessels of 12-16 meters exploiting resources mainly in inshore fisheries (VIIIa area). The second segment characterizes trawlers of 16 to 20 meters. Most of the time, vessels belonging to this segment produce fish in offshore fisheries (WIIIa, VIIh areas), but a few of them spend fishing time in the same grounds as the first segment units. The biggest trawlers compose the third segment, with a length of 20-25 meters. These largest fishing units produce fish essentially in offshore fisheries (VIIh-g areas).

Figure 1 – Fisheries



Individual observations by boat are available over 120 months, from January 1994 to December 2003, and include information on price and quantities by species, technical parameters (length, engine power) and fuel consumption (liters). Months during which boats had no fishing activity have been removed from the analysis (13 observations for 12-16 meters boats, 12 for 16-20 meters boats, and 26 for 20-25 meters boats). If the model is specified on a monthly basis, scores are averaged from individual data based on monthly production by boat and by year. Hence, number of data is 1560 for the 12-16 meters sample (less 13 months with no production), 600 for the 16-20 meters sample (less 12 months with no production), 1320 for the 20-25 meters sample (less 26 with no production).

DEA model had to be specified as follows, respectively for the three segments:

$$Max\ \theta_i$$

Subject to

$$\begin{aligned} \theta_i y_{ilm} \le \sum_{j=1}^{i}\sum_{t=1}^{12}\lambda_{jt} y_{jtm} \qquad & \forall l = 1...12, m \\ \sum_{j=1}^{i}\sum_{t=1}^{12}\lambda_{jt} x_{jtn} \le x_{il\,n} \qquad & \forall l = 1...12, n \\ \sum_{j=1}^{i}\sum_{t=1}^{12}\lambda_{jt} = 1 & \\ \lambda_{jt} \ge 0 & \end{aligned} \tag{6}$$

Table 1 – Fleet characteristics

	12-16 m	16-20 m	20-25 m
No of boats	13	5	11
Average engine power (kw)	214.8	305.4	410.9
Average overall length (meters)	14.8	18.0	21.4
Observations with DEA (boat x month)	156	60	132

Fixed inputs are represented by length and engine power. As abundance index is not available on a monthly basis, a proxy has been built as a catch per unit of fuel consumption from landings by selected species (kg) divided by fuel consumption (litres) at the level of each sample. In empirical applications of DEA, abundance index is considered as fixed input or more precisely "…DEA model also included biomass levels…as additional fixed environmental parameters…"(Dupont et al., 2002). Variable input is included through fuel consumption. The set of target species varies considerably according to the segment fleet observed. The smallest units, so called 12-16 meters, exploit simultaneously and mainly five stocks (nephrops, anglerfish, megrim, hake and sole). Cod and whiting stocks have to be added to the above list in the case of the intermediate segment, 16-20 meters. The biggest trawlers produce a larger panel of fish in offshore fisheries, including those cited previously. Eventually, three species have been selected in DEA analysis (nephrops, anglerfish, megrim) because they are considered as the main valuable products for all three segments. Others species, targeted fishes and by-products, are gathered in a fourth category.

Table 2 – Inputs and outputs used in the DEA analysis

Fixed inputs	Input variable	Outputs*
- Lenght (meters) - Engine power (kW) - Catch per unit of fuel (kg/l)	- Fuel consumption (litres)	- Nephrops - Anglerfish - Megrim - Other species

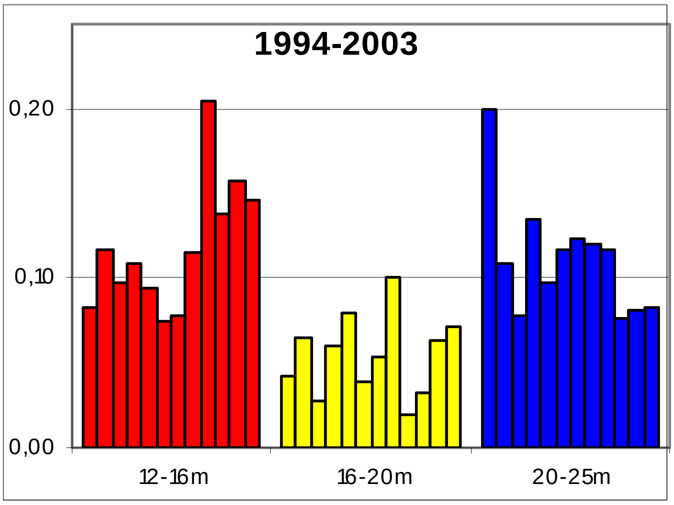
*Landing values have been inflated to 2003 values using a Fisher price index.

4. Capacity utilization and excess capacity

In this work, excess capacity is used as a dual measure of unbiased capacity utilization (CU*). Precisely, the difference between CU* and the number 1, meaning a totally efficient score for the fleet, reveals the scope of excess capacity. As the overcapacity concept, excess capacity means an economic waste of inputs. If the former reveals a long run problem, requiring management measures by a public agency (FAO, 2003a, 2003b), the latter could be, in theory, managed by market forces. Indeed, excess capacity can be defined as "the inability of capital inputs to adjust instantaneously to changes in prices and variable costs and is considered to be a short-run, self correcting phenomenon" (Ward, Mace and Thunberg, 2005).

Average measures of excess capacity are given for all three segments by month for the period 1994 to 2003 (figure 2). The highest scores are devoted to the smallest units in September (20%) and the biggest trawlers in January (20%). The intermediate segment, only described from 5 vessels, has recorded excess capacity of less than 10%. These measures have been produced during different historical contexts. Consequently, it appears more interesting to analyze how fleet segments behaved year by year (figure 3). This approach, based on relative measures of excess capacity within a segment, can be related to input usage modifications. Permanently, fishermen have to respond to input variations, in terms of prices or abundance, and can change their fishing strategy as an adjustment to market forces or biomass variability.

Figure 2 – Average measures of excess capacity on the period 1994-2003

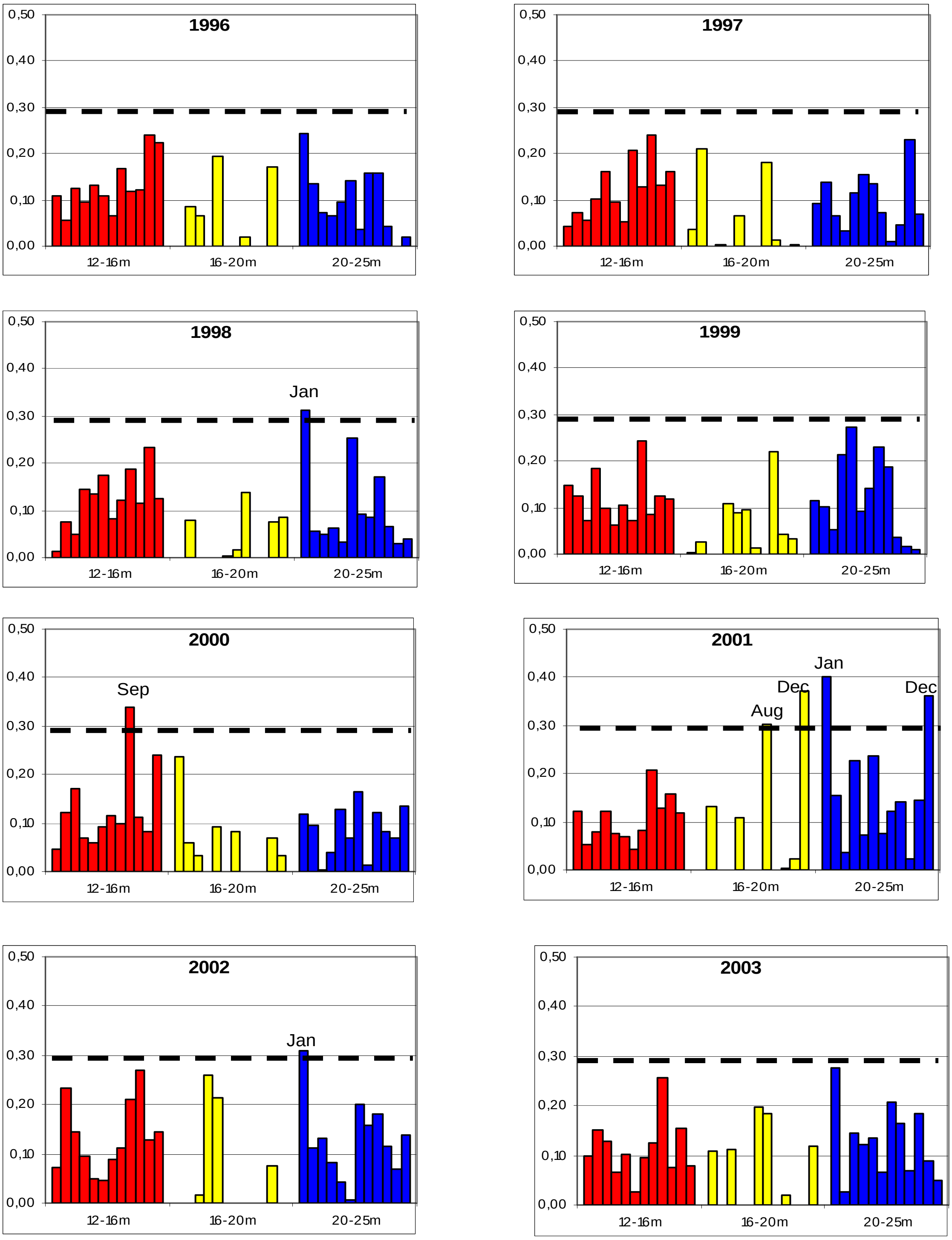


If we consider all scores of excess capacity up to 30%, different historical paths are defined from the figure 3. The 12-16 meters class had an average excess capacity of 34% in September 2000. 8 out of 13 boats had an excess capacity up to 30%, and five of which displayed a level as high as 45%. Usually, they have used fully their capacity utilization in May and June, which means no economic waste of their inputs.

If average measures of excess capacity are low for the 16-20 meters segment for the overall period, these boats had monthly scores up or equal to 30% in August 1994 (30%), August 2001 (30%), and December 2001 (37%). The worse result (December 2001) is explained by the fact that 3 out of 5 vessels have recorded an excess capacity up to 45%.

The biggest units exceeded their capacity by 30%, in January 1998 (31%), in January 2001 (40%), in January 2002 (31%), in April 1994 (36%), and in December 2001 (36%). 8 out of 11 units were in excess up to 30% in January 2001, and 7 of them have scored an excess up to 45%.

Figure 3 – Average scores of unbiased CU



Occurrence of excess capacity situations is explained by short run variations in input and output prices. Other considerations can influence fishermen's behavior, such as biological seasons for target species and weather conditions. When short run variations occur, we can expect an adaptation in fishing strategy, meaning a change in the capacity utilization of vessels. Of course, this is a relative measure of capacity and excess capacity compared with all scores during the study period. In the following section, we make an attempt to explain the highest levels of excess capacity mentioned above with inputs framework, particularly fuel price (as the variable input) and the proxy for abundance (catch per unit of fuel).

5. Excess capacity levels and inputs framework

According to the definition given by Johansen (1968), capacity utilization is : "the maximum amount that can be produced per unit of time with the existing plant and equipment, provided that the availability of variable factors of production is not restricted" (p. 57, cited in Färe et al 1994). Consequently, excess capacity can be interpreted as a result of a non-maximized production in the short term due to fluctuations in fuel price. In a first sub-section, analysis is focused on fuel price evolution and total revenue of landings. The second sub-section suggests an explanation of the highest levels of excess capacity from fuel consumption and catch per unit of fuel consumption. These two analyses are implemented on a monthly basis.

51. Fuel price

Usually, fuel cost appears as the more important variable cost for fishing units, specifically for vessels using active gear (trawling and dredging). For this reason, fishermen's behavior can be influenced in a context of strong variations of fuel price. During the study period, from January 1994 to December 2003, fuel price increased by 0.24% per month (average monthly growth rate). Monthly average price for fuel, providing by the Fishermen Association in Southern Brittany, reached 0.17 € / liter in January 1994[iv], the fuel price index being 0.75 compared to December 2003 as the reference period. In December 2003, fuel price was around 0.23 € / liter. In a retrospective analysis, fuel crisis can be precisely dated for trawlers fleets in Southern Brittany, beginning in February 1999 (the lowest level during the overall period, 0.12 € / liter) and ending twenty one months later in November 2000 (the peak of the curve), with a level of 0.37 € / liter. During this time-span, price fuel was soared every month at an average growth rate of 6 %.

In these conditions, we can expect modifications in fishing strategies through a weaker utilization of potential capacity. Mechanically, labour and capital remuneration decrease with a constant rise in fuel price.

For instance, a permanent increase on fuel price might change fishermen's behavior by a reduction in fishing time, thereby developing an excess capacity phenomenon. This assumption has been made in a clear and concise explanation of excess capacity concept (Ward, Mace and Thunberg, 2005). Indeed, a few fishing companies, managing 30-35 meters trawlers in South Brittany, decided to stop their activity for a short period in August 2000 (Le Monde, 22 August 2000). Table 3 shows measures of excess capacity for the three segments during the period of highest prices for fuel. Only the smallest units had a low score in term of unbiased capacity utilization, 66% of their potential capacity was used in September 2000. This represents an excess capacity of 34%. In other cases, it does not seem that fuel price could be considered as a driving force in fishing behavior modification. On the contrary, the remuneration's share system is often used as a shock absorber in the fishing industry to compensate for the rise of other variable costs such as fuel expenses.

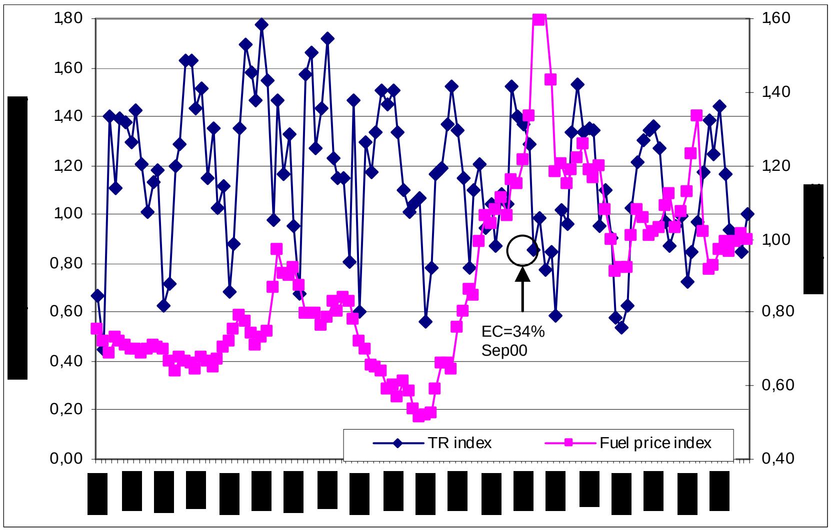
In 8 out of the 9 cases listed in table 3, excess capacity was reached maximum 12%. This means that most of units used almost fully their fishing capacity in a context of high level for fuel price. This apparent paradox can be explained in term of low opportunity cost for labour and capital in fisheries.

Table 3 – Measure of excess capacity during the peak of fuel crisis

	12-16m	16-20m	20-25m
Sept. 2000	34%	0%	12%
Oct. 2000	11%	0%	8%
Nov. 2000	8%	7%	7%

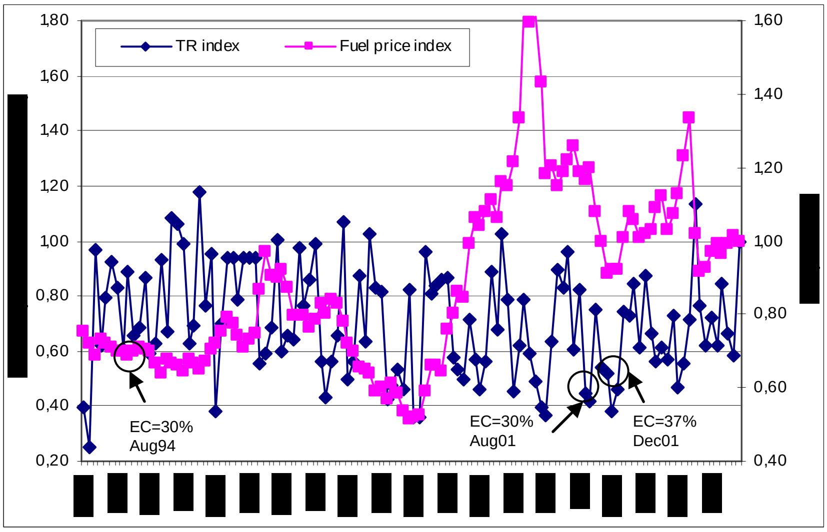
Total revenue index, inflated with a Fisher price (FP) index, and fuel price index are depicted on the following figures. Levels of excess capacity up or equal to 30% are indicated on the total revenue index curve. The 12-16 meters fleet has registered an excess capacity superior to 30% in September 2000, corresponding to a peak in fuel price. However, no boat stopped its activity during the second semester of the year 2000. Moreover, unbiased capacity utilization reaches respectively 89% and 92% in October and November 2000, whereas fuel price is maintained at its highest levels.

Figure 4 – Evolution of Total Revenue (TR) index and Fuel Price index – 12-16 meters



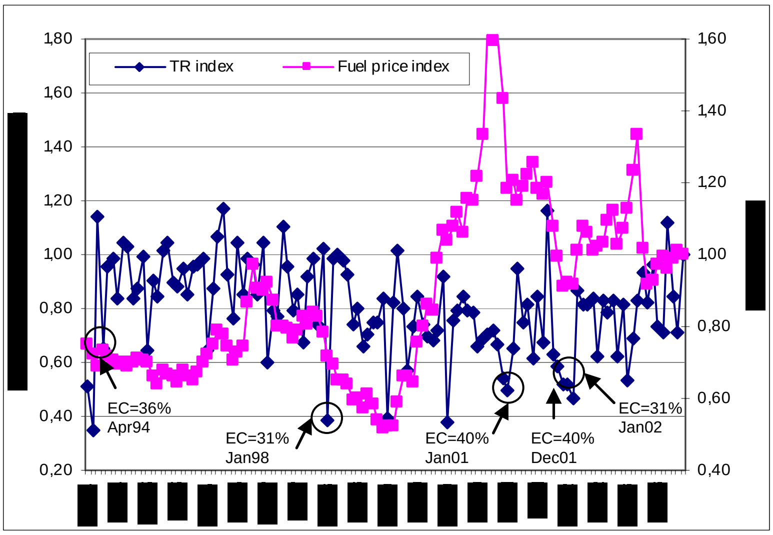
The three excess capacity situations are clearly not related to fuel price for the 16-20 meters trawlers (figure 5), none occurring during the “fuel crisis”. They appeared when monthly total revenue was 39% (August 1994) to 55% (August 2001) less than in December 2003 (the reference period). But if we compare total revenue index to similar months (August and December) during the decade, revenues generated in August 1994, August 2001 and December 2001 were not the lowest landings values. For instance, total revenue in August 1998 was 57% inferior to revenue in December 2003, but excess capacity was only estimated to be 14%. Consequently, high levels of excess capacity (up to 30%) do not mean automatically the worst performance in term of gross revenues.

Figure 5 – Evolution of Total Revenue (TR) index and Fuel Price index – 16-20 meters



Like the first two samples of trawlers, the last one rejects the assumption of a relationship between fuel price and excess capacity (figure 6). Average capacity utilization has been estimated to be a minimum of 80% during the “fuel crisis”. Conversely, DEA analysis has shown that capacity utilization reached the lowest levels before and after this high fuel price period. In only two out of five excess capacity up to 30%, total revenue was the lowest compared to other scores for identical months (total revenue indices are 0.65 and 0.52 respectively for April 1994 and December 2001). The lowest landing values registered in January occurred in 2000, with total revenue of 62% less than in December 2003 (index being 0.38). In spite of this poor result, capacity utilization was slightly in excess of 12%. On the other hand, excess capacity was up to 30% in January 1998, 2001 and 2002. Total revenue indexes were respectively 0.39, 0.49 and 0.52.

Figure 6 – Evolution of Total Revenue (TR) index and Fuel Price index – 20-25 meters



Finally, no clear relationship exists between fuel cost variations and fishermen’s behavior at the fleet level. If the excess capacity phenomenon is supposed to be driven by market forces in the short run, fishermen can use a set of options as a response to market signals. Particularly, multiple-output fisheries are characterized by different target species and by-catch products. Consequently, skip-owners have the possibility to adapt their fishing strategy in the short-run. In DEA analysis, three target species were selected (anglerfish, megrim, nephrops). In the next sub-section, these biological factors associated with fuel consumption are used to analyze fishing behavior specifically for the 9 monthly periods displaying the highest excess capacity levels.

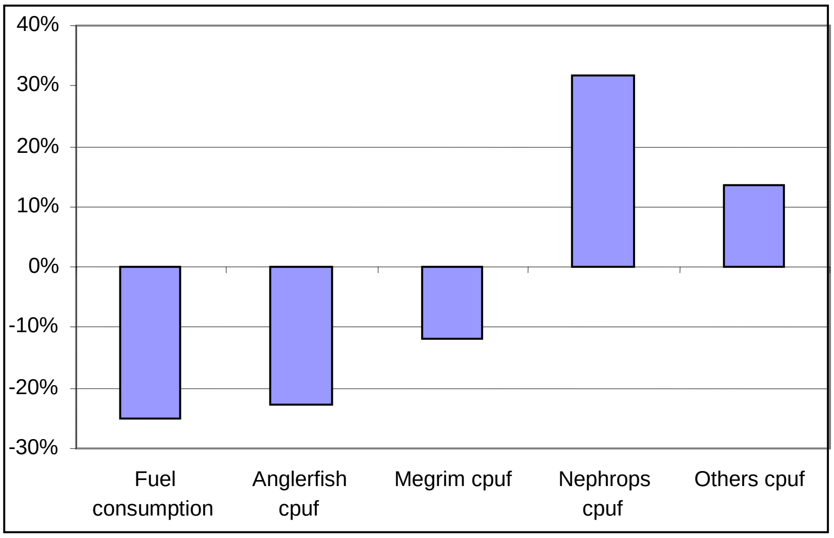
52. Fuel consumption and catch per unit of fuel

Variable cost, expressed through fuel consumption in DEA analysis, and catch per unit of fuel (cpuf), designed as a fixed asset[v], are used in terms of monthly variations. If we can logically accept the assumption of expanding excess capacity when fuel price is rising, it is much more problematic to guess variations of CU face to modifications in proxy for biomass, catch per unit of fuel (estimated at the sample level). According to the law of diminishing returns, we can assume that marginal product of capital decreases (increases) when effort increases (decreases). This expectation has been frequently discussed in fisheries literature (Cunnimgham and al. 1985).

As the law holds only in the short run and is fitted to physical returns (Doll, 1988), total catch (kg) per unit of fuel (liter) should soar (drop) when fuel consumption drops (soars). However, fishermen adapt their fishing effort in a multi-production process, in relation to several target stocks. As catch per unit of fuel were estimated according to target species and by-catches, we can study fishing strategies in the short run (on a monthly basis) for the three segments of trawlers. Analyses are driven during the key periods of excess capacity situations up to 30%.

The 12-16 meters fleet has decreased its fuel consumption by 25% in September 2000 compared with the average level during the same month over the period 1994-2003 (figure 7). As a result, cpuf for nephrops was considerably higher in September 2000 (+32%). Fishing effort is mainly allocated on nephrop stock, so that as this specie represents around 50% of annual total revenue for this segment of trawlers. So, we can assert that nephrops have been primarily exploited and were treated as a target species during this month, as cpuf for other species for which variation was positive (+13%). A possible explanation is a verification of diminishing returns because nephrops production was a decreasing function of fuel consumption in September 2000. On the other hand, anglerfish and megrim landings (kg / litre of fuel) were 23% lower for the first specie and 12% lower for the second in comparison to average values in September from 1994 to 2003.

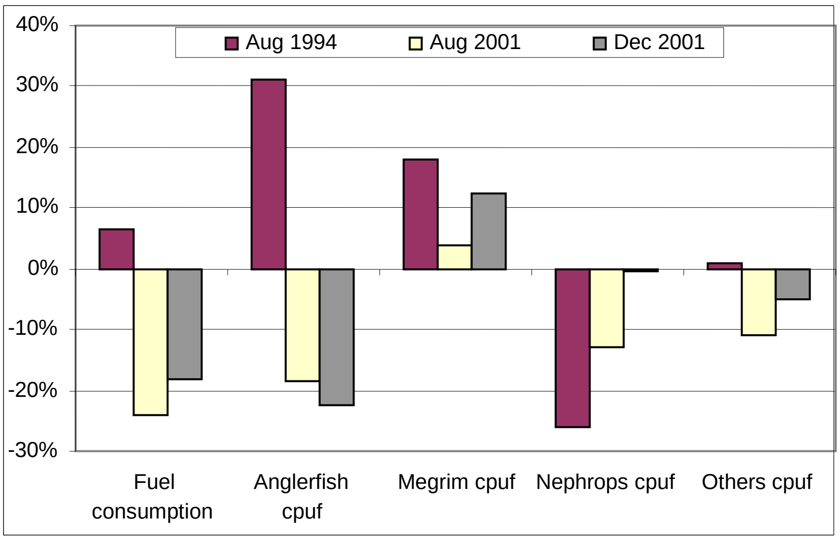
Figure 7 – Average fuel consumption and catch per unit of effort (%) in September 2000 compared to average values in September from 1994 to 2003, 12-16 meters



In August 1994, fuel consumption was superior to average level for the same month during the overall period for the intermediate segment (figure 8). Scores for anglerfish and megrim are positively correlated to fuel utilization. Cpuf for these two species were respectively higher by 31% and 18%. By rank, nephrops and anglerfish are the main outputs in weight and value. If variations are opposite for these two main valuable species in August 1994, they are both negative in August 2001 and December 2001.

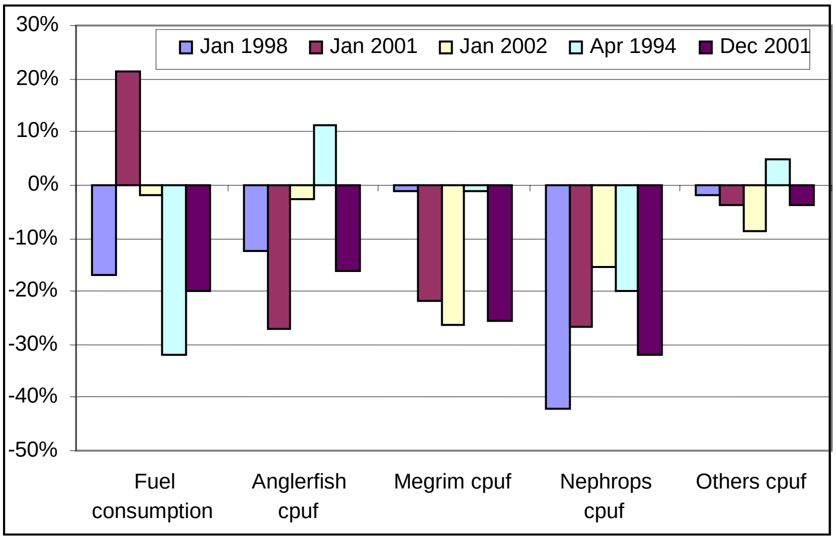
Fishermen reduced fuel consumption in August and December 2001, when excess capacity situations reached respectively 30 and 37%. However, anglerfish, nephrops and by-products landings were lower. Positive variations for megrim appear essentially as a spillover effect, this specie being less valuable for these units and can considered as a by-catch compared to nephrops and anglerfish.

Figure 8. Average fuel consumption and catch per unit of effort (%) in August 1994/2001 and December 2001 compared respectively to average values in August and December from 1994 to 2003 (%), 16-20 meters



On the five cases of excess capacity as great as 30% (figure 9), fuel consumption was higher than the average result on only one occasion, in January 2001 (21%). If we could expect a rise (a drop) in cpuf for target species when fuel consumption decreases (increases), as explained through the law of diminishing returns, this assumption is only verified in 2 cases out of 5. In January 2001, variations are negative for all species (-28% for Anglerfish and Nephrops). In April 1994, only anglerfish production is higher (11%) compared to averages landings in April during the decade, as fuel utilization was lower (-31%).

Figure 9. Average fuel consumption and catch per unit of effort (%) in January 1998/2001/2002, April 1994 and December 2001 compared respectively to average values in January, April and December from 1994 to 2003, 20-25 meters



6. Discussion

An excess capacity phenomenon up or equal to 30% of unbiased capacity utilisation was identified in nine cases for the trawlers fleet located in Southern Brittany (table 4). Smallest units, 12-16 meters segment, were in this situation one single time, in September 2000. At first glance, it could be argued that the highest level of fuel price reached in the same period caused an excess capacity situation. This is a logical assumption, which can be suggested in the short run. Although fuel consumption was reduced by –25% in September, excess capacity dropped 11% and 8%, in October and November 2000. Consequently, no evidence appears between fuel cost variation and capacity utilisation for this first segment. However, the 12-16 meters class was the only one to record an excess capacity up to 30% during the "fuel crisis" (February 1999 to November 2000). The intermediate class, composed of 16-20 meters units, was in strong excess three times, in August 1994, August 2001, and December 2001. None of them was occurred during the "fuel crisis". Our findings show that fuel consumption was higher than the average level in August 1994 (+6%), which is a surprising result to explain excess capacity. In more, cpuf for anglerfish, megrim and slightly for other species were higher than average monthly scores. Finally, the biggest vessels were in excess capacity up to 30% at five occasions. In one case, occurring in January 2001, fuel consumption was greater than the average consumption on the overall period (+21%).

Excess capacity is explained by negative variations of fuel consumption 7 out of the 9 cases. Fixed biological inputs, defined through a proxy for biomass abundance as catch per unit of fuel consumption, showed negative (positive) variations of target species when fuel utilization was decreasing (increasing) in 5 cases. On the other hand, cpuf for target species (mainly anglerfish and nephrops) was dropping (rising) when fuel consumption was rising (dropping), as theoretically expected.

Table 4 - Characterisation of excess capacity situations

Excess Capacity ≥ 30%		Fuel Crisis	TR index			Monthly variations				
		Feb 99-Nov 00	min	score	max	Fuel	Anglerfish cpuf	Megrim cpuf	Nephrops cpuf	Others Cpuf
12-16m	Sep 2000	Yes	0.78	0.86	1.2	-25%	-23%	-12%	+32%	+13%
16-20m	Aug 1994	No	0.43	0.61	0.94	+6%	+31%	+18%	-26%	+1%
	Aug 2001	No	0.43	0.45	0.94	-24%	-18%	+4%	-13%	-11%
	Dec 2001	No	0.39	0.52	1.07	-18%	-22%	+12%	0%	-5%
20-25m	Jan 1998	No	0.38	0.39	0.64	-17%	-12%	-1%	-42%	-2%
	Jan 2001	No	0.38	0.49	0.64	+21%	-27%	-22%	-27%	-4%
	Jan 2002	No	0.38	0.52	0.64	-2%	-3%	-26%	-15%	-9%
	Apr 1994	No	0.65	0.65	1.17	-32%	+11%	-10%	-20%	+5%
	Dec 2001	No	0.52	0.52	1.04	-20%	-16%	-25%	-32%	-4%

Relationship between capacity and inputs framework does not appear so trivial to support the assumption that excess capacity is, for instance, driven through an increase in fuel price. On the contrary, empirical applications have proved that capacity utilization could be optimal (equal or near to one and consequently on the production frontier) whereas fuel price reached a maximum peak. In fact, this research could be oriented toward a behavioral analysis of fishermen. Indeed, two topics deserve a special attention. Firstly, crossed effects can be expected amongst variable inputs, particularly between fuel expenses and labor cost. Labor remuneration, traditionally based on a share process, is often used as a shock absorber to compensate an increase in fuel price (Gaspart, Seki, 2003). Secondly, fishermen are usually said to have low opportunity costs. Consequently, they have no economic incentives to cut back their level of activity in a context of rocketing fuel price. Furthermore, they can expect to receive subsidies from public agencies, as it is the case in the French fisheries.

References

Banker R.D., Charnes A., Cooper W.W., 1984. Some models for estimating technical and scale efficiencies in data envelopment analysis. *Management Science*, 30, pp1078-1092

Charnes A., Cooper W.W., Rhodes E., 1978. Measuring the efficiency of decision making units. *European Journal of Operational Research*, 2, pp429-444

Coelli, T., Rao D.S.P., Battese G.E., 1998. *An introduction to efficiency and productivity analysis*, Kluwer Academic Publishers, USA

Cunningham S., Dunn M.R., Whitmarsh D, 1985. Fisheries Economics: An Introduction. Mansell Publishing, London

Doll, J.P., 1988, Traditional economic models of fishing vessels: A review with discussion, *Marine Resource Economics*, vol.5, pp99-123

Dupont D.P., Grafton R.Q., Kirkley J., Squires D., 2002. Capacity utilization measures and excess capacity in multi-product privatized fisheries, *Resource and Energy Economics*, 24, pp193-210

FAO, 2000. *Report of the Technical Consultation on the Measurement of Fishing Capacity*. FAO Fisheries Report No.615. FAO, Rome.

FAO, 2003a. Measuring and assessing capacity in fisheries. 2. Issues and methods. Fisheries Technical Paper No 433/2. FAO, Rome.

FAO, 2003b. *Report of the Expert Consultation on Catalysing the Transition Away from Overcapacity in Marine Capture Fisheries* - Rome, 15-18 October 2002, FAO Fisheries Report No. 691

Färe R., Grosskopf S., Kokkelenberg E.E., 1989. Measuring plant capacity, utilization and technical change: a non-parametric approach. International Economic Review, 30 (3), pp655-666

Färe R., Grosskopf S., Lovell C.A.K., 1994. *Production frontiers*. Cambridge University Press, UK

Farrell M.J., 1957. The measurement of productive efficiency. *Journal of the Royal Statistical Society Series* A 120 (3), pp253-281

Gaspart F., Seki E., 2003. Cooperation, status seeking and competitive behaviour: theory and evidence. Journal of Economic Behavior and Organization, vol51, pp51-77

Johansen L., 1968. *Production functions and the concept of capacity*. Recherches récentes sur la fonction de production. Centre d’Etudes et de la Recherche Universitaire de Namur

Kirkley J.E., Squires D.E., 1999. *Measuring capacity and capacity utilization in fisheries*. In Greboval D. (ed.), Managing fishing capacity: Selected papers on underlying concepts and issues. FAO Fisheries Technical Paper 386, FAO, Rome

Tingley D., Pascoe S., Mardle S., 2003. Estimating capacity utilisation in multi-purpose, multi-metiers fisheries, *Fisheries Research*, 63, pp121-134.

Vestergaard N., Squires D.E., Kirkley J.E., 1999. *Measuring capacity and capacity utilization in fisheries: the case of the Danish gillnet fleet*. FAO Technical Consultation on the Management of Fishing Capacity, Mexico City, Mexico, November 29-December 3, 1999. FAO, Rome

Ward J., Mace P., Thunberg E., 2005. The relationship of fish harvesting capacity to excess capacity and overcapacity, *Marine Resource Economics*, 19, pp525-529

[i] In the original DEA literature, the generalised term decision making unit (DMU) is used. However, in economic application, the firm is the common concept.

[ii] This model is in fact a linear programming model, and in this case for ease of solution is denoted in the dual-form (see for example Färe et al (1994), Charnes et al (1978) and Coelli (1998) for a complete derivation).

[iii] This is the case for all DEA models presented in this paper.

[iv] Prices were deflated by the price index in 2003.

[v] Catch per unit of fuel is computed separately for target species (anglerfish, megrim and nephrops) and others products.