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The EIAA Model

Methodology, Definitions and Model Outline

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Preface

Since 1999 the EIAA model has been used in a number of occasions within fisheries. In particular, the potentials of the model have been used in 2002-2007 to assess the economic repercussions of the TAC/quota allocations to Member States and fleets of the European Union. Several developments have taken place, but many of these developments have never been described properly. That has, naturally, led to lack of knowledge of what has actually happened, and the use of the model has sometimes left the opinion that the model is black box.

The purpose of this report is to alleviate the lack of insight in the model and what it can do. The report is organised in such a way that some of the earlier published text about the model has been included, and this text has been supplemented to extend the knowledge of the model, in particular the part of the model that goes beyond the 1999 version used for the above mentioned assessments of the EU TAC/quota allocations in fisheries.

Hans Frost is a key person in the development of the model. Thomas Thøgersen has developed the part of the model described in section 3. Ayoe Hoff and Jesper L. Andersen have performed quality checks of the model and this report and Elsebeth Vidø has carried out the final editing.

Director General Henrik Zobbe
Institute of Food and Resource Economics
Copenhagen, February 2009

1. EIAA model development

1.1. History

The data collection work and the first analyses on EU level about economic performance of fleet segments commenced in 1991 (Davidsee *et* al. 1993). The original EIAA model (Economic Interpretation of ACFM[1] Advice) was developed in 1999 as part of the concerted action: Promotion of Common Methods for Economic Assessment of EU Fisheries, 1998-2000, (FAIR PL97-3541). In the subsequent Concerted Action (EAEF), 2002 – 2004: Economic Assessment of European Fisheries (QLRT - 2000 – 01502) and the EC contract FISH/205/12 for the year 2005 the model was used but not developed as part of these programmes. Costs and earnings data in these concerted actions were collected and presented in (AER) reports: Economic Performance of Selected European Fishing Fleets and in a database (CAClient) hosted by LEI, http://www3.lei.wur.nl/ca/.

The gap in 2001 was covered by the Annual Economic Report 2001 on 'Economic performance of selected European fishing fleets' prepared on behalf of the European Association of Fisheries Economists (EAFE) by a group of research institutes which had co-operated earlier under the Concerted Action FAIR PL97-3541. However, the preparation of the 2001 report and the EIAA calculations were only possible due to financial contribution from FOI (the Institute of Food and Resource Economics[2]) and data collected under the EU funded project 'Data on the economic performance of the fisheries sector' (contract no. 00/32).

Since 1999 several developments and extensions of the original EIAA model have taken place mainly by means of FOI. These extended versions have been tested and used in the EIAA calculations after 1999. However, the results presented have only been those that compared to the results of the 1999 version.

More comprehensive applications of the extended version of the EIAA model have been accomplished in the assessments of the sole/plaice and the Northern hake recovery programmes. The results are published in Commission Staff Working Papers of

[1] The Advisory Committee for Fisheries Management of ICES (the International Institute of the Exploration of the Sea)
[2] At that time named SJFI (the Danish Institute for Agricultural and Fisheries Economics)

the EU, see list of references, and submitted to the STECF (Scientific, Technical and Economic Committee for Fisheries), which is the advisory committee to the EU.

1.2. The 1999 version

The first version of the EIAA model was constructed in 1999 (Salz and Frost 2001) and the model had a number of resemblances to a model developed to analyse the Icelandic quota system (Danielsson *et* al. 1997). A graphic outline is shown in figure 1, and the model is described in equations in SEC (2004) 1710. It should be noted that prior to this work (before 1998) model approaches were made in a cooperation between the five research institutes: DIFER (DK), IFREMER (F), IREPA (I), LEI (NL) and SFIA (UK)[3]. These model approaches differed, but were mainly account models for selected fleet segments for which evaluation of changes in parameter e.g. fuel prices could be performed. If data were available the models comprised landings distributed on species, but there was no link to fish quotas and stocks. These models were constructed in different spreadsheets that existed at that time such as Lotus 1-2-3, Quattro Pro and earlier versions of Excel. These spreadsheets did not communicate completely, however.

Therefore, the 1999 model was constructed in an Excel spreadsheet to secure uniformity. The model was organised in 7 sheets and had a size at 400 Kb. In those days the model had to fit a diskette at a size of one mega bite (MB) to facilitate exchange of information between various partners as the internet was not sufficiently developed.

Basically the model is an account model, or a financial model, in which economic indicators are calculated (gross revenue, costs and profit) on fleet segment level. The economic variables are functions of TAC/quotas and Spawning Stock Biomasses (SSB). SSB was introduced in 1999 but data were not available until 2002. The number of vessels and fixed costs are assumed to be constant, which is acceptable as the model is used for short run projections and almost all fleet segments were subject to overcapacity.

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[3] DIFER is the Danish Institute of Fisheries Economics Research (included in University of Southern Denmark in 1998); IFREMER is L'Institut Francais de Recherche pour l'Exploitation de la Mer; LEI is the Dutch Agricultural and Fisheries Economics Institute at Wageningen University; SFIA is Sea Fish Industry Authority

The model calculates for three years: 1) current year, 2) coming year and 3) the long run where all stocks are assumed to have recovered to sustainable level. The data input is lagged and average data over three previous years are used to level out natural variation, see table 1. The calculations and dissemination of the results took place in late October within a two weeks period after data were made available in mid October and before the STECF plenary in the beginning of November.

Table 1. The procedure of the EIAA calculations

Data type	Baseline (3 years average)	Current year (October/November)	Coming year	Long run
Economic	Costs and earnings Landings of species in volume and value	Not known i.e. calculated by the model	Not known i.e. calculated by the model	Not known i.e. calculated by the model
TAC/quota	Known	Known	Known	Estimated
Stock abundance	Estimated for certain stocks	Estimated for certain stocks	Estimated for certain stocks	Estimated for certain stocks

1.3. Extensions of the 1999 version

The following extensions have mainly been made by means of FOI and are not described previously. Results from the model with these extensions are primarily published nationally and not as part of the results of the TAC/quota assessments forwarded to the STECF.

1.3.1. 2001

The model was expanded to calculate "break-even revenue" (the revenue minus variable costs that exactly covers the fixed costs). This extension made it possible to estimate overcapacity in the fleet by comparing break-even revenue with the actual gross revenue. Parameter checks and adjustment coefficients were included. The workbook was organised in 8 sheets at 550 Kb.

1.3.2. 2003

The model was reorganized to facilitate improved transparency and the possibility to change a range of parameter values such as flexibility rates in the price and production functions for scenario tests. Size 15 sheets and 700 Kb.

1.3.3. 2004

The model was expanded to estimate the value of the SSB and allocate SSB shares to fleet segments. This made it possible to calculate remuneration (resource rent) of the fish stocks and take that into account in break-even and overcapacity calculations. Size 15 sheets and 800 Kb.

1.3.4. 2005

The model was expanded to be able to change fixed costs and the number of vessels over time by introducing a decision variable that determines the number of sea days per vessel. Size 19 sheets and 900 Kb. At that time internet or local net facilities were sufficiently available in most meeting venues so that the size of the model was no longer a restriction on exchange.

1.3.5. 2006

The 2005 version that allows for changes in the fleet size in one future year and in one long run year was expanded to work over a time horizon by linking a number of models sequentially to projections of catches and fish stock abundances over a number of future years. This development made the EIAA model fit to long term fish stock and TAC projection in relation to stock recovery programmes. In this model it is assumed that ten years is enough for stocks to recover, and after ten years the situation per year is equal to the situation in year 10.

Further, the model is expanded with a facility that makes it possible to calculate economic consequences of different assumption as to which species are driving the effort. That improvement makes it possible to investigate economic effects with respect to which species are the driver of effort and which species are taken as by-catches. In the former version all species are driving the effort in conjunction. The size of this model is around 5 Mb as five models are linked.

1.3.6. 2007

In the basic version, the EIAA model calculates costs and effort as a function of landings and SSB. This has been expanded with a module calculating landings as a function of sea days and catch per day rates for each of the species in a fleet segment's landing composition. In forward projections using this module the catch per day is adjusted with changes in stock abundance. This module calculates landings, revenues, costs and profits from the input side i.e. as a function of the sea days and the number of vessels, contrary to the “basic” module that calculates economic indicators, sea days, number of vessels from the output side i.e. with TAC and stock biomass as exogenous input. Both module use the same empirical data input that makes it possible to compare the results.

1.3.7. 2008, what can the model do?

The required input is information about fish stock developments and development of TACs from biological projections as well as costs and earnings statistics.

Over a stock recovery period of 10 years the following is calculated assuming that year 10 applies in the years following year 10:

1. Development in a number of economic indicators
2. Required number of sea days to catch the quotas allocated to the Member State
3. Break-even revenue
4. Overcapacity
5. Adjustment in fleet capacity (number of vessels)
6. Landings per species as a function of sea days based on landings per day in the base years and projected stock abundances in the future.
7. Net present value of different scenarios

Figure 1 shows the general structure of the 1999 model. The left hand column contains information used as input in order to parameterize (initialise) the model which is depicted in the centre column. Note that fixed costs and number of vessels are kept constant. This assumption is plausible if there is overcapacity. The only decision rule in this version is the fishing mortality rates leading to the determination of TACs.

Figure 1. The 1999 version of the EIAA model

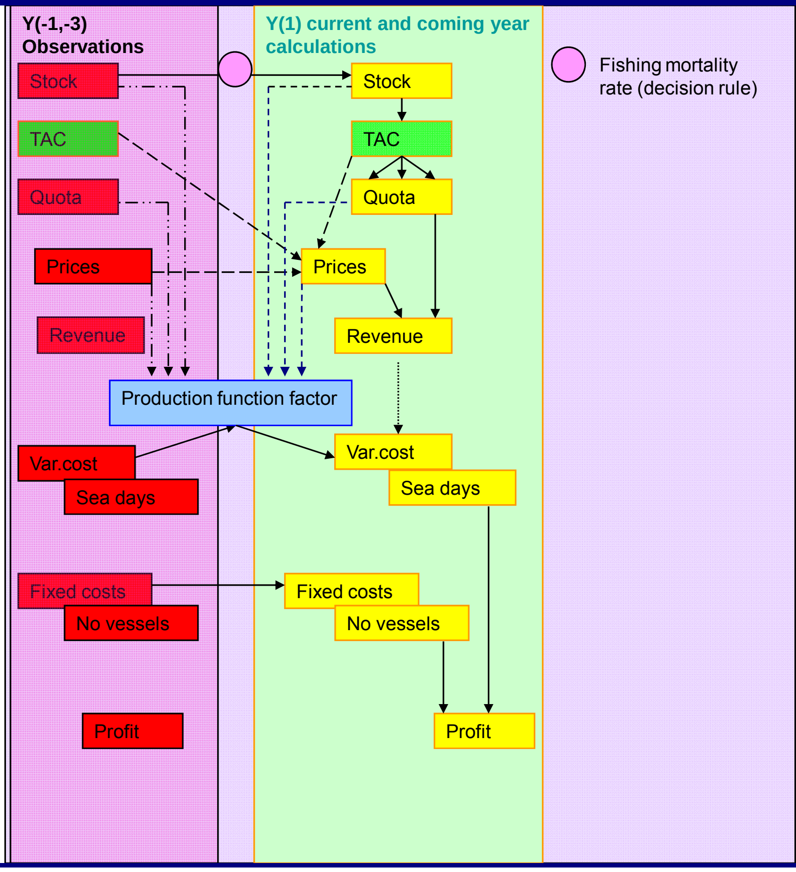
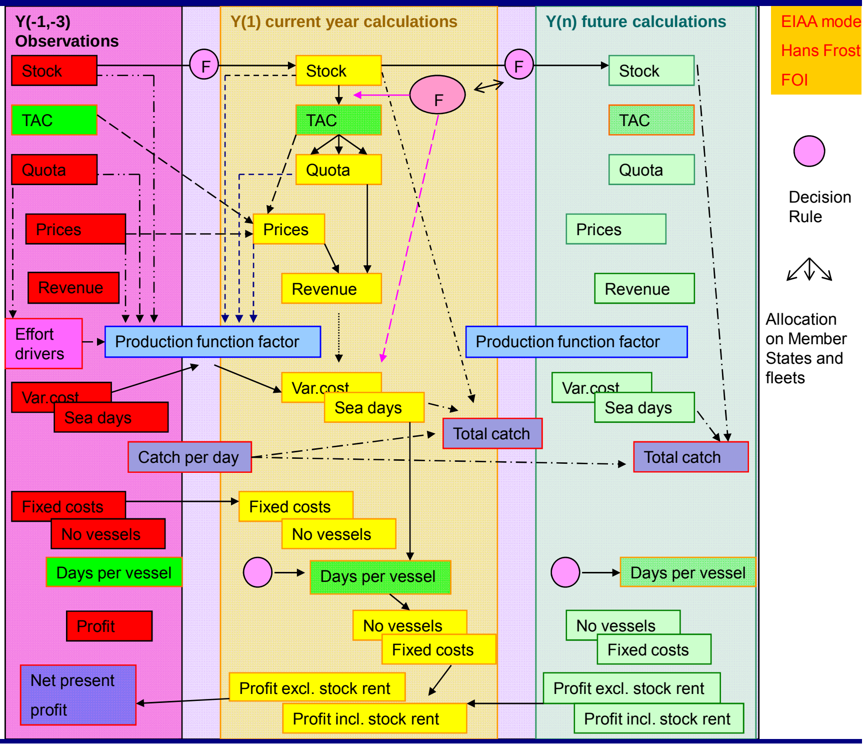


Figure 2 shows the 2007 version. The left hand column contains information used as input in order to parameterize the model that is depicted in the centre column. Compared to the 1999, version the 2007 model is expanded on the economic side making fixed costs and numbers of vessels vary over time. A decision rule regarding the number of sea days per vessel is included. The right hand column is equal to the centre column but runs for future years as a function of future fish stock estimates.

Figure 1. The 2007 version of the EIAA model



1.4. Models derived from the 1999 version

1.4.1. Country model

The EIAA model is designed to work with TAC/quota allocations based on biological advice for stocks exploited by several countries simultaneously. For areas where no stock assessments take place and hence no TAC/quota allocations occur, the model can still be used if target landings are fixed instead of TAC/quotas. Based on these target landings the model calculates the economic performance of the fleets in the same way as the large model.

A reduced version of the 1999 version was developed to cope with such topics. Instead of working at an EU level, this model works at a national level. The model was developed in 2003 and it contains basically all the features as the “normal” EIAA model including the 2003 extensions. This means that the impacts of fish stock abundances i.e. change in catch rates are included. If no stock assessment takes place empirical data are not available. However, the model feature makes it possible to perform evaluations of different scenarios. The country model is only half size of the "normal" EIAA model because all the TAC/quota input is removed and the stock abundance part is limited to indices showing estimated changes in the abundance of the species.

1.4.2. Ressource rent model

The country model has formed basis for a version that is used to calculate the maximum resource rent on a fleet segment level subject to long run development in the fish stock abundance. Instead of setting target landings of the various species the yield of each species are estimated as a function of the spawning stock biomass (*SSB*) with the parameters *g* and *h*: $Yield = g * SSB^{-h*SSB}$.

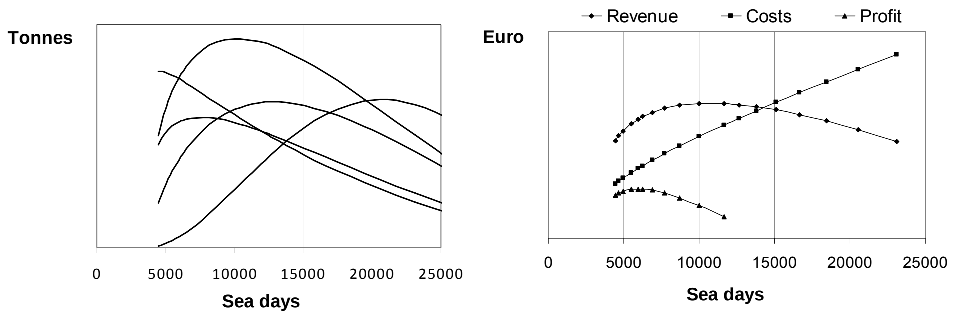
This function is arbitrarily chosen among several options The function is convenient to use for analytical purposes as it contains only two parameters, is flexible and has a convenient shape that can be adapted to the results from age structured fish stock models.

The model applies a loop (the table function of excel) and feed sequentially yield and biomasses into the country model's target landing sheet and the sheet for biomass. Then results equal to the "normal" EIAA results are derived easily.

The corresponding yields of the stocks are allocated to the fleet segments in terms of fixed quota shares estimated from the landings shares of the species of the fleet segment in the base period.

Using the inverse Cobb-Douglas production function in the model, see paragraph 3.4 for further explanation, the effort (sea days) that corresponds with the yield is estimated together with the revenue and costs. The maximum resource rent and the optimal effort are estimated from the profit function. Figure 3 shows an example for one fleet exploiting five different management stocks with different growth rates.

Figure 2. Estimation of resource rent in a multi-species single fleet fishery



The aggregate revenue, costs and profit are shown in the right hand side of the figure. It appears for this case that the maximum profit is obtained at an effort of 6000 days which implies that some species are “overfished” and some “underfished” compared to the peak points of the yield curves in the left hand side of figure 3.

2. The applied 1999 version

The following text is retrieved from earlier reports, see for example SEC(2004) 1710.

2.1. Methodology

2.1.1. Background

The background for the work is the need for economic assessment to supplement the ACFM advice demanded by STECF and other interested agents.

2.1.2. Objective

Taking into consideration the TAC/quota advice given by ACFM the objective is to produce short-term economic projections for the fleet segments specified in the Annual Economic Report, cf. AER several issues.

2.1.3. Data requirements

1. Technical details of fleet segments
2. Landings by species
3. Prices by species
4. Cost information for fleet segments
5. ACFM advice for landings by management stocks

Costs and earnings data are drawn from the Annual Economic Report, while ACFM advisory data are extracted from pertinent ACFM reports by the SGRST (STECF subgroup on Resource Status). From 2003 the SGRST made use of a mixed fishery approach (MTAC), see SEC (2002) 1373 and Vinther, Reeves and Patterson (2004).

2.1.4. Scenario calculations

The EIAA model (and reports) presents scenarios. These scenarios are intended to aid political choice making. Therefore, the scenarios should not be interpreted individually but rather in comparison with one another for each country. Such comparisons indicate what economic change can be expected if one or another quota choice is made.

For many major species the ACFM provides options according to the level of fishing mortality. Different options for various stocks can be combined in the catch composition of the fleet segments leading to a potentially very large number of scenarios, many of them not leading to converging results.

It cannot be foreseen which TAC will be decided upon eventually by the Council of Ministers and to which extent quotas will be swapped between Member States. For some stocks ACFM does not provide any advice. In other cases the advice is not identical to the TAC management areas applied by the EU, and for some (relatively few) stocks precautionary spawning stock biomasses and TACs are estimated. All these inconsistencies imply that the model is used for *projections* of different scenarios rather than *forecasts* of agreed TAC/quotas.

2.2. Data problems

When combining biological assessment and advice with economic assessment and advice, a number of data problems arise. Based on the problems detected in the work with the economic assessment, the problems can be divided into 6 areas:

1. Where quota species constitute a large part of a fleet segment's landings but the final landings data on species level are not available

2. Where quota species constitute a large part of a fleet segment's landings and where the management decisions have been made before the most recent costs and earnings data are available i.e. if quotas are fixed in for example September for the year to come while the most recent costs and earnings data are available in October

3. Where the quota species constitute only a small share of the total landings of a fleet segment

4. Where no biological assessment is made, but precautionary quotas are fixed

5. Where the biological stock assessment areas are inconsistent with the quota management areas

6. Where no stock assessment and no quota management is in function

The model can be applied with necessary adjustments to all areas, which requires use of older data sets and assumptions about future catch possibilities and fish stock sizes.

2.3. Assumptions

In many cases, assumptions have had to be made regarding lacking information. This is essential when using the model. These include composition of costs and catches of specific fleet segments, fishing technology, price flexibility rates of certain species, etc.

2.3.1. Constant fishing patterns but changing catch compositions

The calculations require an assumption regarding the relative shares of the various national fleet segments in the national landings of a specific species. It is assumed that this fishing pattern will not change from the reference year to the year for which the evaluation is made.

It is assumed that the fleet segments catch a constant share of the species. This means that the catch composition of a segment will change when the TACs change.

2.3.2. Effort and catch of non-target species

The model does not include fishing effort as such but rather changes in costs entailed by changes in fishing activity. When a TAC is changed, the activity (effort) and fishing costs on the specific species will have to be adjusted accordingly. These adjustments have been introduced when calculating the share of that species in the total landings value of the fleet segment. The total fishing activity (effort) for a fleet segment is affected by changes in the share of this particular species in the weighting of the new activity of all species with the respective shares in value of landings, see the example in Appendix 2, section 12. Consequently, the effort of a fleet segment shifts away from the species which are to be protected by reduced TACs. However, the activity of a fleet segment is further influenced by price changes on the species e.g. if the price goes up the activity exerted on this particular species will go up. With quota restrictions, this can be interpreted as an activity and hence costs that are connected with discarding. Finally, the activity is influenced by changes in fish stock abundance. The activity (effort) influences the variable costs in the short and long run, while fixed costs are unchanged. Variable costs are assumed to be non-linear in effort, because it is assumed that the stock abundance influences the catch per unit effort in a non-linear way. This implies that a smaller quota requires less fishing effort and therefore lower variable costs. At the same time, a lower stock abundance leads to a lower catch per unit effort, which offsets some of the lower effort needed to catch the lower quota. These assumptions are included in the model through a catch-stock abundance flexibility rate, a catch-gear (technology) flexibility rate and a catch-price flexibility rate.

2.3.3. Live weight equivalents

As the ACFM advice is provided in live weight, all catches and landings are thus assumed to be live weight equivalents. In practice some fish are landed headed or gutted so that also the respective price information regards dead weight price per kg and therefore have to be estimated.

2.3.4. Quota uptake

Nominal quota, as set at the beginning of the year, is used. However, in practice quotas are swapped between countries, some quotas remain unutilised and/or some are exceeded. The total effect of these changes is summarised in an uptake correction factor. This factor allows the projected landings of the coming year to be different from the proposed quota.

2.3.5. Prices

Price levels are adjusted through changes in the volume of landings. Future prices are calculated based on a price flexibility rate, which has a default value at -0.2. Consequently, a lower quota is somewhat (20%) offset by higher prices. The price flexibility rate for each species can be changed in the model and with a value at zero no price changes will occur. Inclusion of global price trends requires information about total world catches, but lack of data has prevented this. Thus only price changes related to the total European Union catches are taken into account. A greater refinement of price elasticity by species should be pursued, however. In the model, price changes are calculated for each species (e.g. one for herring and one for cod species etc.). Landings from third countries are not included.

2.4. Definitions

2.4.1. Gross earnings of the vessel and catches (Value of landings)

Gross earnings of a vessel are determined by annual volume of catches per species and the price of those species.

2.4.2. Variable costs

Variable costs vary directly with activity (effort) i.e. fuel, provisions, repairs. When effort, exerted on a certain stock, is reduced due to a lower TAC, the total variable costs of a fleet segment are reduced relative to the weight of the reduced species in the fleet segment's landings composition, cf. above concerning effort.

2.4.3. Fixed costs

Fixed costs are divided in vessel costs (maintenance, insurance, administration etc.) and capital costs (interest payments and depreciation). They are kept constant and are, therefore, assumed not to vary with effort. This is justified because the invested capital cannot be changed in the short run. In the long run with higher TACs, the associated higher stock abundances and excess fleet capacity is assumed to make it possible for the current fleet to catch the higher volumes.

2.4.4. Gross value added

Gross value added = depreciation costs + interest + crew share + net profit, or,
Gross value added = Gross revenues - all expenses (excl. labour remuneration, instalments and interest payments on loans).

2.4.5. Crew share

Crew share is the percentage of the gross revenue used to pay the crew. In some cases, crew share is calculated from the difference between gross revenue and variable costs.

2.4.6. Gross cash flow

Gross cash flow = gross value added – crew share (= income to the vessel)

2.4.7. Net result

Net result = gross revenues – variable costs – fixed costs – crew share

2.5. Presentation and interpretation of results

EIAA contains a short, a medium and a long-term assessment of expected changes in economic performance. Four main indicators are used for this purpose:

- *Gross revenue:* Is total landing value and is easy to relate to because it compares to total landing volume and are often used as an indicator of gross income.

- *Crew remuneration:* Payments to crew members, including the skipper/owner. An important indicator for the economic attractiveness of the profession. If the figure is divided by an opportunity salary, employment measured in full-time fishermen is easily calculated.

- *Gross cash flow:* Can be considered as the main indicator for the survival feasibility of fishing companies in the short run (2-3 years). Negative cash flows cannot be sustained for longer periods, as the cash expenses exceed cash income. Low cash flows will lead to problems of repayment of loans. The policy of the banks becomes of crucial importance in such situations.

- *Net profit (result):* Represents the "above normal" economic remuneration of invested capital. As this is the 'bottom line' of the calculations, it is very sensitive to changes in earnings or costs. The net result calculated in EIAA model is an economic and not a fiscal indicator. However, if book data for depreciation and interest is available a fiscal indicator can be calculated. This means that it shows the long-term survival feasibility of the sector. A low economic net result may still be quite satisfactory in fiscal terms in the medium run (4-5 years). Net profits are presented in the diagrams relative to the gross revenue, and in this way the result represents a substitute for net profits relative to investments.

The information of these four indicators is presented in diagrams, with the scenarios placed along the horizontal axis. The value of landings, crew share and gross cash flow are shown as histograms. Below each scenario there is a verbal indication of the economic performance of the fleet segment and the precise value of the ratio of net profit to gross value of landings. The classification is derived from this ratio as follows:

- *Profitable:* Net profit/gross value of landings > 5%.
- *Stable:* -5% < net profit/gross value of landings ≤ 5%
- *Unprofitable:* Net profit/gross value of landings ≤ -5%.

In the last situation fishing cannot continue in the long run.

2.6. Specification of the biological data required for the EIAA model

All data specified below must be defined with precise correspondence to the definition of TACs in terms of species and areas for all North East Atlantic stocks.

The following data is required:

- Estimation of long term TAC under precautionary (*pa*) or status quo (*sq*) conditions (yield per recruit at F_{pa} * number of recruits or F_{sq} * number of recruits).
- Time series of SSB, annually up-dated to reflect latest VPA or another indicator reflecting stock abundance under long term sustainable conditions.
- Indication of the multi-species effect, e.g. probability distribution that all stocks will recover at the same time, if management is properly implemented.

If information about fishing mortalities and SSB does not exist, which is the case for a number of management areas, only the TAC fixed for the management area is used in the calculation.

3. The EIAA extension regarding overfishing and sea days

This extension of the EIAA model calculates the expected over- and underfishing for a given TAC/quota proposal, given the assumption that the catch composition of a fleet segment is the same as in the base period, see Frost (1997) for an early approach and Frost and Kjærsgaard (2003) for an application of a large optimization model for the whole Danish fishery.

The purpose of the EIAA extension is to produce advice on the number of sea days that have to be used in order to catch the proposed quotas, assuming that landings compositions are fixed. If none of the quotas is allowed to be overfished, fewer sea days can be deployed and thereby the earnings are reduced. On the other hand, a high number of allowed sea days will lead to higher earnings in the short run, but also a higher amount of overfishing. Therefore, a new quota proposal, which will minimize the expected over- and underfishing, will help managers in taking decisions regarding this problem. The model can optimize the number of sea days that have to be used to achieve this. The model component is outlined in Figure 4.

Landings for each fleet segment are used to calibrate the model. This is done by multiplying the TAC with the relative stability key (between countries) and the assumed relative stability key between fleets within a country. When new quotas are proposed, it will usually not be possible catch all the quotas without overfishing some species if the quotas for all species are exhausted since the species are caught in constant proportions. This part of the EIAA model estimates the landings and the economic performance based on the included information about prices and costs for the base period by an exogenous or endogenous choice of effort (sea days). This approach is opposite to the other part of the model where effort is estimated by an exogenous choice of the TAC/quotas. The most obvious use of this part of the model is:

- To calculate the possible landings of each species for a given number of sea days on fleet segment level. Based on assumptions regarding fisherman behavior and political initiatives, the model can calculate the degree of the expected over- and underfishing through specific sea days regulations. Furthermore, the short run economic consequences of this strategy can be calculated based on price information of fish and costs per sea day.

- To optimize the use of sea days by maximizing different profit objectives. This is for example done by calculating the optimal amount of sea days in order to minimize the total value of over- and underfishing the TAC/quota proposal. The optimization evaluates the economic consequences of species restrictions. As an example, the model is able to find the change in profit, if overfishing of cod is under no circumstances allowed.

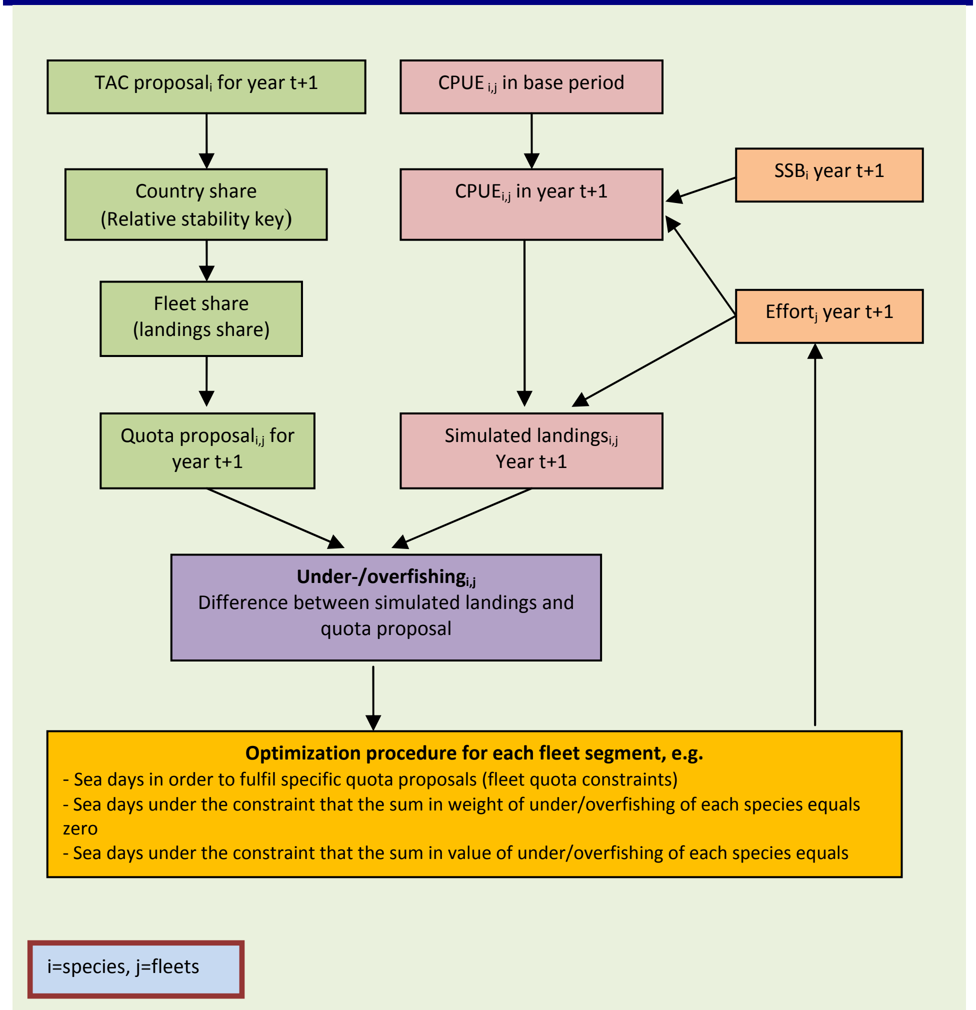
The part of the model based on exogenous effort takes as a starting point the demand for information about the expected overfishing and discards. At the same time, this model part can guide the manager towards the number of sea days necessary to catch the proposed TAC/quotas based on different criteria such as that no quotas are allowed to be overfished or some quotas are allowed to be overfished.

This is done by applying the following steps:

1. CPUE (catch per day) is calculated for the base period of three years.
2. CPUE for coming years are adjusted with the ”catch-stock” and the ”catch-effort” flexibility rates under the assumption of a Cobb-Douglas production function technology.
3. The fleet segment share of the quota allocation and the segment's expected landings are calculated.
4. The landings of the fleet segment with a given amount of sea days are calculated using the CPUE (cf. point 1) and number of sea days
5. The differences between the TAC/quota proposal and the calculated landings (cf. point 4) are found.
6. The result in point 5 can be further elaborated. Instead of using an exogenous given number of sea days, the model can estimate the number of sea days by use of an optimization procedure. This is achieved letting the model find the number of sea days that minimizes the sum of the differences between the fleet segment's quota allocation of species and the landings of the species of the segment.
7. Other optimizations with other objectives can be performed. This could be, for example, that instead of using quotas and landings of the species in weight a value measure based on market prices could be applied. Further, the values of the species could be estimated by use of other measures than the market prices. This option is relevant if the market price does not reflect the risk of extinction of the species.

Currently, the optimization process works for up to four fleet segments, which is the current (2008) number of fleet segments in the workbook. With optimization over more fleet segments, the number of fleet segments must be increased in the work-book.

Figure 4. Effort allocation under joint production[4]



[4] Species are caught in a fixed relationship (fixed catch composition of the fleet segments)

4. The workbooks of the 1999 and the 2007 versions

The workbook contains all the formulas of the model. The model is constructed by use of cell-references, named arrays (vectors) and if-sentences. No macros or virtual basic are used.

A workbook is country specific i.e. costs and earnings information for fleet segments belonging to a specific country is included. The country workbook comprises currently up to four fleet segments. More fleet segments can be handled by using several workbooks for one country.

Each country workbook includes the total number of TAC/quotas on stock management areas of the EU. This adds up to 113 stock-management areas excluding the areas for the Member States that joined the EU May 1. 2004. Each country workbook also includes information about spawning stock biomasses for the 113 stock management areas. However, only around 60 stock-management areas comprising 17 different species are subjected to analytical assessment with respect to stock abundance. The rest of the stocks are kept unchanged in the model.

This procedure secure that a uniform biological data input is used for all Member States. When a workbook is used for one particular country, a country code specified in every workbook must be invoked to extract the quotas and the fish stock information from the data sheets for that particular country.

This is done by use of the relative stability matrix for the Member States of the EU. The relative stability matrix is specified on quota-management areas. The quota-management areas and the stock information are updated every year and the reason for the inclusion of that information in all workbooks is to avoid mistakes with respect to these two variables.

4.1. 1999 version

The workbook of the **1999 version** includes 7 sheets

1. AER Input
    a. Cost and earning information copied from the AER
    b. Catch compositions in volume and value on national level and on fleet segment

   c. Calculated up-take-ratios
   d. Fleet segment shares of national quotas
2. Selected economic indicators and result figures in national and in Euro currency on fleet segments
3. Detailed result tables on fleet segment level
4. Selected economic indicators and result figures in national currency on fleet segments where that apply
5. The same as in sheet 4 but in Euro
6. Data base time series
   a. EU TAC for the base years and the coming year on quota management areas
   b. Spawning stock biomass information on quota management areas
   c. Price flexibility rates and calculated prices
   d. Exchange rates
   e. Interest rates
7. Background information
   a. Relative stability matrix i.e. Member State share of TAC per quota-management area.
   b. Long term TAC on quota management areas
   c. Catch-effort and catch-stock- flexibility rates.

4.2. 2007 version

The workbook of **the 2007 version** is organised in 23 sheets where some of the new sheets arise from reorganising sheet 6 and 7 in the 1999 version:

1. Guidelines that explain what is included in the workbook
2. AER Input
   a. Cost and earning information copied from the AER
   b. Catch compositions in volume and value on national level and on fleet segment level
3. Capital input from the AER, (vessels, employment, sea days etc.)
4. Catch per day calculation for the base period and future landings as a function of sea days (new in 2007)
5. Economic results of the calculation in sheet 4
6. Selected economic indicators and result figures in € on fleet segments
7. Detailed result tables on fleet segments without fleet (capital) adjustment
8. Detailed result tables on fleet segments with fleet (capital) adjustment

9. Selected economic indicators and result figures in national currency on fleet segments where that apply
10. Figures showing ‘overcapacity’ based on the ‘break-even principle’
11. Allocation of shares of spawning stock biomass on fleet segments in terms of value
12. Catch-effort and catch-stock flexibility rates in the primal Cobb-Douglas function
13. Catch-effort and catch-stock flexibility rates in the inverse Cobb-Douglas function. Linked to sheet 12
14. Calculated up-take-ratios
15. Price flexibility rates and calculated prices
16. Fleet segment shares of national quota
17. Spawning stock biomass information on quota-management areas
18. Long term TAC on quota management areas
19. EU TAC for the base years and the coming year on quota-management areas
20. Relative stability matrix i.e. Member State share of TAC per quota-management area
21. Effort drivers that choose the species driving the effort (added in 2006)
22. Calculation of fleet activity changes
23. Auxiliary information such as exchange rates, deflator indices and interest rates.

5. Summary of the EIAA model's data input and output formats

The data information is summarized in the following items:

- Developed in an excel workbook for maximum transparency
- Designed to calculate economic consequences for fleet segments of:
  - Proposed quota scenarios for the current year
  - Proposed quota scenarios for next year
  - Long run situation i.e. long-term TAC (only indicative)
- Uses data input from:
  - The Annual Economic Report (AER)
  - Quota proposals for the European Union
  - Information about sustainable biomasses SSB and long-term TAC (ACFM, ICES WG-reports, and other sources e.g. the MTAC model output)
- Requires that
  - The fleet segments examined need to be subject to quotas (or target landings)
  - Knowledge of the catch composition for the national fleet and for each fleet segment
  - Non-quota species are assumed constant in the model
  - The costs and earnings information is from the Annual Economic Report (AER) or in a similar format.
- Model features are partly dynamic by use of elasticities
- Fixed fleet structure i.e. constant fixed costs and number of vessels
- Prices changes of species according to changes in aggregate EU-quotas
- Changes in catch compositions of the fleets according to the proposed TAC/quotas
- Changes in variable costs (fishing effort) according to
  - Changes in species prices
  - Changes in allocated quotas (catch composition)
  - Changes in stock abundances SSB (catch rates)
- Results presented by
  - A classification based on the ratio between net profit (NP) and total (gross) revenue (TR) (the operating profit margin) the classification is as follows:
    - Profitable: NP/TR > 5%.
    - Stable: -5% < NP/TR ≤ 5%

- Unprofitable: NP/TR ≤ -5%. In this situation fishing cannot continue in the long run

- And economic indicators:
  - Value of landings
  - Variable costs e.g. fuel, provision, repair
  - Crew share e.g. payment to the crew including skipper
  - Gross cash flow e. g. the value of landings minus variable costs and minus crew share
  - Fixed costs divided into vessel costs (maintenance, insurance, administration etc.) and capital costs (interest payments and depreciation)
  - Net result e.g. value of landings minus all costs
  - Gross value added (socio-economic indicator) i.e. remuneration of labour and capital (contribution to gross domestic product).

6. EIAA 1999 model equations

The EIAA model computes future landings value and costs by use of recorded baseline information, which is a three years average, and future TACs as proposed by the EU Commission, ICES etc.

As the TACs and subsequently the quotas to the Member States are determined for the whole EU the EIAA model principally covers all the fish stocks and fleet segments that are subject to TAC management. However, the model is for practical reason designed to work on country level by use of a model features that selects Member State and allocates quotas to the Member States. Quotas are fixed for Member States on quota management areas. Due to data shortage the model does not produce results distributed on management areas, therefore subscript *a* for management area and subscript *m* for Member State are omitted in the following apart from a few equations where it is useful to keep these subscripts. Sections 6.3-6.6 are described at country (or the Member State) level. The model is generally applicable to countries where TAC/quotas are allocated to fleet segments, but as the model, particularly, is developed to suit EU fisheries *m* is referring to Member State. In order to facilitate reading a complete list of variables and parameters is found in Appendix 1.

6.1 Landings of quota species in future periods

The landings of quota species in future periods per fleet segment are calculated by taking the country quota share of the total EU-TAC using the relative stability matrix and distribute it nationally by using the national fleet segment shares in the baseline period. The degree to which the quota is exhausted is taken into account by using an up-take-ratio:

(1) $$L_{t,i,j,m} = \left(\sum_a Q_{t,i,a} \cdot ns_{i,a,m} \right) \cdot nu_{i,m} \cdot \left(\frac{L_{0,i,j,m}}{L_{0,i,m}} \right)$$

where $nu_{i,m}$ can be changed and is defined as:

(2) $$nu_{i,m} = \frac{\sum_j L_{0,i,j,m}}{\sum_a Q_{0,i,a,m}}$$

$L_{0, i, m, j}$	Landings in base years of species i caught by fleet segment j for Member State m (exogenous variable)
$L_{t, i, j, m}$	Landings in year t of species i caught by fleet segment j for Member State m (endogenous variable)
$Q_{t, i, a}$	Quota at year t of species i in area a (exogenous variable)
$ns_{i, a, m}$	Relative stability i.e. the share of species i in area a for Member State m (parameter)
$nu_{i, m}$	Quota uptake ratio of species i for Member State m (parameter, calcu lated by the model).
$Q_{0, i, a, m}$	Quota in base years of species i (exogenous variable) for Member State m.

6.2 Prices in future periods

In order to calculate future landing prices, the first step is to calculate the baseline prices from the landing value and the landing volume. Then, assuming that the price of each species in the future is a function of the total EU-TACs, future prices are calculated. The applied function includes a price flexibility rate which is fixed at –0.2 as a default rate:

(3) $$P_{0,i,j} = \frac{TR_{0,i,j}}{L_{0,i,j}}$$

(4) $$P_{t,i,j} = P_{0,i,j} \cdot \frac{\left(\sum_a Q_{t,i,a}\right)^{\varepsilon_i}}{\left(\sum_a Q_{0,i,a}\right)^{\varepsilon_i}}$$

$\varepsilon_i \leq 0$

$P_{0, i, j}$	Fish prices in base years of species i by fleet segment j (endogenous variable)
$L_{0, i, j}$	Landings of quota species i in base years by fleet segment j (exogenous variable)
$TR_{0, i, j}$	total revenue of quota species in base years of species i by fleet segment j (exogenous variable)
$P_{t, i, j}$	Fish prices year t of species i by fleet segment j (endogenous variable)
ε_i	Price flexibility of quota species i (parameter).

Based on specific knowledge, detailed price flexibility rates can be applied instead of the default value.

6.3 Gross revenue in future periods

Gross revenue (total revenue) in future periods is calculated based on the computed future landings and prices. The value of non-quota species are calculated from the baseline information and added to the computed future value of the quota species. Finally, the computed gross revenue for the future periods is adjusted with a coefficient to account for income outside fisheries:

(5) $$TR_{t,j} = (\sum_i P_{t,i,j} \cdot L_{t,i,j} + K_{t,j}) \cdot \frac{GR_{0,j}}{\sum_i P_{0,i,j} \cdot L_{0,i,j} + K_{0,j}}$$

where $K_{t,j}$ is defined as:

(6) $$K_{t,j} = TR_{0,j} - \sum_i P_{0,i,j} \cdot L_{0,i,j}$$

and $GR_{0,j}$ is defined as:

(7) $$GR_{0,j} = TR_{0,j} + O_{0,j}$$

$TR_{t,j}$	Total revenue in year *t* by segment *j*
$K_{t,j}$	Landings value in year *t* of other species than quota species of segment *j*
$GR_{0,j}$	Gross revenue including non-fisheries specific income of segment *j*
$O_{0,j}$	Income from non-fisheries specific activities of fleet segment *j*

6.4 Variable costs in future periods

A fleet activity variable *A* is calculated and used in the model to adjust the variable costs. Changes are considered only within fleet segments, not between segments. Calculation of fleet activity consists of three elements: landings, stock abundance (catch rates) and prices. The rationale behind this procedure is the Cobb-Douglas (C-D) type of production function, see section 9 for a further elaboration of the C-D function. An explicit functional form for a fleet segment and a single species is:

(8a) $$L = a * A^{\alpha} \cdot SSB^{\beta}$$

The inverse function is:

(8b) $$A = \left(\frac{1}{a}\right)^{1/\alpha} * \frac{L^{1/\alpha}}{SSB^{\beta/\alpha}}$$

where

A:	fleet effort
a:	coefficient
L:	landings
SSB:	spawning stock biomass
α and β	parameters (flexibilities); α ≥ 0; and β ≥ 0

Expanding the inverse production function (8b) to a normalised format in terms of time, species and fleet segment, gives the applied expression in (9). The inverse C-D function is expanded with an element that is a Laspeyres index (fixed weights and current prices). This expansion implies that the activity of the fleet segment is affected by the prices on the species. An increase in prices will entail an increase in activity and *vice versa*. It is assumed that fishermen will allocate more effort to the species with the highest price increases in conjunction with the quotas and catch rates. The prices in future periods are determined by future landings (assumed to be dependent on future quota allocations) and the price flexibility (equation 4).

Further, a factor θ is included in order to determine the activity according to those species which are assumed to drive the vessel effort. This effort driver factor was not included in the first (1999) version of the EIAA model. As the function is normalized, the function calculates the activity change.

The behaviour of the fishermen in terms of effort allocation is then interpreted as the activity change, which is a function of price changes for species caught by a fleet segment, the species assumed to drive the effort, the change in landings of each species, and the change in spawning stock biomass of each species. When $\chi=1/\alpha$ and $\gamma=\beta/\alpha$ one has:

(9) $$A_{t,j} = \sum_i \left(\frac{L_{0,i,j} \cdot P_{t,i,j} \cdot \theta_{t,i,j}}{\sum_i L_{0,i,j} \cdot P_{0,i,j} \cdot \theta_{t,i,j}} \cdot \left(\frac{L_{t,i,j}}{L_{0,i,j}}\right)^{(\chi_{i,j})} \cdot \left(\frac{SSB_{t,i}}{SSB_{0,i}}\right)^{(-\gamma_i)} \right)$$

A numerical example of equation 9 is found in Appendix 2.

(10) $$RC_{t,j} = RC_{0,j} \cdot A_{t,j}$$ function of quota species only, or

(11) $$RC_{t,j} = RC_{0,j} \cdot AA_{t,j}$$ function of all species

where

(12) $$AA_{t,j} = A_{t,j} \cdot \frac{\sum_i P_{t,i,j} \cdot L_{t,i,j}}{TR_{t,j}} + \frac{TR_{t,j} - \sum_i P_{t,i,j} \cdot L_{t,i,j}}{TR_{t,j}}$$

$A_{t,j}$	'Activity coefficient' as a function of quota species in year *t* of fleet segment *j;* $A_{0,j}$ = 1 (endogenous variable) calculated for the baseline period
$L_{t,i,j}$	Landings in volume in baseline period 0, and TAC in year *t* of species *i* by fleet segment *j*
$P_{t,i,j}$	Prices in year *t* of species *i* by fleet segment *j*
$SSB_{t,i}$	Spawning stock biomass in year *t* of species *i* (exogenous variable)
$AA_{t,j}$	'Activity coefficient' as a function of quota and non quota species in year *t* of fleet segment *j;* (endogenous variable)
$\chi_{i,j}$	Activity-landing flexibility rate' of quota species *i* for fleet segment *j*
γ_i	Activity - stock flexibility rate of quota species *i*
$RC_{t,j}$	Running costs in year *t* of fleet segment *j,* includes fuel and other costs dependent on sea days (endogenous variable)
$RC_{0,j}$	Running costs in the baseline period for fleet segment *j*, which inclu des fuel and other costs dependent on sea days (exogenous variable)
$\theta_{t,i,j}$	Effort driver. Selects the species *i* that in year *t* drive the effort of segment *j*. θ = 0 or 1. This is not part of the 1999 version but the 2007 version.

To sum up about the production function: the *'Price-element'* accounts for the incentives to reallocate effort as a function of changes in the relative fish prices. Note that future prices depend on the price flexibility rates, see equation 3 and 4.

The '*Landings-element*' accounts for technological accessibility (over-water accessibility). If χ (χ=1/α) is zero the fish is easily handled (good crew, good space, good weather, no bottlenecks etc.), and if handling becomes harder, χ increases. The default value in the model is $\chi = 1$. The inclusion of this element makes it possible to distinguish between different handling procedures in particular for demersal and pelagic species and different fishing technologies.

The *SSB-element* accounts for accessibility caused by stock abundance (under water accessibility). Setting $\gamma = 0$, $(\gamma=\beta/\alpha)$ implies there is no stock abundance effect on the activity. With full effect $\gamma = 1$. Default values used in the model are between 0.6 and 0.8 for demersal species and between 0.1 and 0.2 for pelagic species

When the activity variable *A* is calculated for each fleet segment, the recorded variable costs $RC_{0,j}$ for the baseline period is multiplied with *A* to obtain variable cost for the future years.

The model contains two options for calculating *A*. One option only takes the effect of changes in the quota species into account. The second option denoted *AA* is adjusted for the value of quota species relative to the total landing value. As default, the model calculates the *AA* to avoid that quota species alone determines the effort. This is in particular important in fisheries where quota species constitutes only a minor part of the landings of a fleet segment. Note also the option θ in the production function (equation 9) that allows for specific choices of species with respect to driving the effort.

When using this procedure, it is assumed that each species in the landing composition can be caught separately. However, in many fisheries joint production prevails entailing that the species are caught in fixed proportions. This problem is addressed in the 2007 model version.

The crew share is calculated in the model for the baseline period by taking the costs of the crew relative to the gross revenue.

(13) $$CC_{t,j} = cc_{0,j}\, TR_{t,j}$$

where $cc_{0,j}$ is defined as:

(14) $$cc_{0,j} = \cdot \frac{CS_{0,j}}{GR_{0,j}}$$

$CC_{t,j}$	Crew share in year *t* of fleet segment *j* (endogenous variable)
$cc_{0,j}$	Crew share coefficient in base period of fleet segment *j* (endogenous variable)
$CS_{0,j}$	Crew share in base period of fleet segment *j* (exogenous variable)

6.5 Fixed costs

Fixed costs are assumed constant, i.e. transferred from the baseline period to future years. The model distinguishes between fixed costs related to the operation of the vessel i.e. semi-fixed costs such as maintenance, insurance and administration and the fixed capital costs depreciation and interest:

(15) $$FC_{t,j} = FC_{0,j}$$

(16) $$DC_{t,j} = DC_{0,j}$$

$FC_{0,j}$	Fixed costs for fleet segment *j* in the base period
$FC_{t,j}$	Fixed costs for fleet segment *j* in period *t*
$DC_{0,j}$	Depreciation and interest costs for fleet segment *j* in the base period
$DC_{t,j}$	Depreciation and interest costs for fleet segment *j* in period *t*

6.6 Indicators of economic performance:

A number of economic indicators are calculated as shown by the subsequent expressions.

a) Cash flow in year *t* for fleet segment *j*:

(17) $$GF_{t,j} = TR_{t,j} - (RC_{t,j} + CC_{t,j} + FC_{t,j})$$

b) Net profit in year *t* for fleet segment *j*:

(18) $$NP_{t,j} = TR_{t,j} - (RC_{t,j} + CC_{t,j} + FC_{t,j} + DC_{t,j})$$

c) Operating profit margin in year *t* for fleet segment *j*:

(19) $$OPM_{t,j} = \frac{TR_{t,j} - (RC_{t,j} + CC_{t,j} + FC_{t,j} + DC_{t,j})}{TR_{t,j}}$$

d) Gross value added in year t for fleet segment j:

(20) $$GV_{t,j} = NP_{t,j} + CC_{t,j} + DC_{t,j}$$

7. A note on the up-take ratio and the need for national landings

The total fleet landings in volume (national landings) are used to calculate up-take ratios and fleet segment shares. Only if up-take ratios are changed in future years (which has to be done exogenously), total fleet landing (or national landings) are necessary. This makes the model flexible in the sense that calculations can be performed for fleet segments without information about the national landings if the up-take ratios are considered constant for a Member State.

The following proof shows that in the EIAA model, the 'value of landings of TAC species' is calculated by using the following formula:

$$L_{t,i,j,m} = \left(\sum_a Q_{t,i,a} \cdot ns_{i,a,m}\right) \cdot nu_{i,m} \cdot nf_{i,j}$$

where

$L_{t,i,j,m}$	Landings in weight in year *t* of species *i* by fleet *j* of Member State *m*
$Q_{t,i,a}$ >	Quota in year *t* for species i in area *a*
$ns_{i,a,m}$	Relative stability (Member State share of quota) for Member State *m* of species *i* in area *a*
$nu_{i,m}$	Up-Take ratio of Member State *m* of species *i*
$nf_{i,j}$	Fleet segment share for fleet *j* of species *i*

The up-take ratio is the share a Member State catches of the allocated quota. It is calculated as follows:

$$nu_{i,m} = \frac{\frac{1}{3}\sum_{\tilde{y}=1}^{3} L^{TOT}_{\tilde{y},i,m}}{\frac{1}{3}\sum_{\tilde{y}=1}^{3}\left(\sum_a Q_{\tilde{y},i,a} \cdot ns_{i,a,m}\right)}$$

$\tilde{y}$	Number of years in the base period. In 2006, projections are made for 2007 (and 2006), while the base period is 2003-2005
$L^{TOT}_{\tilde{y},i,m}$	Total landings in weight for the whole fleet in year $\tilde{y}$ of species *i* for Member State *m*

This means that the up-take ratio for species i is calculated by the average of a Member States historical landings, divided with the average of their historical quotas.

The fleet segment share is the share taken by fleet j of the total national landings, and it is calculated as follows:

$$nf_{i,j} = \frac{\sum_{\tilde{y}=1}^{3} L_{\tilde{y},i,j,m}}{\sum_{\tilde{y}=1}^{3} L_{\tilde{y},i,m}^{TOT}}$$

Then the following can be deducted:

$$nu_{i,m} \cdot nf_{i,j} = \frac{\frac{1}{3}\sum_{\tilde{y}=1}^{3} L_{\tilde{y},i,m}^{TOT}}{\frac{1}{3}\sum_{\tilde{y}=1}^{3}\left(\sum_{a} Q_{\tilde{y},i,a} \cdot ns_{i,a,m}\right)} \cdot \frac{\sum_{\tilde{y}=1}^{3} L_{\tilde{y},i,j,m}}{\sum_{\tilde{y}=1}^{3} L_{\tilde{y},i,m}^{TOT}} = \frac{\sum_{\tilde{y}=1}^{3} L_{\tilde{y},i,j,m}}{\sum_{\tilde{y}=1}^{3}\left(\sum_{a} Q_{\tilde{y},i,a} \cdot ns_{i,a,m}\right)}$$

The last equation implies that total national landings are not necessary to perform calculations at the fleet segment level if up-take ration are constant.

8. EIAA 2007 model equations

The 2007 version includes all the equations in the 1999 version plus the equations listed in the following paragraphs of this section.

8.1. Break-even and 'overcapacity'

The 2007 version, gradually developed since 2001, of the EIAA model contains information that makes it possible to calculate the gross revenue that is required to cover fixed costs exactly with the given variable costs - denoted the break-even revenue (included in 2001). With salary to the owner/skipper of the vessel included in the variable costs, the break-even revenue is thus the revenue, where net profit is zero after deduction of all costs.

The model includes two different estimates of break-even revenue based on: case 1) total revenue from quota and non-quota species and fixed costs in terms of interest and depreciation only; and case 2) total revenue from quota and non quota species and fixed costs in terms of interest, depreciation and the remuneration of the spawning stocks (resource rent).

These two estimates can be supplemented by a number of other estimates taking into account for example whether fixed costs and semi fixed costs (insurance, maintenance and administration) are all considered fixed, and which species are driving the effort i.e. the variable costs. Further it can be taken into account whether the species not subjected to stock assessment shall be taken into account in the remuneration of the spawning stock biomasses.

The break-even concept is applicable for all periods in time. In case 1 for the base period, it has the form:

(21) $$BR_{0,j} = \frac{DC_{0,j}}{gf_{0,j}}$$

Where the cash flow coefficient *gf* is calculated as:

(22) $$gf_{0,j} = \frac{TR_{0,j} - (RC_{0,j} + CC_{0,j} + FC_{0,j})}{TR_{0,j}}$$

Overcapacity is then defined and calculated for the base period and future periods as:

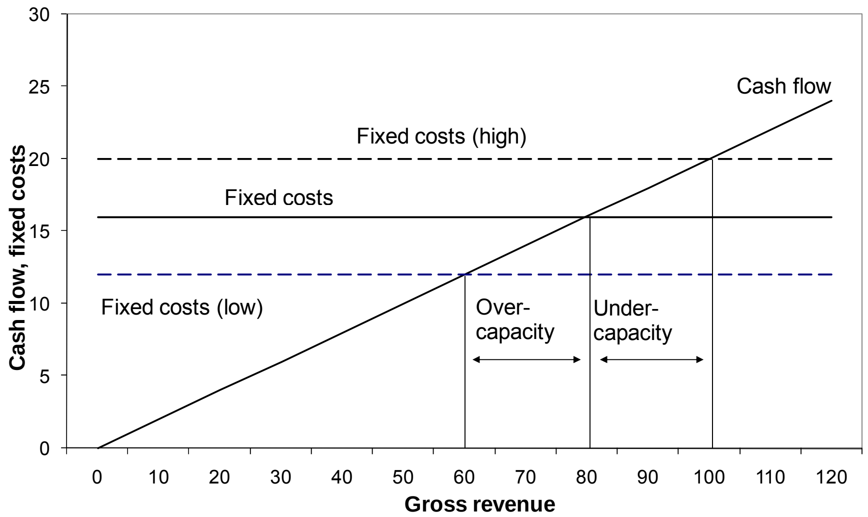
$$Overcapacity = \frac{break\ even\ revenue\ -\ current\ revenue}{break\ even\ revenue}$$

The expression to calculate overcapacity *OC* is:

(23) $$OC_{t,j} = 1 - \frac{TR_{t,j}}{BR_{t,j}}$$

The application of the concept is shown in Figure 5. The cash flow (gross revenue – variable costs) per gross revenue unit is calculated from the account statistics and cash flow is made a function of gross revenue (*GF = gf * TR)*. This allows for sensitivity analyses with change in parameters such as fish prices costs, catch per unit effort and fixed costs. If the current gross revenue is 80 and the fixed costs are 16, gross revenue exactly covers the fixed costs.

Figure 5. Over- and undercapacity by use of break-even revenue



If the current gross revenue decreases to 60 for example, the fixed costs can no longer be covered. Hence the fixed costs should be reduced by 25% to 12 in order to be at the break–even level. If capital, measured for example by number of vessels or GT, is assumed to be linear in fixed costs, the overcapacity is 25%. If, on the other hand, the current gross revenue is higher than 80, the break-even calculation will show undercapacity.

If the break-even revenue and the actual revenue are compared, an indication of fixed cost changes in order to comply with break-even level is obtained. Assuming that fixed costs are a proxy for capacity, an indication of over- and undercapacity is provided. The result does not indicate whether a required change in fixed cost is possible in practice, only that it is necessary.

Further, as stated in case 2 above, it is possible with the information in the model to estimate remuneration of the fish stocks, i.e. include resource rent. If the required/desired resource rent is included in the fixed costs of a fleet segment, the obtained result indicates the level of capacity if the fish resource 'capital' is remunerated in the same way as the capital invested in fishing vessels. Break-even revenue (*BRLS)* is in this case calculated as:

(24) $$BRLS_{t,j} = \frac{(DC_{t,j} + \sum_{i} SSBLC_{t,i,j})}{gf_{t,j}}$$

The value share of the spawning stock biomass (SSBLC), is calculated for each fleet segment subject to quotas of each fleet segment and Member State:

(25) $$SSBLC_{t,i,j,m} = rl \cdot P_{t,i,j,m} \cdot \left(\sum_{a} SSB_{t,i,a} \cdot ns_{i,a,m} \right) \cdot nu_{i,m} \left(\frac{L_{t,i,j,m}}{L_{0,i,m}} \right)$$

The overcapacity is then calculated as:

(26) $$OCLS_{t,j} = 1 - \frac{TR_{t,j}}{BRLS_{t,j}}$$

The value of other species (*SSBNC)* (non-assessed quota species) is calculated as:

(27) $$SSBNC_{t,j} = rn \cdot \frac{\sum_{i} SSBLC_{t,i,j}}{rl} \cdot \frac{TR_{0,j} - \sum_{i} P_{0,i,j} \cdot L_{0,i,j}}{\sum_{i} P_{0,i,j} \cdot L_{0,i,j}}$$

The break-even revenue (*BRTS)* with all stock values included is then:

(28) $$BRTS_{t,j} = \frac{DC_{t,j} + \sum_i SSBLC_{t,i,j} + \sum_i SSBNC_{t,i,j}}{gf_{t,j}}$$

The overcapacity is therefore:

(29) $$OCTS_{t,j} = 1 - \frac{TR_{t,j}}{BRTS_{t,j}}$$

$BR_{t,j}$	Break-even in year *t* for fleet segment *j*. It is optional to include *FC*
$OC_{t,j}$	Overcapacity in year *t* for fleet segment *j*
$SSBLC_{t,i,j}$	Spawning stock biomass costs of quota species in year *t* of species *i* for fleet segment *j*
rl	Remuneration percentage of the quota fish stocks
$BRLS_{t,j}$	Break-even in year t for fleet segment *j* including remuneration of quota species
$OCLS_{t,j}$	Overcapacity in year *t* for fleet segment *j* taking stock remuneration (resource rent) of quota species into account
rn	Remuneration percentage of the non quota fish stocks
$SSBNC_{t,i,j}$	Stock biomass costs of non quota species in year *t* of species *i* for fleet segment *j*
$BRTS_{t,j}$	Break-even in year t for fleet segment j including remuneration of quota species
$OCTS_{t,j}$	Overcapacity in year *t* for fleet segment *j* taking stock remuneration (resource rent) of quota and non quota species into account.
	Fixed costs are divided between fixed operational costs on one-hand and depreciation and interest payments on the other. These are assumed constant throughout time.

8.2. Change in number of vessels (fixed costs)

The number of sea days (*SD)* for a fleet segment to catch the allocated quotas is calculated using the inverse production function (see equation 9):

(30) $$SD_{t,j} = AA_{t,j} \cdot SD_{0,j}$$

An effort control rule (*ecr*) allowing a vessel to execute a certain number of sea days per year is applied. The number of vessels (*NV)* and hence the fixed costs (FC) are then calculated:

(31) $$NV_{t,j} = \frac{SD_{0,j}}{SD_{t,j}^{ecr}} \cdot NV_{0,j}$$

(32) $$FC_{t,j} = FC_{0,j} \cdot \frac{NV_{t,j}}{NV_{0,j}}$$

8.3. Effort approach

The background for extending the EIAA model with an effort based approach is described in Section 3. The methodology has some resemblance to the methodology used in the Fcube-approach (ICES 2006). But while fishing mortality rates and catchability rates are included explicitly in the Fcube-approach, the approach used in EIAA model only uses sea days, catch per day, landings and quotas. If information about historical fish stock abundance is available, and accounted for when calculating catch rates in the EIAA, the catch per unit effort (*cpue*) can be derived as follows:

(33) $$cpue_{0,i,j} = \frac{L_{0,i,j}}{SD_{0,j}}$$

(34) $$cpue_{t,i,j} = cpue_{0,i,j} \cdot \left(\frac{SD_{0,j}}{SD_{t,j}}\right) \cdot \left(\frac{SD_{t,j}}{SD_{0,j}}\right)^{\alpha_{i,j}} \cdot \left(\frac{SSB_{t,i}}{SSB_{0,i}}\right)^{\beta_i}$$

Or

(34a) $$cpue_{t,i,j} = cpue_{0,i,j} \cdot \left(\frac{SD_{t,j}}{SD_{0,j}}\right)^{-1+\alpha_{i,j}} \cdot \left(\frac{SSB_{t,i}}{SSB_{0,i}}\right)^{\beta_i}$$

Note, that if catch per unit of effort (*cpue*) is a function of spawning stock biomass (*SSB*) and landings (*L*), the equation looks, cf. the AHF model (Hoff and Frost 2006):

(34b) $$cpue_{t,i,j} = cpue_{0,i,j} \cdot \left(\frac{L_{t,i,j}}{L_{0,i,j}}\right)^{1-\frac{1}{\alpha_{i,j}}} \cdot \left(\frac{SSB_{t,i}}{SSB_{0,i}}\right)^{\frac{\beta_i}{\alpha_{i,j}}}$$

(35) $$L_{t,i,j} = cpue_{t,i,j} \cdot SD_{t,j}$$

For future periods, *SD* could be chosen arbitrarily subject to exogenous decisions. Such a decision could be that effort is limited to a minimum effort level (*minSD*) required to catch the lowest quota for a species or the quota for any other selected species. That implies the model solves the problem with respect to *SD*, see equation 36-37:

$$\max TR_{t,j} = \left(\sum_i P_{t,i,j} \cdot cpue_{t,i,j} \cdot SD_{t,j} \right) \tag{36}$$

Subject to:

$$cpue_{t,i,j} \cdot SD_{t,j} \leq Q_{t,i,j} \tag{37}$$

Alternatively, an optimisation procedure can be applied to find the number of sea days that minimises the sum of the differences between landings and quota (*LVD*) of a fleet segment. The model then solves the problem in equation 38-39 with respect to *SD*:

$$\min LVD_{t,j} = \left(\sum_i P_{t,i,j} \cdot (cpue_{t,i,j} \cdot SD_{t,j} - Q_{t,i,j}) \right) \tag{38}$$

$$\min LVD_{t,j} \geq 0 \tag{39}$$

where:

$cpue_{t,i,j}$	catch per sea day in year *t* of species *i* by fleet segment *j*
$SD_{t,j}$	Sea days in year *t* by fleet segment *j*
$LVD_{t,j}$	Landings value different for the quota value in year *t* for fleet segment *j*

8.4. Long run version

The long run version of the EIAA model is a nested version of five short run versions. The short run versions include information for the base period and perform projections for two years plus a long run "sustainable" situation. The long run calculation is disregarded when results are extracted from these models into the long run version. Five nested models then make it possible to perform calculations for ten years. After ten years, the long run model calculates the economic performance for the following 20 years under the assumption that the years 11 to 30 are the same as the one in year ten. Most stocks are able to recover within ten years given that the fishing mortality rates are set properly

The input to the long run EIAA model is projections of stock abundances and corresponding yield. The model can use any stock projections as long as the stocks have recovered before year eleven. The result is evaluated by calculating the net present value (NVP), where the first element on the right hand side calculates NPV for the first ten years while the second element calculates the NPV for the years after year ten:

(40) $$NPVGF_j = \sum_{t=1}^{10} GF_{t,j} \cdot (1+r)^{-t} + GF_{10,j} \cdot \frac{1-(1+r)^n}{r} \cdot (1+r)^{-10}$$

(41) $$NPVNP_j = \sum_{t=1}^{10} NP_{t,j} \cdot (1+r)^{-t} + NP_{10,j} \cdot \frac{1-(1+r)^n}{r} \cdot (1+r)^{-10}$$

Where:

$NPVGF_J$ Net present value of cash flow for fleet segment *j*

$NPVNP_J$ Net present value of net profit for fleet segment *j*

r Discount rate

n The number of years after year ten

9. The composite dynamic production function of the EIAA-model

9.1. The problem

The fish stock assessments and projections as well as the yield that can be extracted from the stocks in biological equilibrium are not an integrated part of the EIAA model. However, the model makes use of this information in such a way that the information about biomass and yield determines the points on the economic production function that comply with the biological equilibrium. The economic production function determines the output in terms of catches (landings) as a function of the production factors effort and spawning stock biomass.

The EIAA model is not a feed back model between the biological, i.e. fish stocks, and the production, i.e. the fishing fleets, sectors. The reason for this is that the objectives for the development of the fish stocks are assumed to control the system through harvest control rules for the fish stocks. Therefore, and for practical reasons the exogenous input to the EIAA model is calculated separately in stock assessment and biological productions models and fed into the EIAA model's production function.

Different production function could be chosen, see Boom, Frost and Sørensen (2008). Among the most popular are the Cobb-Douglass and the translog functions.

The Cobb-Douglas function, $Y=aE^{\alpha} B^{\beta}$, is more restrictive than the translog because of the functional form. The function has a direct economic interpretation that helps fixing the parameters if estimates are not available. First, if $\alpha + \beta =1$, the technology shows constant returns to scale. If the sum is larger than one increasing returns to scale prevail, and decreasing returns to scale prevail if the sum is smaller than one (Varian 1999 chapter 18). A number of investigations show that many fisheries are subject to constant returns to scale (or close to), see Eide, Skjold, Olsen, and Flåten (2003), Garza-Gil, Varela-Lafuente, and Suris-Regueiro (2003), and Da-Rocha and Gutiérrez (2006) for useful contributions.

The Cobb-Douglas production function has many useful attributes such as that the elasticity of substitution is equal to one which means that if for example the biomass is reduced by 10% the effort has to be increased by 10% to produce the same output as before. This feature is not sensible if the system is far away from an optimal adjustment, but sensible if it is close to. Further, α and β shows the output elasticity of the fishing effort and the fish stock i.e. how much output is increased once the input is increased. Finally, if there are constant returns to scale ($\alpha + \beta = 1$) α and β also shows the shares of effort and fish stocks of the output (landings) i.e. the value of the landings distributed on production factors. All these features help to specify α and β on an empirical level and to interpret how the production system is functioning.

The Cobb-Douglas function shows linearity of the logarithm and it is possible to derive the Cobb-Douglas function from a translog function. The conversion, $lnY = lna + \alpha lnE + \beta lnB$, of the Cobb-Douglas function illustrates that the function is a special case of the translog function where an explicit form with two input factors could be:

$$lnY = ln\ a + \alpha lnE + \beta lnB + \psi(lnE)^2 + \omega(lnB)^2 + 0.5\delta lnB\ lnE$$

Y denotes yield, B biomass and E effort. This function is often referred to as “flexible” with respect to fitting to data, as a major advantage of the translog function is that it allows for changes in the returns to scale as output changes. Often the long run average production (and cost) function is assumed to have a U-shape so that first there are increasing then constant and finally decreasing returns to scale.

The translog function is, however, more complex to work with in economic models as the parameters α, β, ψ, ω and δ needed to estimate the elasticity. While α and β are output elasticities in the Cobb-Douglas function the output elasticities in the translog are “adjusted” by ψ, ω and δ i.e. output elasticity (α in the C-D) with respect to effort is $\alpha + 2\psi lnE + 0.5\delta lnB$ and the output elasticity with respect to biomass (β in the C-D) is $\beta + 2\omega lnB + 0.5\delta lnE$. If the function is not estimated it is difficult to fix these parameters based on theory or knowledge transfer. Further, the parameter estimates of the translog are very likely subject to multi-colliniarity. This implies that the elasticity estimates are unstable.

The question of technological progress can easily be handled by the Cobb-Douglas function although it is disregarded in the EIAA model. It is handled simply by adding an element for the technical progress. I should be noted that a simple increase in the amount of production factors for example by using more powerful engines that can tow larger trawls is not technical progress. Technical progress occurs if the engine is constructed in such a way that it can produce more power with the same amount of fuel. There is no reason to believe that the technical progress in fisheries in the long run is higher than it is for the society as a whole. Dornbusch and Fisher (1994) refer a number of significant studies about economic growth in Western economies over a long (100 years) time period. In these studies of economic growth Cobb-Douglas functions are used. The results are that the growth in output has been 3% per year on average. Of these 3%, increase in the use of production factors accounts for around 2%, while technical progress accounts for around 1%, see also Eide, Skjold, Olsen, and Flåten (2003) who arrive at similar results for fisheries alone.

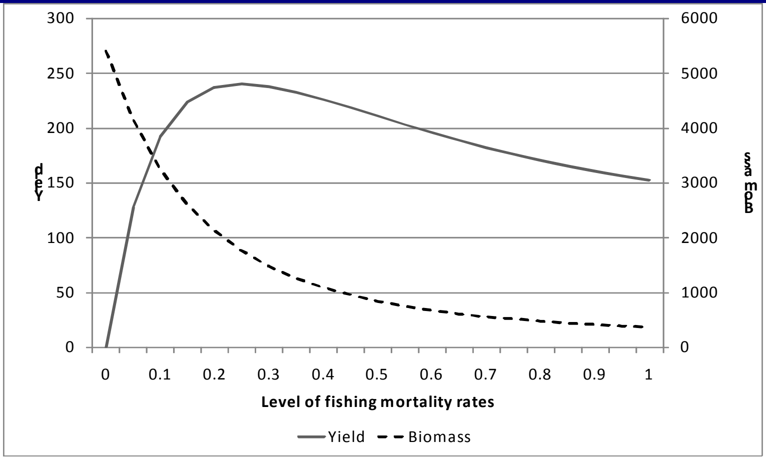
It is reasonable to assume that the fishery is characterized by constant or decreasing returns to scale. With respect to effort, in the short run where further vessels cannot be inserted into the fishery doubling the effort cannot be expected to double catches with a constant biomass because of bottlenecks in the handling of the fish on board the vessel, increasing strain on the fishing gear and equipment, and worse weather conditions when fishing time is expanded etc. In the long run it would be possible to duplicate the most effective vessels but that would lead to only constant returns to scale. With respect to the biomass, doubling the biomass in the short run is not possible and in the long run doubling the biomass with a constant effort would not lead to doubling the catches. Not only is it necessary that "underwater" access becomes double easy but also that the larger catches can be handled with the constant effort. In order to more than double the catches in the Cobb-Douglas technology with a doubling of all productions factors, biomass and effort, positive externalities associated with finding, catching and handling the fish must prevail. It is more likely that the externalities are negative. Therefore the properties of a Cobb-Douglas production function are reasonable in fisheries.

A couple of numerical examples of how the Cobb-Douglas function works in conjunction with the biological yield function are shown in figure 6. In the short run only the number of sea days, the labour input and the use of the engine power can change and this will imply decreasing returns to scale. In the long run the EIAA model is working subject to the constraint that the catches must be equal to the resource yield determined by the projection of the biomass and the yield of the stocks. The first figure (6.1) shows an example of a conventional projection of biomass and yield (landings) as a function of fishing mortality rates for the age groups in the stock. The curves show the biological equilibrium at each level of fishing mortality.

The second figure (6.2) shows the yield (landings) as a function of effort (A) with two biomass levels for which the fishing mortality rates in one case is half (0.25) of the fishing mortality rates in the other (0.5). The parameters in the production function reflect that the fish stock, represented by β at 0.6, has a larger impact on yield than effort represented by α at 0.4 and in total constant returns to scale prevail. The lower curve shows the current situation with a low biomass (fishing mortality level at 0.5). With an effort of 10,000 sea days landings exactly correspond to the yield (landings) in the projection shown in the Figure 6.1. If fishing mortality is reduced to half (0.25) of the current, the upper curve of Figure 6.2 shows the new situation where only 4,500 sea days are required to catch the projected yield at 241. The reduction in sea days is in this case of the same magnitude as the reduction in fishing mortality. This is not always the case, because it depends on the production technology and the properties of the species as shown in the third Figure 6.3.

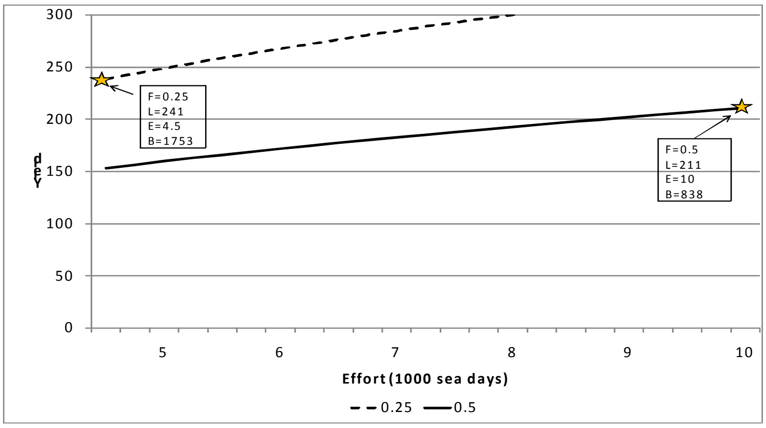
In Figure 6.3 it is assumed that the stock size has very little impact on the landings (β = 0.1) as it is for example the case in pelagic fisheries with schooling stocks. On the other hand, the technology has a great impact (α = 0.9) and the result is that if the fishing mortality rate is reduced to half of the current, the production function actually requires an increase in effort to equalize the yield projected in Figure 6.1.

Figure 6. The restricted production functions of the EIAA model under different assumptions



6.1. Long run equilibrium yield and biomass as a function of fishing mortality levels. Assumed starting values in 6.2 and 6.3 are:

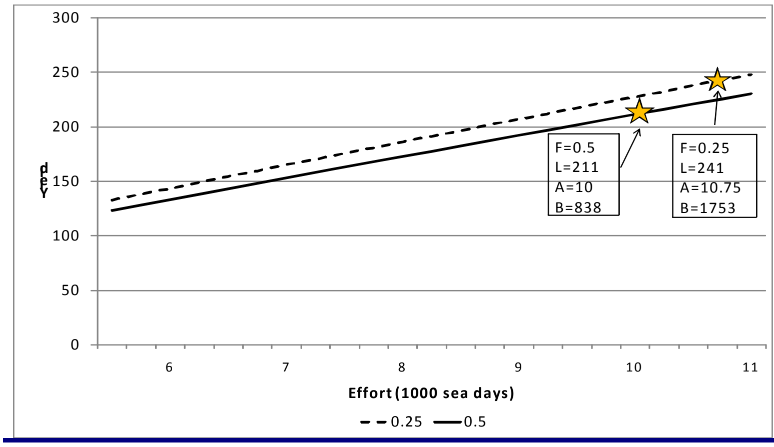
F = 0.5
Yield (L) =211
Biomass (B)=838



6.2. Cobb-Douglas production function assuming less impact of effort and larger impact of stocks

$$L_t = k\left(\frac{A_t}{A_0}\right)^{\alpha}\left(\frac{B_t}{B_0}\right)^{\beta}$$

α= 0.4
β=0.6
k=211



6.3. Cobb-Douglas production function assuming large impact of effort and litte impact of stocks

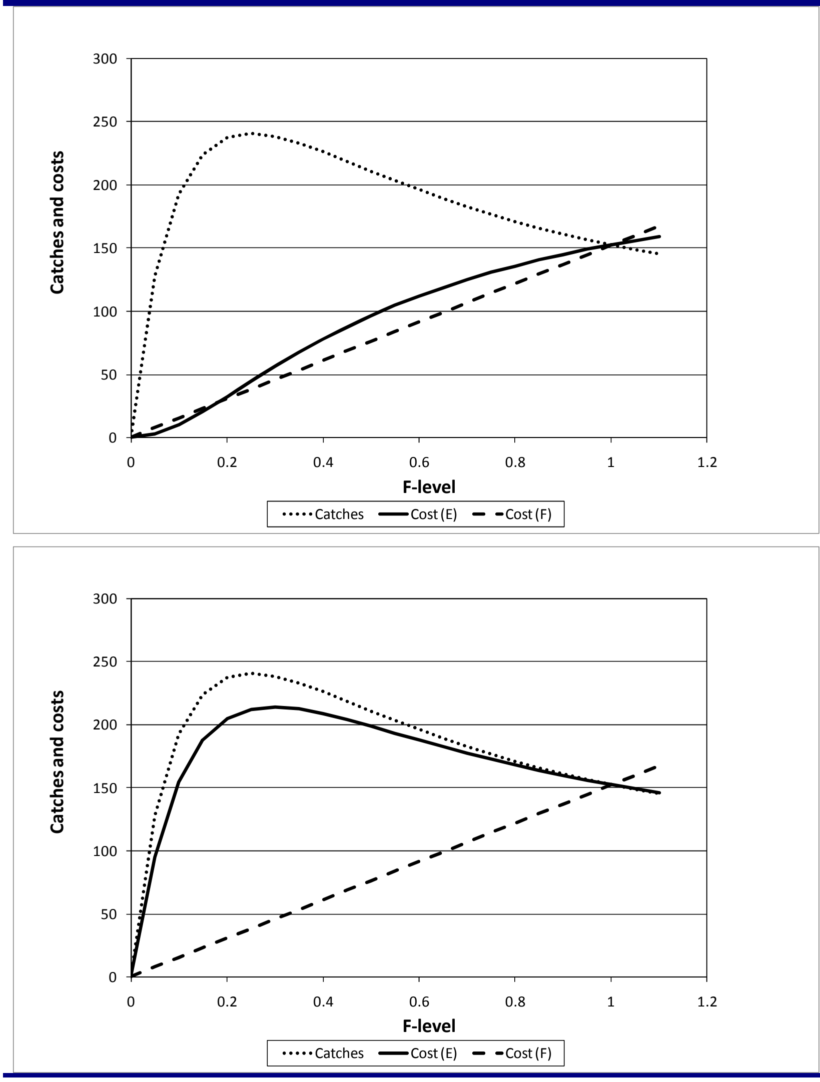
$$L_t = k\left(\frac{A_t}{A_0}\right)^{\alpha}\left(\frac{B_t}{B_0}\right)^{\beta}$$

α= 0.9
β=0.1
k=211

The results of the EIAA calculations in this example are, not surprisingly, sensitive to the assumptions about the production function i.e. the type of fishing technology and the characteristics of the fish stocks. However, projections of effort using production functions are flexible in the sense that sensitivity analysis can be made by changing the function parameters. Finally, the change in effort calculated by the production function is only in very special cases the same as the change in effort based on an assumption of linearity between the fishing mortality rate and the effort and costs. This is shown in Figure 7 where the yield is shown as a function of fishing mortality level *F*. If it is assumed that costs are linear in *F*, the cost function *Cost (F)* shows the costs. If it is assumed that costs are non-linear in F, i.e. that fishing effort is non linear in F and cost are linear in effort, the costs are shown by *Cost (E)*. The two examples 7.1 and 7.2 depend on the catch-stock flexibility α and the catch-effort flexibility β represented by the exponents in the Cobb-Douglas function.

In particular, it is noted that if the fishery is conducted under the assumption, shown in Figure 7.2, the economic gains, measured in absolute terms and not in relative terms, by moving from a higher fishing mortality level to a lower one is small. Taking into account the discount rate, the number of years for a stock to recover, and the loss in landings in the first years of the recovery period it often implies that there is an economic loss to fishermen and to society.

Figure 7. Catches and costs under different assumptions about the relationship between fishing mortality and effort.



7.1 Cobb-Douglas production function

α= 0.4
β=0.6

Low catch-effort flexibility
High stock-catch flexibility

7.2 Cobb-Douglas production function

α= 0.9
β=0.1

High catch-effort flexibility
Low catch-stock flexibility

In the following paragraphs, the formal development of the dynamic restricted production function of the EIAA model is offered to indicate the structure and complexity taking the fishing mortality rate F as the harvest control rule with respect to how the TACs are determined. Note that the equations are number from one and forward with the section number in front in order to avoid confusion with the numbering in section 6.

9.2. Single species case

Stock recruitment R:

(9.1a) $$R_t = gB_{t-1}e^{(1-B_{t-1}b)}$$ Ricker

where B is the fish stock biomass.

(9.1b) $$R_t = g\frac{B_{t-1}}{1+B_{t-1}b}$$ Beverton-Holt

(9.1c) $$R_t = gB_{t-1}(1-bB_{t-1})$$ Deriso

The stock development function:

(9.2) $$B_t = B_{t-1}e^{-(F_{t-1}+M)} + R_t$$

The biological catch function:

(9.3) $$L_t = B_t(1-e^{-(F_t+M)})\frac{F_t}{F_t+M}$$

where F and M are fishing and natural mortality respectively.

Equation 9.1 and 9.2 are "steady state" developments of stocks and landings as a function of fishing mortality F.

The economic production function:

(9.4a) $$L = aA^{\alpha}B^{\beta}$$

(9.4b) $$L_t = L_0(\frac{A_t}{A_0})^{\alpha}(\frac{B_t}{B_0})^{\beta}$$

For equation 9.3 equal to equation 9.4b:

(9.5) $$B_t(1-e^{-(F_t+M)})\frac{F_t}{F_t+M}=L_0(\frac{A_t}{A_0})^{\alpha}(\frac{B_t}{B_0})^{\beta}$$

With equation 9.5 solved for A_t:

(9.6) $$A_t = A_0(\frac{1}{L_0})^{\frac{1}{\alpha}}\frac{B_0^{\frac{\beta}{\alpha}}}{B_t^{\frac{\beta-1}{\alpha}}}(1-e^{-(F_t+M)})^{\frac{1}{\alpha}}(\frac{F_t}{F_t+M})^{\frac{1}{\alpha}}$$

If A_t is set equal to 1 in the base year $A_0 = 1$ and equation 9.6 becomes:

(9.7) $$A_t = (\frac{1}{L_0})^{\frac{1}{\alpha}}\frac{B_0^{\frac{\beta}{\alpha}}}{B_t^{\frac{\beta-1}{\alpha}}}(1-e^{-(F_t+M)})^{\frac{1}{\alpha}}(\frac{F_t}{F_t+M})^{\frac{1}{\alpha}}$$

A_t is then an index with A_0 as base. Note that B_t could be included in equation 9.7 as a function of *F, M* and *R* using equation 9.2.

9.3. Multi-species one fleet case

It is necessary to use a weighting procedure when several species are included. The value share of each species is used. This procedure also allows for inclusion of behaviour as it is assumed that the fishermen direct effort towards species with the highest prices "first". Further, the weighting procedure allows for taking into account whether one or several species are "driving" the effort (parameter θ). This parameter takes the value 1 or 0, where species marked with 1 drives effort.

(9.8) $$A_t = \sum_i \left[\frac{P_t^i L_0^i \theta^i}{\sum_i P_0^i L_0^i \theta^i}(\frac{1}{L_0^i})^{\frac{1}{\alpha^i}}\frac{(SSB_0^i)^{\frac{\beta^i}{\alpha^i}}}{(SSB_t^i)^{\frac{\beta^i-1}{\alpha^i}}}(1-e^{-(F_t^i+M)})^{\frac{1}{\alpha^i}}(\frac{F_t^i}{F_t^i+M})^{\frac{1}{\alpha^i}} \right]$$

9.4. Multi-species multi-fleet case

In the multi-fleet case prices, landings, effort driver, and productivity coefficients must be specified on fleet segment level.

(9.9)

$$A_t = \sum_j \sum_i \left[\frac{P_t^{i,j} L_0^{i,j} \theta^{i,j}}{\sum_i P_0^{i,j} L_0^{i,j} \theta^{i,j}} \left(\frac{1}{L_0^{i,j}}\right)^{\frac{1}{\alpha^{i,j}}} \frac{(SSB_0^i)^{\frac{\beta^{i,j}}{\alpha^{i,j}}}}{(SSB_t^i)^{\frac{\beta^{i,j}-1}{\alpha^{i,j}}}} \left(1 - e^{-(F_t^i + M)}\right)^{\frac{1}{\alpha^{i,j}}} \left(\frac{F_t^i}{F_t^i + M}\right)^{\frac{1}{\alpha^{i,j}}} \right]$$

(9.10)

$$P_{t,i,j} = P_{0,i,j} \cdot \frac{\left(Q_t^i\right)^{\varepsilon_i}}{\left(Q_0^i\right)^{\varepsilon_i}} \quad ; \varepsilon < 0$$

10. Relevant EIAA reports

10.1. Selected references

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10.2. Working group reports

(In chronological order)

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"The Lassen Report" (1996) Report of the Group of Experts to Advise the European Commission on the Forth Generation of the Multi Annual Guidance Programmes.

AER. Economic performance of selected fishing fleets. Annual report from Concerted Action (Q5CA-2001-01502) of the European Union. ISBN 90-5242-958-8. Several issues.

EIAA Specimen Report. Example of Application of the Methodology. Document no. 5 (1998) of the concerted action (FAIR CT97-3541): Promotion of common methods for economic assessment of EU fisheries. (Available from the Danish Institute of Food and Resource Economics, FOI).

EAFE-AC REPORT (2001) The Potential Economic Impact on Selected Fishing Fleet Segments of TACs Proposed by ACFM for 2002 (EIAA-model calculations). A Report of the European Association of Fisheries Economists' Advisory Committee.

Report of the 1st Meeting of the STECF Sub-group investigating the Scientific basis for a follow up to the fourth generation of Multi-annual Guidance Programmes (MAGP IV) Brussels, 23-27 October 2000.

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11. Appendix 1 List of variables and parameters

11.1. Subscripts

0	Base period, three years average
t	Time
i	Fish species
j	Fleet segment
a	Management area
m	Member State (country)

As the TACs and subsequently the quotas to the Member States are determined for the whole EU the EIAA model, principally, covers all the fish stocks and fleet segments that are subject to TAC management. However, the model is for practical reasons designed to work on country level by use of the relative stability matrix and a model features that allocates quotas to the Member States. Quotas are fixed for Member States on quota management areas. However, due to data shortage the model does not produce results distributed on management areas, therefore subscript a and the subscript m for Member State are omitted in the following apart from a few equations where it is useful to keep these subscripts.

11.2. Variables

Exogenous variables are given from outside; endogenous variables are calculated by the model.

$A_{t,j}$	'Activity coefficient' as a function of quota species in year t of fleet segment j; A0, j = 1 for the baseline period, (endogenous)
$AA_{t,j}$	'Activity coefficient' as a function of quota and non quota species in year t of fleet segment j, (endogenous)
B	Total Stock (is not used in the model, only in the model description)
$BR_{t,j}$	Break-even in year t for fleet segment j. It is optional to include FC
$BRLS_{t,j}$	Break-even in year t for fleet segment j including remuneration of quota species

$BRTS_{t,j}$	Break-even in year t for fleet segment j including remuneration of quota species
$CC_{t,j}$	Crew share in year t of fleet segment j (endogenous)
$CS_{0,j}$	Crew share in base period of fleet segment j, (exogenous)
$DC_{0,j}$	Depreciation and interest costs for fleet segment j in the base period, (endogenous or exogenous)
$DC_{t,j}$	Depreciation and interest costs for fleet segment j in period t, (endogenous)
F	Fishing mortality (is not used in the model, only in the model description)
$FC_{0,j}$	Fixed costs for fleet segment j in the base period, (exogenous)
$FC_{t,j}$	Fixed costs for fleet segment j in period t, (endogenous)
$GF_{t,j}$	Gross cash flow for fleet segment j in period t, (endogenous)
$GR_{0,j}$	Gross revenue including non-fisheries specific income of segment j, (exogenous)
$GV_{t,j}$	Gross value added by fleet segment j in period t, (endogenous)
$K_{0,j}$	Landings value of other species than quota species by fleet segment j in base years, (exogenous)
$K_{t,j}$	Landings value in year t of other species than quota species of segment j, (endogenous)
$L_{0,i,j\,m}$	Landings in base years of species i caught by fleet segment j for Member State m (exogenous)
$L_{t,i,j,m}$	Landings in year t of species i caught by fleet segment j for Member State m (endogenous)
$LVD_{t,j}$	Difference between the landing value and the quota value in year t for fleet segment j
M	Natural mortality (is not used in the model, only in the model description)
$NP_{t,j}$	Net profit for fleet segment j in period t, (endogenous)
$NPVGF_J$	Net present value of cash flow for fleet segment j
$NPVNP_J$	Net present value of net profit for fleet segment j

$NV_{0,j}$	Number of vessels in fleet segment j in the base period
$NV_{t,j}$	Number of vessels in fleet segment j in year t
$O_{0,j}$	Income from non-fisheries specific activities of fleet segment j, (exogenous)
$OC_{t,j}$	Overcapacity in year t for fleet segment j, (endogenous)
$OCLS_{t,j}$	Overcapacity in year t for fleet segment j taking stock remuneration (resource rent) of quota species into account, (endogenous)
$OCTS_{t,j}$	Overcapacity in year t for fleet segment j taking stock remuneration (resource rent) of quota and non quota species into account, (endogenous)
$OPM_{t,j}$	Operating profit margin for fleet segment j in period t (coefficient), (endogenous)
$P_{0,i,j}$	Fish prices in base years of species i by fleet segment j (endogenous), calculated by use of landing value and landing weight
$P_{t,i,j}$	Fish prices year t of species i by fleet segment j (endogenous)
$Q_{0,i,a,m}$	Quota in base years of species i for Member State m (exogenous)
$Q_{t,i,a}$	Quota for year t of species i in area a (exogenous)
$RC_{t,j}$	Running costs in year t of fleet segment j, includes fuel and other costs dependent on sea days (endogenous variable)
$RC_{0,j}$	Running costs in the baseline period for fleet segment j, which in cludes fuel and other costs dependent on sea days (exogenous variable)
$SD_{t,j}$	Sea days in year by fleet segment j
$SDecr_{,t,,j}$	Sea days per vessel in fleet segment j in year t determined by an effort control rule (ecr)
$SSB_{t,i}$	Spawning stock biomass in year t of species i (exogenous variable)
$SSBLC_{t,i,j}$	Spawning stock biomass costs of quota species in year t of species i for fleet segment j
$SSBNC_{t,i,j}$	Stock biomass costs of non quota species in year t of species i for fleet segment j
$TR_{0,i,j}$	Total revenue of quota species in base years of species i by fleet segment j, (exogenous)

$TR_{t,j}$	Total revenue in year t by segment j, (endogenous)

11.3. Parameters

Parameters are either exogenous or calculated in the model; they are, however, subject for possible change by the model user for sensitivity analyses)

a:	Coefficient (is not used in the model, only in the model description)
$cc_{0,j}$	Crew share coefficient in base period of fleet segment j
$cpue_{t,i,j}$	catch per sea day in year t of species i by fleet segment j
$gf_{0,j}$	Gross cash flow coefficient for fleet segment j, (cash flow per unit gross revenue) in the base period
$gf_{t,j}$	Gross cash flow coefficient for fleet segment j, (cash flow per unit gross revenue) in year t
n	The number of years after year ten
$nf_{t,j}$	Fleet segment share for fleet j of species i
$ns_{i,a,m}$	Relative stability i.e. the share of species i in area a for Member State m (parameter)
$nu_{i,m}$	Quota uptake ratio of species i for Member State m (parameter, calcu lated by the model). Can be changed for future years
r	Discount rate
rl	Remuneration percentage of the quota fish stocks
rn	Remuneration percentage of the non quota fish stocks
α *and* β	Parameters (flexibilities); α □ 0; and □ □ 0
ε_i	Price flexibility of quota species i
$\theta_{t,i,j}$	Effort driver. Selects the species i that in year t drive the effort of segment j. $\theta = 0$ or 1.
$\chi_{i,j}$	Activity-landing flexibility rate' of quota species i for fleet segment j (parameter)
γi	Activity - stock flexibility rate of quota species i (parameter)

12. Appendix 2. Numerical examples of the calculation of fleet activity A

All species drives the effort (The activity variable A for period t is in this example is 0.971)

												Stock abundance SSB				**Total**
Landings and quotas																
												Base	Year t			Year t
Species	Landings/ quotas	Price	Revenue	Quota	Price Flex (ε)	Price	Revenue	'Price effect'	Chi (χ)	'Volume effect'	Total effect	SSB	SSB	Gamma (γ)	'SSB effect'	Total effect
1	50	12.0	600	50	-0.2	12	600	0.308	1	1	0.308	200	200	1	1.000	0.308
2	40	10.0	400	30	-0.2	10.5	420	0.215	1	0.75	0.162	150	100	1	1.500	0.242
3	30	5.0	150	45	-0.2	4.5	135	0.069	1	1.5	0.104	100	200	1	0.500	0.052
4	10	70.0	700	15	-0.2	63	630	0.323	1	1.5	0.485	50	75	1	0.667	0.323
5	5	20.0	100	7.5	-0.2	18	90	0.046	1	1.5	0.069	50	75	1	0.667	0.046
Total	135		**1950**	147.5			1875	0.962			1.12692					0.971

With effort driver. Selected species drive the effort (The activity variable A for period t is in this example 1.181)

												Stock abundance SSB				**Total**	
Landings and quotas																	
	Base year			Year t								Base	Year t			Year t	
Species	Landings /quotas	Price	Revenue	Quota year t	Price Flex (ε)	Price year t	Const. catch revenue year t	"Price effect"	Chi (γ)	Volume effect'	Total effect	SSBb	SSB2	Gamma (γ)	SSB effect	Total effect	Effort driver
1	50	12.0	0	50	-0.2	12	0	0	1	1	0.000	200	200	1	1.000	0.000	0
2	40	10.0	400	30	-0.2	10.5	420	1.05	1	0.75	0.788	150	100	1	1.500	1.181	1
3	30	5.0	0	45	-0.2	4.5	0	0	1	1.5	0.000	100	200	1	0.500	0.000	0
4	10	70.0	0	15	-0.2	63	0	0	1	1.5	0.000	50	75	1	0.667	0.000	0
5	5	20.0	0	7.5	-0.2	18	0	0	1	1.5	0.000	50	75	1	0.667	0.000	0
Total	135		**400**	147.5			420	1.05			0.7875					1.181	