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MEASUREMENT OF ECONOMIC IMPACTS OF FISHERY MANAGEMENT DECISIONS

The Dutch Case

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Abstract:

With FAIR funding, fishery economists from Germany, Spain and The Netherlands have developed a model to measure the economic effects at individual boat level of fishery management measures.

The model is a mixed integer programming model, optimising gross margin. It simulates fishery patterns in terms of times spent in various activities (fishing, steaming, etc.), choice of fishery and grounds visited. The basic design has been worked out for a variety of 'standard vessels' from the countries involved. The model requires an extensive set of data and restrictions.

The Dutch case includes a 2000 HP beam trawler and a 300 HP multi-purpose 'Eurocutter'. Substantial effort went into tuning of the model to arrive at a basic run that comes acceptably close to reality. The results of these basic runs are presented. Finally, the shortcomings and the potential of the present model are discussed, leading to conclusions and recommendations for further development.

Introduction

In March 1997, a two-year research project was started in the framework of the EU FAIR programme with the objective "to identify the likely consequence of different management decisions within the scope of the European Common Fisheries Policy". To this end, a simulation model would be developed for the measurement of the economic impacts of such decisions on specific fleet segments. 'Standard vessels' would represent the segments, so in fact the model was to simulate effects on a single boat level.

Participating in the project are two German institutes: Bundesforschungsanstalt für Landwirtschaft FAL in Braunschweig and Bundesforschungsanstalt für Fischerei BFA in Hamburg, the Spanish institute: Gabinete de Economia de Mar GEM in Barcelona, and from The Netherlands LEI in The Hague. Initiator and co-ordinator of the project is Rolf Lasch from FAL.

As a logical choice in connection with the participating institutes, the fleet segments to be included in the project were operating in the Baltic, the North Sea and the Mediterranean. The diversity of fisheries and operational behaviour was intended to make sure that the basic model structure would allow to take into account as wide a variety of fisheries as possible.

The project is in its final stages and will be concluded in May.

This paper will mainly go into the experience of simulating the behaviour and financial results of the two Dutch fishing boat types by the model. As an introduction to that, some explanation will be given of the model and its data requirements. After presenting the simulation results, merits and flaws of the model will be discussed, ending with the (not unusual) conclusion that a lot more work can be done.

The Model

At LEI and many other institutes, a variety of simple, straightforward calculating models are in use, to estimate effects of changes in the 'economic environment' of fishing boats or fleets. The model we aimed at in this project was meant to go a step further, by taking into account the operational behaviour of the fisherman. The model's boat operator should be able to make choices of fishing grounds, target species, fishing gears, landing ports, etc., like in real life, within the constraints of his normal practice and those imposed on him from outside.

The type of model that was chosen for this purpose is a mixed integer programming model, that is a linear programming optimisation model, where some of the variables can only be whole numbers. (In this case, these are e.g. the number of trips.) The model was developed with GAMS (Brooke et. al, 1997), basically by Rainer Klepper, who was specially appointed for this and who presented papers on the project on several occasions.

Target variable of the model, that is the one that has to be maximised, is the Gross Margin, the difference between Proceeds and Variable Costs. We have restricted ourselves to developments on a short term, that is a single year, so fixed costs can be left out of consideration. Within the implicit and explicit constraints given, the model builds up a sequence of trips from those ports to those fishing grounds, using those gears and catching those species that result in the highest gross margin.

Time plays an essential role in the model. A distinction is made between active and inactive time, the first being the time connected to the fishing activity and the latter the remaining time. The active time is partitioned into trips, each composed of steaming time from port to grounds and back, fishing time or time on the grounds or effort time, and port time necessary for unloading and preparing the boat for the next trip. The inactive time includes time for repairs, holidays, bad weather delays and idle time (that might be used for fishing). Trip length can vary and scheduling of trips is done by the model on a monthly basis, but the optimum is basically sought over a whole year.

For assessing the effects of changes in the ‘economic environment’, apart from direct changes in inputs, they can also be brought into the model by using factors affecting catch rates, fish prices, cost levels, etc.

Data Requirements

The above implies the availability and input of a substantial and complex set of data.
First, there is the definition of fishing grounds and ports, and the distances, or more precisely, the steaming times it takes from ports to grounds. For modelling the Dutch cases, eight fishing grounds were defined in the North Sea, each composed of a number of ICES rectangles where Dutch boats have been fishing. For reasons of simplicity, in the model IJmuiden, a central major fishing port in Holland, was chosen as homeport. Generally, all (model) fishing is done from this port, except for shrimping that can also be done from the Danish port of Havneby.

Then, monthly average catch rates of the various relevant species on each ground are included for each gear (in kg per hour fishing). In fact, these should be provided by biologists, but we have derived them provisionally from logbook and landing records. In addition to the catch rates, monthly average landing prices are given for each species.

The variable cost structure has been unravelled meticulously according to the dependence of the items on factors like: value and weight of landings, number of trips, type of fishery, fishing time, steaming time, port time, repair time and idle time. For each cost item, the relation with the relevant factors is entered. The allocation was based partly on onboard measurements, partly on interviews with fishermen and partly on institute expertise.

A general time schedule is included to define the time available for activities, giving for each month the number of days in total and the days not available for fishing, e.g. because of holidays, or repairs, or bad weather. Dutch fishermen, like the Spanish on the Mediterranean, generally stay in port during the weekend, so this has also been put into the model.

Finally, restrictions resulting from fisheries management (or any other interference with the fishery), like quotas or sea time restrictions, have to be put into the model as constraints.

Evidently, these data should all be tuned to the (type of) vessel under consideration. As we will see, this can make quite a difference in the simplicity or complexity of the model.

Standard Vessels

The mostly skipper-owned cutters make up the main branch of the Dutch fishing fleet. As a result of regulatory measures, the fleet is gravitating towards two boat types:

- the 2000 HP (1470 kW) beam trawler, fishing for sole and plaice;
- the 300 HP (221 kW) multi-purpose ‘Eurocutter’, generally able to fish for flatfish, roundfish and shrimp.

Together cutters around these sizes account for close to 50% of the total cutter fleet in numbers. These boat types were the logical choice to serve as guinea pigs for the model; the first as it is actually restricted in its activity by ITQ limits, the second as its complexity makes for an extra challenge. Of both types a good number of boats are participating in the LEI-panel for costs and earnings studies, so data are amply available. As at the outset of the project this was the most recent year where a complete set of data was available, all model data were derived from 1995.

2000-HP boats are the largest and most powerful new-built beamers allowed in The Netherlands. The characteristics of the 16 boats of this size in the LEI panel are summarised in table 1. In 1995, sole contributed 58% to the average total proceeds of 2.94 mln.NLG and plaice 24%. The balance was shared by 13% other flatfish (turbot, brill, dab) and 5% other species. The fishing grounds are mainly in the southeastern North Sea, but some make trips up into the Norwegian Zone.

Table 1 ***Vessel characteristics of the 2000-HP beam trawler standard vessel***

		average	maximum	minimum
Length over all	[m]	41.48	45.98	35.79
Beam	[m]	8.59	9.50	8.00
Depth	[m]	4.95	5.60	4.10
Gross Tonnage	[GT]	455	572	301
Main engine power	[kW]	1471	1489	1467
Age of hull	[y]	5	12	1
Age of main engine	[y]	3	11	1

Eurocutters are the largest boats allowed to trawl for flatfish as well as shrimp within the 12-mile zone and in the ‘plaice box’. The LEI-panel has 17 Eurocutters, with characteristics as given in table 2. These are modern, very versatile boats, able to switch from one fishery to another at short notice, sometimes within a trip. Most boats do a succession of seasons, including beam trawling for flatfish (mainly sole and plaice, like their bigger brothers), pair or otter trawling for cod and whiting, and beam trawling for shrimp. Total revenues of 0.97 mln.NLG in 1995 were composed of 38% sole, 10% plaice and 8% flatfish by-catches, 30% shrimp, 7% cod and whiting and 7% other by-catches. The fishing grounds are, not surprisingly, mainly along the coast in the 12-mile zone, but some boats venture also further offshore. For shrimp there is a special fishery in the German Bight, where boats operate from Havneby on the Danish isle of Rømø.

Table 2 ***Vessel characteristics of the ‘Eurocutter’ standard vessel***

		average	maximum	minimum
Length over all	[m]	23.61	25.00	22.06
Beam	[m]	6.19	7.00	5.70
Depth	[m]	2.94	4.00	2.32
Gross Tonnage	[GT]	102	160	77
Main engine power	[kW]	221	221	221
Age of hull	[y]	10	32	3
Age of main engine	[y]	5	15	1

Results

Before starting to simulate the effects of changes in fisheries management or other elements of the fishing company's environment, extensive tuning and test runs were necessary in the Dutch case, before a set of 'basic runs' emerged that simulated reality acceptably well. In fact, this absorbed so much effort that we still have to do the simulation runs with management changes. Therefore, we can just present the results of the basic runs, but in view of the complications involved, these are already most interesting.

Critical points in judging the level of reality achieved by the model are the resulting fishing pattern, defined by grounds fished, number and composition of trips, the landings, the proceeds, fuel costs, crew wages and, of course, gross margin. As more or less equivalent proceeds were considered as a leading element in the Dutch cases, the active day length was reduced to compensate for the inherent efficiency of the optimisation model. This has somewhat distorted the results, but not to the extent that they are completely unrealistic.

2000-HP beamer

The following tables summarise the results of the basic run for the 2000-HP beam trawler. Table 3 gives a survey of the fishing pattern. Table 4 shows the division of time, the landings and proceeds, and the costs and gross margin, all compared to the actual data in 1995.

Table 3 Basic run 2000 HP beam trawler: Simulated fishing pattern

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Calendar days		31	28	31	30	31	30	31	31	30	31	30	31	365
Available active days		27	24	27	26	27	26	18	18	26	27	26	27	299
<u>Beam</u>	Trips	4	4	4	0	4	4	3	3	4	5	4	4	43
	Active days Total	24	24	24	0	24	24	18	18	24	27	24	24	255
	Danish coast								*18*					*18*
	Offshore England		*24*	*18*		*24*	*24*			*12*	*27*	*12*		*141*
	Friesian grounds	*24*						*18*		*12*		*12*		*66*
	North coast												*24*	*24*
	South coast			*6*										*6*
	Inactive days	3	0	3	26	3	2	0	0	2	0	2	3	44

The fishing pattern shows that apparently the grounds Offshore England are the most profitable for the big beamer under the given conditions. The available ITQs are insufficient to keep the boat fully employed: 44 out of the nearly 300 available days stay unused. Remarkably, most of these are concentrated in April, when no fishing is done at all. This is partly a peculiarity of the model that operates by month; a fisherman would prefer shorter periods of inactivity, unless he has to do a major maintenance job. (Vacations and maintenance time has been reserved in July and August.) The model can be easily adapted for a minimum level of activity in each month.

The model is more efficient than the real beamer is, as table 4 shows. In roughly 10 percent less time, nearly 10 percent more proceeds are produced and this results in a 15 percent higher gross margin. But in view of the differences in information available to the model and to the average skipper, the result can be considered as quite promising. With some more fine-tuning, a closer resemblance to reality lies well within reach.

Table 4 Basic run 2000 HP beam trawler: Time, landings, proceeds, costs and gross margin

		Beam Trawl	% of actual
Trips		43	*91*
Active days		255	*99*
	Effort time [hrs]	*3 780*	*88*
	Steaming time [hrs]	*774*	*102*
	Total sea time [hrs]	*4 554*	*90*
	Time in port [hrs]	*1 032*	*91*
Total active time [hrs]		*5 586*	*90*
Landings [kg]			
	Plaice	259 144	*119*
	Sole	123 886	*100*
	By-catch flatfish	66 067	*115*
	By-catch other fish	65 137	*94*
	Total	514 234	*110*
Proceeds [NLG]		3 162 254	*108*
Costs [NLG]			
related to:	Effort	549 129	*88*
	Steaming	72 597	*102*
	Port	5 614	*91*
	Trips	37 410	*90*
	Landing	226 225	*117*
	Crew wages	855 568	*110*
	Fuel oil	*387 917*	*90*
	Subtotal active costs	1 746 543	*102*
Provisional gross margin		1 415 711	*116*
	Repair & inactive time	7 648	*183*
	Total costs	1 754 191	*102*
Gross Margin		1 408 063	*115*

Eurocutter

The results of the basic run for the Eurocutter are presented in table 5, with the fishing pattern, and table 6, giving time division, landings and financial results.

The Eurocutter posed the most complicated problem for tuning the model in the whole project. Here we had a boat doing a variety of fisheries, each with its own target species, catch rates, cost structure and the possibility to switch to another port for one of the fisheries. By restricting the choice of fisheries to three: beam trawl, pair trawl and shrimping, the degrees of freedom were sufficiently reduced to arrive at a solution at all. But even then, the model had to be run in two shifts, one for each half year. This also implied e.g. that the available ITQs had to be split up in a way that did not affect the fishing pattern to an unacceptable extent.

The fishing pattern and financial results that eventually emerged were surprisingly realistic. Table 5 shows a very natural flow from one fishery and fishing ground into another, starting with beam trawling off the South Coast, with a short pair trawling intermezzo. Shifting north in March, it does the regular shrimping season near Havneby in April and resumes beam trawling in May. After the holiday period in August, pair trawling is tried again, but beaming is still more attractive. Then the shrimping season starts in September, to continue through November. Here a little flaw in the pattern occurs, when one very short beam trawl trip is interrupting the shrimping season. The year is finished with beam trawling again.

Table 5 Basic run Eurocutter: Simulated fishing pattern

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Calendar days		31	28	31	30	31	30	31	31	30	31	30	31	365
Available active days		17	14	19	22	23	22	14	14	22	23	18	19	227
Beam	Trips	5	3	3	2	6	6	4	3	1	1		5	39
	Active days Total	17	12	11	7	23	22	14	12	4	2		19	143
	Danish coast						*20*			*4*				*24*
	German Bight					*20*								*20*
	Friesian grounds			*4*	*7*	*3*			*12*					*26*
	North coast												*11*	*11*
	South coast	*17*	*12*	*7*			*2*	*14*			*2*		*8*	*62*
Shrimp	Trips				5					6	7	6		24
	Active days Total				15					18	21	18		72
	Danish coast				*15*									*15*
	German Bight											*18*		*18*
	Friesian grounds													*0*
	North coast										*3*			*3*
	South coast									*18*	*18*			*36*
Pair	Trips		1	2					1					4
	Active days Total		2	8					2					12
	Danish coast													*0*
	German Bight													*0*
	Friesian grounds													*0*
	North coast		*2*	*8*										*10*
	South coast								*2*					*2*
Total	Trips	5	4	5	7	6	6	4	4	7	8	6	5	67
	Active days Total	17	14	19	22	23	22	14	14	22	23	18	19	227
	Danish coast	*0*	*0*	*0*	*15*	*0*	*20*	*0*	*0*	*4*	*0*	*0*	*0*	*39*
	German Bight	*0*	*0*	*0*	*0*	*20*	*0*	*0*	*0*	*0*	*0*	*18*	*0*	*38*
	Friesian grounds	*0*	*0*	*4*	*7*	*3*	*0*	*0*	*12*	*0*	*0*	*0*	*0*	*26*
	North coast	*0*	*2*	*8*	*0*	*0*	*0*	*0*	*0*	*0*	*3*	*0*	*11*	*24*
	South coast	*17*	*12*	*7*	*0*	*0*	*2*	*14*	*2*	*18*	*20*	*0*	*8*	*100*
Unused days		0	0	0	0	0	0	0	0	0	0	0	0	0

All available days are being used, and more would have been used, if less weekend and bad weather days had been included. This might well have been done, as the total active time is less than in reality, as table 6 shows. Again, the model is more efficient than the real boats, arriving at the same proceeds in less effort time. The difference in effort to steaming time ratio is remarkable. This is probably connected with the model assumption of IJmuiden as homeport. Generally these boats operate close to port, and if some far away ground appears to be more prolific, they shift their operating basis to a more nearby port, as e.g. is shown in the shrimp fishery. To provide for this, more ports would have to be built into the model.

Overall, the financial results are very similar to the actual ones, in spite of a rather different catch composition. The model catches much more plaice and finds little profit in fishing for roundfish. Boats from the LEI-panel appear to have exchanged part of their plaice ITQ for cod, but according to the model, this was not a very sensible move (unless, of course, they got some good money in the bargain as well). Shrimping is quite popular in the model, as it has no quota restrictions. It took quite some tuning to curb the activity to a reasonable extent.

Table 6 Basic run Eurocutter: Time, landings, proceeds, costs and gross margin by fishery

		Total	Beam	Shrimp	Pair	*% of actual*
Trips		67	40	24	3	*89*
Active days		227	145	72	10	*92*
	Effort time [hrs]	*2 571*	*1 759*	*649*	*163*	*81*
	Steaming time [hrs]	*1 240*	*862*	*330*	*48*	*131*
	Total sea time [hrs]	*3 811*	*2 621*	*979*	*211*	*92*
	Time in port [hrs]	*804*	*480*	*288*	*36*	*89*
Total active time [hrs]		*4 615*	*3 101*	*1 267*	*247*	*92*
Landings [kg]						
	Plaice	46 974	46 974			*154*
	Sole	25 458	25 458			*96*
	Shrimp	55 531		55 531		*120*
	Cod	14 037			14 037	*73*
	Whiting	69			69	*2*
	By-catch flatfish	10 776	9 595	885	296	*79*
	By-catch other fish	30 131	24 626	4 541	963	*105*
	Total	182 975	106 653	60 957	15 365	*103*
Proceeds [NLG]		976 070	601 978	333 583	40 509	*100*
Costs [NLG]						
related to:	Effort	119 000	84 512	23 019	11 469	*84*
	Steaming	36 425	25 305	9 704	1 416	*131*
	Port	2 501	1 456	896	149	*89*
	Trips	20 603	11 993	7 380	1 230	*89*
	Landing	67 158	41 389	22 827	2 942	*100*
	Crew wages	326 961	198 592	115 006	13 363	*101*
	Fuel oil	*69 108*	*51 010*	*15 400*	*2 698*	*93*
	Total activity costs	572 647	363 247	178 832	30 569	*98*
Provisional gross margin		403 423	238 731	154 752	9 940	*105*

Inactivity costs	3 381	*89*
Total costs	576 028	*98*
Gross Margin	400 042	*105*

Discussion

Linear programming is a well-accepted and widely used technique in agronomy and agricultural economics. In fisheries economics, it has found little application and certainly our modelling of a fleet segment's or single vessel's behaviour and economic results is completely new.

The full efficiency pursued by linear programming models can be seen as a drawback of the method. In practice fishermen will never be able to reach the results arrived at by the model, simply because they do not avail of the set of information we have put into the model. This includes the presumption that the course of events regarding catch rates by fishing ground, weather, possible breakdowns etc. can be foreseen, which in fact they can not. Also, the model does not know the feeling that some real life fishermen appear to have, that enough can be enough to call it a day (or a week). To compensate for this, a couple of inefficiencies had to be built into the models for the Dutch cases, in order to arrive at basic runs that represented real life more or less realistically.

The model is originally designed for fisheries managers wanting to know how their decisions affect the fishing fleets economically. For that purpose, the fleets are supposed to be composed of more or less homogeneous segments that can be represented by a single boat, having average characteristics and operational behaviour. This works rather well in cases where the segments are more homogeneous indeed, like the German and Spanish examples, where the boats come from one port and are all having the same fisheries on the same grounds. In the Dutch case, however, the segments are less homogeneous, in the sense that the boats included are from different ports, and are fishing on different grounds (that are not very well defined, at that). By artificially stationing the model boats in the centrally situated (and major) port of IJmuiden, they were at least enabled to visit a variety of the grounds frequented by the segments they represented. Happily, they did so in an almost natural manner, but leaving many grounds untouched that in reality attract substantial effort from the segments involved. As a consequence, the fleet segment's behaviour as a whole is less well represented. Apparently the delineation of fleet segments should take this aspect into account and aim at (more) homogeneity in homeports and fishing grounds as well.

In fact, the model can only simulate the behaviour of a single boat, and as such serve very well as a planning device for skippers or fishing boat operators in general, allowing them to analyse the consequences of various operational options. For the private operator, the superior efficiency of the model might be less of a problem, as he could put in data and tune the model to his best knowledge, and play around with the assumptions, to assess the sensitivity of his decisions for uncertainties in those.
Another aspect of the model, that has particular consequences for the Dutch examples, is that it does not really follow the calendar. This can easily result in trip sequences that are inconsistent with the Dutch weekly pattern of trips, with weekends spent in port. A relaxation of the present build-up of trips of full days only, to allowing part days as well, might bring an improvement in this respect, but this possibility has yet to be explored.

As it is, the model has been built and applied only for active, in fact trawling fisheries. In these fisheries, the fishing effort and the resulting catch is rather directly connected with the active time of the boat, or at least with the time on the fishing grounds. In passive fisheries, like gill netting or lining, the connection between boat activity and fishing effort is less clear. The model is therefore not directly applicable for such fisheries and would probably require a different set up.

From the above, it will be clear that the model asks for a lot of well specified data on operational costs and behaviour of the fleet segment concerned. In general, such data are not directly available and our Spanish colleagues have had to put enormous effort into gathering them. Even in our case, having quite well specified costs and earnings data at our disposal, considerable effort has been put into processing and preparing them for model use. Most effort, however, went into building of the data set of monthly catch rates per fishing ground, data that should basically be provided by fishery biologists. Presently, as far as I know, such data exist only for plaice (Pastoors et al., 1997)

Finally, the model is not yet very user friendly, meaning that it is not ready for use by any manager. Not only would further tuning be required for the types of fisheries we have used for testing, it should also be adapted and tuned for other fisheries. Also, the implementation of management measures in the model should be made easier, without having to go through the model-program. Eventually, the ideal would be a model, where you can choose your fishery and management measures through menus, without having to bother what the program is actually doing, although we have to be aware of possible sorcerer's apprentice effects then.

Conclusion

In our project proposal, this model-building project was announced as an approach, indicating that we were not sure about how far we could get. Now we are in the final stages of the project, and in our opinion, for an approach we have come quite a long way. Of course, the present model is still far from perfect, but it shows very promising potential for use by fishery managers on all levels and for all kinds of fisheries. Therefore, the work already done should be continued and expanded along the lines indicated above.

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