The significance of economic incentives in fisheries management under the CFP
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Publication date: 2001

Document Version
Publisher's PDF, also known as Version of record

Citation for published version (APA):
The Significance of Economic Incentives in Fisheries Management under the CFP

Final Report

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København 2001
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Preface

The report “The Significance of Economic Incentives in Fisheries Management under the CFP” is the result of a study carried out with financial support from the European Union’s research programme in the fisheries sector (FAIR) under the 4th framework programme.

The study views the Common Fisheries Policy (CFP) of the European Union from a new angle. The restrictions that are imposed on the exploitation of the fish stocks by the resource and the structural policies try to correct the imbalance between the size of renewable fish resources, based on considerations of sustainable fish stocks, and the fishing capacity and the fishing effort. Lack of balance between these two will lead to creation of incentives that influence the fishermen to behave in a way that goes against the objective of sustainable fish stocks, as specified in the CFP.

The purpose of the study was two-fold: First to identify economic incentives within quota, effort, and capacity management, and secondly, to view the consequences of the incentives in a world with asymmetric information, i.e. in a world where the fishermen in many areas have more information than the manager.

Restricted economic optimization was used in the study to identify incentives based on qualitative economic modelling, linear programming, and investment theory, including entry and exit behaviour in an industry. Issues arising from asymmetric information was analysed using the economic theory of information, including the principal-agent approach.

The study modifies the results of the deterministic bioeconomic analyses in the sense that it is important to implement measures that entice the fishermen to reveal their true type and their true actions. Successful implementation of such measures will reduce the need for monitoring, enforcement, and legal punishment, which already form an important part of the CFP.

The principal-agent approach has not been used to any large extent in fisheries economics analyses contrary to environmental economics, which has strong resemblance to fisheries economics. The extensive approach taken in this study, covering the resource and the structural policies of the EU, has indicated that economic and financial gains could be achieved by the inclusion of the theory of information economics in future policy making about fish resource exploitation.
The study was carried out in cooperation between a number of researchers affiliated to two universities and four research institutes from Denmark, France, Italy, The Netherlands, and United Kingdom. A total of 14 researchers have been involved in the study, which was headed by senior economic adviser Hans Frost, SJFI, formerly of The University of Southern Denmark, Department of Environmental and Business Economics, which served as the responsible coordinating partner throughout the whole project period.

An anonymous referee recommended a number of valuable changes to the report, which is greatly acknowledged. The diversity in the use of the English language performed by these researchers with different native tongues has been slightly standardized by the efforts of Erik Lindebo, a British ‘native’ working at SJFI. The researchers’ use of different formats and incompatible software programmes has equally challenged Elsebeth Vidoe, secretary at SJFI.

The Danish Institute of Agricultural and Fisheries Economics (SJFI), September 2001.

Ole P. Kristensen
Director, SJFI
Executive summary

Project background
Fisheries management is associated with a number of monitoring, enforcement and control measures. A reason for this is that the objectives of society and the fishermen do not conform to one another due to the characteristics of the exploitation of the fish resources where externalities entail that social costs differ from private costs. The EU fisheries management system has tried to correct these failures by introducing stricter and stricter, and hence even costlier, control measures. This raised the idea of studying the economic incentives of fishermen and the way they act. In the economic literature, such problems are addressed in e.g. the theory of information economics and principal-agent methods. Managing authorities (principals) can use economic incentives to induce a particular response or behaviour from the fishermen (agents), either by reducing profits (negative incentives) or by increasing profits (positive incentives). On request from the EU Commission it was the aim to quantify economic incentives in terms of in shadow values wherever possible.

Participants in the project
During the research period from January 1998 until August 2000 the following institutes have participated in the study:

The Danish Institute of Fisheries Economics Research (DIFER), University of South Jutland, and subsequently from 1999 the University of Southern Denmark, Denmark (coordinator). The Danish Institute of Agricultural and Fisheries Economics (SJFI), Denmark, from 1999.

University of Portsmouth Centre for the Economics and Management of Aquatic Resources (CEMARE), United Kingdom.

IFREMER, Service d'Economie Maritime, France.

IREPA (Instituto Ricerche Economiche per la Pesca e l'Acqua-Coltura), Italy.

LEI-DLO, (Landbouw - Economisch Institut), The Netherlands.
Materials and Methods

Case studies were selected in the five Member States participating in the project:

- Effort management systems were studied in Denmark, Italy and the Netherlands.
- Capacity adjustment programmes were studied in France, the United Kingdom, and Italy.
- Quota management systems were studied in the United Kingdom, the Netherlands and Denmark

The project work was organised on three levels: 1) Methodology development, 2) National studies 3) Compilation and comparison of national studies in three cases to be included in the final report.

Presentation and discussion of general features of economic incentives and the principal-agent method formed the basis of the study. The national descriptions were carried out to identify areas that could be studied. Specific methodologies were developed and the analyses were carried out linking the overall principal-agent methodology with applied and more specific methodologies including: 1) Qualitative, formal optimization procedures 2) Linear programming 3) Bio-economic modelling and investment theory. The specific methodologies have been used to identify economic incentives and their magnitude, with a strong view to the principal-agent approach and information economics theory.

Economic incentives and the use of economic incentives in principal-agent agreements have a broad interpretation ranging from economic interpretations, based on profit maximization, to sociological and anthropological interpretations where relations between the principal and the agent with a view to credibility, trustworthiness, and respect play an important role for the system to function. The approach, however, is based on economic theory. The literature distinguishes between two types of information problems: Hidden actions (moral hazard) and hidden information (adverse selection). Hidden actions occur if the principal does not know what the agent will do after the contract has been signed; in such cases it is important how the risk-bearing scheme is designed, and the case seems particularly relevant in quota regulation where exceeding the quotas is an example of moral hazard behaviour for profit maximising agents. Hidden information problems occur in cases where the principal does not know much about e.g. the revenue (utility), the cost functions of the agents,
or the production technology (production function); all that is known is that they are
different for each agent or groups of agents, and that the agent knows his own func-
tions; the case is particularly relevant in capacity adjustment situations (decommis-
sioning and laying-up) and in effort regulation.

Results

Quota management systems are studied for different designs by use of qualitative
formal models where fishermen behaviour is analysed by calculating shadow prices
(the change in profit from changes in restrictions). Although in-efficiency problems
are solved by changing the system from general non-transferable quotas to individual
transferable quotas, the incentives for the fisherman to hide actions are changed but
not removed entirely in the system. Still incentives to discard fish, high grade and
land illegally exist which calls for monitoring, enforcement and control of catches.
The alternative is the introduction of a subsidy/tax system that gives the fisherman an
incentive to act efficiently and responsibly with respect to changes in the fish stocks.

Effort management systems are not applied as the sole measure in any Member State
but limited number of fishing days are applied in Holland, and laying-up premiums as
an effort management measure was applied in e.g. Italy. If the fisherman’s utility ex-
extactly corresponds to the money value of the grant, he would act by leaving the fishery
if the premium was larger than the profit from continuing fishing. The problem could
be viewed as a hidden information problem, and reasons for non-expected actions are
investigated by questionnaires. In Denmark and Holland shadow prices from restric-
tions by the number of fishing days are calculated for fleet segments, as sufficient
economic information is available. The shadow price calculation reveals differences
viewed from the perspectives of the principal (society) and the agents (fishermen).
Allocation of fishing days based on shadow prices still embodies a problem with hid-
den information and possible disparity between money value and utility.

The capacity adjustment programme is an important policy instrument in the CFP but
is applied differently in the Member States. By use of an investment model in view of
the principal-agent method, the premium that is required to withdraw capacity was
calculated for France under various assumptions. One assumption is that the utility of
the fisherman is equal to the premium. This is not always the case as was investigated
in the Italian case for both laying-up premiums and decommissioning grants. In the
UK case an auctioning procedure was used and it was found that such a procedure

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embodies utilities, expectations, and spill-over effects that do not necessarily reflect
the true utility of the fisherman.

The general result is that applying the economic theory of information in conjunction
with economic incentives provides a good basis for better insight into the difficulties
of improving the functioning of the CFP of the EU. The theory of information in a
principal-agent perspective appears to be a method that could be used with the aim to
make fishermen react responsibly with respect to minimising discard, illegal landing
etc. and to secure that the fishermen receive grants, laying-up premiums, individual
quotas and efforts allocations in a way that is in agreement with the type of fisherman.
The achievements of the CFP could be improved if information problems are ad-
dressed, specifically in the economic analyses.
1. Introduction

1.1. Project background

Fisheries management is associated with a number of monitoring, enforcement and control measures. A reason for that is that the objectives of society and the fishermen do not comply due to the characteristics of exploitation of the fish resources, where externalities entail that social cost differs from private cost. The management system has tried to correct these failures by introducing stricter and stricter and hence even costlier control measures. This raised the idea to have a closer look at the economic incentives of the fishermen, where were incentives created to induce fishermen to react as they do, and what could be done to make them act in a way that was in compliance with society’s objective. Problems like that are, in the economic literature, often addressed in the theory of information economics and principal-agent methods.

The aim of the project was to examine the implementation at the national level of those key policy components of the CFP, which are intended to control fishing effort and fishing mortality. The focus of the project was therefore on the measures adopted by different Member States in order to fulfil their obligations under the basic conservation and management regulation relating to the observing of national catch quotas and the achieving of reductions in fleet capacity agreed under the MAGPs.

The focus of the investigations was put on the subsequent types of management:

1. Quota management systems (output regulation)
2. Effort management systems (input regulation)
3. Fleet capacity adjustment

Economic incentives can be used by managing authorities (principals) to induce particular responses or behaviours from investors or actors (agents) in the fishing industry, either by reducing profits (in the case of negative incentives) or by increasing profits (in the case of positive incentives). When trying to determine the minimum value of the premium which should be paid by the principal (managers) to the agent (fisherman) to switch from one target species to the other, for example, fisheries managers are faced with an optimization problem with a number of economic constraints.
On request from the EU Commission it was the aim to quantify, wherever possible, economic incentives materialised in the shadow value of circumventing or violating specific management stipulations. This could occur along the lines explained in the above optimization problem, once it has been identified where, when and how economic incentives are implemented through existing management schemes. It was envisaged that quantification should take various forms, which would have to be determined after the objectives of the CFP on Member State level and the economic incentive types, have been identified. Because the area was largely un-explored within fisheries it was not possible at the beginning of the project to lay down any precise approach and methodology, but a number of aims could be listed:

**Effort management**

In the investigation of effort regulation the limitation of number of vessels and fishing days with respect to certain quota limitation would lead to a larger profit of given species. This profit will be calculated in an optimization model used in the sub-project. The profit will lead to a reallocation of effort by the fisherman towards this species. Should managers want to prevent fishermen from targeting this species, the necessary compensatory payment would be calculated as equal to the profit (marginal) from fishing this species. The method used is to construct a model that optimises the profit of a vessel or group of vessels, subject to a number of constraints (linear/non linear programming). The optimization produces marginal profits, which are the shadow value of having the constraints relaxed e.g. have an extra fishing day or an extra tonne of fish. It should be emphasized, however, that effort regulation is rather the exception than the rule in the measures employed by Member States.

**Capacity adjustment**

A different type of possible quantification is the premium that is paid for decommissioning (capacity adjustment). Here the managers lay down the economic incentive in advance, and the sub-project would investigate the premium structure and the size of payment and relate this to the numbers of vessels, GRT and horsepower withdrawn. The premium is the economic incentive to persuade fishermen to choose decommissioning rather than to keep on fishing.

**Quota management**

A third type of quantification is associated with individual transferable quotas. The price of the quota is an estimate of the premium that has to be paid to fishermen to, reduce the catches of a particular species. If a quota market exists, managers could
use the price of a quota as an indication of the magnitude of the economic incentive a fisherman needs to go on fishing, and consequently what is needed to prevent him from fishing. Where no legal quota trading exists, quantification may be difficult. Nevertheless, the capital that is accrued in these rights is an estimate of the magnitude of an economic incentive and it would be important to identify where and how the capital is accrued in the absence of a market. In principle the same method as the one used in effort regulation could be applied in an attempt to estimate the value of quota rights.

1.2. General objective

Founded on the aims listed above the objective of the project was to investigate the role and significance of economic incentives in the management of European fisheries, within the framework of the Common Fisheries Policy. This entailed that in particular it should be examined how the behaviour of fishing firms in response to national policy measures have aided or hindered the achievement of management objectives; and if possible to produce a set of guidelines for policy makers suggesting how the design of fishery management measures could be improved by taking economic incentives into account.

1.3. Participants in the project

During the research period from January 1998 until August 2000 the following people have been working at the project:

The Danish Institute of Fisheries Economics Research (DIFER), University of South Jutland, and the University of Southern Denmark (SDU)\(^1\), Denmark (coordinating partner): Senior research fellow Hans Frost\(^2\), research fellow Carsten L. Jensen, research assistant Mette P. Bergholt, and Ph.D. student Frank Jensen.

University of Portsmouth Centre for the Economics and Management of Aquatic Resources (CEMARE), United Kingdom: Senior research fellow Aaron Hatcher.

\(^1\) In 1999 the Danish universities in the South-western part were united into one university. The researchers formerly employed at DIFER were transferred to the new University of Southern Denmark (SDU).

\(^2\) Hans Frost left SDU at the end of 1999 and became employed at the Danish Institute of Agricultural and Fisheries Economics but continued on the project. SDU continued as coordinating partner with senior lecturer and head of department Niels Vestergaard, SDU, Department of Environmental and Business Economics hereinafter as the official project leader.
IFREMER, Service d'Economie Maritime, France: Head of department Regis Kalaydjian, research fellow Fabienne Daures, research fellow Olivier Guyader.

IREPA (Istituto Ricerche Economiche per la Pesca e l'Acqua-Coltura), Italy: Head of department Vincenzo Placenti, research assistant Loretta Malvarosa. Research fellow Paolo Cupo, University of Napoli has been associated with the project via IREPA.

LEI-DLO, (Landbouw - Economisch Instituut), The Netherlands: Senior research fellow Wim Davidse, research fellow Erik Buisman, research fellow Ellen Hoefnagel.

1.4. Structure of the report

The result from the study is to a large extent based on theory application rather than theory development along the line: what could theory tell us about the way the Common Fisheries Policy of the EU is applied. The general methodology is presented in chapter 2 and supplemented by formal analyses in appendices A-C. To apply principal-agent theory and methods directly to fisheries was not straightforward, as most of them are managed in a complex manner. The principal-agent method normally views a problem from the angle that the principal pays the agent, and the agent hands over the production value to the principal. This is not directly the case in fisheries, but the use of subsidies (and penalties) in the CFP of the EU to affect the agents’ behaviour makes it plausible to use the approach and construct analogies. The choice of case in each country has been determined by the relevance of the problem with respect to possible management decisions and data availability.

The presentation of the results in three chapters, 3, 4, and 5, is based on the content of the reports, working papers, and discussion papers listed at the end of this report:

- Economic incentives and effort regulation
- Economic incentives and capacity adjustment
- Incentives in quota regulation

The chapters are not structured identically, but the main topics are common such as: selecting cases, assumptions, development of specific methodologies, and application of methodologies. Each chapter is concluded with a discussion and conclusion section.
2. Materials and Methods

2.1. The study approach

Case studies were selected in the five Member States participating in the project:

Denmark, France, Italy, the Netherlands and the United Kingdom in such a way that three countries each participated in two cases while France participated in one case labour shortage reasons at the time the study took place:

- *Effort management systems* studied in Denmark, Italy and the Netherlands;
- *Capacity adjustment programmes* studied in the United Kingdom, France and Italy;
- *Quota management systems* studied in the United Kingdom, the Netherlands and Denmark;

The overall analysis of the role and significance of economic incentives in fisheries management will be approached from the perspective of the economic theory of *agency*. This characterises the contractual relationships between individuals in the economy in terms of a *principal* and one or more *agents*. The principal (in this case the fishery management authority) seeks to ensure that the aggregate of the choices of all the individual decision-making agents (fishing firms) is in the interest of the principal. However, the (private) interests of the individual agents may not be the same as the (public) interests of the principal. If perfect enforcement of desired behaviour on the part of all agents is not feasible, the principal must try to establish an *incentive scheme* that will align the interests of the agents with those of the principal. Where this is not achieved there is an incentive alignment problem that will tend to produce a sub-optimal outcome (at least from the principal's point of view). This conceptual approach has been applied to a variety of problems within economics. Only few analyses with direct relevance to fisheries exist, and among those are non-point pollution problems, of Segerson (1988) that have some resemblance to the infliction of fishing mortality to the fish stock from unknown fishermen. The modelling of international fisheries relations Clarke and Munro (1987) should also be mentioned.

Against the general background of this conceptual and contextual framework, the relevant groups of participants would then develop the specific methodology for each of the case studies. Each specific casestudy methodology should be adapted to the
particular type of management measure under consideration, the precise details of national policies in this area, and the nature of the requisite datasets identified.

The basic questions that each of the studies were to answer at the national level may be summarised as follows:

- How was the national management system designed and implemented?
- What were the general and detailed objectives in terms of Community obligations and national priorities?
- What were the results in terms of the stated objectives, and what other results were apparent that might be of interest to policy-makers?
- What were the economic incentives affecting the behaviour of fishing firms in response to the management measures that impacted on the results observed?

The work in the project has been organised on three levels:

- National studies
- Compilation and comparison of national studies in three case study reports
- The final synthesis report

However, general features about economic incentives and the principal-agent method were first addressed. National descriptions were the carried out to identify areas which could be studied. The specific methodologies were developed and the analyses were carried out. Partly because of the wish for quantification and partly for the complexity of the implemented regulations, it has not been an easy task to link the principal-agent methodology with more than the specific methodologies selected for each case.

The selected specific methodologies are:

- Qualitative, formal optimization procedures (mainly in the quota case)
- Linear programming (mainly in the effort case)
- Bio-economic modelling and investment theory (mainly in the capacity case)

These methodologies have been used to identify economic incentives and if possible the magnitude. The methodologies have then been employed with a strong view to the
principal-agent approach and information economics theory. In particular, imperfect information has been of interest as it pays a central role in the principal-agent approach. In theory, no problems exist with full information, because in that case the principal always knows what the agent is doing and is therefore able to react precisely on that information.

Economic incentives and the use of economic incentives in principal-agent (P-A) agreements have a broad interpretation, ranging from economic interpretations based on utility to sociological and anthropological interpretations where relations between the principal and the agent with a view to credibility, trustworthiness, and respect play an important role for the system to function. In systems where the principal-agent link is between governments and fishermen it is sometimes not possible to establish this mutual relationship, but it could be argued that co-management systems, e.g. as in Holland, is a good basis for that. Although the basis for this investigation has been economic, institutional problems, as mentioned above, have been included in the considerations of the group. In the following part of the chapter the aim is to outline the basis for the investigation, supported by the formal analyses included in appendices A-C.

2.2. Imperfect information

Economic analyses are often based on assumptions of perfect information on the market. Because the explicit price on a market is associated with an implicit perception of content (e.g. the quality) of the product or service, it can be demonstrated that if the knowledge of the product is imperfect then the solution prescribed by the theory based on perfect information will differ from the solutions based on imperfect information, of Akerlof (1970) and Varian (1996). Akerlof (1970) demonstrates that in a market for used cars where the buyer cannot distinguish between the quality of the same type of cars from two different dealers, but knows that there are differences, a market equilibrium cannot be established, and the dealer with the best quality would then have to use supplementary instruments (e.g. written guaranties) to the price to sell his cars. Varian (1996) demonstrates that with imperfect information, sharing the crop produced by the agent on behalf of the principal between the principal and the agent is a better solution than the solution where the principal pays the agent a fixed salary to produce. The latter solution is the best with full information. Examples include travelling salesmen that cannot be controlled by the manager. By sharing the revenue from the sales, the salesman gets an incentive to produce, or a tenant gets an
incentive to grow the crop on a piece of land. In fisheries, because it is very difficult to monitor what the fishermen are doing at sea, and because the fish resource, in principle, is owned by the society, the relationship between the fisherman and the manager (on behalf of the society) is characterised by imperfect information. The literature distinguishes between two types of information problems that are associated with the actions of the agents and what types they are, viewed from the principle’s perspective.

A mathematical description of moral hazard is to be found in Laffont and Tirole (1993) who characterise moral hazard as a situation where the endogenous variable is unobservable. Hanley et al (1997) define the concept as:

‘Moral hazard arises when the actions of one person are unobservable to a second person.’

For this reason Varian (1992) and (1996) calls moral hazard models for models with hidden actions.

Adverse selection as described by Laffont and Tirole (1993) is a situation where there is asymmetric information about exogenous variables. Hanley et al (1997) write:

“adverse selection exists when one person cannot identify the type or character of the second person.”

For this reason Varian (1992) and (1996) describes adverse selection models as models with hidden information.

**Moral hazard (hidden actions)**

If the principal does not know what the agent will do after the contract has been signed a moral hazard problem arises. In such cases it is important to know how the risk-bearing scheme is designed, cf. the tenant example. The problem with a fixed salary to the tenant is that the tenant does not have an incentive to maximise the value of the crop in the interest of the owner. The tenant may have other interests, which imply that the action of the tenant is associated with some uncertainty. He can choose between different options associated with different types of risk. He could be risk adverse and value the risky alternatives (i.e. securing the harvest in bad weather, or selling part of it on the black market) lower than the possible wages he will get from that
alternative. In such a case the agent will not bear any risk and choose the safe alternative. The principal has to bear the risk. An incentive scheme with risk sharing could solve the problem. The case seems relevant in fisheries in e.g. quota regulation, where exceeding the quotas without risk lead to moral hazard behaviour for profit maximising agents.

*Adverse selection (hidden information)*

In such cases the principal does not know much about e.g. the revenue (utility) or the cost functions of the agents, or the production technology (production function) he uses. All that is known is that the functions differ between agents and that the agent knows his own functions. It is further assumed that the agent wants to maximise his own profit. In such cases it is important for the principal to find out what type the agent really is (cf. the used car example). These cases are named adverse selection cases, because the central problem here is that the agent hide information. The case seems particularly relevant in capacity adjustment situations (decommissioning and laying-up) and in effort regulation where the aim is to distribute capacity reduction or effort in an efficient manner.

*Monopoly or competitive market*

In many markets the principal can find himself in a competitive situation where the agents may shift if they feel badly treated. The principal will have to take the market conditions into consideration when he formulates his agreements with the agent. In fisheries, however, the Government will act from a monopoly angle while co-managements bodies e.g. producer organisations with responsibilities for production plan, will have to act from a competitive market angle.

### 2.3. A simple model of economic incentives and a principal-agent solution

The principal-agent method is addressed more formally in appendices A-C, but the following very simple example shows the design applied to fisheries. Suppose we have full information. Suppose a fisherman has two alternatives. He could target species $s_1$ or he could target species $s_2$. Suppose fishing for species $s_1$ gives him the largest profit. If he is acting economically rational, he will go for species $s_1$.

Suppose further that society (managers) would prefer the fisherman to go for species $s_2$ because species $s_1$ is threatened by overfishing. How could the manager achieve this objective? Of course he could force the fisherman to fish the way the manager
wants e.g. by quota restriction, but because this is not in compliance with the fisherman’s objective he has an incentive to cheat in particular if it is without risk. Instead of command and control the principal could affect costs and revenue of the fisherman either through technical measures (which is partly command and control) or better by subsidies or levies.

Let us assume society would pay the fisherman to fish for species $s_2$. The economic incentive is the money value (more precise the utility of the fisherman) that is required to make the fisherman shift from $s_1$ to $s_2$. Society could also punish the fisherman by placing a levy on species $s_1$, which would reduce his profit from that species. With full information there is no control problem with respect to species and production volume, because if the fisherman lands the wrong species or volume the premium will disappear. With imperfect information it is, however, not that simple, cf. later in section 2.5 and appendices A-C.

In a formal economic principal-agent analysis the problem is to maximise the principal’s profit (utility) subject to two constraints associated to the behaviour of the fisherman. From the principal’s point of view without economic incentives the fisherman’s two alternatives are:

$$\text{Profit}(s_1) = \text{Revenue}(s_1) - \text{Costs}(s_1)$$
$$\text{Profit}(s_2) = \text{Revenue}(s_2) - \text{Costs}(s_2)$$

and:

$$\text{Profit}(s_1) > \text{Profit}(s_2) \text{ for the fisherman}$$

with economic incentives the fisherman’s alternatives are:

$$\text{Profit}(s_1) = \text{Revenue}(s_1) - \text{Costs}(s_1)$$
$$\text{Profit}(s_2) = \text{Revenue}(s_2) + \text{Premium} - \text{Costs}(s_2)$$

now:

$$\text{Profit}(s_2) > \text{Profit}(s_1) \text{ for the fisherman}.$$
arises and it would of course not be in the interest of society because consumers are deprived of fish.

In this example society receives the revenue from the fisherman’s fishing on $s_2$, and society’s “costs” are the premium paid to the fisherman. The problem for the principal (society) is to find the lowest possible amount society could offer the fisherman to make him fish for species $s_2$ and deliver the correct volume to society.

The determination of the premium is some sort of a game between the principal and the fisherman. From a sociological or anthropological angle this is largely a matter of credibility and trust. From a pure economic point of view the solution of the problem is easy, in principle, because society (principal) has to choose the premium $^{3}$ in a way that maximises society’s utility (“profit”) subject to two constraints:

maximise: $\text{Revenue}(s_2) - \text{Premium}$

subject to:
1. $\text{Premium} - \text{Costs}(s_2) > \text{Profit}(s_1) = \text{Revenue}(s_1) - \text{Costs}(s_1)$
2. $\text{Premium} - \text{Costs}(s_2) > \text{minimum Premium accepted by the fisherman}$

The minimum acceptable premium of the fisherman expressed in constraint no. 2 need not be the same as his $\text{Profit}(s_1) + \text{Costs}(s_2)$ from constraint no. 1, in particular if the premium is made dependant on the production volume of $s_2$ or various types of uncertainties occur. Therefore the inclusion of the two types of constraints is necessary. Constraint no. 2 is referred to as the participation constraint in the literature, cf. Varian (1992), and no. 1 is the incentive compatibility constraint. Further restrictions are discussed in Section 2.5.

The literature is not clear about how to define the principal-agent problem. Three definitions can be distinguished implying that the principal-agent occurs if:

1. A participation restriction is included in the problem
2. Asymmetric information prevails
3. The principal wants the agent to do something that is costly to the agent

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$^{3}$ In social objective functions taxes (premium) are not included. Essentially, the tax is a transfer. However, in our case the premium could be considered society’s opportunity cost of fishing.
The first definition focuses on the issue that all agents already in the system are kept in business by the action of the principal cf. Clarke and Munro (1987). The principal’s solution could be designed so that no agents are forced to leave. In the second definition only problems where the agent has more information than the principal are of interest, of Jebal and Lando (1997). That means that if the principal has full information then it is not a principal-agent situation (contrary to definition 1). Finally, definition 3 focuses on cases where the agent by himself is not doing what the principal wants, of Wickers and Yarrod (1989). The solution to the problem is to design a system that functions according to the principal’s wishes. From definition 3 the mere exploitation of the fish resources is a principal-agent case i.e. fishing is a principal–agent case by itself. In our investigations the analyses take a broad approach using all the definitions in various ways for the three country cases.

2.4. Traditional management proposal

The proposition of a principal-agent approach must be seen against the background of what could be named the traditional proposals for managing fisheries. One line of criticism of the traditional proposals is that they require substantial information to implement. This leads to the proposal of the principal-agent approach as the relevant method for developing a benchmark case for evaluating the economic incentives of quota management, effort management and fleet capacity adjustment.

This section answers the questions of whether quota management, effort management and fleet capacity adjustments perform well in light of economic efficiency. It should be pointed out that economic efficiency is equivalent to maximising social welfare. The maximisation of social welfare has the implication that distributional questions are bypassed in the study of economic incentives. Whether the fishery is concerned primarily with efficiency or with equity is a topic that has been vigorously debated, see Clark (1985).

In discussing the quota system we must distinguish between individual transferable quotas (ITQs) and total allowable catch (TAC). In the economic literature it is a well-known result that an ITQ system can achieve economic efficiency under restrictive assumptions, see e.g. Clark (1985). One of these assumptions is that the manager has perfect information about some important aspects of each quota holder. A further assumption is that there is no violation of the quota e.g. the enforcement costs are zero. Criticism of these information requirements leads to the suggestion that fishery management must be studied with the principal-agent approach i.e the method for analys-
ing economic incentives under asymmetric information. It is also a well-known result that a TAC system does not achieve economic efficiency; see e.g. Clark (1985). A TAC system forces the fishermen to compete furiously for the catches. Further, there is an information problem with enforcing the TAC: violation is often observed. This again leads to the suggestion to study management regimes under asymmetric information.

Effort management taken as the time a fisherman must fish does not achieve economic efficiency, of e.g. Dupont (1990) and Campbell and Lindner (1990). Further, the information requirements for effort regulation are substantial, and this again leads to the suggestion of the use of the principal-agent approach. The same conclusion may apply to fleet capacity adjustment, of e.g. Frost et al (1995).

2.5. The general methodology and application to fisheries

The manager wishes to induce the fishermen to something that is costly for the fishermen. The regulator’s problem is to design an economic incentive that induces the agent to the best behaviour from the regulator’s point of view. The fisherman’s behaviour sets two restrictions for the regulator:

- A participation restriction. The fishermen can have another possibility at his disposal
- An incentive compatibility restriction. The fisherman chooses the best behaviour for himself and the principal can only influence the fishermen’s behaviour indirectly by the chosen economic incentive. One implication of this restriction is that it is in the interest of the fishermen to report their true behaviour to the principal.

However, in fisheries the principal has to take into account one more restriction, which in most cases is:

- The resource restriction

The resource restriction is included to secure that the catches are not exceeding the natural growth of the fish stock. The resource restriction could be included either as a function explaining the natural growth or simply as a quota restriction that is derived from biological estimates of the possible natural production of the fish stock.
Within fisheries, the fishermen are often better informed about individual catches, effort and cost functions, which constitute the relevant information from the point of view of the principal. It is therefore the asymmetric information problem that is relevant for the analysis of fishery economics. But how can the principal-agent approach be used in the study of fishery? This is illustrated in figure 2.1.

The management of fishermen within the EU could be viewed as a double principal-agent relation. The first principal-agent relation is between the EU and its member states. The EU asks the countries to implement the regulation. The countries often have some interests of their own and may therefore be interested in hiding information from the EU in the same way, as the fishermen may be interested in hiding information from the national authorities that are responsible for the direct implementation.

The solution to the economic incentive problem is very sensitive to the information assumptions: a) full information, b) asymmetric information, or c) lack of information. It is important to note that information is relevant from the point of view of the principal. This leads to the suggestion that the relevant economic incentive cases must be selected from the Member State-Fishermen areas. The EU-Member State case is left out partly to avoid complicating the analysis, and partly because it is assumed that the Member States adhere to the EU agreements. The problem in the EU-Member State relation is often that the Member States cannot reach an agreement, rather than the Member States hiding information from the EU.
Let us resume discussing the case where the principal has full information about all relevant aspects of the agent. In this case there are, as mentioned, many solutions to the problem of constructing an incentive scheme, which induces the agent to behave in accordance with the principal’s wishes. In the case of the fishery the assumption of full information is clearly not relevant because the managers often lack information about:

- Fishermen’s catches
- Fishermen’s cost functions
- Fishermen’s effort
- Use of capacity after decommissioning or laying-up premiums

As mentioned above asymmetric information means that the agent (fisherman) has more information about his own activity than the principal (manager). With respect to management, the three selected cases: Quota management, effort management, and capacity reduction embody the asymmetric information in different ways. In the economic analyses the information problems are related to the cases in the following way:

- Moral hazard (Hidden actions)
  - Illegal landings
  - Discards

- Adverse selection (Hidden information)
  - Individual quota allocation
  - Individual effort allocation
  - Allocation of decommissioning grant and laying-up premiums

This moral hazard behaviour occurs because after the fishermen have been allocated access (rights) to the fish resources, either in terms of catches, the number of fishing days each vessels could exert, or a contract to withdraw has been agreed, there is an incentive for the fishermen to change behaviour. The success of management is very dependant on the possibility to observe the action of the fishermen. It is therefore important to characterise quota management, effort management and fleet capacity adjustment from the perspective of moral hazard, and in particular to what degree moral hazard applies to each case. In quota management the landings can normally be observed while it is the catches that matter with respect to changes in the fish stock size. In effort management moral hazard takes place if the fisherman fish more days than allocated to him or fish at other fishing grounds than permitted. However, moral hazard is not viewed as important in effort regulation as in quota regulation. In case a
fisherman does not stop fishing after a decommissioning or laying-up grant has been accepted a moral hazard problem arises. However, it is often easier to observe whether or not a vessel is used, and moral hazard is not viewed as being of big importance in this case either.

The adverse selection problem occurs in all the cases in association with the principal’s aim to allocate the fishing rights to the fishermen in a way that secures economic efficiency. If individual quotas, the individual number of fishing days, or the decommissioning grants are allocated the fisherman may benefit from not revealing his true type to the principal. The fisherman does not necessarily change behaviour after he has been allocated his fishing right, but he could still be in a better position in terms of profit making by announcing a wrong type to the principal. The adverse selection problem addresses how the principal can make the fisherman to reveal his true type.

To conclude this part, a few words about lack of information. This case refers to the situation where both the principal and the agent lack information about relevant parameters. It is important to emphasise that it is relevant information from the point of view of the principal/society. In developed fisheries it is hard to imagine that neither the fisherman (agent) nor the society (principal) are totally without information about catches, costs or effort. Therefore this situation is not included in the study.

It is assumed the Member States adhere to the EU provisions. The double principal-agent problem described above is therefore reduced to a problem between the Member State Government and the fishermen. The problem that the EU asks the countries to implement regulations, which the countries do not comply with because of interests of their own, is ruled out in our context. Central questions are therefore:

- How is the national management system designed and implemented?
- What are the general and detailed objectives in terms of EU policy and national priorities?
- What were the results in terms of stated objectives?
- What economic incentives do quota management, effort regulation and fleet capacity adjustment generate?
- Can we develop an economic incentive with moral hazard and adverse selection as a benchmark case?
This first attempt to identify problems within the study areas: Quota regulation, effort regulation, and capacity reduction is based on the principal’s interests, which from an economic point of view is economic efficiency, but from other viewpoints could be the pursuit of specific policy objectives based on economic efficiency. The policy objectives could be pursued because it is realised that economic efficiency is not possible because of information problems in the pursuit of economic efficiency, or because of distribution problems that call for solutions of second best type.

What characterises moral hazard is that the action taken by the agent is unobservable to a second person. This means that the agent reacts to the signals from the principal but the principal cannot be sure what the agent actually does. Contrary to that, adverse selection is characterised by the type or character being unobservable to the principal. With full information, obviously, there is no problem with regulation because the principal could design a payment scheme that exactly induces the agent to do what the principal wants.

It should be noted that an incentive scheme could take the form of subsidies and taxes (economic incentives) without any other legal implications than punishment if taxes are not paid, or it could be a punishment scheme with legal implications such as penalties (license withdrawn) or imprisonment, which is, basically, a sort of payment scheme. Therefore, the distinction between command and control and economic incentives is not always clear.

2.6. The general methodology applied to the cases

Although all cases embody both moral hazard and adverse selection elements in the way the regulation is implemented, it could be argued that quota regulation is dominated by moral hazard, and effort and capacity regulation is dominated by adverse selection. In the appendices the formal analyses are carried out in such a way that the moral hazard example is drawn from the quota regulation (appendix C) and the adverse selection is drawn from the effort/capacity regulation (appendix B).

This means that in the quota case including Denmark, the Netherlands and the UK the descriptions and analyses mentioned in section 2.5 have been made with a strong view to information problems of the type moral hazard. To what extent is it possible for the fishermen to change actions?
In the effort and capacity cases including Denmark, Italy and the Netherlands and France, Italy and the UK respectively, the main information problem is characterised by hidden information or adverse selection. How much should be granted to the fishermen and should the grants be organised to make the fishermen reveal their true type and thereby be able to limit effort and reduce capacity in an efficient way? Effort limitation is deployed most directly in Italy by use of laying-up premiums, while in Denmark and Holland the number of fishing days are controlled as supportive measures to quota regulation. In both cases it is important to know the type of the vessel in order to allocate grants and limitations efficiently.

The main issue in the capacity case is also how to reduce capacity in the most efficient way. The allocation of grants is dependant on revelation of type or the incentive for the fishermen to “self-select” or “adverse select”.

A formal analysis using the principal-agent method under full information is included in appendix A. In accordance with the approach that the principal pays the agent to do something, the analysis is organised in such a way that the manager pays the fisherman to fish, and the fisherman hands over the landings to the manager. The fisherman only takes into account that his profit is maximised so that the marginal payment equals his marginal costs of fishing. The analysis is for one fish stock and the principal has to take into account that the fisherman requires a positive profit (participation restriction) and that the catches do not exceed the growth of the fish stock (resource restriction). The third restriction that secures the fishery taking place on one particular species relative to another (incentive compatibility restriction) is not included because only one stock is considered. Inclusion of two stocks would require inclusion of one more resource restriction together with the incentive compatibility restriction that complicates the analyses. In the detailed analyses that form bases for the results in chapter 3 the method applied is linear programming. Finally the analysis is carried out with respect to optimal effort, but it could have been carried out with respect to optimal catches instead. The results would not differ.

The result is that the principal takes into account the effect on the fish stock (user cost of the fish stock) in his optimal allocation of fishing days. This means that the number of fishing days from the principal’s point of view should be smaller (or larger if the stock is under-exploited) relative to what the agent wants. This should be reflected in the payment from the principal to the agent. If user costs are positive (over-exploitation) the marginal payment is equal to the marginal revenue of the fishermen from one more fishing day minus the impact on the stock (user costs) and plus the
impact on the stock if the stock is under-exploited. This result could be used as a benchmark case for comparison with the results derived in appendices B and C about imperfect information.

Effort regulation

Because the full information case is analysed with respect to effort the analysis presented in appendix B is about effort. Effort regulation is managed by allocating fishing days to each vessel. In an economic efficient fishery the number of fishing days should be fixed according to the marginal revenue product equal to the marginal costs of each vessel. Because the manager does not have this information, hidden information (adverse selection) is the dominant problem here. Moral hazard is not profound because the hidden action: cheating with fishing days is more difficult. It is relatively easier to monitor the number of fishing days, than to monitor the catches and catch composition. The measure to change fishermen’s incentives is in this case often subsidies in practical fisheries, rather than taxes.

The formal analysis in appendix B is carried out in such a way that the principal pays the fisherman to produce a certain number of fishing days and hand over the landings to the principal. The principal wants to design the payment scheme in such a way that the fisherman reveals his correct type with respect to costs or productivity. At the same time the principal wants to take into consideration the impact on the fish stock (user costs). Relative to the case with full information the principal has to add the incentive compatibility restriction, which in this case often is named the self selection restriction. If this restriction is fulfilled by the design of the payments scheme the fishermen will reveal their true types. Further, because the principal does not know the type of the fisherman with certainty but only with some probability, this probability is included in the problem. The analysis deals with only two types.

The result of the analysis is that the payment has to be designed in such a way that the type of fisherman fishing with the lowest costs (or highest productivity) receives a marginal payment equal to the marginal revenue from one more fishing day, minus the fisherman’s impact on the fish stock (user costs) if the stock is overexploited, and vice versa. This result is the same as under full information. However, for the high cost type fisherman the payment is smaller than what he would have had under full information. Because the principal does not know the type the probability of being the high cost type relative to being the low cost type determines the reduction in payment relative to what had been the case under full information. If the fisherman claims to
be of the high cost type and the probability of being the high cost type is high, which could be assessed according to certain characteristics of the vessel, the reduction in payment is small. But if the fisherman claims to be a high costs agent and the probability is low then his payment is reduced. This has the effect that there is no (or little) incentive for the low cost fisherman to claim that he is a high cost fisherman. The effect of a low cost fisherman being viewed as a high costs fisherman is that he will receive a total payment that is smaller than what he would have got claiming to be a low cost fisherman. But because he fishes with low costs his marginal revenue is higher than his marginal costs at the effort level equal to what is exerted by the high cost fisherman, and because effort in a subsidy system like this is not controlled, he can expand effort beyond that level and sell the fish illegally. Thereby his total profit will be above the profit he would receive claiming to be a low cost fisherman. The high cost fisherman will never have an interest in claiming to be a low cost fisherman because his higher fishing costs will not allow him to produce the required volume of fish, and once the principal realises that the principal can take action. Put in other words, the low cost fisherman is granted an information rent for the revelation of his true type. Finally it should be noted that the payment scheme could be changed in such a way that the fisherman is permitted to keep the catch and pay a fee equal to the difference between the revenue from the fish and payment from the principal in case the fish is handed over.

Capacity

This area is distinguished from the other two in the sense that the incentive scheme used here is based purely on subsidies in practice. Hidden actions are not dominant because hidden action would require that the fishermen give false information about whether or not they have stopped fishing after a decommissioning grant has been received.

In this case hidden information dominates because the principal does not know the type of the vessel with respect to productivity or costs, which is important information once the decommissioning grant is fixed.

The adverse selection problem is the same as above and is analysed in appendix B with the addition that the assumption about payment from the principal to the agent is intuitively more acceptable here than in the effort case, because the payment should induce the fisherman to stop fishing. In principle the analysis would require an inclusion of incentive compatibility restrictions that secures that the fisherman will select
the decommissioning or lay-up option rather than to go on fishing. If, however, the payment to the fishermen is higher than what is calculated in appendix B the incentive compatibility restriction will not be binding and could be left out.

**Quota regulation**

Quota regulation with TACs (total allowable catches), further allocated to the fishermen as individual non-transferable quotas, contains an adverse selection problem which is addressed above. However, a moral hazard problem is the dominant situation in the case of quota management in the sense that it is economically profitable for the fisherman to submit wrong catch records to management bodies about catches and discards, in particular if the probability of being detected is low. Because the principal does not have fully reliable information, the problem for him is to design a scheme that induces the fishermen to act and report truthfully. The current regulation is based on a command and control scheme where fishermen are inspected by chance, then inspected, and then punished if anything is illegal.

The moral hazard problem is that the fishermen have two choices: a) they could fish legally or b) they could fish illegally by exceeding the quota and/or discard fish which has impact on the future size of the fish stock. The principal would prefer the fishermen to choose b) and therefore he could put a fine on illegal landings and discards, but if the fishermen are not disclosed or punished they would choose action a), which would then represent the lower fishing cost case to the fishermen. In the current system we allow the fishermen to choose action a without any other punishment than paying a legal fine if detected. The problem is, however, that it is difficult to observe catches while it is easier to observe landings. A variable that could be observed is therefore required. Such a variable could be the state of the fish stocks that is estimated every year in the biological assessment of the stocks. In the moral hazard case it is necessary to induce the agent to act in a responsible way i.e. parallel to avoid that the car is stolen by locking it even if it is insured. The fishermen should therefore be induced to act responsibly with respect to preservation of the fish stocks. Introducing a payment scheme that is dependant on the net change of the stock size after capture of fish could do that.

Although it is disregarded in this study it should be mentioned that there could be a moral hazard problem on the EU-Member State level, with the lack of motivation of the Member State to adhere to the agreed quotas after they have been fixed. In princi-
ple the Member State has the same incentives relative to the EU to act, as the fisherman has relative to the Member State.

It should also be mentioned that while moral hazard is profound within TAC regulation and non-transferable quotas, it exists, but may not be that significant, in an individual transferable quota system (ITQ system) because it could be argued that value of the ITQ is dependent on the size of the fish stock. In the long run an ITQ system will also solve some of the problems associated with adverse selection because the trade with quotas make the fishery more efficient. Further, the individual allocation of quotas could be made dependant on submission of some kind of information that, although not always precise, may be regarded to be better than the kind of information that could be collected in a general quota system. However, adverse selection problems are still relevant, at least because the principal’s interference by purchasing and selling quotas (“open market operation”) depends on the costs of the vessels if economic efficiency is pursued.

Before turning to the results from the formal analysis about solving moral hazard problem in appendix C, which is based on the inclusion of a tax/subsidy depending on the change of the fish stock size, an obvious example to go through is discards, and to consider whether it is possible to solve the problem.

The fisherman can avoid discards (catch of small fish) if he does something about it, such as using selective gears or carefully selecting fishing grounds - like locking a car to avoid theft. This is costly however. The principal wants the fisherman to avoid discards, and the principal’s goal function is to maximise the revenue from the fisherman when he tries to avoid discards. However, even in cases where fisherman avoids discards there is still some probability that he catches small fish that must be discarded. That would be associated with a penalty, which is a cost to the fisherman. In a market system the fisherman could insure himself (pay a small fee) so that the insurance company pays the penalty. We are assuming here that the fishermen will not cheat. The insurance company could be the Government, which collects the fee, and at the same time pays the penalty for the fishermen. This could be made operational if the fisherman is induced to bringing the fish they would normally discard onshore in such a way that the fisherman has no net benefit/loss from doing that. Although no literature reference is available this is probably the system that is used with discards or over-quota landings in New Zealand.
However, the fisherman has another choice compared to trying to avoid discards. He could fish with non-selective gear where the probability of avoiding discards is low. He could still insure himself against the penalty he would have to pay. The answer to this problem is that the profit in the case where the fisherman uses selective gear (equal to revenue from legal species-the insurance fee-the penalty-the extra cost of selective gear) is larger than the profit in the case where the fisherman uses non-selective gear. Moreover, the use of selective gear should result in a profit that is larger than a certain minimum level determined by the fisherman. The Government (acting as an insurance company) will calculate the insurance fee in such a way that it maximises profit (the Government may not pursue this objective ultimately) and make sure that the fisherman will choose selective gear.

In a voluntary system the fisherman may cheat, however, because he can hide information about discards, and then he will not have to pay the insurance fee. But if it is compulsory to pay a fee then he does not have to care because the insurance company will pay the penalty in any case. Therefore, there is no incentive for the fisherman to avoid discards, in the same way that there may be no incentive for people to avoid that the car is stolen unless the fee is fixed at a very high level. The system could be designed in a way that places a cost on the fisherman if he catches fish that are discarded in the same way as with cars, where an extra fee is paid if the car is actually stolen. This opens up for cheating because while it rather easily can be observed that a car really is stolen the fisherman will throw discards overboard in order to avoid paying this extra fee. This is more difficult to observe, and the discard problem is difficult to solve this way.

The model used in appendix C addresses this problem. The model is designed in such a way that the principal wants to maximise the long run economic rent from a fish stock and a tax is put on the individual fisherman, dependant on the change in the fish stock over a period, normally a year. If the stock is reduced the fisherman will have to pay an extra tax while he will receive a subsidy in case the stock grows. This means that the catches of the individual fisherman should be fixed at a level where the price of the fish is equal to the marginal costs of the fisherman, including the costs he inflicts on all other fishermen because of the marginal reduction in the stock size he causes. Because the principal does not know the change in the stock, he will have to work with an expectation of the change in his objective function at the beginning of the year.
The individual fisherman views the tax as a cost and he knows that the tax is dependant on the deviation of the stock size from the optimal stock size (which could be calculated in the biological assessment). The individual fisherman will know his own impact on the stock with a given tax rate and he will catch a quantity where his marginal profit from fishing, minus his own impact on the stock size (user costs) relative to the change in the cause by his catch, is equal to the tax rate. In other words he is not able to take into account the impact on other fishermen.

The principal will have to determine the tax rate at the beginning of the year and communicate it to the fisherman. In that exercise the principal will take into account not only the user costs of the fisherman in question but also the impact he has on other fishermen’s costs because of the change in the stock he causes. It is assumed that all fishermen reacts to the tax imposed on them in a responsible way.

The result is that the tax rate the principal communicates in optimum will be higher than the tax rate determined only based on the catches of the fisherman in question. Because the tax rate is communicated to the fisherman at the beginning of the season it has to be adjusted by the difference in the principal’s expectation of the marginal fishing costs and the real marginal fishing costs, which are not known until the end of the year.

The incentive to free riding for the individual fisherman is eliminated with such a tax system. However, it could be argued that the required information is substantial. This is correct if the tax rate is fine tuned and determined for each single fisherman. On the other hand, what is important in the tax formula is the impact on all other fishermen’s costs from the individual fisherman’s activity. Therefore the problem could be reduced to fixing a tax rate that is equal to the individual fisherman share of the total user costs from reducing fish stock relative to the optimal stock size.

References to Chapter 2


3. Economic Incentives and Effort Regulation

3.1. Introduction

The proposition of a principal-agent approach must be viewed against the background of the traditional proposals for regulating fisheries. One line of criticism against the traditional proposals is that they require substantial information to implement, see e.g. Clark (1985). This leads us to propose the principal-agent approach as the relevant method for developing a benchmark case for evaluating the economic incentives of quota management, effort management and fleet capacity adjustment. The principal-agent approach requires use of taxes and tax concessions (subsidies). Although taxes are very often opposed to strongly, e.g. Conrad and Clark (1994) this instrument used properly is probably more acceptable now than years ago. It should be pointed out that economic efficiency is the basis for the evaluation. The implication of this is that distributional issues are bypassed; see e.g. Anderson (1991).

In the analyses of the Danish and Dutch systems linear programming is used to investigate the optimal allocation and the shadow values. In the Italian case that analysis the effect of laying-up premiums the fishermen’s behaviour is evaluated relative to the subsidy they are granted and the expected net profit form continuing fishing.

Basically the following restrictions are included directly or implicitly in the analyses depending on the specific problem:

- A participation restriction. The agent has another option at his disposal.
- An incentive compatibility (self-selection) restriction. An implication of this restriction is that it is in the interest of the agent to report his true behaviour or type to the principal.
- Resource restrictions in terms of quotas based on biological assessment for DK and NL.

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4 The contents of the chapter is based on working papers carried out by: F.C. Buisman, W.P. Davidse and E.W.J. Hoefnagel (LEI, Holland); V. Placenti and L. Malvarosa, (IREPA, Italy) and H. Frost and F. Jensen (SJFI and SDU, Denmark). The reports are mentioned in the references list. Hans Frost is responsible for the use and interpretation of the working papers.
Although this is not always the case it is assumed here that the Member States adhere to the agreements at the EU-level, which makes it possible to exclude the EU-member state relationship and concentrate on the national relationship between managers and fishermen.

3.2. Application of the General Methology

3.2.1. The Self Selection Problem

With full information, the economic incentives that secure economic efficiency points to the following factors being important, Jensen and Vestergaard (1999):

- The marginal tax revenue
- The marginal compliance and enforcement costs
- The marginal value of the fish stock

If private and social costs and benefits differ, the solution to achieve socio-economic efficiency is to impose a correcting tax to reduce effort. In the current EU management policy the use of subsidies to reduce effort, in particular, by application of laying-up programmes is dominant. Disregarding budget effects the result would be the same. With imperfect information the tax/subsidy has to be levied on an observable variable in such a way that the agent has an incentive to act in the interest of the society (principal). The observable variables differ between fisheries. The subsequent analysis is associated with regulation of fishing effort being the observable variable and with the restriction that the catches must not exceed certain limits.

The solution of changing the incentives to achieve economic efficiency is to impose a first-best tax on effort where, in principle, also compliance and enforcement costs should be included. Compliance and enforcement costs are not included in this analysis, but the topic is addressed briefly below (cf. figure 3.4) to show that incentives to cheat occur, as the tax cannot be determined optimally in practice.

Theoretically, the optimal tax secures that marginal social benefit (MSB) is equal to marginal social costs (MSC) when the fishermen select effort. The marginal tax consists of the value of the marginal tax revenue (profit minus compliance and enforcement costs) and the marginal value of a fishery stock. The reason for including the marginal value of the fishery stock is to correct the externality that arises from the stock being a public input. This solution can be considered as a benchmark case.
against which the existing regulation can be evaluated. If it can be argued that MSB < MSC for e.g. total allowable effort in the current regulation, the current regulation produces wrong economic incentives.

Full information is, however, not the relevant paradigm for analysing effort management, since the manager often lacks information about:

- Catches (not equal to landings)
- Costs (both endogenous and exogenous costs)
- Effort (more specific: fishing time multiplied with capacity)
- Capacity (potential production power)
- Catch per day (mainly denoted productivity, sometimes also accessibility or catchability is heard)

If all the required information is available it is only a matter of imposing the correct- ing tax. To address problems about asymmetric information, first it must be identified if hidden action or hidden information problems are dominant in effort regulation.

Effort regulation is managed by allocating fishing days to each vessel. In an economi- cally efficient fishery the number of fishing days should be fixed according to the value of the marginal product and the marginal costs of a fishing day for each vessel, subject to the resource (target quota) restriction. Because the manager does not have this information, hidden information (adverse selection) is the dominant problem here. Moral hazard (hidden action) is not profound because the hidden action i.e. cheating with the number of fishing days is more difficult. It is relatively easy to monitor the number of fishing days.

An example of a hidden information problem arises within effort management where the manager’s objective is to control catches in order to maximise economic welfare. Controlling catches is in the interest of the manager because the fish stock size matters to him. He can observe total catches, but is unable to observe those for each vessel. He is able to observe effort i.e. number of fishing days, but he cannot observe catch per day that is the link between effort and catches. Therefore he cannot observe the value of the marginal product and the costs. The fisherman can choose the number of fishing days (endogenous variable) and he knows his own catch per day. The asymmetric information problem arise because this is unknown to the manager, and the manager has to find a way to get correct information in order to fix an optimal number of fishing days.
The individual fisherman can get a larger share of the fish stock (quota) if the manager underestimates his catch per fishing day (or year). If the fisherman keeps this information secret, the manager has difficulties in allocating the right number of fishing days to the fishermen. One option is to allocate the same number of days to all fishermen. The low catch per day (high cost per output unit of fish) fishermen would eventually go bankrupt and the target catches will, in the short run, be exceeded because the high productivity (high catch per day) vessels would catch more than expected by the manager. If the manager at the end of the year only knows that the catches have been high but not the distribution on vessels he is in the same position next year. A detailed monitoring and data collection programme may be a solution but may also be expensive.

In the long run it would be of benefit to society if the low productivity producers leave the industry, but in the short run the objective is to avoid catches in excess of the target quota managed by the number of fishing days together with a correcting tax or subsidy. In the principal-agent theory it is a restriction to keep the agents in business; this is controlled by the inclusion of the participation constraint. The incentive compatibility constraint on the other hand secures that the fishermen (agent) produces the kind of fish the principal wants. The manager has to find a system to make the fishermen reveal their true type. The value of the marginal product minus the marginal cost is the shadow price for the fisherman. The shadow price for the manager (society) is obtained by correcting the shadow price for the marginal value of the fish stock and, in principle, enforcement and control costs. The shadow price is then equal to the marginal tax per fishing day.

Suppose two types of agents are fishing: A low productivity and a high productivity agent. Apart from the factors under full information the following factors are important:

- The probability of being the low/high productivity type.
- The productivity (catch per day) difference between types

As explained below allocating fishing days to the two different types with the aim to obtain the optimal catches is not sufficient because shadow prices different from zero produces incentives to cheat. With full information about the number of fishing days those could be monitored, but the fisherman will still consider cheating if his shadow price per fishing day is higher than the penalty per fishing day. With full information the taxes could be levied correctly. But with hidden information a choice between
high and low taxes, i.e. same tax per fishing day multiplied with the number of fishing days, would make the low productivity agent select the low tax. But it would be beneficial to the high productivity producer to select the low tax as well i.e. saying he is a low productivity type. He will then be granted a lower number of fishing days than if he revealed his true type, but economically he could easily be better off because his profit less tax could be higher than in the optimal situation. If the high productivity agent calculates that the manager will impose a low tax on all fishermen because the manager is left with the impression that low productivity fishermen dominate, then the high productivity fisherman will very likely be better off. Furthermore, the incentive to cheat for the high productivity fisherman will be strong if the risk of being caught is low and the penalty small. This is shown in figure 3.1, 3.2, 3.3 and 3.4.

Suppose we start with that the manager has full information. In a fully adapted short run fishery vessel type 1 (high productivity) uses fishing days index 95, and type 2 (low productivity) uses fishing days index 70. This is determined by the intersection of the revenue of the marginal product (MP) and the marginal costs (MC) for each vessel type cf. figure 3.1. The total catch is 462 (say ‘000 tonnes), cf. figure 3.2 at fishing days index 95. Now suppose that the manager based on long term considerations wants to reduce catches to say 400. Reducing the number of fishing days for each group achieves this.

Reducing the number of fishing days produces positive shadow prices, which create incentives to exceed the number of fishing days. Therefore, the fishing days limit is accompanied by a tax to correct the incentive to derogate. Total catch of 400 is produced at fishing days index 74 for type 1, and 48 for type 2 with full information, cf. figure 3.2 (with tax type 1&2). Without full information the manager using the Type 1&2 catch curve as an estimate might have guessed at fishing days index 60 for each type.
With asymmetric information, all the manager knows is the catch volume of 462 (000 tonnes) of the species, and that two different types of vessels operate with different productivity (catch per day) levels that are known. Assuming homogeneous technology, he knows that costs per day are equal for both types of vessels but he has no information about how productivity is distributed on the two types of vessels. The vessel owner himself (the agent) knows whether he is a high or a low productivity type, and the vessel owner is able to choose the number of fishing days he wants to exert.

If the two types claim they are low productivity types, the manager is able to estimate the catch function Type 2* in figure 3.2. The manager knows, however, that this cannot be true. The real catch function, based on rational economic behaviour, is Type 1&2, and the manager must find a way to make the vessel owners reveal their true type. If the manager considers both of them low productivity types he (the society) cannot maximise catches subject to the catch restriction.
If the manager imposes a certain tax per day, cf. figure 3.2, to make fishermen choose and comply with the optimal number of fishing days, the optimal solution is 74 and 48 index days respectively for the two types. With a uniform tax per day some of the resource rent (infra marginal rent) is allocated to the fishermen. To extract the whole resource rent the tax should be calculated in a way that difference between revenue and costs (including normal profit). The tax – interpreted as the price for a certain number of fishing days is then the triangles between the curve of the revenue of the marginal product and the marginal costs cf. figure 3.3.

If the manager wants to allocate a certain number of fishing days (with or without an accompanying tax), the optimal allocation depends on the type of vessel. With the aim to provide incentives for the fisherman to reveal his true type a self selection constraint is introduced in the sense that that the compatibility constraint is interpreted to distinguish between two types of vessels rather than two types of production or products.
The tax collected from the two types consists of the fixed tax per day (the rectangle between MC and MC-tax) and the variable tax per day represented by vertically and horizontally marked triangles for the two types. It is clear that the high productivity vessels would never ask (buy) 74 index days because this would leave him with only normal profit. He would ask for 48 index days and pay the tax represented by the shaded area below the MP2 curve. Then he would get the infra marginal profit between the MP2 and the MP1 curves from zero to 48 index days. The principal (society) will lose out because the quota is not caught. The solution to the problem, according to the subsequent algebraic exposition, is to reduce the number of fishing days for the low productivity vessels to a level where the high productivity vessels would ask for the large number of fishing days. The society will also lose out from this solution but the loss will be smaller than the loss from all vessels choosing the low number of fishing days.
The solution is, therefore, a second best solution, and the tax developed below is a second-best tax for the case with asymmetric information about productivity types. Four things are worth mentioning in connection with this analysis.

First, the highproductivity agent must be allowed at least as high an effort level as the low productivity agent. Secondly, the principal extracts the whole surplus of the low productivity agent while the high productivity agent receives an information rent in the shape of a lower tax relative to what he would have paid with full information. This information rent is equal to differences in the value of the total product between types. Thirdly, the highproductivity agent must be allowed a higher effort level as under full information; this is parallel to a lower tax due to information rent. Fourthly, the effort level selected for the low productivity agent must reflect that the high productivity agent must be given an incentive to reveal his type correct. This effort level is lower than the level fixed with full information.

The optimal marginal tax below is developed based on Jensen and Vestergaard (1999). In the algebraic exposition it is assumed that the manager (society) knows that fisherman \( i \) belong to one of two types: a high productivity of type 1 and a low productivity of type 2. It is assumed that the manager has incomplete information about the type of fisherman \( i \), but he fixes a probability, \( \pi_h \) for \( h = 1, 2 \), to type \( h \). Assume that catches, \( h_i \), are linked to effort, \( e_i \), through the function \( e_i = q_i e_i x \), where \( x \) is the stock size and \( q_i \) is the productivity parameter e.g. catch per day if \( E \) is measured as standard fishing days. Furthermore it is assumed that the single crossing property is fulfilled which implies that \( q_1 > q_2 \). This property says that the vessel with the highest total catches also has the highest marginal catches, and it means that the iso-production curves for the high productivity vessel only crosses the iso-production curves for the low productivity vessels one time at the most. If this is not the case a second best optimum cannot be determined. The marginal product of effort is \( q_i x \) and the value of the marginal product is \( pq_i x \), where \( p \) is the output price.

As mentioned above in the graphical exposition, the incentive problem is that the high-productivity agent may pretend to be a low productivity agent, because he can benefit from this. The aim of the manager in order to maximise surplus to society is to design the tax system in such a way that there is an incentive for the fisherman to reveal his correct type.

It is assumed that the fisherman disregards any fish resource restrictions i.e. quota restrictions and maximises his profit net of taxes. Therefore fisherman \( i \) maximises:
Max \( (pq_i e_i x - c_i(e_i) - t_i(e_i)) \) \hspace{1cm} (3.1)

Where \( c_i(e_i) \) is the total cost function. It is assumed that the marginal costs are constant such that \( c_i'(e_i) = c_i \). The tax function is \( t_i(e_i) \). Note that the tax is variable in effort and that a non-linear tax function is assumed.

With effort as the choice variable, the first-order condition that maximises profit is:

\[ pq x - c_i - t_i'(e_i) = 0 \] \hspace{1cm} (3.2)

It is seen that the individual fisherman fixes effort where the value of the marginal product of effort equals the marginal costs, which includes the marginal tax.

Society is assumed to maximise the expected resource rent from the fish stocks in the long run. In the short run this resource rent should rather be interpreted as some sort of infra-marginal producer’s surplus arising from some fishing days being more productive than others.

The tax is imposed to correct the resource externality i.e. secure higher fish stocks in the future. Because the tax revenue could be used to alleviate tax distortion elsewhere in society leading to loss of welfare, the tax revenue is of benefit to society (double dividend hypothesis). Consequently, the manager’s objective function that maximises rent to society is in the case with two agents:

Max: \[ \pi_1(pq_1 e_1 x - c_1(e_1) + t_1(e_1)) + \pi_2(pq_2 e_2 x - c_2(e_2) + t_2(e_2)) \] \hspace{1cm} (3.3)

subject to: \[ f(x) - q_1 e_1 x - q_2 e_2 x = 0 \] \hspace{1cm} (3.4)

\[ pq_1 e_1 x - c_1(e_1) - t_1(e_1) \geq 0 \] \hspace{1cm} (3.5)

\[ pq_2 e_2 x - c_2(e_2) - t_2(e_2) \geq 0 \] \hspace{1cm} (3.6)

\[ pq_1 e_1 x - c_1(e_1) - t_1(e_1) \geq pq_1 e_2 x - c_2(e_2) - t_2(e_2) \] \hspace{1cm} (3.7)

\[ pq_2 e_2 x - c_2(e_2) - t_2(e_2) \geq pq_2 e_1 x - c_1(e_1) - t_1(e_1) \] \hspace{1cm} (3.8)
The natural growth of the fish stock \( f(x) \) determines the size of the fish quota. The implication of (3.4) is a steady-state equilibrium where the annual yield from the fish stock is equal to catches. Equations (3.5) and (3.6) are participation restrictions implying that the manager wants to keep the fishermen in business with positive (or at least zero) profit.

Equations (3.7) and (3.8) are the self-selection restrictions (incentive compatibility restrictions). They express that every fisherman must be given an incentive by correctly determined taxes to reveal their types. It is assumed that if e.g. a high productivity agent pretends to be a lowproductivity agent, he must also execute a lowproductivity agent’s effort, costs and catches and pay a lowproductivity agent’s tax level, cf. figure 3.3.

It appears from figure 3.3 that the high productivity agent is executing an effort level that is at least at large as the one of the low productivity agent \( e_1 \geq e_2 \). This is shown formally in Jensen and Vestergaard (1999). It is also shown that type 2’s participation restriction and type 1’s self-selection restriction is binding. The binding restrictions also appear from figure 3.3. It appears that the manager can only extract the shaded area below \( MP_2 \) and above \( MC \) or less if he wants to keep agent 2 in the fishery, while agent 1 would earn a positive profit here (participation restriction) if the manager extracts a tax revenue equal to the type 2 revenue. However, for agent 1 the decisive problem (binding constraint) is whether he acts as type 1 or type 2. This means that equations (3.6) and (3.7) from above are of interest. Rewritten in terms of tax:

\[
t_1(e_1) = pq_1e_1x - c_1(e_1) + p(q_2 - q_1)e_2x
\] (3.9)

\[
t_2(e_2) = pq_2e_2x - c_2(e_2)
\] (3.10)

Equation (3.10) indicates that the tax is designed in such a way that all the surplus of the lowproductivity agent is extracted. Equation (3.9) shows that type 1 receives a surplus (an information rent) since \( p(q_2 - q_1)e_2x < 0 \). This information rent is equal to the difference in the value of the total product between types. In figure 3.4 below this tax scheme is approximated by a constant tax per fishing day leaving information rent to both types but with the highest rent to the high productivity vessel. As shown in figure 3.4, an incentive not to reveal the correct type for the high productivity vessel may still exist with such a scheme.
When the manager considers the tax level, he has to include the fish stock (resource) restriction, which in practice is obtained by fixing catch quotas. Apart from being a self-selection tool the tax should also correct for overexploitation of the fish stock.

Looking at the manager’s objective function (3.3) the problem is addressed by substituting (3.9) and (3.10) into (3.3), a rewritten maximisation problem is obtained and a Lagrange function is constructed by the rewritten equation (3.3) and the fish stock constraint (3.4):

\[
L = \pi_1[pq_1e_1x - c_1(e_1) + (pq_1e_1x - c_1(e_1) + (pq_1e_1x - c_1(e_1) + p(q_2 - q_1)e_2x)] + \pi_2[pq_2e_2x - c_2(e_2) + (pq_2e_2x - c_2(e_2))] + \lambda[f(x) - q_1e_1x - q_2e_2x]
\]  
(3.11)

Where \(\lambda > 0\) is the shadow price (user cost) of the fish stock.

The first-order condition for the effort levels is:

\[
\delta L/\delta e_1 = \pi_1(2(pq_1x - c_1)) - \lambda q_1x = 0
\]  
(3.12)

\[
\delta L/\delta e_2 = \pi_2(2(pq_2x - c_2)) - \lambda q_2x + \pi_1(px(q_2 - q_1)) = 0
\]  
(3.13)

As the manager wishes to maximise benefit to society, the expected marginal benefits should be equal to the marginal costs. From the manager’s point of view, from type 1 agent (3.12), the expected marginal benefits consist of the marginal producer’s rent \(\pi_1(pq_1x - c_1)\) and the value of the marginal tax revenue \(\pi_1(pq_1x - c_1)\). These two items are of the same magnitude. The marginal costs further consist of the effect on the fish stock (\(\lambda q_1x\)) in the shape of future loss in yield.

In principal-agent models it is a standard result that the high productivity agent must be allowed the same level of effort as under full information, see Varian (1992). This effect does not apply to fisheries economics and the reason for this is the inclusion of the fish stock (quota) restriction in the maximisation problem. With asymmetric information type 1 must be allowed a higher effort than under full information, because an information rent must be granted to the high productivity agent, see Jensen and Vestergaard (1999).

For the low productivity type 2 agent there is an extra cost to the manager. Because type 1 is present and must be given an incentive to reveal his type correctly, the first-
order condition for type 2 (3.13) must be corrected with the difference in marginal products of effort between types, which is referred to as the marginal incentive costs. With reference to figure 3.3 this implies that the optimal allocation of effort (fishing days) is to the left of the intersection between MP2 and MC+tax.

From the manager’s (principal’s) point of view it is of interest to determine the optimal tax that take into account that the type of fishermen should be revealed correctly and that account is taken to the fish stock abundance.

The marginal taxes may be found by equating (3.12) and (3.13) respectively with (3.2) and rearranging:

\[ t_1'(e_1) = \frac{1}{\pi_1} \cdot \lambda q_1 x - (pq_1 x - c_1) \] (3.14)

\[ t_2'(e_2) = \frac{1}{\pi_2} \cdot \lambda q_2 x - (pq_2 x - c_2) + \frac{\pi_1}{\pi_2} (px(q_1 - q_2)) \] (3.15)

Equations (3.13) and (3.14) state the marginal taxes that are paid by type 1 and type 2 fishermen to the principal with optimal allocation of fishing days in a second best optimum, where first best optimum is the case where full information exists.

The marginal tax for type 1 consists of the marginal stock costs (shadow price) \( \lambda \) multiplied by the catch per effort unit effort \( q \), the fish stock size \( x \), and the reciprocal probability of being type 1 reduced by a tax equal to type 1’s marginal profit \( (pq_1 x - c_1) \), Jensen and Vestergaard (1999).

An interesting point is that the marginal tax revenue is less than the revenue equal to the shadow value of the fish stock i.e. for type 1 \( (\lambda q_1 x) \). This result occurs because the tax revenue for the principal is considered a benefit to society together with the production revenue from the exploitation of the fish stocks. This is a consequence of the double dividend hypothesis, and it is in the interest of the principal to allow higher fishing effort to increase total revenue relative to fishing effort corresponding to the solution where tax revenue is not considered of benefit to the principal (society).

For type 2, the marginal incentive costs \( \frac{\pi_1}{\pi_2} (px(q_1 - q_2)) \) are also included in the marginal tax revenue. This element is \( > 0 \), therefore his tax is adjusted upwards relative to the tax for type 1.
A particular problem in the CFP of the European Union is associated with the fluctuations in the fish stocks and temporary overcapacity in terms of fishing effort. In such cases, for stock recovery reasons, the aim is to reduce fishing effort temporarily. To do so subsidies are used, which effectively means that the compatibility restriction is changed to make it more favourable for the fishermen to choose the alternative action.

3.2.2. Derogation problems

If the manager tries to overcome the incentive not to reveal type, the manager could fix one single tax per fishing day as an approximation to \(1/\pi_1 \lambda q_1 x + \pi_1/\pi_2(px(q_1-q_2))\) in (14) and (3.15) and leave some of the infra marginal rent to the fishermen \((pq_1x-c_1)\) and \((pq_2x-c_2)\). This would not necessarily solve the problem as explained below – not exactly because the taxes are approximations but because, in reality, the high productivity type 1 agent may have an incentive to cheat. This is addressed briefly in figure 3.4.

The number of fishing days each vessel type is granted is equal to the number of days where \(MP = MC + \text{tax}\). The low productivity vessel has an incentive to state the correct number of days with the knowledge the fisherman has about his own economic performance. But the high productivity vessel still does not necessarily have this incentive. If he states he is a low productivity vessel, he would be granted a smaller number of fishing days relative to what he would have had, and the manager is not able to maximise economic rent because the total volume of fish would not be caught. In figure 3.2, the fishery takes place along the curve “with tax Type 1&2” with a catch of 328 (,000 tonnes). The manager would actually think that only 300 (,000 tonnes) is produced if all vessels are low productivity types with 48 fishing index days for each group.

The manager’s interest is to make an agreement with the high productivity vessels to make the vessels fish more, and that could be accomplished by offering some of the forgone profit (the rectangle between the MC+tax and MC from fishing days index 48 to 74) to those vessels. The high productivity vessel owner knows that because of bargaining position, and if he could be granted some of the tax revenue from fishing days index 48 and above he would reveal his true type. It could be argued that as soon as the manager realises that the total volume of fish is not being caught, the manager would be interested in an \textit{ex post} allocation of fishing days. In the \textit{ex post} situation the high productivity vessel will be in a rather strong position for negotiations.
There are other reasons for the high productivity vessel not to reveal the true type. If the manager considers him type 2, a relatively small derogation (excess) from 48 days will contribute substantially to his profit if monitoring and control is costly, and therefore not very strict. In the example in figure 3.4, the number of fishing days only has to be exceeded by about 15% to break even with the extra producer’s surplus he would obtain from legal fishing.

Let us focus on differences from the full information problem. Three differences arise. First a self-selection restriction is included in order to secure optimal selection of type. The implication of this is that the high productivity agent must be allowed an “information rent” to secure that the agent does not pretend to be a low productivity agent. Secondly the optimal marginal tax for both types must reflect the probabilities for various types. This result runs contrary to the traditional principal-agent result; see Varian (1992). In Varian the high productivity agent is taxed in the same way as un-
der full information. The reason for this difference in results is the inclusion of a fish stock restriction. Lastly, the optimal marginal tax for the high productivity agent must be corrected with the cost differences between types, if any. The reason for this correction is that the high productivity agent must be given an incentive to reveal the correct type.

It was postulated above that hidden action in effort regulation was not a serious problem. Hidden action arises in an effort regulation system where it is in the interest of the fishermen to change fishing behaviour i.e. target species after the agreement about the number of fishing days has been carried through, or to misreport catches and discards. In this case catches must be taxed and the incentive compatibility restriction must be designed to secure that the fishermen choose the right species. In effort regulation there are no incentives to misreport catches because these are not restricted unless some legal restrictions interfere with the nature of the fishery. The question about species composition is rather a hidden information problem because the fisherman knows his own catch composition and it is a matter of making him reveal what species he targets by inclusion of a self-selection restriction for species. A hidden action problem would occur if the fisherman stopped fishing after the tax had been paid and the number of fishing days allocated. That would entail a loss to the manager (society), but this would only happen if the tax would be reimbursed to the fisherman if he stopped fishing; refer to the situation of the bicycle theft where the agent is compensated by the insurance company if the bicycle is stolen unlocked.

As mentioned above, a problem that faces the CFP of the EU is how to reduce fishing effort temporarily for stock recovery reasons. The lack of balance is a result of variations in stock recruitment and growth, and the objective of the manager is to reduce effort in the cheapest way by use of subsidies. In a sense this is a special case of figures 3.3 and 3.4 because the manager does not know the fishing effort of the each vessel. Is it possible to design a subsidy system that secures that the low productivity vessel does not claim it is a high productivity vessel and thereby receive a laying-up premium that is higher than its net productivity? This is the problem of the Italian case study included in this report.

3.2.3. The fleet segments
It is not an easy task to apply principal-agent theory and methods directly to fisheries because of the very complex way most of them are managed. Given the resource limitations of the project, cases from practical fisheries have been selected with respect to
effort regulation although effort limitation does not occur in any country as the only mean. The choice of case in each country has been determined by the relevance of the problem with respect to possible management decisions and data availability.

Economic incentives with respect to effort regulation have been investigated for:

- The Netherlands
- Denmark
- Italy

Effort limitation is not the only mean to restrict fishing activities in any of these countries, and the conditions in the countries are different. In Denmark and the Netherlands focus has been placed on optimal allocation of effort and associated shadow values indicating possible incentives to circumvent effort regulation. If shadow values are not neutralised fully, incentives not to comply fully with the managers’ wishes still exist.

In Italy effort regulation is investigated with respect to optional suspension of effort i.e. how much should be granted to the fishermen to make them choose not to fish as opposed to fish, and to what extent the fishermen react to the offered grants.

3.2.4. The Dutch beam trawler fleet
The beam trawl fleet is the most important fleet segment of the Dutch fishing fleet. The main target species for this fishery are sole and plaice. The fishery is restricted by ITQ’s for sole and plaice. All beamtrawl fishermen have small bycatch quota for roundfish. Other important bycatch species are turbot, dab and flounder. On average, bycatch species represent about 30% of total revenues.

Fishing effort is restricted by fishing days. Each fishing vessel is allowed to fish a certain number of days per year.

Catches per unit of effort usually to differ throughout the year. The same applies for prices of sole and plaice. Hence, the optimal allocation of fishing days over the year from an economic point of view is not immediately clear. In practice, fishing effort is distributed more or less evenly over the year. Buisman, Davidse and Hoefnagel (2000) have examined the optimum distribution of fishing effort over the year from a short term economic point of view in order to see what kind of economic incentives
may influence the strategies of vessel owners and whether they are in line with the collective long term interest of stock conservation. This refers in particular to the fishing effort in the spawning time for plaice. It is often argued that, in order to promote stock development, this effort should therefore be limited during the first quarter of the year. Sometimes it is also argued that this would be optimal from a short term economic point of view, because during spawning time the quality is poor and prices are low. Buisman, Davidse and Hoefnagel (2000) also aim to give more insight into this question.

3.2.5. The Danish Baltic Sea cod trawler fleet

The most important way of regulating the selected Danish case: the Danish cod fishery in the Baltic Sea in the short run is by ration limitation. Restriction in the number of fishing days is not used directly but is derived from the ration limitation system. Catch rations are viewed as proxies to fishing days in this context.

The system implies that the annual quota for a specific management stock (area) is subdivided into smaller rations be it on a monthly, a fortnightly, or a weekly basis. The general rule is that it is not allowed to start fishing on next period’s ration until the start of the next period, if the ration for the current period has been caught. A vessel can shift between fisheries only if the ration for the current fishery has not been caught. The most comprehensive management of stocks and fleets takes place for the Baltic Sea cod fishery. For the Baltic Sea a permit to catch cod is required. Once a permit is granted the vessel holding the permit must not fish outside the Baltic Sea. With a permit two choices exist:

- Ration fishery or
- Annual individual non-transferable allocations.

The main difference between the two systems is the planning period. While the annual allocations make it certain for the fisherman how much he is allowed to catch and when, the rations may change over time and the ration for one period cannot be transferred to other periods.

The rations differ over time. The Danish Fisheries Directorate fixes the ration based on proposals forwarded by the Danish Fishermen’s Association. The initial rations for various vessel sizes are changed through the year according to the exploitation rate of the total quota.
The annual allocation is the property right of the fisherman/owner of the vessel. It is not transferable, however. Possibilities for adjustments are built into the allocation. In brief, the vessels that have caught at least 80% of the initial allocation before June 10th are granted, if applied, additional amounts. If the vessel does not catch the allocated annual quantity, a reduction may be applied in the subsequent year, cf. Frost and Jensen (2000).

The Danish pelagic fishery conducted by large trawlers was investigated in Jensen (2000). It examined what impact output regulation will have on an industry of multiple outputs where production of regulated and unregulated outputs are combined. The industry’s response to output regulation is critical depending on whether the regulated and unregulated outputs are produced as complements or substitutes in the production process. The elasticity between restricted and unrestricted outputs measure the output transformation in the regulated industry. Applied on a regulated fishery that consists of revenue maximizing firms the paper examines how a tightening of the output regulation will affect the exploitation of the unregulated fish resources. The applied methodology is regression analysis contrary to linear programming that was applied in the other Danish case and in the Dutch case. For results refer to Jensen (2000).

3.2.6. The Italian Tyrrhenian bottom trawler fleet
In Italy the fishing effort reduction measure through temporary suspension of the fishing activity takes on different characteristics according to the reference areas. With respect to bottom trawlers and mid-water pair trawlers, the regulation provides for a 45-day suspension of the fishing activity. The regulation on temporary withdrawal has been substantially changed over the years both with respect to the duration of the suspension of the activities and to the nature of the suspension itself (compulsory or optional). This measure is differently enforced on the Adriatic and Tyrrhenian coasts. The main difference relates to the nature of the suspension: compulsory suspension for vessels operating along the Adriatic coast, optional suspension for the other vessels. The reference period varies as well. Usually suspension covers the months of July and August in the Adriatic area and September – October in the Tyrrhenian and Ionic area. The reproduction period of the species living in the Italian coastal area is in fact very long and diversified.

The application of the P – A model limited the range of choices. The Italian case study, chosen for this research, was the case of the vessels holding bottom trawler licenses only and operating in the Tyrrhenian Sea as:
The only temporary suspension measure is the one associated to bottom trawlers, mid-water pair trawlers and dredges; the latter two fishing gears are mainly performed in the Adriatic sea; it is meaningless to include into the P – A model a compulsory suspension (as in the Adriatic sea),

The temporary suspension measure is mainly aimed to recruit stocks of demersal resources mainly caught by trawl nets. Multipurpose vessels and small-scale fishery vessels usually use this equipment also. However, as there is no temporary suspension measure regulating the activity of the vessels using these fishing gears, we were forced to choose vessels holding bottom trawler licenses only, cf. Placenti and Malvarosa (2000a) and Placenti, Cupo and Malvarosa (1998-99).

3.3. Specific Methodology

The specific methodology used in the cases of Denmark and the Netherlands is linear programming, which is a restricted optimization procedure that complies with the nature of the principal-agent model. This methodology allows, in principle, to include participation restrictions. This is not done in the model, however, because of lack of information about how many vessels were actually participating in the fisheries. Many vessels participated temporarily and were not easy to identify. The aim was to construct a model that makes it possible to calculate shadow prices and optimal allocation of fishing days and, in the Danish case, number of vessels due to lack of information about the actual number of vessels and the individual vessel allocation of rations.

In the Italian investigation the model is designed to investigate why some fishermen accept premiums while others do not, although the observable characteristics of the vessels are the same. The two model approaches are separate in the sense that the linear programming model investigates incentives from an apparently full information outset while the Italian model more clearly works with asymmetric information. In both cases the wish is to make fishermen act the way the principal wants.
3.3.1. Restricted optimization model for the Dutch and the Danish cases

In fisheries where constraints are imposed, hidden values (shadow values) are created. Those shadow values reflect that the fishery is not allowed to adjust to the point where marginal revenues are equal to marginal costs. The shadow value shows the contribution to profit with an extra fishing day.

Further complications arise in a system where the principal (manager) and the agents (fishermen) share the same objective: to maximise profit, but where maximising is subject to different constraints.

The fisherman’s objective is to maximise profit $\pi$ of his vessel. For a vessel in fleet segment $k$:

$$\max_{\pi} = \sum_{tij} (p_{tijk} * q_{tijk} * NOFD_{tij} - cd_{tij} * NOFD_{tij} - cv_{tij} * p_{tijk} * NOFD_{tij} - c_t * q_{tijk} * NOFD_{tij} - cf_t)$$

(3.16)

The principal’s objective is to maximise profit $\Pi$ (rent) from the whole fishing ground, therefore the principal’s function also includes the optimal number of vessels:

$$\max_{\Pi} = \sum_{tij} (p_{tijk} * q_{tijk} * NOFD_{tij} - cd_{tij} * NOFD_{tij} - cv_{tij} * p_{tijk} * NOFD_{tij} - c_t * q_{tijk} * NOFD_{tij} - cf_t) * V_k$$

(3.17)

Where:

- NOFD: number of fishing days per time period
- V: number of vessels

and

- $p$: price on species $i$
- $q$: catch per day on quarter, species, vessel segment
- cd: cost per day at sea coefficient (fuel, provision, etc.) on fleet segments
- cv: landing value cost coefficient
- cl: landing volume cost coefficient
- cf: fixed costs per vessel on fleet segments

---

Indices are:

t: quarter
i: species
j: fishing area
k: fleet segment

The next restriction is a participation restriction. But in the optimization it is allowed that vessels with positive profit are expelled because other vessels are more profitable. An additional participation restriction could be included, namely that all vessels fishing currently with positive profit should be allowed to continue. This is not done, however, in this calculation:

\[ \pi, \Pi > 0 \quad (3.18) \]

The fisherman’s constraints are physical and economic constraints. In the short run in this calculation the time period are fixed at quarters, therefore:

\[ \text{NODFD}_{tk} \leq 90 \quad (3.19) \]

Where NOFD is days per quarter; measured in days at sea the maximum number of days is even lower per quarter than 90.

Other restrictions imposed by the manager are designed to control the amount of capital e.g.:

\[ V_k \leq U_k \quad (3.20) \]

Where \( U \) is the maximum number of vessels in a segment for one reason or another.

Finally, contribution to the margin in the short run and the profit in the long run has to be larger than zero. Otherwise the fisherman will not continue.

In a system where effort regulation is applied, the constraints differ for the fisherman and the manager. The fisherman faces a limited number of days per time period while the
manager faces a resource constraint expressed in fish stock yield per species. Further, the manager’s restrictions are that the quotas must not be exceeded:

\[
\sum_{i,j,k} q_{i,j,k} \cdot NOFD_{i,j,k} \cdot V_k \leq Q_{ij}
\]  

(3.21)

Given the assumption the model produces a first best optimum in the sense that economic rent is maximised for the Danish case. With proper participation restrictions the optimum is rather second best because total adjustment is not allowed. In some sense this is the basis for the Dutch calculations.

3.3.2. Principal-agent model for the study of Tyrrhenian bottom trawler fleet

The aim of the Italian methodological approach is to demonstrate that in the principal–agent model the fishing effort reduction measure (temporary suspension of the activity against economic incentives of continued fishing) can give rise to adverse selection phenomena. For a theoretical analysis of the bonus scheme within the principal-agent model, the definition of the subjects involved and of their targets is crucial.

The principal is the subject which, in order to achieve his objective, has to induce the agent to adopt a given behaviour. To adopt a given behaviour is based upon the contract proposed by the principal and the acceptance of the agent.

The methodology is to construct a management model of the fishing policy in which the degree of “co-operation” of the operators plays a crucial role. In order to achieve its target, the principal sends a signal (premium or allowance) whose aim is to induce the agent to adopt behaviour consistent with the achievement of the pre-set targets. The agent will then evaluate whether to accept or decline this signal; the target will be achieved if the principal has defined the signal properly. A proper signal is the signal that, meeting the agent’s expectations, will induce him to accept the contract proposed by the principal. The principal who sets the target proposes the contract.

The analysis of the case study must then start from the principal’s target function (reduction in the fishing effort to minimise catches). The principal pursues this target also by granting a premium to the agents accepting the contract.

---

6 Based on Placenti, V. and L. Malvarosa (2000)
The target function will then be:

\[
\text{Min} : Y \quad (3.22)
\]

with the constraint

\[
P \geq Y \quad (3.23)
\]

where:
Y: income from catch of demersal species;
P: premium or allowance granted to the vessel (agent) accepting the suspension of the activity (contract).

The constraint is included in the principal’s target function allowing for a rational process, i.e. the agent will not accept the contract if the premium will not be at least equal to the potential income that it could gain during the suspension period.

The identification of the value of P, will be the result of the minimisation of (3.23). For (3.23), the prime derivative of Y and P against D (fishing days) is calculated and assumed equal to zero:\n
\[
\frac{\Delta Y}{\Delta D} dY - \frac{\Delta P}{\Delta D} dP = 0 \quad (3.24)
\]

therefore

\[
\frac{\Delta Y}{\Delta D} dY = \left( \frac{\Delta P}{\Delta D} \right) dP \quad (3.25)
\]

This means that the minimum point of the target function, against D (fishing days), will correspond to the level of D where the premium and income variations with respect to each agent are equal.

To calculate the premium the principal should theoretically allow for this variation (elasticity). If we impose a linear relationship between income and fishing days, the average variation in income will be equivalent to the marginal variation. The analysis will then be made based upon the average income per unit of working days on board (fishing days).

---

7 Also the premium P, being related to income, will be a function of D.
For the agent to be induced to accept the contract it is necessary to give him an allowance balancing the suspension period (45 days), the loss of income and the loss of interest accruing as result of any delays in granting the premium.

Income loss will be equal to:

\[ C = \sum_{i=1}^{n} Y_i (1 + s)^{-(i-1)} \]  \hspace{1cm} (3.26)

i.e. the agent’s opportunity cost where:

- \( n \): days of suspension of the fishing activity;
- \( Y_i \): potential income of the \( i \)-th day;
- \( s \): discount rate calculated on a daily basis.

The principal’s calculation is based on a capitalisation operation on \( C \) for the period \((n-1)+t_p\):

\[ C_p = c'(1 + r)^{(n-1)+t_p} \]  \hspace{1cm} (3.27)

Where:

- \( C_p \): present value of the discounted income flow for the suspension period;
- \( r \): interest rate on public investments (return on treasury bonds), calculated on a daily basis;
- \((n-1)\): capitalisation period from the beginning of the suspension period \((n-1)\) to the end
- \( t_p \): is the “delay” - \( \text{vis-à-vis} \) the conclusion of the suspension period – in granting bonuses (a delay taken into account by the principal).

The agent will accept the contract only if the premium granted by the principal will balance the income losses resulting from its temporary withdrawal from the activity, also allowing for the delay factor. The premium expected by the agent is the result of a logical process similar to the one made by the principal. However, while the principal calculates the premium based upon average values, the agent will calculate it based upon his own information (elastic average value).

The agent will expect a premium equal to:

\[ C_a = c''(1 + r)^{(n-1)+t_a} \]  \hspace{1cm} (3.28)
where the difference, compared to (3.27), lies in the figures (elasticity value) of each single agent and in the agent’s anticipation of the value of the delay factor. In fact, while \( t_p \) denotes the delay expected by the principal and allowed for in his planning of the activity and of the structure of the bonus grant systems, \( t_a \) denotes the previous delay experienced by the agent.

If the agent’s evaluations are based on economic factors, the condition of acceptance of the contract will be:

\[
C_a \leq C_p
\]  
(3.29)

Actually, \( C_p \) is equal to the bonus established every year by ministerial decree and granted to the units accepting the temporary withdrawal. This decree also provides for the application period of the measure hereinabove.

The acceptance condition in (8) will then become:

\[
C_a \leq P
\]  
(3.30)

where the bonus \( P \) is calculated in compliance with the regulation in force on temporary suspension of the fishing activity.

The assumptions underlying this methodology of analysis are:

1. The agent perfectly knows the value of its opportunity cost \( C \);
2. The acceptance condition is based on economic evaluations only;
3. Information about variation in opportunity costs may not be properly transferred to the principal; this might be due to a voluntary behaviour of the agent or to faults in the information transfer channels. In case of not observed data the error may also be due to the estimation method used.

Once the values of \( C_a \) and \( P \) have been calculated with respect to each single agent, in relation to these two elements four situations can be outlined which will hold true provided that the assumptions listed hereinafter are correct:

1. if \( C_a \leq P \) and the agent accepts, rational behaviour from the economic standpoint
2. if \( C_a \leq P \) and the agent does not accept, there are non economic rationales
3. if \( C_a > P \) and the agent accepts, as 2.
4. if \( C_a > P \) and the agent does not accept, as 1.

3.4. Application

The questions addressed and discussed by applying the principal-agent method below on the various cases are how could contracts, e.g. transfer payments, be made between the manager and the fishermen taking into account that a) the manager wants to maximise economic rent from the fish resources b) the fisherman wants to maximise his own profit c) the participation restriction e.g. positive net profit (after coverage of all costs) and d) the self selection restriction (e.g. is the fisherman and the manager satisfied) is to be adhered to.

Although quite a lot of information is available in the Dutch and the Danish cases, still information is missing, or at least not used properly, about catch per day which is dependant on the accessibility coefficient.

3.4.1. The Dutch beam trawl fisheries\(^8\)

This fishery is investigated using linear programming in the short run situation where the “contract” between the manager and the fisherman is the number of fishing days and the individual quotas that are allocated to the vessel. The model is operated with only one representative vessel in two fleet segments because, in the Dutch case, the fishing activity is basically restricted on an individual vessel level contrary to e.g. Denmark. The questions raised are:

1. What is the optimum distribution of effort over the year for an average individual vessel given the constraints of ITQs and days at sea?
2. What is the optimum allocation of effort over two fleet segments from an industry point of view?
3. What is the optimum distribution of effort over the year for an average individual vessel given only the constraints of ITQs?
4. What is the optimum annual profitability for an average individual vessel if the limitations of ITQs and days at sea are lifted?

\(^8\) Based on Buismann, Davidse and Hoefnagel (2000)
Optimising over the first question provides information about the shadow value that faces the fisherman given that he reacts individually. The second optimization may be viewed from the manager’s chair because it provides information about collective activities of the two segments, which is in the interest of the manager in order to maximise rent. The third question concerns the participation restriction, and the fourth question concerns the issue of free fishing (open access), which provides information about over capacity problems under constant stock sizes.

The self-selection problem is not addressed directly. However implicitly we know from theory that the allocation of fishing days or quotas in a system where trade is not possible causes problems. In the Dutch case trade is possible and this aspect is not that important.

The assumptions the model works with are:

- Constant sole-plaice landings ratio within each vessel segment. The model uses catches per unit of effort, based on historical catch data, as input.
- Constant prices. The optimization is elaborated on basis of historical price data. In other words price flexibility is assumed to be zero.
- Prices and catchability of by-catch species do not influence the optimum distribution of effort. In the model by-catches are not considered. However, for all optimal solutions of the model, almost 30% less cost of extra quantities and proceeds should be added to total revenues in order to take the revenues from by-catches into account
- Discards are not considered.

The constant segment landings ratio entails that for the fishery as a whole the ration is not constant, but the individual fisherman is not able to change it. The manager may however change the overall ratio by the share or number of fishing days he allocates to each vessel segment. The manager is also able to influence the discard level in that way. The discard problem is in the context of the individual fisherman of interest in the sense that if discarding occurs then the fishery for each vessel segment may take place until all the vessel’s quotas are caught. In the model the difference between total catches of each species and the quota would be subtracted from the vessel’s gross revenue. Changes in prices over the year will influence the result of the optimization. It is, however, reasonable to assume that prices do not influence the behaviour of the fishermen very much because of the uncertainties with fishing.
The two segments that are included are:

Segment A: engine power > 2000 BHP  
Segment B: engine power 1500 – 2000 BHP

The results of individual optimization and collective optimization measured in terms of fishing days are shown in table 3.1. The results are based on the individual quotas for each vessel of each species in each segment. No discarding is taking place implying that the fishery stops as soon as one of the quota restrictions have been met.

<table>
<thead>
<tr>
<th>Table 3.1.</th>
<th>Comparison of results from individual versus collective short term profit maximization</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Individual profit maximizing</td>
</tr>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>Number of fishing days per year</td>
<td>175</td>
</tr>
<tr>
<td>Net profits</td>
<td>335</td>
</tr>
</tbody>
</table>

It appears that, given the conditions in 1997, the quotas and subsequently the number of fishing days are not determined correctly to realise a maximum overall profit. Obviously, there is room for self-selection problems if the market cannot adjust by quota trade. Given overall quota restrictions the manager wishes to reallocate the number of fishing days relative to what, at least, segment B wants. The participation restriction is fulfilled because the vessels operate with surplus.

Due to the total number of vessels and the quota restrictions the number of fishing days are smaller than what could be inserted. This gives rise to a shadow value for e.g. A at 2.02 in net profit per fishing day on average (given linearity equal to the marginal value per day). The net profit is after coverage of all costs operating costs. Whether this would give an incentive to cheat depends on the fisherman’s marginal income preferences.

Information about the participation restriction – when it becomes binding is part of the output from the optimization procedure. Apart from that it could also be investigated how the optimal allocation would be if the quotas are close to the lower limit for profitability.
If the quotas are reduced by 50% the optimal allocation of fishing days from the point of view of the manager differs from the original one with the same maximum number of fishing days in both situations. Segment A would deploy as much effort as possible in the first and the last quarter (45 and 51 days) while segment B would place most of the effort in the third quarter, cf. table 3.2. The net profit of segment A is calculated to 124 (compare with table 3.1) while segment B runs with negative net profit at –199. Gross revenue minus variable costs is positive, however, keeping the segment B in business in the short run.

| Tables 3.2. The reduction in number of fishing days following a 50% quota reduction |
|-----------------------------------------------|-----------------------------------|-------------------------------------|
| Optimal solution 1997 quota allocation | Optimal solution with 50% quota reduction | Max number of fishing days |
| NOFD | A | B | A | B | A | B |
| 1st Quarter | 45 | 46 | 45 | 0 | 45 | 46 |
| 2nd Quarter | 50 | 50 | 11 | 0 | 50 | 50 |
| 3rd Quarter | 51 | 52 | 0 | 52 | 51 | 52 |
| 4th Quarter | 51 | 23 | 51 | 7 | 51 | 52 |
| Year | 197 | 175 | 107 | 59 | 197 | 200 |

To investigate the importance of fishing day limitations relative to a situation with no fishing days, restrictions but only quota restriction, an optimization is carried out for each segment based on each segment’s individual quota. The result is shown in table 4.3. The maximum number of fishing days is fixed at 72 per quarter to avoid that the model solution places all the fishing days in the best quarter, which in practice is impossible. The segments have been optimised separately. It is noted that the number and distribution of fishing days differ from the result shown in the other calculations, which implies that information about catch per fishing day is important if limitation of fishing days is used.

| Tables 3.3. Effort under optimization of ITQ uptake |
|-----------------------------------------------|-------------------------------------|
| NOFD | ---- Optimal solution ---- A | B | ---- Max NOFD ---- A | B |
| 1st Quarter | 72 | 59 | 72 | 72 |
| 2nd Quarter | 30 | 72 | 72 | 72 |
| 3rd Quarter | 0 | 72 | 72 | 72 |
| 4th Quarter | 56 | 0 | 72 | 72 |
| Year | 158 | 203 | 288 | 288 |
The landings are equal to the quotas as shown in table 3.4. This is not a surprise because the number of fishing days is calculated from the vessel quotas. The relevance of table 3.4 is rather that it shows a long run feature, namely the potential capacity of the vessel if it is fully deployed. This appears if the result in the left hand side of table 3.4 is compared with the right hand side.

<table>
<thead>
<tr>
<th>Landings</th>
<th>Individual quota restriction without fishing day restrictions</th>
<th>Fully employed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>------------------- A ------------------- B ----------------</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total (tonnes)</td>
<td>QUOTA (t)</td>
</tr>
<tr>
<td>Sole</td>
<td>71</td>
<td>71</td>
</tr>
<tr>
<td>Plaice</td>
<td>194</td>
<td>194</td>
</tr>
</tbody>
</table>

The excess capacity seems obvious. Whether there would be an incentive to increase effort above what is equal to the quota cannot be concluded from these figures however. It depends on the vessel owner’s marginal income preferences. If his preferences approach zero at least after all costs over the year have been covered, no incentive would exist. If his marginal income preferences are positive an incentive to continue fishing is apparent. This type of problem is the subject of the Italian approach.

The model outcomes from the 1998 data confirm the conclusion that short term individual incentives seem to be in contradiction with the long term collective interests of stock conservation since a good catchability in spawning time for plaice generally more contributes to optimal profits than good prices.

3.4.2. The Danish Baltic Sea cod trawler fleet

For the Danish case the same type of calculation as for the Dutch case has been carried out. The difference is however that in the Danish case the optimization takes place over the number of fishing days and the number of vessels. In the Danish case it is not possible to calculate the optimal number of fishing days and the distribution over the year because the rations allocated to the various segments are higher relative to what they can actually catch in most cases, and the rations are adjusted frequently. It would have been possible to make the calculation for annual allocations (årsmængder) but information about the individual quotas were not available to the project.

9 Based on Frost (2000)
In this project, information is lacking about how many vessels actually participated in the Danish cod fishery in the Baltic Sea. Costs and earnings information and information about average catches per day were available for the selected fleet segments. Therefore, in some respects, the calculations do not comply with the participation constraint because the objective function of the manager allows the number of vessels to be reduced. With the expectation of overcapacity this means that a number of vessels “are not offered a contract”.

The incentives are calculated by use of an optimization model applied on catch, costs and earnings data for the Baltic Sea for 1997. The quota restriction is the total Danish quota for the Baltic Sea. The same basic assumption about constant catch composition within vessel segments and about prices as mention under the Dutch case also applies to the Danish case.

The model is linear in effort measured in days at sea. Therefore the fisherman will push effort to the physical limit, given the limitations in inputs of the vessel. It is assumed that the manager controls these inputs.

The model contains three fleet segments and five species groups. The catch composition of the fleet segments is made up of these species in different compositions. The model maximises the remuneration to the crew excluding the skipper/owner and the net profit. This is chosen because a collective decision between skipper and crew is assumed if derogation from the restrictions is going to be accomplished successfully.

The economic characteristics of the three fleet segments are displayed in table 3.5. Although not shown for the Dutch fleet segments, the organisation of costs and earning are similar in the Dutch and the Danish cases. Revenue and costs are shown for an average vessel, and the costs are distributed (dependant) on number of fishing days (NOFD), landings in volume (C(LAND)), value (C(VLAND)), crew (C(Wages)) and fixed costs (FC). Because the result is shown for one vessel in table 3.5, vessel profit (VESPROF) is equal to segment profit (SEGPROF) in the table.
The average landing composition on an annual basis per vessel is shown in table 3.6. With respect to the self-selection restriction, the attribute that signals difference is the length of the vessel. The length is easy to identify and monitor. There is, however, a rather big variation within the segments and further division would require investigations in what factors determine productivity (catch per day).

There are three immediate ways to restrict effort, either to restrict number of vessels or number of fishing days, or both. The optimal solution will reduce the number of vessels and maximise the number of fishing days in accordance with the quota restriction. In principle it is possible to fix the number of fishing days for each vessel in the same way as it is possible break the quota down on individual vessels. Without the adjustments allowed by trade the fishing day allocation would only by accident comply with the optimal incentive structure where marginal cost is equal to marginal revenue for each vessel.
The complexity of the problem may be illustrated further with respect to the two restrictions in the principal-agent approach: 1) the participation constraint and 2) the self-selection constraint.

On average all fleet segments comply with restriction 1) cf. table 3.5. If the number of fishing days have to be restricted and are allocated based on profit (or productivity) assuming linearity, most days will have to be allocated to the largest segment C. This would almost certainly entail that all quotas are not caught e.g. the manager is not maximising rent. Because the catch is composed of many species, the identification of type is not sufficient by using only length of the vessel. As long as catch restrictions are linked to the fish stocks, some relation that associates effort with the stock is necessary. The problem may be illustrated by looking at table 3.7. The table shows the productivity per fishing day on average for the three fleet segments in question. It appears that if measured in cod only fleet segment B is the most productive in all four quarters. Therefore they could claim the largest number of fishing days. Looking at table 3.7 again, the recorded high herring catches per day, not least in the 3rd and 4th quarter, reflects that it may be possible to catch the allocated quota, but because the big vessels have better opportunities many of them will actually not fish, e.g. the self-selection (incentive compatibility restriction) is not fulfilled.

The number of fishing days has to be associated with the number of vessels. But the number of days could be limited initially taking into account the size and the fishing patterns of the vessels. The vessels in the large segment C do not, in general, fish in the Baltic Sea from May until October; therefore the number of fishing days is fixed at a low level. With reference to the principal-agent method the low number of fishing days is based on knowledge about self-selection e.g. the manager knows the type, and he knows that the opportunity costs for these big vessels not belonging to the Baltic Sea are very high in those quarters. So there is no point in granting those vessels fishing days in advance.
### Table 3.7. Productivity measured as landing per day in Euro

<table>
<thead>
<tr>
<th></th>
<th>12-14m</th>
<th>14-24m</th>
<th>24m-</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Quarter Plaice</td>
<td>33</td>
<td>36</td>
<td>14</td>
</tr>
<tr>
<td>1st Quarter Reduction</td>
<td>43</td>
<td>52</td>
<td>1156</td>
</tr>
<tr>
<td>1st Quarter Herring</td>
<td>0</td>
<td>77</td>
<td>648</td>
</tr>
<tr>
<td>1st Quarter Cod</td>
<td>973</td>
<td>1689</td>
<td>1438</td>
</tr>
<tr>
<td>1st Quarter Other</td>
<td>193</td>
<td>279</td>
<td>105</td>
</tr>
<tr>
<td>1st Quarter All</td>
<td>1242</td>
<td>2133</td>
<td>3363</td>
</tr>
<tr>
<td>2nd Quarter Plaice</td>
<td>27</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>2nd Quarter Reduction</td>
<td>60</td>
<td>246</td>
<td>1763</td>
</tr>
<tr>
<td>2nd Quarter Herring</td>
<td>8</td>
<td>64</td>
<td>459</td>
</tr>
<tr>
<td>2nd Quarter Cod</td>
<td>541</td>
<td>1531</td>
<td>719</td>
</tr>
<tr>
<td>2nd Quarter Other</td>
<td>105</td>
<td>49</td>
<td>11</td>
</tr>
<tr>
<td>2nd Quarter All</td>
<td>742</td>
<td>1897</td>
<td>2952</td>
</tr>
<tr>
<td>3rd Quarter Plaice</td>
<td>23</td>
<td>25</td>
<td>0</td>
</tr>
<tr>
<td>3rd Quarter Reduction</td>
<td>70</td>
<td>480</td>
<td>376</td>
</tr>
<tr>
<td>3rd Quarter Herring</td>
<td>0</td>
<td>77</td>
<td>4534</td>
</tr>
<tr>
<td>3rd Quarter Cod</td>
<td>340</td>
<td>745</td>
<td>23</td>
</tr>
<tr>
<td>3rd Quarter Other</td>
<td>60</td>
<td>77</td>
<td>817</td>
</tr>
<tr>
<td>3rd Quarter All</td>
<td>493</td>
<td>1403</td>
<td>5750</td>
</tr>
<tr>
<td>4th Quarter Plaice</td>
<td>31</td>
<td>34</td>
<td>0</td>
</tr>
<tr>
<td>4th Quarter Reduction</td>
<td>87</td>
<td>660</td>
<td>376</td>
</tr>
<tr>
<td>4th Quarter Herring</td>
<td>6</td>
<td>121</td>
<td>4534</td>
</tr>
<tr>
<td>4th Quarter Cod</td>
<td>319</td>
<td>624</td>
<td>23</td>
</tr>
<tr>
<td>4th Quarter Other</td>
<td>137</td>
<td>128</td>
<td>817</td>
</tr>
<tr>
<td>4th Quarter All</td>
<td>579</td>
<td>1568</td>
<td>5750</td>
</tr>
<tr>
<td>Year All</td>
<td>3055</td>
<td>7001</td>
<td>17815</td>
</tr>
</tbody>
</table>

An optimization using linear programming shows that all segments use the maximum number of days apart from segment B in the first quarter, cf. table 3.8. The result is not straightforward compared to what would have been expected using table 3.7. The importance of identifying the type of vessels correctly with respect to productivity and with respect to restriction compliance is demonstrated by removing the restriction in the number of fishing days for segment C. Allowing for 75 days in all quarters would entail that segment B is driven out leaving 14 vessels in segment C and 269 in segment A.
An important tool in the determination of the possible behaviour and hence the allocation of effort (days and vessels) is the shadow values. The shadow values may also be important in the compliance process because taxes based on shadow values could substitute or at least support control and enforcement of effort restrictions. The following part is concentrated on the shadow values that are produced in the optimization process. Still information problems exist because the shadow values are estimated on average for the fleet segments.

### 3.4.3. Shadow prices and economic incentives

The result is shown in table 3.9 from the fisherman’s (agent’s) and the manager’s (principal’s) point of view. The table also shows the marginal contribution to the remuneration of labour (after fixed remuneration of capital) from extra vessels and fishing days. The solution is limited by the number of fishing days that is fixed by the manager for each vessel in each fleet segment but there are no other restrictions. Because only one vessel operates within each fleet segment the marginal contribution to each vessel is the same as the overall marginal contribution to the manager (e.g. the whole fishery). This will be the case until one of the resource restrictions is reached.

Given profit maximising behaviour of the fisherman he would add DKK 2.28 mln to the remuneration if he employed one more vessel of type C. If the type C vessel could be employed one more day in the second quarter he would add DKK 20.8 thousand. If the same vessel was employed in the third quarter no contribution was obtained; in this case because this type of vessel does not catch anything in the third quarter either because of natural variation in stock availability (physical restriction) or because opportunity costs (revenue from other fisheries) are too high.
Assuming profit maximising behaviour it is obvious that the fisherman would try to expand his fishing.

If the problem is considered from the manager’s point of view (principal), the results are different because of the fish stock limitations. From biological calculations the size of the fish stock and subsequently the yield is exogenously given. This is invoked in the model as restrictions for the whole fishery – in our case the whole Danish Baltic Sea fishery.

Given the resource restrictions and the catch compositions of the fleet segments, the optimal solution is the number of vessels and fishing days in the quarters as shown in table 3.9. The remuneration is different from the agent’s and the principal’s (manager’s) point of view because – given the restrictions – an addition of one more vessel in any of the segments would only lead to reduction in other segments from the manager’s point of view. The manager (sole owner) would have no interest in increasing the number of vessels, while this would be the case for an owner of a single or more vessels because he could earn more profit. There is a conflict of interest between the manager and the individual fisherman because the fisheries have to adjust subject to (different) restrictions.

### Table 3.9. Marginal profit and wages on single vessel basis with respect to fishing day restrictions

<table>
<thead>
<tr>
<th>Variable name</th>
<th>Solution value</th>
<th>Marginal remuneration from agent’s view DKK</th>
<th>Marginal remuneration from principal’s view DKK</th>
<th>Marginal remuneration per crew DKK</th>
</tr>
</thead>
<tbody>
<tr>
<td>NUMVES A 12-14m</td>
<td>1 &amp; 16</td>
<td>812189</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>NUMVES B 14-24m</td>
<td>1 &amp; 192</td>
<td>1925058</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>NUMVES C 24m-</td>
<td>1 &amp; 5</td>
<td>2284576</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>No of vessels 1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No of days at sea</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st Quarter A</td>
<td>55</td>
<td>7531</td>
<td>8308</td>
<td>3765</td>
</tr>
<tr>
<td>1st Quarter B</td>
<td>60</td>
<td>11587</td>
<td>-47559</td>
<td>3862</td>
</tr>
<tr>
<td>1st Quarter C</td>
<td>75</td>
<td>18318</td>
<td>28200</td>
<td>4580</td>
</tr>
<tr>
<td>2nd Quarter A</td>
<td>55</td>
<td>4191</td>
<td>8672</td>
<td>2096</td>
</tr>
<tr>
<td>2nd Quarter B</td>
<td>60</td>
<td>11192</td>
<td>137185</td>
<td>3731</td>
</tr>
<tr>
<td>2nd Quarter C</td>
<td>25</td>
<td>20805</td>
<td>67427</td>
<td>5201</td>
</tr>
<tr>
<td>3rd Quarter A</td>
<td>55</td>
<td>2533</td>
<td>4042</td>
<td>1266</td>
</tr>
<tr>
<td>3rd Quarter B</td>
<td>60</td>
<td>8499</td>
<td>523495</td>
<td>2833</td>
</tr>
<tr>
<td>3rd Quarter C</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4th Quarter A</td>
<td>55</td>
<td>3103</td>
<td>20911</td>
<td>1551</td>
</tr>
<tr>
<td>4th Quarter B</td>
<td>60</td>
<td>9178</td>
<td>947539</td>
<td>3059</td>
</tr>
<tr>
<td>4th Quarter C</td>
<td>60</td>
<td>28744</td>
<td>55324</td>
<td>7186</td>
</tr>
</tbody>
</table>

1) From the agent’s (1 vessel) and the principal’s point of view
The table further informs the manager that a change in fishing day restrictions e.g. allocating 61 fishing days to fleet segment B in the fourth quarter would contribute DKK 947.5 thousand in total subject to the resource restrictions. This is DKK 3.9 thousand per vessel in segment B while the individual vessel owner in this segment would think he would contribute DKK 9.2 thousand, cf. table 3.9.

The manager’s limitation with respect to the fish stock is shown in table 3.10. It is shown how much is caught of each species or species group and whether the quota limitation is exhausted or not.

<table>
<thead>
<tr>
<th>Species</th>
<th>Total catches</th>
<th>Marginal remuneration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plaice</td>
<td>628</td>
<td>0</td>
</tr>
<tr>
<td>Reduction</td>
<td>160000</td>
<td>22</td>
</tr>
<tr>
<td>Herring</td>
<td>27000</td>
<td>936</td>
</tr>
<tr>
<td>Cod</td>
<td>35000</td>
<td>6653</td>
</tr>
<tr>
<td>Other</td>
<td>2449</td>
<td>0</td>
</tr>
</tbody>
</table>

If the marginal remuneration (the Lagrange multiplier in constrained optimization) is positive the quota is exhausted and the figure shows the marginal remuneration of labour from one more tonne of fish. One more tonne of cod contributes DKK 6,653 equal to 6.6 DKK/kg. Reduction species contribute the least. Therefore a derived long run objective for the manager is to keep the cod stock in good shape.

3.4.4. The Italian Tyrrhenian bottom trawler fleet

The Italian case addresses subjects somewhat different from what is dealt with above, or in other words, the Italian case investigates within fleet segments and not as much between them. The information problem covers the fact that the preference scheme for all fishermen within a segment is not addressed sufficiently thoroughly using only one single measure applied on an average basis. It is observed in the Italian case that one single grant may not induce fishermen to stop fishing temporarily the way it was expected because the principal cannot identify the agents precisely. Auction schemes may function as a market-based measure to reveal preferences (information) but if the objective is to reduce fishing effort an auction scheme may not solve the problem.
anyway, because the link between fishing effort and the reason for accepting a grant is not established.

As the theoretical model of the principal-agent is consistent only with an optional management measure, the analysis was focused on a sample of vessels holding bottom trawler licenses only and carrying out their activity in the Tyrrhenian and Ionic waters in the year 1998.

After defining the case study, the investigation and model development was undertaken as follows:

1. First identification of the vessels included in the sample and participating in the temporary suspension of the activity in 1998 was carried out.

2. Then identification was made of the reference year for the calculation of the agents’ opportunity cost (foregone income from fishing), cf. below.

3. With respect to the year for which opportunity costs were calculated, identification was made of a sample of vessels with technical characteristics similar to those of the vessels included in the sample referring to the year 1998.

4. The opportunity cost of each single production unit was calculated, and the bonuses to be granted to the vessels which accepted the suspension of the activity.

5. Finally, with respect to each single agent, comparison between the opportunity cost and the bonus calculations was performed.

As regards item one with the aim to identify the vessels, which accepted the suspension of the activity in 1998, reference was made to the vessel note transmitted by each single analysis unit during the activity suspension period, i.e. from September 14th to October 28th.

As regards item two over the years in the Tyrrhenian and Ionic coasts suspension was both compulsory and optional. The first year, before 1998, in which operators were free to decide whether to participate or not in the temporary suspension of the fishing activity was the year 1995. To identify the reference year for calculation of opportu-
nity costs it was necessary to analyze a year where the temporary suspension was optional.

Vessels with tonnage, (GRT), outboard length (m.) and engine power (kW), which were not very different, compared to the vessels under investigation, were considered as being similar. Priority was given to size, in terms of gross registered tonnage; the second parameters for comparison were the vessel length and engine power.

For each vessel investigated the daily value added achieved in 1995 in September and October was calculated, usually the months covered by the activity suspension in the Tyrrhenian and Ionic Sea. Based upon this value the opportunity cost of each single agent (vessel) was calculated in relation to the biological rest days set out by the decree of 1998.

The opportunity cost is equal to the present value of the income flow, which can be obtained by each unit during the suspension period. The daily value added, which was calculated based upon the data of 1995, was adjusted to the increase in the cost of living, allowing for a percentage increase in prices, from September 1995 to September 1998, equal to 6.77%. The reference time-discounted rate is the official discount rate in force from April to October 1998, calculated on a daily basis. The resulting capitalization based upon the return of treasury bonds in force as of 31.12.1998, was calculated on a daily basis as well, cf. Placenti and Malvarosa (2000) annex I.A table I.2.

The suspension of the fishing activity for 1998 is regulated by ministerial decree of 16.06.98 providing for “the modes of implementation of the technical suspension of the fishing activities involving bottom trawlers and/or mid-water pair trawlers” and by the decree of 09.07.98, providing for the associated social measures to be addressed to the units which accepted the temporary suspension. This latter decree provides for three types of allowances: to the crew minimum payments per person, and to the ship-owner social security contributions and capacity adjustment premium depending on vessel size.

Based upon the information on the average number of the crew members, the allowance (premium) was calculated allowing for the composition of the crew; only one unit is considered to be the skipper, cf. Placenti and Malvarosa (2000) annex I.A table I.3.
The comparison between the agent’s opportunity cost and the premium granted to him by the national authorities in case of his acceptance of the grant, made it possible to evaluate what might happen should the agent’s decision-making process be based on merely economic evaluations.

According to the model, the agent who will be granted a premium higher or equal to his opportunity cost will accept the contract. It was then possible to check whether the real answer given by the sample vessels to the signal sent by the principal (acceptance or rejection of the contract) corresponds to the situation, which would occur in the presence of the assumed rational behavior.

Empirical evidence showed that the fishermen did not react uniformly according to the decision rules in chapter 3. Owners of vessels with similar characteristics showed different behavior. As a consequence of this project questionnaires were sent to the fishermen with the aim to explain reasons for this difference in behavior.

The analysis of the correspondence between the real situation and the situation assumed by the model led to the following conclusions:

1. The real situation and the economic rational answers correspond and is modelled correctly in 11 of the 22 cases under consideration; i.e., 50% of the cases. This means that the model of analysis can explain half of the cases. Three of them reproduce situation no. 1 (Ca ≤ P and the agent accepts) and 7 cases reproduce situation no. 4 (Ca > P and the agent does not accept). This means that agents have an economic rational behaviour only in 50% of the cases (see Placenti and Malvarosa (2000) Annex 1A, table I4);

2. Out of the five regions investigated, only in Tuscany the model holds true in 100% of the cases. The degree of correspondence between the real situation and economics rational answer in the Ligurian region is equal to 67%, followed by Lazio (44%) and Calabria (33%) regions. In the Campania Region, the answers given by the agents were just the opposite compared to the expected ones resulting from the application of the model.

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10 It was assumed that, in case of a premium slightly lower than the income that might be generated by the fishing activity, the agent decides to withdraw temporally from the activity, thus preferring a certain income (although slightly lower)- rather than an uncertain (but higher) income from fishing.
3. In the model exercise, 50% of the cases investigated reproduce situation no. 3; i.e. the agent accepts the contract despite that its opportunity cost, in some cases, is much higher than the allowance granted by the principal. Such behaviour suggests that the agent’s decision is not based upon economic evaluations only.

3.5. Conclusions and recommendations

Conclusions and recommendations have to be drawn in view of the institutional framework that applies. Certain difficulties arise here, mainly because the management system uses many different regulatory measures in combination with one another. However, one of the first conclusions that could be drawn is that this is actually a result of imperfect information, which requires not one but many measures to function. In theory it is possible to construct a tax/subsidy system that changes incentives taking into account imperfect information. However, many taxes/subsidies are needed, and it could be argued that proxies to those taxes/subsidies are some of the physical measures used. To narrow down the complexities of the system the chapter addresses the following issues:

- Information problems – what type?
- Can information be revealed?
- Economic incentives and command and control
- Could incentives be changed to increase economic rent from fisheries?

The problem with effort regulation from the manager’s (society or principal) point of view is to fix the number of fishing days in such a way that economic rent to society is maximised. It has been argued that in effort regulation hidden information (adverse selection) rather than hidden action (moral hazard) prevails. If the most broad definition of principal - agent is used: to make an agent do what the principal wants and if full information is available, it is possible to determine, for each single vessel, the optimal number of fishing days. This is where the value of the marginal product of a vessel as a function of fishing days is equal to marginal costs, taking into account the fish stock restrictions.

It is however very costly to collect all the required information and, therefore, the relevant case is a case where all the information is not available, i.e. the case of asymmetric information. It is argued and strongly indicated in the whole study that in general the current regulation is optimal only by accident because the marginal social
benefit is smaller than the marginal social costs. In effort limitation, physical restrictions in general such as fishing days, catch limitations etc., produce wrong economic incentives, which should be corrected.

With the aim to correct incentives, effort limitation measures must be accompanied by extraction of the supernormal profit earned by the fishermen because of the restrictions. If such extraction does not take place the system is in a state where economic gains from derogations are apparent, and this has to be accompanied by command and control measures, enforcement and penalties. In other words, a backwards-working system relative to the one where the supernormal profit is extracted right away.

Comparing the full information situation with the asymmetric information situation, it has been pointed out in the analyses that three differences arise. First, to secure optimal selection of type, a self-selection restriction must be included in the analyses to make the fishermen reveal their true type. The implication of this is that the high productivity agent must be allowed an “information rent” (tax concession) to secure that the agent does not pretend to be a low productivity agent. Secondly, the optimal marginal tax for the agent types must be adjusted with the probabilities for being one of the possible types. Lastly, the optimal marginal tax for the high productivity agent must be corrected with the cost differences between types, if any. The reason for this correction is that the high productivity agent must be given an incentive to reveal the correct type.

If information about costs and earnings and productivity (catch per day) is available for each single vessel it is only the administrative resources that put limits onto the determination of the number of fishing days. On the other hand the administrative costs are very likely of prohibitive size relative to the economic gains from better management. Improved management system with low demand for information is therefore still of big importance.

For the Dutch and the Danish case it is argued that combining optimization procedures such as linear programming with the principal-agent theory and methods may provide useful insight in fisheries. By itself the optimization procedure produces information about allocation of fishing days and vessels and shadow values, but the advantages of viewing fisheries in a principal agent context is the insight in the type of information needed and the way the information should be interpreted. By use of taxes and tax concessions/subsidies the fishermen would be given an incentive to reveal correct information about their type and activities.
Because of limited resources within management and data collection, often information for only representative vessels is available. When a particular vessel is applying for fishing days the immediate observable characteristics of the representative vessel could be compared to the observable characteristics of the applicant. As shown in the Italian case this is not enough unless productivity (or profit) is linked uniformly to the characteristics. Differences, economic and non-economic, may exist within the categories that are considered homogeneous. In those cases it is relevant to apply a system with tax concessions/subsidies that forces the applicant to think carefully about what he actually wants. The principal-agent approach with revelation of type is in this respect parallel to auctioning fishing away, but in an auctioning system the principal may not always know the background for the bid, and he may run into problems that are characterized by moral hazard implying that the principal cannot be sure that economic rent to society is maximized.

A system where the number of fishing days is allocated on an even bases to apparently homogeneous groups of vessels and then afterwards allowing the vessels to trade among each other may correct some of the problems, but the drawback with such a system is the windfall gains, which could be limited though taxes on such gains.

From the calculations of the shadow prices it is argued that if a fishery is not able to adapt freely, shadow values are created. Based on the assumption of rational economic behaviour the shadow values are considered indicators for incentives not to comply with the regulations. Command and control may solve the problem if the risk of being detected times the size of the penalty is larger than the shadow value. The incentives could be adjusted if a tax per fishing day is associated with the fishing days restriction. The magnitude of the tax could be calculated if productivity, cost and price data are available.

The Italian case proves that it is necessary to know the agent’s full preferences to be sure that they will react as expected. The circumstance that some fishermen accept and others do not indicate the preference map of the fishermen is not enlightened by vessel characteristics. In the cases of Denmark and Holland levies on fishing days have not been implemented. Traditionally, many attempts to circumvent the restrictions have been recorded. It is, however, yet to be investigated what impact a fishing day levy may have. A proper regulation requires economic information, and for areas where good economic information exists it is possible to calculate the magnitude of

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the levy. If that is supplemented with investigations about the view and reaction to the levies, a good basis is formed for improved regulation.

In addition to the variables taken into account, it is then necessary to identify the other variables that generate a different behaviour compared to the one outlined in the model. To this purpose a questionnaire was applied to the previous units under investigation containing questions aimed to investigate adhesion or lack of adhesion to the “contract” offered by the principal. Results reported are:

- Among cases of acceptance of the “contract” - 14 out of 22, the relevant motivation is the possibility to enjoy a rest from fishing activity even in 3 cases where the premium is lower than the opportunity cost (the real answer and the economic rational one do not correspond)

- Among cases of no acceptance of the “contract” - 8 out of 22, merely economic rationales prevailed, that are: (a) immediacy and continuity of income flow deriving from fishing activity; (b) in case of adhesion, a fall of fish prices at the restarting of fishing activity. Furthermore the disagreement of most Tuscany and Ligurian fishermen with the structure of the biological rest has to be considered.

Answers from questionnaires enabled us to reach a definition of another variable \( U \) resulting from the difference between the amount required by the agent to accept \( C_a \) and the offered premium \( P \). Then \( U \) represents utility of an economic good either monetary or non-momentary that will assume different features for each single agent. In fact, in the cases of acceptance of the contract, the positive value of \( U_{11} \) represents utility of the rest from fishing activity, that is the value that the agent attributes to the possibility to stop fishing for a period of time equal to the biological rest; for this he receives an allowance equal to the premium. This implies that even if the value of \( C_a \) is larger than the value of \( P \), the agent accepts because this difference represents for him the value of the rest.

It is straightforward to assert that the rationale of both principal and agent include an information problem. It seems also that the nature of the asymmetric information problem depends on the nature or genesis of the analysis. The microeconomic approach of the principal–agent theory cannot fit good results for a macro context.

fact, in the determination process of the premium, the manager (principal) takes into account medium values of the variables that influence the agent’s decision, that is, the representative agent.

The result of this process is the setting of a premium by the principal as a market signal, according to medium values that will not able to satisfy expectations of all the agents. Every single agent has, in fact, his own utility level related to the goods that make up his own consumption basket or welfare. In the Italian case study, rest and income from fishing activity have different values for different geographical areas and for different surveying units.

It can be concluded that there is not a single level of the premium, determined by the manager at national level, that can reach the result of a general adhesion to the “contract” – the temporary stop for biological rest. Only if the determination process of the premium is supplemented with investigations about each single agent’s utility, and his view and reaction to the current effort regulation, can a good base be formed for a better setting of a system of economic incentives based on market signals.

Managing by economic incentives relative to command and control is an interesting question. The work carried out in this project indicates that command, control and penalty could to some extent be substituted by a tax/subsidy system that corrects the economic incentives that are produced by wrong allocation of effort.

One of the disadvantages with command and control is the rather substantial amount of costs that are associated with detection of the crime (inspection costs), information processing, prosecution and trial.

At least detection of crime, prosecution and trial is avoided in an economic incentive system. Information collection costs and information processing may not be as substantial as in command and control, because with improved information the economic incentive systems move towards better information, which improves the functioning of the system. Correct incentives may also be considered a relief for agent and principals because the interest of the principal and the agents are brought into better harmony. Unless all supernormal profit is taxed, a properly working incentive scheme cannot be expected. It is a very complicated matter to introduce that in practice. Therefore, even with taxes wrong incentives are produced and derogations will occur, and monitoring and control is required. However, using the taxes and tax concession
in different ways seems to embody potentials for improvement, and it is worth considering how it is possible to proceed along those lines.

**References to Chapter 3:**


**Reference list of project papers for Chapter 3:**


**Papers presented at Conferences**

4. Economic incentives and capacity adjustment

4.1.1. Introduction
The aim of the paper is to focus on the significance of economic incentives in capacity adjustment policy especially under the Common Fishery Policy. In order to do so, it resorts to the principal-agent theory to investigate the broader dimension of "economic incentives under imperfect information" – the principal (managers) has imperfect information about the agents' behaviour. Economic incentives can be used by managers to induce particular responses or behaviours from the actors of the fishery sector. The problem is that actors are different in nature and pursue their own specific objectives, especially at European Union level where national administrations, fishermen organisations or simply individual fishermen are concerned with the implementation of the capacity adjustment policy. This policy has an economic incentives dimension. When trying to determine the minimum value of the premium which should be paid by the principal to the fishermen to leave the fishery sector, fisheries managers are faced with an economic incentives problem. Under the assumption of asymmetric information between principal and agents, the principal-agent theory can be helpful to define contracts which could lead to the adequate incentives to agents.

4.1.2. Definition of capacity and economic incentives
The definition of capacity is a critical issue for a capacity adjustment policy, but is subject to different approaches. If the objective is to harvest a target sustainable yield from the resource stock, capacity output as a production flow can be compared to this target and the corresponding level of capital stock determined (Kirkley and Squires 1999) but equating the capital stock to capacity requires some specific assumption. Input and output-oriented measures of capacity can be distinguished. An input-oriented measure considers how inputs may be reduced relative to a desired level of output, such as Total Allowable Catch. An output oriented measure indicates how output could be expanded to reach the maximum possible output level, given the capital stock and full or partial utilisation of variable input utilisation. However, the analysis of production technologies in the fishing industry harvesting multiple renewable resource stocks ( multispecies fishery) with multiple inputs leading to multi-

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12 The contents of the synthesis report is based on working papers carried out by: V. Placenti. L. Malvarosa (IREPA, Italy), A. Hatcher (CEMARE, United Kingdom), Régis Kalaydjian, F. Daurès and O. Guyader (IFREMER, France) The reports are mentioned in the references list, but the responsibility for the use and interpretation of the working papers is assumed by O. Guyader and R. Kalaydjian.
output production needs special attention in order to design adjustment in capacity. This question is not the purpose of this study.

As opposed to the other two major topics addressed in the project, i.e. quotas (output) and effort (variable input), capacity is a fixed input (or a capital stock) in the short term, whereas output and effort may vary much more rapidly. In theory, capital stock is considered as non-malleable in the short term. In practice fishing vessels can be considered more or less as a fixed input but all production factors that enable fishing firms to harvest (human capital, access rights, etc.) should be taken into account. Capacity is a stock but capacity adjustment is a dynamic process that can be positive or negative depending on the magnitude of entry or exit flows. The paper focuses primarily on reduction flows even if the problem of capacity increases is allowed for. Capacity adjustment policy can be viewed as a means to achieve accelerated change in expected outcome (stock recovery, fleet profitability, ...). Capacity adjustment is then used by the principal to resolve the imbalance between the current and the desired levels of capacity. At this stage, the question of time duration or more specifically the transition period to reach expected outcomes should be considered in the analysis.

In the project, economic incentives are viewed as a tool to incite (or deter) agents to take (or from taking) given types of decision. It is assumed that economic incentives differ from regulation in nature and can have a monetary or a non-monetary dimension. The economic incentives considered here are mainly of a financial dimension, e.g. subsidies given by the principal within the framework of a public policy. However, the question of the economic and institutional framework of the capacity adjustment policy has to be considered. First, the fishing industry is subject to a fluctuating economic environment specific to fisheries (stock availability, fish prices, etc.) but also to exogenous economic factors that may alter economic incentives to firms. Second, the institutional context, i.e. regulation and the fiscal and political components also induce signals to the agents that may modify the economic incentives provided by the principal in the context of capacity adjustment policy. Fisheries policy generally uses a number of tools to control or ration activity. Quotas, effort regulation, barriers to entry such as fishing rights allocation and transferability, have to be discussed as policy components that may influence a capacity adjustment process.

The implementation of decommissioning schemes and the financial compensation to fishermen who are led to decommission their vessels are the two critical issues, which will be examined in depth below, through the following questions:
What are the main features of decommissioning schemes?
How capacity reduction can be related to principal-agent theory?
How sensitive to economic (monetary and non-monetary) incentives is the willingness to leave the fishery?
What are the effects of capacity adjustment (decommissioning schemes) in function of the principal's information on the fishermen's willingness to leave the business?
What are the potential effects of different constraints on the principal expressed in terms of: budget rationing, delays of implementation, degree of control of the real fleet capacity considering technical progress, skill improvement, …?
What are the consequences in terms of cost-benefit or cost effectiveness analysis?
What are the advantages and disadvantages of different mechanisms of premium allocation, such as administrative and market driven allocation?

The paper is a synthesis of different contributions and is organised as follows. The first part deals with the implementation of decommissioning schemes and the objectives pursued by principals. Based on a review of institutional processes within the CFP, the second section intends to apply the principal-agent conceptual framework to the capacity adjustment policy. The problem of the lack of, or asymmetric, information is examined, as well as the question of policy coherence within the "structural policy" of the EU. The specific methodology to address the question of economic incentives in the context of decommissioning schemes is then described and case studies are presented. The latter provides the basis for the application of the specific methodologies and for the discussion on the effectiveness of the current economic incentives schemes. Finally, different experiences of decommissioning policy are reviewed in light of economic incentives.

4.1.3. Decommissioning schemes
Several countries have implemented vessel or licence withdrawal schemes for fisheries, including Australia, USA, Canada, the European Union, Iceland Norway, Japan and Taiwan. Such schemes, i.e. "Buyback programmes", are not specific to the fishing industry, and a number of components of public policy are implemented with the purpose of reducing capacity in other industries in Europe. For example, the agriculture policy, faced with slump in prices or oversupply, dedicates budget to buyback pro-

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Decommissioning schemes imply the vessel scrap or the allocation the vessel to another use. This is not always the case for buyback programme.
grammes in order to temporarily or definitely reduce the size of ground installation or crops (Bartoli and Meunier 1982). In a quite different context, in order to stimulate demand for new products, governments may give premiums to customers: this was put in place in France to boost the car manufacturing industry. Finally, buyback programmes may also target firms whose business has adverse environmental impacts.

The reasons for implementing buyout programmes in the fishing industry are diverse but are mostly linked to fish stocks being in a bad state or assessed to be close to depletion. More accurately, the different main objectives pursued by buyback programmes are:

- the conservation of fish stocks, especially when future recruitments are at risk,
- economic efficiency objective through fleet adjustment and rationalisation, and
- distributional objectives such as the redistribution of catch rights from one sector to another (from commercial to recreational activities in order to reduce conflicts) or exclusion of the fleets, especially distant fleets from fishing areas.

Transfer payment to the fishing industry also provides the impetus for such programmes. Buyback programmes can target many production inputs but most of them have focused on the capital stock, i.e. vessels, sometimes gear; the right to stay in business can be linked to the vessel or to both the vessel and gear (Holland et al. 1999). However, the implementation of these programmes, i.e. decommissioning schemes, may vary from one programme to another.

Different approaches to decommissioning schemes.

First of all, fishermen’s application for decommissioning can be either voluntary or mandatory. At least three fundamental mechanisms of premium allocation for decommissioning can be considered to select vessel units:

- Fixed or variable premium defined by the principal,
- Negotiated amounts between the agents or groups of agents and the principal,
- A tendering system with either Dutch or reverse auction or sealed bids organised by the principal.

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14 Due to the implementation of individual transferable quotas as a fixed amount and not a fixed rate of the TAC, New Zealand government has had to buyback quota to fishermen (Sissenwine and Mace 1992)
In the European Union, most of the countries except the UK adopt a system based on fixed rates, following directly EU guidelines (Frost et al. 1995) (Nautilus 1997). In the UK, vessel owners were invited to submit tenders which were ranked in terms of £ per vessel capacity unit (see below): this system is also applied in numerous countries around the world in order to minimise the cost of the decommissioning programmes. Whatever the system, the premium is defined in terms of capacity unit but the unit differs from a country to another: physical in most EU countries, monetary in Iceland where the insurance value is considered as an economic indicator of capacity (Klemensson 1998).

The question of qualification for the schemes is also a key issue for the selection of fishing units. The principal to discriminate between potential applicants may use different conditions. They define the a priori rules to qualify for the schemes and the a posteriori rules that the successful applicants have to comply with. Some programmes do not use specific qualification criteria whereas others relate qualification criteria to target objectives (catch composition, activity rate, …) of the decommissioning programmes. As the common objective of most decommissioning programmes is to reduce fishing mortality, indicators such as the level of historical catch per unit of premium offered are sometimes used as a way to improve the effectiveness of the plans. Thus, the agents are compelled to reveal the real or estimated impact of their harvest on the stocks.

<table>
<thead>
<tr>
<th>Tabel 4.1. Examples of the qualification criteria and rules</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A priori conditions to be accepted as an applicant</strong></td>
</tr>
<tr>
<td>Minimum % of specific species in fishing revenues or landings</td>
</tr>
<tr>
<td>Location restriction, licence restriction, size …</td>
</tr>
<tr>
<td>Share of the insurance value</td>
</tr>
<tr>
<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
This short review of decommissioning schemes shows that there are several ways of implementing capacity adjustment but the amount of budget dedicated to these programmes has a strong influence on the design of decommissioning schemes (Metzner and Rawlinson 1998).

4.2. The two-tier Principal-Agent relationship and policy effectiveness

The project views the Principal-Agent Approach as instrumental to study the role of economic incentives in the CFP. In a context of an enormous lack of information at management level, it is relevant to have a clear and structured view of the relationship between managers and the industry: originally based on a practical knowledge of the insurance market, the principal-agent theory is helpful in that, as well as it may be helpful in identifying the scope for improving policy effectiveness through incentives in general and in the CFP in particular.

In terms of management process, the brief chronological survey of the EU legislation shows that the relationship between the EC and member states is important (Kalaydjian 2000). The latter may eventually limit the scope of the EC's proposals in terms of capacity reduction. As shown in particular by the legal acts which followed the issue of the two independent reports (Gulland and Lassen reports), mortality objectives were recommended and effort reduction was proposed by the EC; Council decisions followed, adopting significantly lower capacity reduction objectives. Then member states implement the decisions and not all correctly fulfil in time their obligations in terms of both kW and GRT.

The negotiation process plays therefore an important role in the shaping and implementation of capacity management measures. In this context we suggest that there is a two-tier Principal-Agent relationship: at member state-industry level (let us call it the "lower" PA relationship); and at EU-member state level (the upper PA relationship).

The lower PA relationship is the classic one, where state regulatory authorities are seen as the manager, and the industry, the agent. Asymmetric information issues are raised by the difficulty for the manager to identify the nature of capacity and to measure it. The problem is also to give the right economic incentives schemes (e.g. premium) to incite fishermen to scrap their vessels. The upper PA relationship develops at EU level. The European Commission acting on the basis of both expertise reports

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15 Mainly based on Kalaydjian (2000)
and the EU legislation applying to fisheries represents the Principal. The EC has to verify the application of these rules, especially MAGPs, by member states. The latter, negotiating in the frame of the Council with both the other member states and the EC, can be seen as the agents which try to limit the regulatory constraints either by influencing legislation or by implementing it in a specific way (e.g., lag in the implementation of programmes) usually influenced by their own political constraints. Actually, this upper relationship is complicated as member states appear to have to comply with legal acts that they adopt themselves in the Council.

The global chart below is illustrative of this two-tier relationship. The starting point is the CFP objectives as spelt out in the Rome Treaty as amended later. "Intermediary objectives" result from the EC's proposal and are based on recommended mortality objectives: they lead to the capacity reduction objectives as proposed by the EC. The MAGP objectives result from these intermediary objectives and from negotiations at Council level. Then the implementation of programmes at national level, the national and regional aids/premiums in certain countries for decommissioning and construction, constitute the conditions under which the lower PA relationship operate and result in entry/exit decisions, with their effects on the state of stocks (biology, environment) and the economic situation of fisheries. The difference between real outcomes and expected outcomes in terms of intermediary objective measures the effectiveness of the scheme.

The literature distinguishes between two types of information problems that can be applied to the question of capacity reduction:

4.2.1. **Hidden actions (moral hazard)**

If the principal does not know what the agent will do after the contract has been signed, a hidden action problem arises. In such cases the design of the risk-bearing scheme is critical, as shown by insurance contracts. This situation seems to be relevant to capacity adjustment in the case of the upper principal-agent because the European Commission (the Principal), who has to bear the risk, does not have complete information about the real behaviour of each member state (the agent) and the willingness of each agent to fulfil MAGP objectives. In theory, the solution to this problem could be to reward the agent when he reaches the objectives or to sanction him if he does not respect the commitments of the contract.
4.2.2. **Hidden information (adverse selection)**

In this situation, the principal has incomplete information about e.g. the revenue (utility) or the cost functions of the agents or the production technology (production function). All what is known is that they are different and that the agent knows his own functions. Hidden information is relevant to capacity adjustment situations, especially decommissioning where the principal would like to allocate capacity reduction in an efficient manner but there is a lack of information about the economic situation of fishing firms and especially their willingness to leave the business. A classical "solution" to hidden information is "market signalling" where the agent is incited to reveal his economic type. In the context of the CFP, the problem of hidden information can apply to both the upper and lower principal-agent relationships.

In the first case, each member state, as an agent, is incited to give incomplete information on the real situation of its fleet in terms of capacity indicators. In the second case, fishermen are a heterogeneous population, and the member state responsible for the implementation of the capacity adjustment policy has incomplete information about the economic situation of the fishing firms (catches, effort, revenues, profitability, capacity). As these characteristics change over time, they can be all the more easily hidden, at least partly, by "agents", i.e. fishermen. Anyhow it is possible for the principal to get more detailed information on capacity; but the question is: at what cost?
This has obvious implications on the management of capacity by incentives. In the legislation, the European Council uses kW and GRT as capacity units serving to establish MAGPs. This has the advantage of simplicity and transparency; but to the detriment:
of a fine tuned regulation of capacity which would be more accurately based on experts' recommendations on fishing mortality, depending on stocks, and which would need to use/monitor a broader set of indicators, at a higher cost for the principal;

- of the efficiency of capacity management, as it is uncertain whether structural measures, if based on these classical capacity units, actually result in a significant decrease in capacity.

Hence there is a trade-off between:

- the cost of acquiring more information on capacity, and the efficiency and accuracy of capacity management

Both information and public policy issues compound the problem of capacity management. The information issue is related to measuring capacity and has implications in terms of a principal-agent approach. The policy issue is linked with the existence of a structural fund supporting the Commission’s structural and modernisation policy.

Policy effectiveness: capacity reduction vs modernisation
In 1993, MAGPs were integrated into a single structural fund, the Financial Instrument for Fisheries Guidance (FIFG), intended to include all measures taken to enhance the modernisation of the fleet. The purpose of the EU is to make FIFG consistent with the resource conservation policy: Council Regulation on the FIFG, adopted in 199916, stipulated that the tasks of the structural measures are, among others, "to contribute to achieving a sustainable balance between fishery resources and their exploitation" (art 1); and that "member states shall ensure that [their] fleet restructuring interventions under the FIFG are consistent with their obligations under the CFP and in the MAGPs" (art 2).

However, it could be useful to examine whether and how the adjustment of capacity on the one hand and modernisation on the other can go alongside one another and to what extent they may compete one another. But this is a difficult task. Technological progress is admittedly a factor of fishing capacity increase17, estimated at a yearly rate of 2%; one thus needs to decrease the total number of kilowatts by 10% in five

17 The report will come back to the technological progress issue in the simulation exercise (see below).
years if one wants to keep the "fishing capacity" of a given fleet more or less constant over the same period. Council Regulation of 17 Dec 1999 (see above) addresses the capacity adjustment vs modernisation issue and tries to set out arrangements where the two objectives could work together.

### Table 4.2. FIFG and state aids for 1994-1999

<table>
<thead>
<tr>
<th></th>
<th>Effort and capacity adjustment</th>
<th>Construction and modernisation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FIFG</td>
<td>National public funding</td>
</tr>
<tr>
<td>Belgium</td>
<td>5.2</td>
<td>5.2</td>
</tr>
<tr>
<td>Denmark</td>
<td>37.7</td>
<td>37.7</td>
</tr>
<tr>
<td>Finland</td>
<td>4.1</td>
<td>4.1</td>
</tr>
<tr>
<td>France</td>
<td>16.2</td>
<td>16.2</td>
</tr>
<tr>
<td>Germany</td>
<td>8.7</td>
<td>12.7</td>
</tr>
<tr>
<td>Greece</td>
<td>31.8</td>
<td>10.6</td>
</tr>
<tr>
<td>Ireland</td>
<td>5.6</td>
<td>1.9</td>
</tr>
<tr>
<td>Italy</td>
<td>104.6</td>
<td>104.6</td>
</tr>
<tr>
<td>Netherlands</td>
<td>9.5</td>
<td>9.5</td>
</tr>
<tr>
<td>Portugal</td>
<td>82.1</td>
<td>28.0</td>
</tr>
<tr>
<td>Spain</td>
<td>379.0</td>
<td>188.1</td>
</tr>
<tr>
<td>Sweden</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>UK</td>
<td>19.2</td>
<td>13.8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>707.5</td>
<td>436.4</td>
</tr>
</tbody>
</table>

Unit: million Euro at 1994 rates, 1995-199 figures for Finland and Sweden
Figures exclude overseas territories
Source: DG XIV.

Finding a compromise between FIFG and the objectives of MAGPs is probably a political issue. However, FIFG can also be assumed to serve MAGPs' purpose, in this sense that it gives a bargaining power to the EC, which could use fleet renewal aids to obtain capacity management measures at member state level in return. The following table gives orders of magnitude of the funding in the framework of structural measures for the recent period: both states aids and FIFG, including individual decommissioning as well as modernisation projects.

The share of aids allocated to adjustment appears to be greater than that allocated to modernisation; it is noteworthy that the difference is bigger for national aids than for FIFG. However, it is interesting to underscore the fact that the global amount invested in the fishery sector (1664 m) was bigger than the amount of money allocated to adjust fishing effort (1144 m). It is not possible at this level to assess the global impact of these subsidies on the fishing capacity but it has probably led to distortion effects on the capital markets and not given the right incentives to the fishermen to invest in
the industry (Hatcher and Robinson ed, 1998). The amounts allocated to certain southern EU states also show that FIFG has general structural policy objectives, linked to economic development. At this stage, it is difficult to get further into details in terms of the effects of capacity management: it would be necessary to have more detailed information on the breakdown of the above amounts according to relevant fleet categories yet to be defined, and on the effects of structural measures on catches and the state of stocks. However it appears that the "principal" takes capacity management decisions under uncertainty about the real value of indicators used and about the information provided by agents. The question then revolves around the cost of obtaining more detailed information as compared to the expected benefits of a more fine-tuned regulation of capacity. But the question is also about the political acceptance of an ill-informed regulation, based on a limited set of average indicators.

Though the capacity manager pursues the same kind of objective as quota and effort managers do, and is confronted with the same sort of constraints, the nature of his task differs. Quota and effort management, all else equal, are repetitive actions which develop in a relatively short term (generally one year or less). In the EU context, capacity management is implemented through five year programmes (MAGPs) and therefore develops in the relatively long run. In addition, a new programme starts from a situation quite different from that of the former, for obvious reasons; the result of a programme provides the starting point of the new one, with different conditions on vessels costs and efficiency. In other terms, capacity management is not repetitive; it is a continuous process under continuously changing conditions. Therefore it appears to be impossible to model capacity management in the same way as quota and effort management.

4.3. Specific methodology
The specific methodology used in the case of France and Italy is a micro-economic model of exit behaviour based on the discounting theory. The objective of this section is to model fishermen’s behaviour in a certain environment and their decision to leave, or to stay in, the business. The aim of the model is to help to assess the role of different economic incentives on fishermen’s behaviour and their impacts on the willingness of fishermen to leave the industry or a specific fishery. More accurately, we assume that vessel-owners are able to value the net present benefits (losses) to stay in the fishery and the opportunity cost or present benefit if they leave the fishery. The calculation gives, in comparative static, the valuation of the minimum willingness to accept (WA) to leave the fishery that can be compared with the premium offered by
the decommissioning programme organised by the principal. This provides the basis for the Italian and the French applications. In the Italian case, a questionnaire has been addressed to the fishermen in order to improve the results of the model.

In the French case, the micro-economic model is linked to a more standard bio-economic approach that enables to assess the macro-economic results of decommissioning programmes as a function of the premium, the public budget constraints and other parameters. This leads to a cost-benefit and a cost-effectiveness analysis of capacity adjustment; we focus on the problem of lack of information in the public policy and especially on the consequences in terms of windfall gains effects.

Finally, the methodology proposed reviews some of the empirical lessons of decommissioning schemes at national level for the United Kingdom, France and Italy.

4.3.1. A Model of exit behaviour or economic incentives to stay or to leave the fishery

The sub-coordinator proposed a general framework that could be adapted to the each specific case study. The model considers that the decision to stay or to exit the fishery depends on the fisher’s estimation of the expected benefits from staying-leaving. It can be expressed as:

\[ \sum_{t=1}^{T_i} Y_{it} (1+r)^{-t} + PK_{i, T_i} (1+r)^{-T_i} + PL_{i, T_i} (1+r)^{-T_i} \leq P(\text{grt.age})_t + PK_t + PL_t \]  

Equation (1) denotes the acceptance by the agent of a “contract” proposed by the principal, where withdrawal or capacity adjustment is required to get a premium (allowance). Specifically, the left hand side of the inequality (1) is the opportunity cost of leaving the fishery, expressed as the sum of:

\[ \sum_{t=1}^{T_i} Y_{it} (1+r)^{-t} : \text{ Net present value of income flows in the discounting period} \]

\[ PK_{i, T_i} (1+r)^{-T_i} : \text{ Net present value of the capital value at the end of the discounting period} \]

\[ PL_{i, T_i} (1+r)^{-T_i} : \text{ Net present value of the licence at the end of the discounting period} \]
while the right hand side is the sum of:

\[ P_{(grt)} : \text{ Premium offered to the agent to scrap his vessel} \]
\[ PL_{it} : \text{ Licence value at the current period} \]
\[ PK_{it} : \text{ Capital value at the current period} \]

Generally, the agent will accept the contract if its opportunity cost will be lower or equal to the economic incentive provided by the principal, increased by the value of the vessel and of the fishing license. Such an acceptance condition is based on the assumption that the agent’s decision is driven by merely economic evaluations.

4.3.2. Bio-economic simulation of decommissioning programmes

The second step of the proposed methodology is to link the micro-economic component, developed above, to a biological component. The basic model considers that the individual catches are a function of the resource stock.

The production function for each vessel is then:

\[ C_{it} = f (E_{it}, K_i, S_t) \quad \forall i = 1..N \quad \text{with} \]
\[ C_{it} : \text{ the vessel catch} \]
\[ E_{it} : \text{ the variable input index (ex: days at sea)} \]
\[ S_t : \text{ stock index} \]
\[ K_i : \text{ capital index (GRT, age of the boat, etc)} \]
\[ N : \text{ the number of vessels} \]

The dynamics of the stocks is given by:

\[ S_{t+1} = S_t - \sum_i C_{it} + R_t \quad (4.3) \]

with \( R_t \) the recruitment (it is supposed to be exogenous and fixed at an average level)

The vessel owner's opportunities must be reconsidered at each iteration on a spreadsheet in order to take care of the changing bio-economic environment and incentives.
The simulation output gives the evolution of different indicators such as the biomass level, individual production, the production and turnover of the fleet, surplus, public cost, etc. The objective of the dynamic bio-economic model is to simulate the effects of fishing fleet adjustment schemes on a fishery dynamics in order to compare the relative efficiency of different financial incentives and management plans to achieve the principal's objectives. This gives a basis for the assessment of policy effectiveness. This methodology is applied to the French case study but the absence of scientific data on the state of swordfish stocks makes it impossible to apply it to the Italian case.

4.3.3. Case studies
The choice of the case studies in each country has been determined by the relevance of the problem with respect to real and possible management decision and data availability.

4.3.3.1 The “Spadare” fishery (Italy)\textsuperscript{18}
The case study covers the Italian “Drift net Programme”, also called “Spadare Plan”, for the rationalisation and re-conversion of drift nets vessels which will be banned the 1 January 2002. This programme attempted to provide for a final solution to the controversial issue of fishing by drift nets which stand accused of not being sufficiently selective, see Placenti and Malvarosa (2000b) for more details. This programme was in place until the end of 1999 and framed EU assistance to Italian enterprises and crews affected by the ban. It offered financial incentives to vessel owners prepared to abandon drift nets and convert to more selective techniques, retrain or leave the fishing sector.

Vessels that are legally authorised to use driftnets are 594 units in 1998 and represent 3.6% of the national total. In 1998, total landings reached 9.8 thousand tonnes with a value of 160 billion ITL (EUR 82.6 mln).

\textsuperscript{18} “Spadare” is the Italian name for drift nets used for swordfish fishery
The options provided by the plan are a clear example of “capacity adjustment” measures. Vessel owners or owners/vessel owners are entitled to receive retirement allowance, in case of a final withdrawal from any fishing activities or re-conversion allowance, if they want to continue their activity by using fishing gears other than set drift-nets. The members of the crew can join the Plan only if the vessel owner participates as well. In this case each member of the crew can decide whether to apply for retirement allowance or re-conversion one. The allowances addressed to vessel owners or owners/vessel owners are related to the vessel tonnage (GRT) and to the year of participation in the plan. It represents a radical condition to test acceptance or not of the “contract” offered by the Principal, meant as a economic incentive signal. The study of the effects resulting from the implementation of an allowance-based system is focused on a sample of 8 vessels, belonging to three Sicilian administrative districts traditionally devoted to this type of fishery. Driftnetters located in the above area account for 240 units (35.3% of the national fleet devoted to this technique).

4.3.3.2 The Scallop fishery in the Saint-Brieuc Bay (France).

The Saint-Brieuc scallop fishery is located in the Eastern part of the English Channel (ICES area VIIE) and is not shared with other European countries. Both the Common Fishery Policy and national policy apply to this fishery as well as to other fisheries outside the territorial French waters. The area is exploited by vessels using dredge gear, registered in the maritime districts of northern Brittany. The fleet is composed of 253 small multipurpose vessels (10.3 meters long on average and 127 kW for their
engine power) carrying out trawl, gillnets, pots, etc., outside the scallop season from October to April and outside the in-season fishing time. The scallop turnover account for between 30 and 40 percent of their total turnover. For the purpose of this study, the scallop fleet is divided into four categories expressed in terms of engine power (kW) with different level of productivity and costs (variable and fixed costs, taxes loan payments, opportunity cost of labour, etc.) for each sub-segment.

### Tabel 4.4. Figures regarding the scallop fishery – average data over the 1993-1998 period

<table>
<thead>
<tr>
<th>Fleet segment</th>
<th>[0-60kW]</th>
<th>[60-120kW]</th>
<th>[120-185kW]</th>
<th>[&gt;185kW]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vessel number / category</td>
<td>26</td>
<td>101</td>
<td>96</td>
<td>30</td>
</tr>
<tr>
<td>kW / vessel</td>
<td>44</td>
<td>92</td>
<td>151</td>
<td>242</td>
</tr>
<tr>
<td>Crew / vessel</td>
<td>1.5</td>
<td>1.9</td>
<td>2.5</td>
<td>3.5</td>
</tr>
<tr>
<td>Scallop landings / vessel (tonnes/year) *</td>
<td>7.1</td>
<td>20.4</td>
<td>22.5</td>
<td>23.1</td>
</tr>
<tr>
<td>Scallop turnover / vessel (KF**)</td>
<td>95.1</td>
<td>275.6</td>
<td>297.4</td>
<td>306.9</td>
</tr>
</tbody>
</table>

The Saint-Brieuc scallop fishery has been subject to a "non licence-transferable licence" programme since 1973. Its aim is to limit entry to the fishery but the regulation of inputs such as hours at sea, maximum engine power, vessel length and mesh size limits has been implemented to indirectly control the fishing mortality to the stock. However overcapacity in the fishery has been demonstrated, and Guyader, Fifas (2000) have shown that a reduction in fleet capacity could increase the producers' rent on a long term equilibrium. Note that decommissioning costs were not considered in the demonstration though they may reduce the benefits of capacity reduction.

### 4.4. Applications

Although quite a lot information is available in the French and the Italian cases, the data on incentives schemes as well as the data necessary to apply the model are heterogeneous. That is why there are some differences between the two case studies.

#### 4.4.1. Application and adjustment of the model to the Sicilian “spadare” case

The application of model (1) to the specific Italian case study requires some adjustments and their analysis includes a detailed description.

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19 Based on Placenti, Malvarosa (2000b)
First, in calculating the agent's opportunity cost the value of the licence is not taken into account; in fact, due to the deadline set out for the use of drift nets, including in the calculation the value of a license, which cannot be re-used, is useless.

Secondly, it has to be outlined that the adhesion to the Spadare plan with the retirement modality (and clearly with the re-conversion one) does not imply necessarily the vessel scrap. The vessel owner who applies for the retirement bonus cannot exercise any fishing activity anymore; he has only to deliver drift nets and the related fishing license but not the vessel\(^20\). So he has different options (not provided in the plan): to retain the vessel ownership, to sell it or to ask for the premium for final withdrawal (scrapping). The first option is not considered in this case study as it is the least rational from an economic point of view.

Furthermore, it is useful to include, in the calculation of the right member of equality (1), the capital value of the vessel at the moment of the agent’s acceptance of the contract or the value of the premium for final withdrawal, only if the vessel owner asks for the retirement bonus. Only in this case a definitive end of fishing activity takes place as well as the sale of the boat. On the other hand, if the vessel owner asks for the re-conversion bonus, he can use the vessel for other fishing activities; in this case the sale of the boat is no more a consequence because it can be re-used.

In order to better explain the real decision process of the agent (in this case composed by the vessel owner and by the whole equipment\(^21\)), we have to consider the different form that the model will assume in correspondence to the different types of renunciation asked to the owner of the boat and to the fishermen by the plan in the two cases (retirement and re-conversion). In fact, vessel owners or owners/vessel owners are entitled to receive:

- a retirement allowance, in case of a final withdrawal from any fishing activities \((\text{that is he is allowed to exercise any economic activity other than fishing})\);
- a re-conversion allowance, if they want to continue their activity by using \textit{fishing gears} other than driftnets.

\(^{20}\) This condition is required in re-conversion case too but in this latter case fishing license has to be delivered to maritime authorities and substituted with the new one.

\(^{21}\) This configuration of the agent depends on the crucial role that the rationales of the fishermen have on the owner’s decision process to accept or not the contract.
On the other hand, the crew of the vessel included in the plan are entitled to receive:

- a retirement allowance, if they commit themselves not to carry out any economic activities (that is they have to withdraw definitively from all the economic sector);
- a re-conversion allowance if they shift to other fishing activities carried out by gears other than driftnets or to other economic sectors.

Based on these assumptions, in the “spadare” case the model (1), the value of staying in the fishery ($C$) becomes:

$$C = Y + PK + WgO(T_i, N) + WgF(T_i, N)$$  
(see legend below)  
(4.4)

The opportunity cost of staying ($P_i$) is then:

$$P_i = P_{rt}O + Pk + WgO(t_i, N) + P_{rt}F$$  
(4.5)

under the assumption of retirement followed by selling of the vessel, and

$$P_2 = P_{rt}O + PS + WgO(t_i, N) + P_{rt}F$$  
(4.6)

under the assumption of retirement followed by the scrapping of the vessel.

$$P_3 = P_{rt}O + WfO(t_i, N) + P_{rt}F + WgF(t_i, N)$$  
(4.7)

under the assumption of re-conversion

where:

- $Y$ is the net present value of income flows in the 1997 – 2001 period; this value represents the summation of the remuneration both of vessel owner and crew members labour;
- $PK$ is the net present value of the 2001 capital value of the vessel (selling of the boat);
- $WgO (T_i, N)$ is the net present value of the expected stream of a generic wage on the labour market for the vessel owner after the banning year 2001;
the net present value of the expected stream of a generic wage on the labour market for the crew members after the banning year 2001; 

\[ P_{i, O} \]

the net present value of the capitalised value of the retirement bonus for the vessel owner; 

\[ P_{r, F} \]

the net present value of the capitalised 1997 value of the vessel; 

\[ P_{i, O} \]

the net present value of the capitalised value of the retirement bonus for the vessel owner; 

\[ W_{gO}(t, N) = \sum_{i=t}^{N} W_{gO}(r, 1+r)^{(N-t)} \]

the net present value of the expected stream of a generic wage of the labour market by vessel owner after the acceptance of the adhesion to the plan with retirement modality; 

\[ P_{i, F} \]

the net present value of the capitalised value of the retirement bonus for crew members; 

\[ P_{i, O} \]

the net present value of the capitalised value of the allowance for final withdrawal (scraping of the vessel); 

\[ P_{r, O} \]

the net present value of the capitalised value of the re-conversion bonus for vessel owner; 

\[ W_{jO}(t, N) \]

the net present value of the expected stream of a wage on the fishery labour market for the vessel owner after the acceptance of the adhesion to the plan with re-conversion; 

\[ P_{r, F} \]

the net present value of the capitalised value of the re-conversion bonus for crew members; 

\[ W_{gF}(t, N) \]

the net present value of the expected stream of a generic wage on the labour market for the crew members after the acceptance of the adhesion to the plan with re-conversion; 

with: 

\[ i \]

the generic agent (vessel owner + crew members) 

\[ O_{i} \]

the generic vessel owner 

\[ F_{i} \]

the generic member of the crew 

\[ n_{i} \]

the number of crew members of the generic vessel. 

\[ t \]

time 

\[ t_{i} \]

the beginning time of the considered period (in this case 1997) 

\[ T_{i} \]

the ending time of the considered period (in this case 2001) 

\[ N \]

the ending of the time horizon of the agent 

Of course the reference period for the analysis was the period of implementation of the “Plan for the Rationalisation and Capacity Adjustment of the Spadare”, that is

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1997-99 (see details in Placenti, Malvarosa 2000). In order to give a time horizon to the analysis, it has been decided to consider a short term period as the reference for the economic decision process of the agent (both vessel owner and crew members). This could lead to the comparison of the calculated values of $C$ and $P_i$ and to discuss the implementation of the contract.

The study of the effects resulting from the implementation of an allowance-based system is focused on a sample of 8 vessels, belonging to three Sicilian administrative districts traditionally devoted to this type of fishery, namely vessels belonging to the districts of Mazara del Vallo, Palermo e Syracuse. Driftnetters located in the above area account for 240 units (35.3% of the national fleet devoted to this technique). As of 31.12.99, out of the 240 vessels of these districts, 63% applied for participating in the plan. The model was applied and the different steps in the analysis to calculate the different indicators can be found in Placenti, Malvarosa, (2000b).

4.4.2. Model results
The comparison mentioned above led to the following conclusions:

The difference between $C$ and $P$ is positive in 38% of the cases; for these cases ($C - P > 0$ or $C > P$) swordfish represents most of the catches. In the remainder 62% it results that $C - P < 0$ or $C < P$; in particular we have that the value of $P_1$ (retirement followed by the sell of the boat) is the higher value among $C$, $P_1$, $P_2$ (retirement followed by the scrap of the boat) and $P_3$ (re-conversion). In these latter cases catches are composed partly (3.4% to 28.4%) by small pelagic species, like anchovies and sardines. The average price of these species, generally lower compared to that of swordfish, influences the average price of the productive mix and, as a consequence, of total revenues (the base for the calculation of $C$). At a first sight these results suggest that the market signal sent by the Principal – the premium – is, somewhere, lower than the Agent opportunity costs. Only for boats with lesser swordfish target specification the Principal-premium is higher than the Agent opportunity costs. In other words, the principal settled the premium according to weighted values of the fleet segments without catch composition order consideration.
4.4.3. Improving results and conclusions: complementary desk-case study and questionnaires

Model results exposed hereinabove have successfully been completed with a complementary desk-case study. In order to have a more detailed view of the real effectiveness of national policy measures concerning adjustment capacity, specifically measures provided for in the Italian “Spadare” Plan, a questionnaire has been given to the units under analysis. The aim of the questionnaire is to investigate the adhesion of the “contract” offered by the principal and also to investigate rationales, either economic or non economic that influenced each agent to accept or decline the “contract”. The Questionnaire results are hereinafter reported:

- 87.5% of the vessels belonging to the sample adhered to the Plan, that is accepted the “contract”, on the starting year of it, that is 1997; only one unit adhered in 1998.
- 50% of vessel owners asked for retirement bonus while the other 50% asked for the re-conversion bonus.
- Only the 15% of the crew asked for retirement bonus, i.e. 3 units out of 20; on the contrary, 14 crew members (70% of the total) asked for re-conversion to other fishing activities; finally 3 crew members asked for no bonus at all.
- The agents’ decision to accept the “contract” was influenced mainly by the following reasons: a) fishing by the use of drift nets of a maximum allowed length of 2.5 kilometres is considered to be non profitable by fishing operators; b) controls on driftnet fishery are considered to render fishing activity difficult to carry out; in other words, the situation of moral hazard is to be considered impracticable – now and in the future.
- In 50% of the cases, even if agents accepted the “contract”, the premium $P$ is lower than the opportunity cost of each agent. In particular it results that in half of these latter cases $C_1 > P_1 > P_2$ and in the other half that $C_1 > P_3$ (see Annex IB, table I.9).
- In the remainder 50% of the cases it can be seen that $P > C$. In particular it results that in half of these latter cases $P_1 > C > P_3$ and in the other half that $P_3 > C$. (see table I.9).
- The correspondence between real and rational answer to the contract is verified in 50% of the cases. This means that the model of the analysis can explain half of the cases.
### Table 4.3. Calculation of opportunity cost of the premium on the basis of questionnaire answers (ITL '000) and comparison between rational and real answer to the contract.

<table>
<thead>
<tr>
<th>Registration number</th>
<th>Adhesion form of shipowner</th>
<th>C (a)</th>
<th>P (b)</th>
<th>Rational answer to the contract</th>
<th>Real answer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>p1</td>
<td>p2</td>
<td>p3</td>
<td></td>
</tr>
<tr>
<td>01MZ00846</td>
<td>B</td>
<td>1.043.533</td>
<td>612.630</td>
<td>501.547</td>
<td>no</td>
</tr>
<tr>
<td>01MZ00937</td>
<td>R</td>
<td>1.230.020</td>
<td>-</td>
<td>-</td>
<td>no</td>
</tr>
<tr>
<td>01MZ00988</td>
<td>R</td>
<td>1.122.485</td>
<td>-</td>
<td>-</td>
<td>no</td>
</tr>
<tr>
<td>06MZ00397</td>
<td>B</td>
<td>1.050.993</td>
<td>776.530</td>
<td>546.855</td>
<td>no</td>
</tr>
<tr>
<td>04PA00919</td>
<td>R</td>
<td>431.380</td>
<td>-</td>
<td>782.400</td>
<td>yes (p3)</td>
</tr>
<tr>
<td>04PA00959</td>
<td>R</td>
<td>545.764</td>
<td>-</td>
<td>573.309</td>
<td>yes (p3)</td>
</tr>
<tr>
<td>04PA10404</td>
<td>B</td>
<td>869.744</td>
<td>917.422</td>
<td>698.503</td>
<td>yes (p1)</td>
</tr>
<tr>
<td>01SR00936</td>
<td>B</td>
<td>782.442</td>
<td>922.211</td>
<td>771.539</td>
<td>yes (p1)</td>
</tr>
<tr>
<td><strong>Average values</strong></td>
<td></td>
<td>574.257</td>
<td>282.087</td>
<td>290.584</td>
<td>672.433</td>
</tr>
</tbody>
</table>

Source: Irep 2000

(a) see table 1.7

(b) \( p_1 = C + O + G; p_2 = D + O + G; p_3 = O + H + I \) (see tables 1.4; 1.5, 1.6, 1.7 and 1.8). \( p_1 \) represents retirement (for the shipowner) followed by the sell of the vessel; \( p_2 \) represents retirement (for the shipowner) followed by scrap of the vessel (see paragraph 4 of the paper). In fact, because the information related to the vessel's destiny after the adhesion to the driftnets plan, is not known, we have considered both the options.

If the aim of the “Spadare” Plan was to induce operators (agents) using driftnets to a general adhesion or to a general acceptance of the “contract”, it can be concluded the aim has been reached. Nevertheless, the main reason should not be conducd to “economic rationality” or, in this case, to the premium offered by the Principal. The premium has not performed as an equivalent to “economic incentives” in every case. The Sicilian case study of the “spadare” demonstrates that rationales underlying the agents’ decision process cannot be justified in the framework of the microeconomic model of the Principal and Agent. The agents’ decision process was not purely influenced by financial logic. In fact, in many cases, fishing by the use of driftnets allows obtaining an income much higher than the bonuses granted by Ministry for Agriculture and Forestry Policy for the adhesion to the “Spadare” Plan. As such, from a theoretical point of view, the Agents should have to refuse the “contract” offered by the Principal instead of accepting.

22 This conclusion is probably valid also for the other Italian geographical areas devoted to this type of fishery.
Command and control policy seems to be the general framework environment underlining the agent’s decision. More precisely, the premium as a proxy of an economic incentive inducing operators to stop driftnet fishing before the 1\textsuperscript{st} January 2002 deadlines was not the main cause for acceptance.

In the applied case, the market signals do not always give a quantitative measure of the influence on the agents’ behaviour and on their decision to accept the “contract”; therefore, the minimum allowance premium does not perform as economic incentives. Premium was accepted only to partially compensate losses. The main reason to a general adhesion, or to a general acceptance of the “contract”, was the impossibility to follow a moral hazard environment thanks to a command and control scheme. So far, economic incentives were not a substitute of rules set upon a command and control scheme for capacity reduction.

It is not by chance that the premium allowance was undertaken only and exclusively because of the crucial socio-economic implications of the ban. The allowed provisions compensate only partially the negative economic and social impact on the communities concerned. As that, economic incentives, meant as a free market signal for underlying agents’ decision process, should not be confused with minimum allowances and vice-versa. The previous results demonstrate that in the case of hidden information or adverse selection the \textit{Principal} is not able to set economic incentives meant as correct free market signals and the \textit{Agents’} decision process is not influenced merely by economic logic. By conclusion, market signals can’t be the only economic instruments.

\subsection{The French scallop fishery – static results\textsuperscript{23}}

Some adjustments of the model (1) are required in the French case in order to take account of the special nature of the fishery (small scale fishery, skipper-owner) and of the specific contract proposed by the principal at national level. The net present value of the fishing activity ($npv$), or the opportunity cost of leaving the fishery sector, is the sum of the following terms:

\begin{equation}
npv_{it} = \sum_{t=1}^{T} ncs_{it}(\cdot)/(1+r)^t + PK_{itT}/(1+r)^T_t + \sum_{i=1}^{T} nls_{it}(\cdot)/(1+r)^t
\end{equation}

with

\textsuperscript{23} Based on Guyader, Daures (2000)
The decision to stay or to leave the fishery at any time of the simulation depends on the form of the inequality:

\[ A_{it} = T_i - t \]

is the delay between the expected period of vessel retirement (T) and the current period (t) but an other basis can be used. The discounting period may be the difference between the period of the retirement of each fisher and the current period. As shown in Daures and Guyader (2000), the age of the vessel has played a crucial role in the decommissioning decision of the French fishermen, more than the age of the skipper.

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\[ npv_{f, it} \geq npv_{e, it} \quad \forall t = 1, \ldots, T \] (4.11)

As shown hereafter, a fisher exits from (stay in) the fishery when the net present value of fishing is less (greater) than the net present value of leaving it. From inequality (7), the premium per GRT obtains, for which the two options are equivalent.

\[
s^*_i = \left[ \sum_{t=1}^{T_i} ncs_{i} \cdot (1 + r)^t + PK_{i} \cdot (1 + r)^{T_i} + \sum_{i=1}^{T_i} nls_{i} \cdot (1 + r)^t \right] / \text{grt}_i
\] (4.12)

This quantity reflects the minimum willingness to accept (WA) per GRT, necessary to incite vessel owners to leave the fishery. According to the model, it is the optimal premium from the principal point of view if his objective is to reduce the fleet capacity or the fleet segment at the least cost.

### 4.4.5. Static results

The willingness to accept to leave the fishery, WA, can be expressed in many ways that need to be discussed in terms of how relevant they are to reflect fishermen's behaviour. Six cases, defined below, are considered to analyse the sensitivity of WA to different economic incentives and reflects the different equations specified before. It gives the possibility to compare the revenues of the exit through the second hand market (Cases 3,6) and through the decommissioning schemes (Cases 1,2,4,5). As shown in table 4.4 below:

- Case number 1 includes only the net capital flow and the decommissioning premium. This reflects the situation of an exclusive vessel-owner or entrepreneur who is earning only the revenues of capital and the revenue of the entrepreneur resulting from the combination of production factors within the fishing firm.
- Case 2 is not so different: only the resale price of the vessel is added to the left hand side of the inequality.
**Table 4.4. Components included in the expression of WA (discounted values)**

<table>
<thead>
<tr>
<th>Component</th>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
<th>Case 4</th>
<th>Case 5</th>
<th>Case 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net fishing owner income (e.g. accounting flows)</td>
<td>✡</td>
<td>✡</td>
<td>✡</td>
<td>✡</td>
<td>✡</td>
<td>✡</td>
</tr>
<tr>
<td>Vessel resale price at the end of the actualisation period</td>
<td>✡</td>
<td>✡</td>
<td>✡</td>
<td>✡</td>
<td>✡</td>
<td>✡</td>
</tr>
<tr>
<td>Net fishing skipper income (wage)</td>
<td>✡</td>
<td>✡</td>
<td>✡</td>
<td>✡</td>
<td>✡</td>
<td>✡</td>
</tr>
<tr>
<td>Vessel resale price at present time</td>
<td></td>
<td></td>
<td>✡</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Opportunity cost of labour</td>
<td></td>
<td></td>
<td></td>
<td>✡</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decommissioning Premium</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✡</td>
<td></td>
</tr>
</tbody>
</table>

Note: Different basis for income flow actualisation can be used: the income of the last year or the net income average over the two or three last years.

Cases 3 to 6, defined as follows, are probably more appropriate to the ownership structure of firms in the Bay of Saint-Brieuc fishery.

- Cases 3 and 6 consider the situation in which there is no premium offered. Exit is open to fishermen and they decide to stay or to exit by comparing the alternative revenues of these two options. The difference is that case 3 does not use labour revenues when case 6 does.
- Finally, Cases 4 and 5 make nearly the same distinction (case 4 includes wage incomes in the fishery but no opportunity cost) but it gives the opportunity to the fishermen to be compensated from the withdrawal of their vessels.

Not surprisingly, the different model options described above result in very different values of WA. For a typical firm from [60-120 kW], the WA varies from FFR 21,000 to nearly FFR 207,000 in the simulation, cf. table 4.5. In the latter case, WA4 merges all fishing revenues for the vessel owner and vessel skipper who is supposed to have no opportunity cost (e.g. the fisherman is not granted an unemployment insurance or is not able to find a new job in another sector). The incentives to leave the fishery are very low; conversely the value given to the fishing activity is very high. The introduction of the opportunity cost of labour in the region (case 5) lowers the minimum premium per GRT that the vessel owner may claim in order to leave the fishery. WA5 drops to FFR 89,900. A comparison between WA2 and WA5 shows that including labour remuneration in the fishermen’s programme has little influence on WA because [60-120 kW] fishermen do not earn quasi-rents in the fishery with regard to the best opportunities in the economy. Conversely, this leads to positive effects for the last two class [120-185 kW] and [>185 kW]. The [0-60kW] fishermen are in the opposite situation because their WA declines and becomes negative so that there is a
natural economic incentive to leave the fishery this year. If we retain the 6th case as the best indicator of the fisher's behaviour, and as there is no buy-back policy (WA6), only vessels of the [0-60 kW] category are incited to leave the fishery and to sale their vessel on the second-hand market. Their present value of net benefits is lower than the resale price of their unit, and exit flows from the fishery of the first category can be expected to happen.

<table>
<thead>
<tr>
<th></th>
<th>0-60 kW</th>
<th>60-120 kW</th>
<th>120-185 kW</th>
<th>&gt;185 kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>WA1</td>
<td>33.6</td>
<td>64.4</td>
<td>55.1</td>
<td>56.8</td>
</tr>
<tr>
<td>WA2</td>
<td>50.7</td>
<td>93.8</td>
<td>83.6</td>
<td>91.1</td>
</tr>
<tr>
<td>WA3</td>
<td>11.1</td>
<td>24.8</td>
<td>16.9</td>
<td>10.4</td>
</tr>
<tr>
<td>WA4</td>
<td>170.7</td>
<td>206.6</td>
<td>153.8</td>
<td>143.8</td>
</tr>
<tr>
<td>WA5</td>
<td>-30.8</td>
<td>89.9</td>
<td>86.2</td>
<td>110.3</td>
</tr>
<tr>
<td>WA6</td>
<td>-70.4</td>
<td>20.9</td>
<td>19.5</td>
<td>29.7</td>
</tr>
</tbody>
</table>

Private actualisation rate = 5% - actualisation period = 10 years
Opportunity cost of labour in the region (net wage for skilled worker)
Figures in thousands francs

Taking into account and characterising the opportunity costs of labour, which could vary among fishermen, is critical for this analysis, because its introduction in, or exclusion from, the fishermen's programme can have important effects in terms of economic incentives and on the value of WA. The dynamics of the fleet will depend clearly on these values. The previous table also shows differences between WA results within vessel categories for the same model structure. In the third case, WA of the [>185 kW] vessels is FFR 10,400/GRT the lowest so that they will likely be the first to exit, then the [0-60 kW] vessel with FFR 11,100/GRT will leave the fishery sector if the premium offered is greater or equal to WA. These differences are mainly explained by the gap between the economic performances of vessel categories and by distortions in the allocation of subsidies. Different capital cycles lead to differences in interests paid among vessels.

In contrast, the demography of vessels (or fishermen) may have a strong influence on time scales used by each fisherman. According to the expression of the net present value, the higher the discounting period, the higher WA. For a typical vessel of category [>185 kW], the WA5 shift is valued at about FFR 40,000/GRT when discounting period changes from 5 to 15, cf table 4.6. The age structure of the population of the fishermen has a strong influence on vessel exits per category.
### Table 4.6. Sensitivity of the Willingness to Accept to discounting period. FFR '000

<table>
<thead>
<tr>
<th>Actualisation period (years)</th>
<th>WA5</th>
<th></th>
<th></th>
<th>WA1</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
<td>10</td>
<td>15</td>
<td>5</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>0-60 kW</td>
<td>-4.6</td>
<td>-30.8</td>
<td>-54.2</td>
<td>19.2</td>
<td>33.6</td>
<td>42.0</td>
</tr>
<tr>
<td>60-120 kW</td>
<td>69.9</td>
<td>89.9</td>
<td>105.4</td>
<td>34.5</td>
<td>64.4</td>
<td>87.6</td>
</tr>
<tr>
<td>120-185 kW</td>
<td>69.1</td>
<td>86.2</td>
<td>99.3</td>
<td>31.3</td>
<td>55.1</td>
<td>73.5</td>
</tr>
<tr>
<td>&gt;185 kW</td>
<td>86.7</td>
<td>110.3</td>
<td>128.7</td>
<td>32.2</td>
<td>56.8</td>
<td>75.9</td>
</tr>
</tbody>
</table>

Private actualisation rate = 5%
Figures in thousands francs

As shown by the model, the [0-60 kW] vessels will exit first whatever the population structure and with or without a decommissioning programme. The owner of a typical [>185 kW] vessel who expects to retire in five years will not leave the fishery if other owners have the same age and the same discounting period because WA is the highest (FFR 86,700/GRT for a 5 years period). Moreover, if the expectation to find another job elsewhere is poor, WA will have a higher value. But if other fishermen of his vessel category or the next category are younger and would like to retire in 15 years, he will be incited to leave earlier because they will need a higher premium per GRT; respectively FFR 105,000 and 99,000 for [60-120 kW] and [120-185 kW] vessels.

In conclusion, the structure of the fisher population through demographic consideration and the structure of the fleet in terms of economic results may explain exit behaviour. More than vessel performance over time, individual considerations like age and opportunity cost of labour may have a straightforward influence in the decision making process and the model seems to be a good tool to assess individual WA. Nevertheless, it could be difficult in practice for the principal using this model to adjust its premium to the value of WA assessed because of the results of sensitivity and to tune the model by comparing WA to real premium offered by the principal and accepted by the fishermen because of the possible windfall gain captured by the fishermen. Windfall gain is the difference between principal premium and minimum willingness to accept of the agents.
4.4.6. Cost-benefit and cost-effectiveness of decommissioning programmes in the French scallop fishery

Biological dynamics exploitation parameters are based on a structural and single species approach that take into account cohorts and individual growth of the scallops. A more complete description of the model as a whole can be found in Guyader et al. (2000). Notwithstanding biological impact of decommissioning schemes can be valued only from the scallop stock point of view, economic impact can be assessed especially in terms of scallop activity but also in considering the different activities as a whole.

We assume now that the principal decides to fix the premium per GRT offered and it is the same for the four vessel categories. Total budget available for administration is limited and we assume that government is able to choose the elected vessels to the decommissioning plan (e.g. the firms with the lowest WA first exit the fishery). Then, fishermen apply (or not) to accept the total premium and their decision to stay in the fishery is open each year and it depends on economic incentives and public decision to organise (or not) a decommissioning plan.

The status quo results named as scenario 0 is first compared to a specific decommissioning plan output (scenario 3), cf. table 4.7. The latter scenario provides administration with a FFR 30 mln budget to be used in the first two years (1998 and 1999) and equally affected to both. Premium offered by administration to leave the fishery is allocated on an egalitarian basis and is equal to 50 000 francs per GRT (Basis 100).

The evolution of WA is given in Guyader and Daures (2000). As regards global fleet adjustment, respectively 34% of the scallop fleet and 20.6% of total fishing capacity expressed as total engine power in kW is decommissioned by this plan. But this policy can be viewed as not effective in reaching its objectives if the reduction in fishing power must reach 30 %. The amount spent in decommissioning has costs of FFR 30 mln, where the sum of total minimum willingness to accept to leave the fishery is valued at FFR 20.53 mln by the model. The difference is the total windfall gain transferred from taxpayers to fishermen and windfall gains leads to huge distribution effects. Whatever the scenarios, the impact of these policies can be assessed through different indicators.
Reduction in fishing capacity and in fishing mortality gives rise to the shift of harvest profile per vessel and total landings. The difference between scenarios is small at the beginning of the period but firms rapidly benefit from the stock growth due to lower fishing mortality. Landings increase in both cases but the fishery encounters a difference in supply estimated at 660 tonnes in year 2000; this gap is reduced by 120 tonnes in 2010. As a result, stock recovers from 9,800 to 20,600 tonnes in scenario 3 and the increase is limited from 9,800 to 15,100 tonnes in scenario 0. Stock rebuilding is due to better recruitment during the period than over the last period; this is why the stock adjusts to a new balance.

From an economic standpoint, the impact of status quo or decommissioning scheme can be assessed at both firm and fleet levels. At micro-level, one can see that average willingness to accept per kW necessary to leave the fishery increases in both case, but the implementation of scenario 3 yields higher values than status quo: by nearly FFR 10,000 for a FFR 80,000 value. Macro-analysis is used in this study and the indicator of producer surplus from scallop harvesting is used to assess the economic efficiency of the policy. Clearly, vessel withdrawal yields a higher annual economic rent than status quo, except in the first two years when the decommissioning plan has not produced its effects. As early as 2001, the rent produced by the fishery will be higher by around FFR 1 mln, and this difference will continue to increase to reach nearly FFR 5 mln in 2010.

The cumulative sum of these differences represents FFR 31.9 mln, cf. table 4.8 (balance S3-S0) but annual flows have to be discounted. Discount rates vary from 0 to 10 percent. Whatever the discount rate value, the net present values (NPV) of the producer's surplus under scenario 3 exceeds the one under scenario 0. Consequently, the implementation of a decommissioning programme can be judged as the best policy if
the public authority considers this indicator as the criterion for decision-making. Moreover, the cost-benefit analysis that relates the cost of public policy to surplus yields shows that the balance is always positive, from FFR 22.9 mln to FFR 6 mln over the reference period (see table 4.8 right column). The difference is nil only for a 20% discount rate in this simulation.

<table>
<thead>
<tr>
<th>Discount rate</th>
<th>Producer surplus* Scenario 0</th>
<th>Producer surplus* Scenario 3</th>
<th>Balance* Scenario 3-S0</th>
<th>Public cost* Scenario 3</th>
<th>Net Surplus* Balance including policy cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>82.9</td>
<td>114.8</td>
<td>31.9</td>
<td>9.0</td>
<td>22.9</td>
</tr>
<tr>
<td>5%</td>
<td>57.5</td>
<td>77.3</td>
<td>19.8</td>
<td>8.2</td>
<td>11.6</td>
</tr>
<tr>
<td>8%</td>
<td>46.9</td>
<td>62.7</td>
<td>15.8</td>
<td>7.8</td>
<td>7.9</td>
</tr>
<tr>
<td>10%</td>
<td>41.3</td>
<td>54.9</td>
<td>13.6</td>
<td>7.6</td>
<td>6.0</td>
</tr>
</tbody>
</table>

* Figures in Million Francs.

Note: As the scallops revenues account for 30% of the vessel turnover, we use the assumption that 30% of the total public cost plan is dedicated to this fishery.

In France, public assessment of public scheme actually use discount rates (opportunity cost) values between 2% and 8%.

Different conclusions result from this particular simulation. Although the decommissioning plan does not achieve its objective expressed in kW, its effects are positive in terms of policy efficiency. Producer surplus increases with the decommissioning programme and the net surplus is also positive for a reasonable value of discount rate. On the other hand, technical progress incorporated by fishermen into their vessels may lead to counterproductive effects in the case of the decommissioning programme as well as in the status quo situation (see Guyader et al. 2000). The problem is that a trend increase in the fishery will probably gives rise to a harsher competition between fishermen, capital stuffing (Townsend 1985) that could dissipate the rent created by the decommissioning programme.

The other main problem from a public policy perspective is the misuse of public budget because of the windfall gain problem valued at around FFR 9 mln in the scenario. The definition of an optimal premium for each fishing firm at a higher level than their individual WA but closer to the WA gives the opportunity to save money. And this sum could be allocated to buying back other vessels and to reach MAGP objective and increase efficiency.
Actually, public authorities may adjust the level of the premium on a trial and error basis in order to minimise windfall gains. Unfortunately, this behaviour can lead to adverse effects and the next section examines the problem. We now consider that budget is equal to FFR 20 mln. The option available to the public authority is always to define the basis of the premium but also to define the plan duration: scenario 1 for two years and scenario 2 for four years. In the second case, the budget is split over the four years rather than two. The annual allocation is then reduced; the effect of premium level variation is analysed in the following sections.

4.4.7. Premium equal to 0.75 of the value of the basis scenario
Consider the different scenarios during the first period, cf. Guyader and Daures (2000b). In both cases, vessels of class [0-60 kW] leave the fishery because their willingness to accept is lower than the premium, and annual budget allocation is sufficient to cover the resulting cost. During the second period, the second class vessel owners [60-120 kW] scrap their units but in both cases, limited budgets do not enable them to exit the fishery. Actually, 52 and 18 vessels respectively leave the fishery in the first and second scenario. In the last two years, increase in WA of all categories does not lead to any exit. The consequence is that the budget is not entirely used (50% of the FFR 20 mln). If the MAGP objective is to reach a 10% reduction in total kW, scenario 2 does not suit very well because only 2,780 kW out of 3,210 are decommissioned. On the other hand, the first scenario exceeds the target with a 5,850 kW reduction and this is not far from a 20% withdrawal. To reach the same target as in scenario 1, the public authority shall implement another decommissioning programme in period five and take care of the fact that premium basis is too low. In the best case, the case for which premium is slightly higher than WA (it increases from FFR 39,000/GRT to 60,000/GRT over the period), they have to adjust the premium basis from 0.75 to 1.2 and to get an additional FFR 20 mln budget to fund the scrapping. The total cost of this scheme is not FFR 20 mln, like in the first scenario, but FFR 30 mln. The difference measures the public cost of the mis-specification of the adjustment plan. One can add to this amount the fines (or loss of subsidies to build new vessels) for agents not achieving objective at convenient time.

Not only does it cost more to the public authority but the objective is reached in the fifth period contrary to second period for the first scheme. It implies that this delay yields different surplus profile during the transition period. The unsuitability of scenario 3 from MAGP objective conducts also to lower level of producer surplus than scenario 2 and this gap increases with time. The scenario 2 modified (S2m) that leads
to another exit flow in 2002 yields the lowest surplus at first due to fleet reduction. But the gap is reduced with time and comes close to scenario 1 in 2001.

<table>
<thead>
<tr>
<th>Tabel 4.9. Economic indicators. Mln FFR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discount rate</td>
</tr>
<tr>
<td>8%</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>5%</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Note: 0.75 premium basis

The present value of these schemes in table 9 indicates that scenario 1 give the best results but S2m discounted net surplus exceeds S2 net surplus only for a 5% discount rate. Even if it is more expensive to buy back vessels (FFR 30 mln versus FFR 10 mln), the increase in costs is compensated by the surplus increase, and MAGP objectives will be achieved. Consider now a change in the premium level.

4.4.8. **Premium equal to 1.25 of the value of the basis scenario**

In both cases, MAGP objectives are reached under the premium basis scheme. A four year plan leads to a 3,290 kW buy-back (43 vessels) and two year plan to 3,370 kW buy-back (49 vessels). However, the delay in implementing the plan (scenario 2) induces a different fleet structure at the end of the plan. Moreover, the pace of exit is slower in the second case but the influence on producer surplus variation is very low, no more than FFR 2 mln between the two scenario. There is nevertheless a significant gap between the results of 0.75 and 1.25 basis valued at 8.5% in terms of surplus and 73.6% in terms of MAGP objective for scenario 1.
Table 4.10. Cost-benefit analysis. FFR mln

<table>
<thead>
<tr>
<th>Discount rate</th>
<th>Scenario</th>
<th>S1</th>
<th>S2</th>
</tr>
</thead>
<tbody>
<tr>
<td>8%</td>
<td>Surplus</td>
<td>57.4</td>
<td>55.9</td>
</tr>
<tr>
<td></td>
<td>Public cost</td>
<td>5.3</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>Net surplus</td>
<td>52.1</td>
<td>50.9</td>
</tr>
<tr>
<td>5%</td>
<td>Surplus</td>
<td>70.7</td>
<td>68.9</td>
</tr>
<tr>
<td></td>
<td>Public cost</td>
<td>5.6</td>
<td>5.3</td>
</tr>
<tr>
<td></td>
<td>Net surplus</td>
<td>65.1</td>
<td>63.6</td>
</tr>
</tbody>
</table>

Note: 0.75 premium basis

Considering the context of this simulation, we can conclude that it is better from a bio-economic point of view to apply the buy-back budget within a limited number of years rather than to spread it over a longer period. Even if the premium is high enough, this leads to losses from the cost-benefit analysis. Nevertheless, these conclusions could be opposite if the situation of the fishery is worse during the buy-back programme. Public authority can lower its premium and save money.

4.5. Some empirical lessons from decommissioning schemes

The objective of this section is to review the national experiences of decommissioning schemes in the UK and France\(^{25}\) and to extend the empirical analysis to other case studies external to the project. A comparison between decommissioning schemes and their results is however difficult because of the problem of data accessibility and heterogeneity.

The UK decommissioning scheme operates on the basis of competitive tenders, bids being ranked in an ascending order whereas in France an administrative premium procedure has been implemented. This big difference adds a major interest to the comparison. In the first case, successful applicants are paid the amount of their bids and have to decommission their vessels and surrender fishing licences. In the second case, fishermen receive the premium according to the rate in force and to the EU rules. As a result, fishermen lose their national fishing permits (PMEs), which are not transferable under the current national regulation.

\(^{25}\) Based on Hatcher (1998), Daures and Guyader (2000)
4.5.1. The United Kingdom

Under MAGP 3, the fleet adjustment had also to be based on a limit to the number of
days at sea and on a decommissioning scheme in order to reach the “effort” reduction
objectives according to EC regulation. However, the opposition from the fishing in-
dustry to days at sea regulation led to the postponement of the implementation of the
scheme and to an indefinite suspension. It was originally intended that a decommis-
sioning would run for a definite period and budget but the time period and the budget
of the scheme were extended to reach the targets. The qualification rules evolved over
the time duration of the scheme in order to exclude the segments which were consid-
ered to have already met their MAGP targets, or to target the vessels harvesting the
most sensitive stocks, or segments requiring the largest cuts.

Moreover, the government hoped that the UK fishing vessel licensing system would
serve to reduce the fleet capacity, in particular through an increase in capacity penali-
ties for licence transfer and aggregations. Licences for fishing on different stocks are
transferable; each licence is assigned a number of vessel capacity units (VCUs) but
the transfer of licence is possible, for example, to large and powerful vessels, pro-
vided that the capacity of the vessel, measured in VCU, is less – with increased re-
striction over time - than the combined capacity of the original licences, see

In the UK, Nautilus (1997) estimated that a significant part of the fleet capacity which
was scrapped would have been retained in the industry, through licence aggregation,
without a decommissioning scheme. This result confirms that fishing right transfer-
ability which is governed by economic incentives (e.g. a market based system) is not
a sufficient mechanism to cope with the capacity problem. The transferability of
rights is often considered as a mean to rationalise the capital utilisation in the fisher-
ies. However, even if restrictive limits are set to licence aggregation by transfer to ac-
tive vessels, the non active vessel or vessel without a licence still has a potential ca-
pacity either in the UK fleet or in third countries. If the opportunity cost of a vessel in
the fishing industry is positive, there is an incentive to use it and excess capacity re-
mains in the industry.

Considering the vessels which were decommissioned, the tendering system led to sav-
ings of £20 m as compared to a flat-rate scheme based on the EC maximum rate.
However, in France, maximum rates were not systematically applied. Moreover, it
was estimated that the application of EU rates would have removed different vessels
as compared to the tendering system, and consequently led to different results in
terms of fleet reduction. One of the conclusions of Hatcher (1997) is that certain fleet segments were clearly over-represented in the decommissioning schemes while other segments were under-represented. This result probably stems from a mis-specification of the targets within the tendering system, as there is no or little discrimination between fleet segments and most of the vessels are able to submit bids. The decommissioned vessels are the oldest, about 85 percent of them were more than 20 years old.

| Table 4.11. Evolution of the decommissioning cost per capacity unit. |
|-------------------------|--------|--------|--------|--------|
| Decommissioning Cost per VCU (£) | 332    | 346    | 436    | 536    |


The mean cost of decommissioning per VCU has increased from £332 to 536 between 1993 and 1996, probably because of the increase in profitability of the fleets and licence price. It was also estimated that rising licence prices would soon make even EC grant rates inadequate to remove all but few vessels. Repeated bids and the fishermen’s knowledge of the previous bids have also led to an increase in bid proposals. As regards the information problem, the solution is not to implement repeated bids but to space tenders in order to avoid learning and collusion effects between fishermen and fishermen’s organisations. On the other hand, one of the interests of decommissioning in one shot is that the principal does not have to pay the increase in the willingness to accept to exit due to the rationalisation of the fleet and consecutive profitability improvements (cf. simulation results).

The value of assets is important to consider in a decommissioning scheme. In the UK, the government proposed the owners of decommissioned vessels to transfer or sell their landing track records or quota entitlements to another vessel, thus encouraging lower bids (Hatcher 2000). On the other hand, it was clear that the fleet segments with the highest average licence plus vessel value were the least represented among the vessels successfully decommissioned. That strengthens the economic theory that shows that under regulated fisheries and certain conditions, the resource rent is capitalised in the value of tradable fishing rights (quotas, licences, …). As demonstrated by Flaaten, Heen and Salvanes (1995), the discounted value of expected rents may be also totally or partly captured in the exchange value of the vessels on the second hand market if fishing rights are not transferable but associated to vessels.
In a tendering system, the fishermen's bids represent their willingness to accept to leave the fishery (WA) by scrapping their fishing units. The UK case confirms that WA does not only reflect the value of capital and/or fishing rights but personal consideration (in some cases, fishermen refrained from applying because of their personal attachment to their vessels). Different costs incurred when fishermen leave the fishery such as scrapping or, generally speaking, transaction costs must also be included into the economic analysis of exit. The sale of the equipment if authorised may cover the cost of scrapping.

4.5.2. France

The results of the empirical study show that the capacity adjustment policy carried out by the EU has led the member state to change its internal policy. As member states have to fulfil MAGP targets to get subsidies for vessel building or modernisation, MAGP and linked decommissioning plans were seen as a second best policy. This condition can be viewed as economic incentives for agents in the frame of the "upper" principal-agent relationship. The analysis shows that decommissioning plans were implemented when delays in MAGP target appeared. A fishing licence (PME) works as a barrier to entry but natural exits from the fleet were not sufficient to meet the objectives of the programmes.

A significant part of the decommissioned vessels were old relative to the age of the fleet. Nearly 65 percent were over twenty years, with an average age of 26 years for the 1991-1996 period. According to the end of life age in the French fleet, the authors conclude that a share of the decommissioned vessels would have probably left the sector in the near future if the decommissioning schemes had not been implemented. Vessels owners probably received windfall gains with the allocation of a fixed rate premium especially in the beginning of the programmes. On the other hand, the distribution of the vessel owner's age is not very different from those of the active vessels, this is probably fishermen who decided to scrap their vessels were able to re-invest in the fishery sector. In fact, a share of the fishermen who have scrapped their vessel have also bought another vessel and have probably used the money of the decommissioning schemes to re-invest in the industry.

In France, financial compensations for scrapping vessels come from European Union, National State or local authorities (Regions and/or Departments). This context is of importance in light of the principal-agent framework. The objective of each local authority is to retain the fishing industry in their area. Their interest is not to reduce the
size of the local industry if the other regions do not co-operate and do not accept an equivalent effort in terms of financial contribution to the premium per GRT or kW. The problem comes from the absence of local (regional and/or departmental) plan for capacity reduction and a local budget dedicated to it. As a consequence, the definition of a fair premium is difficult to reach for the government authority who has to implement the decommissioning scheme.

The premium offered to the vessel owner is a combination of a fixed part and a variable part, functions of the gross tonnage. Actually, based on the recalculation of the premium per kW, the incentive scheme shows that discrimination between vessel size categories is not very high. However, except the over 60 m vessels, the very small vessel category is the one that receives the highest premium per kW, as shown in the following table.

<table>
<thead>
<tr>
<th>Vessel Size</th>
<th>Premium per GRT (1991-96)</th>
<th>Premium per kW (1991-96)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 12 m.</td>
<td>27 874</td>
<td>3 269</td>
</tr>
<tr>
<td>12 to 16 m.</td>
<td>16 861</td>
<td>2 931</td>
</tr>
<tr>
<td>16 to 25 m.</td>
<td>14 053</td>
<td>2 828</td>
</tr>
<tr>
<td>25 to 60 m.</td>
<td>5 234</td>
<td>2 085</td>
</tr>
<tr>
<td>More than 60 m.</td>
<td>3 778</td>
<td>3 762</td>
</tr>
</tbody>
</table>

Source: IFREMER based on administrative data

French studies show that the average return to owner-operators take care of human capital remuneration increases with the vessel size. According to this result, one can conclude that, all things equal, the economic incentives for fishermen to decommission their vessels are higher for the smallest vessels because the premium is inversely linked to profitability. It is not possible in this study to assess the impact of such incentives in terms of MAGP segments but this can lead to serious problems from policy effectiveness point of view, because the decommissioning premium is not linked to the value of staying in the fishery sector that can be measured by economic indicators.

Nevertheless, the French administration currently uses information on the vessel price on the second hand market - giving a price per kW or GRT - to adjust the premium level. The objective is to give fishermen the incentives to exit by proposing a pre-
mium per kW or GRT at national level slightly above the value of kW or GRT on the capital market. The disadvantage of this process is that it is difficult to take care of each individual situation. Vessel prices mostly include the value of PMEs and the associated fishing licences that vary from a fishery to another, from one region to another. Successful applicants may benefit from this asset value even if they do not hold any fishing rights.

4.5.3. Italy
Some of the empirical lessons of decommissioning schemes or retirement programmes are highlighted through the “spadare” example described before in the text (Plancenti, Malvarosa 2000a). An overall description of the Italian measures on capacity control under MAGP III is given in Plancenti, Malvarosa, 2000b) with a detailed analysis of the national regulations (licences, withdrawal) within the framework of the Multi-Annual Guidance Programme and public subsidies allocated to the fishery sector.

4.5.4. Different ways to improve incentives to leave the fishery sector
This section addresses the question of the structure of decommissioning plans and the incentives it provides to the fishermen to leave the sector. It reviews the problem of human capital adjustment, cost recovery and fiscal component.

Several tools are used to various degrees of intensity to assist in the adjustment process (Metzner and Rawlinson 1998). As labour factor or human capital may be also affected by capacity adjustment process, different policies have been implemented to encourage and facilitate exit. Skill enhancement is often required to assist in the development of alternative opportunities in the economy for fishermen (crew and skippers) leaving the sector. Certain countries also use grants or direct subsidies to give fishermen the incentives to re-establish in another sector or specifically in the post-harvesting sector.

The question of cost recovery deals with the distributional and equity consideration and is subject to public debate. If the programme is fully funded by the public authority, only the taxpayers pay for fishermen leaving the fishery sector while those remaining in the fishery benefit from windfall gains from any improvement in the fishery. Different points can be argued to adopt or decline such a mechanism. If the objective of capacity adjustment is to increase long term economic return to the partici-
pants who benefit from the commercial use of a public resource, then the industry should bear the adjustment cost. Cost recovery mechanisms may provide clear incentives for fishermen to implement management measures in order to circumvent the effect of input stuffing. However, fishermen or fishermen’s organisations' contribution to capacity adjustment requires that there be some benefits for them exceeding the cost of policy implementation. As regards this problem, crucial is the question of the effectiveness of the policy from the fishermen’s point of view. If the programme is not credible, fisher’s participation may not be sufficient to establish new management rules and to fund decommissioning programmes. Industry repayment is not without risk for the public authority if the fishery does not recover and if fishermen do not have the possibility to pay for the subscribed loan. However, in a transnational case in which individuals or groups are not incited or able to arrange to fund the adjustment programme, public budgets may be useful to develop viable grant funding (Metzner and Rawlinson 1998). Finally, the need for adjustment may result from inappropriate management by the public management authority, so its liability through public funding could be analysed. Different types of funding can be considered; direct public finance with the potential participation of different institutions or administrations, indirect public finance through loans to fishermen’s organisations for funding buyback at market or subsidised rate, public finance with industry repayment and finally total industry funding. Mixed or combinations of the previous systems are also organised. In Australia, the issue of buyout funding was overcome by designing a fee/levy scheme, translated into the legislation, in order to fund certain ongoing programmes. It applies not only to commercial but also to recreational fishermen.

The fiscal component is also of interest, for fishermen leaving the fishery and receiving money, but also from the government perspective spending money at first but recovering money if the grant is subject to taxation. In a way, each European member state indirectly collects a share of the public subsidy dedicated to decommissioning as well as construction or modernisation programmes. As a consequence, this may influence the incentives for government and the country as the whole to “apply” for these programmes.

4.6. Conclusions and recommendations

This section proposes a synthesis of the main elements discussed above and addresses the question raised in the beginning of the report.
At European level, the question of capacity adjustment policy has to be considered within a specific institutional context that may be analysed in terms of a principal-agent relationship with implications in terms of an information problem and an economic incentives dimension. In a simplified way, a two-tier Principal-Agent relationship appears, a more classic one at the lower level between the member state and the industry and a second one at the upper level between the EU and each state regulating authority. Each member state plays simultaneously the role of a principal and an agent with his own interests. As a result, the policy of capacity reduction through decommissioning schemes is decided on and implemented in a context of asymmetrical information between the different players, which may give rise to complex strategies. Adverse selection as well as moral hazard, though two classic concepts of the principal-agent theory, has been identified herein as two major components relevant to explain the players' strategies.

In most of the cases, the member state is faced with internal constraints and tries to reduce the impact of the EU capacity reduction policy in order to minimise the effects on its national fleet. Moral hazard then appears. This behaviour is rational owing to the pressure of national interest through fishermen organisation and the lack of credibility of the MAGP policy at EU level. It is common knowledge that capacity indicators used in the guidance programmes (GT or kW) are biased measures because of possible substitutions between inputs. This leads to an adverse selection problem. However, the main economic incentives for member state to comply with MAGP is the reward granted by the structural policy. It enables shared subsidisation by the EU and the State of the fishing industry through modernisation and building of new vessels. Of course, the coherence of the structural policy, aiming at reducing the capacity on the one hand and developing it on the other hand, can be questioned. This study highlights this problem and the consequences in terms of policy effectiveness from the CFP objectives. A necessary but not sufficient solution to the problem of capacity could be to stop subsidising, as subsidies tend to increase fishing capacity. Incentives to fulfil with MAGP objectives could be increased by laying down penalties if member states do not achieve the targets.

Another adverse selection problem occurs within the "lower" principal-agent relationship. In such case the principal (ie the manager) does not know much about the reve-

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26 Note that the two-tier relationship is even more sophisticated when a member state has to negotiate with other kinds of agents, e.g. the regional communities which have to fund decommissioning schemes, like in France.
nue (utility) or the agents' cost functions or the production technology (production function). This is a hidden information issue. All that is known by the principal is that production functions vary among agents and that each agent knows his own functions. The principal does not have information about the fishermen's willingness to leave the fishery sector and does not know how to fix the premium offered to fishermen.

A classic market solution to hidden information is signalling where the agent is incited to reveal information. A competitive tendering system well organised may lead fishermen to reveal their willingness to leave. In theory, this system reduces the windfall gains problem (e.g. the difference between the premium offered by the principal and the true willingness of each fisher) but it also faces difficulties like in the UK case. The fishermen's increasing knowledge about each other's information as a result of bids gives fishermen incentives to overestimate their own bids as compared to their real willingness. A one shot tender or one based on multiple shots sufficiently spaced could then be required to resolve this problem. On the other hand, an administrative definition of premium is used in most countries, based on the practical knowledge of the management authority and based on a trial-error system. The disadvantage of this process is that it is difficult to take care of the evolution of the economic situation of the firms and more specifically of the fleet segment targeted by the guidance programme. Real or expected increasing incomes will increase the opportunity cost of leaving the fishery sector and premium rates could be inefficient to give fishermen the right incentive. Conversely, decreasing revenues will, in theory, reduce the willingness to leave the fishery and so the necessary premium that has to be offered to the fishermen. In most cases, it is impossible to adjust the premium on a short term basis and the consequence is that fishermen receive windfall gains. This leads to a mis-utilisation of public funds even if the public managers responsible for decommissioning schemes try to minimise the cost of these programmes. In countries like France, the public authority presently uses the second hand market price for vessel as a reference in order to establish the right premium and circumvent the problem of lack of information about fishermen's willingness. It is considered that the premium given for vessel scrapping must be at least equal or superior to the value of vessels given by the market in order to incite fishermen to choose the first option.

From a public policy perspective, one of the objective of the methodology developed in this project was to model fishermen’s behaviour and their decision to leave or to stay in the fishing industry. The aim of the tool is to assess the role of different economic incentives individual fishermen are faced with and their impact on the fishermen’s willingness of to leave the fishing industry or a specific fishery, expressed in
monetary terms. This tool and empirical results may provide some advice to the principal for the administrative fixation of the premium but some aspects have to be underscored. First, the model does not integrate non monetary welfare effects which can be significant for fishermen and this leads to under-estimating the willingness to leave as proved in the Italian case study. Research has to be developed to consider this problem. Secondly, a sensitivity analysis on different parameters of the model (for example labour revenues and opportunity cost of labour in the economy) induces large variability of the individual willingness to accept (WA) to leave the sector. More generally, the estimation of WA raises a number of difficulties, including the fact that fishing firms take decisions in an uncertain environment; in particular, the future value of economic variables is uncertain. Apart from this fact (often solved in assuming that firms act under certainty), many other problems remain. The conclusion is that accurate estimation of WA needs a large amount of economic indicators about the fleets but also elements about technical and social situation of the fishermen (vessel age, skipper-owner age, …)

Nevertheless, the retrospective analysis of decommissioning schemes underlines the fact that premium allocation could be used in a discriminative way. In the French case, the premium per capacity unit is more important for small vessels than for the biggest; even the economic revenues and fishing mortality per capacity unit of the biggest is most of the time higher. All else equal, the economic incentives provided by the principal target a specific part of the fleet and the problem of the policy effectiveness must be examined with regard to MAGP objectives. It is interesting to underscore that qualification criteria applied to select applicants for the decommissioning schemes do not include the current level or historical level of catches that prove that the vessel have an impact on the stocks in term of fishing mortality.

In order to cope with the difficulty of assessing the long term results of decommissioning schemes at national level, the bio-economic model of decommissioning schemes applied to a case study provides information on the dynamics of the fleet and the stock and on the feed-back effects on the economic situation of the fishery. The problem of public cost is included at this stage. The classical analysis of fleet adjustment does not include the cost of such programmes and then overestimate their social benefits. Moreover, most approaches fail to consider the problem of asymmetrical information between regulators and fishermen. Our results in terms of cost-benefit analysis show that decommissioning policies improve the net surplus (e.g. producers’ surplus less public cost) for the "collectivity", i.e. all the agents of the economy. Of course, this leads to distributional transfers from taxpayers to fishermen. One of the
conclusions of the study is that windfall gains could be useful in an administrative premium system in order to be sure that fishermen will leave the sector and decommissioning policy will reach its objectives. Policy effectiveness will depend on the premium and on the budget level dedicated to decommissioning programmes.

Transferable rights based system such as individual transferable quotas or transferable licences are often considered as a substitute for decommissioning schemes to reduce fishing capacity. A qualitative result is that market signals provide incentives for economic agents to rationalise production. However, this study assumes that capital or capacity is not scrapped when the capital is non malleable or when the opportunity cost of capital is positive. This leads in most cases to a transfer of redundant capacity to another fishery inside or outside the country but always in the fishing industry. Capacity remains on a short or medium term basis in the fishery sector if not on a fishery subject to individual transferable quotas. Our conclusion is that decommissioning schemes may be seen as a necessary tool to reduce capacity and to adjust the fleet to the desired levels. The principle of cost recovery could be used to share the cost of the programmes that benefit to the fishermen and that may provide incentives for the implementation of better means of controlling the increase in capacity through the implementation of right based fishing. However, the subsidies dedicated to capacity reduction distort economic signals to the industry because fishermen are sure to earn money for vessel scrapping (Arnason 1998). A capacity reduction scheme may finally generate capacity increase and consequently generate certain inefficiencies, but subsidies to building and modernisation lead probably to higher adverse effects.

Executive summary of the recommendations

The Principal-agent theory applied to the analysis of economic incentives and capacity adjustment at EU level shows that compliance with the policy of capacity reduction is often seen by the agents (member states and fishermen) as a means to use the public subsidies to modernise or build fishing vessels. This condition is very attractive for the agents but the net effect on the whole capacity and the consecutive impact on the fishing mortality, fish stocks can be questioned because of the contradictory effects of the structural policy. This creates a problem of policy effectiveness and the allocation of subsidies to the fishing industry should be revised in order to deal with the problem.

- The level of subsidies allocated to the fishing industry should be reduced in order to avoid distortions in economic signals to fishermen.
If the level of subsidies offered to the fishing industry has to stay at the same current level, the allocation should be revised in order to increase the funds dedicated to the capacity reduction policy and to give agents subsidies to comply with capacity reduction objectives that do not lead to capacity increase.

Decommissioning schemes implementation including monetary incentives to scrap vessels can reduce capacity. This can lead to positive effects in terms of policy effectiveness and economic efficiency (increase in net surplus). Decommissioning schemes can be viewed as a complementary tool to regulatory measures such as individual quotas, licences, transferable (or not). However it is a necessary but not sufficient tool to reduce capacity in fisheries at EU level. Attention should be paid to the definition of the programmes at EU level to improve their effectiveness.

The duration of each decommissioning scheme should be reduced (one or two years) and not spread over many years as in actual MAGP.

Proof of fishing mortality reduction (historical catches of the vessel scrapped) should be used as a qualification criteria

The design of the decommissioning schemes should be improved at national level and should include a description of the means used to reach MAGP objectives (budget dedicated, fleet segment or group of vessels targeted, level of premium offered by segment or group of vessels, comparison of the premium offered with the economic indicators on the value of capital (ex: current value of the vessels on the second hand market)).

Administrative premium allocation should take care of the opportunity cost of vessels on the capital market and the opportunity cost of crew on the labour market.

Premium discrimination between fleet segments and the different fishing firms should be improved to adjust the level of the premium to the real situation and economic opportunities of the vessel owners and crews. It is useful to give the right incentives and to spare public money.

Redeployment of labour in other economic sectors should be facilitated through for example the development of alternative opportunities in the economy for fishermen (crew and skippers), skill improvement.

A competitive tendering system to select applicants could save public money and avoid windfall gains but need to clearly specify the objectives of the decommissioning schemes. However, the risk of collusion between fishermen exists because of the small number of applicants.
In most of the case, fishermen who have decided to scrap their vessel are able to re-invest the premium earned in the fishing industry. Means to reduce this behaviour should be found.

References to Chapter 4


Reference list of project papers for Chapter 4


Kalaydjian R. (2000) Principal-agent approach of the capacity policy, Ifremer


Communications or papers presented for Conferences


5. Economic Incentives and Quota Regulation

5.1. Introduction

5.1.1. Output controls in the fishery
Controls on output in a fishery are designed to regulate fishing mortality directly. From estimates of stock biomass and associated dynamics a Total Allowable Catch (TAC) is established for each species in the fishery, usually on an annual basis. In the case of a fishery involving more than one nation (as is the general rule within the EU) the TACs may be divided into national quotas.

Adherence to the TAC should, in theory at least, restrict fishing mortality to the target value on which the TAC is calculated, i.e. to the level desired by the management authority. In practice, however, ensuring adherence to the TAC is usually difficult (and therefore costly). Also, the manner in which the management authority or regulator attempts to ensure adherence has profound economic implications for the fishery. This chapter focuses on the economic incentives which drive fishing vessels to exceed quotas or otherwise to confound the manager’s objectives in terms of fishing mortality levels. It also addresses the incentive structure which makes economic outcomes sensitive to the way in which managers implement quota controls.

5.1.2. Quota regulation as an asymmetric information (agency) problem
Considering a single species fishery to which a TAC is applied, we assume that the TAC is less than the total capacity of all the vessels in the fishery, where we define capacity simply as the (feasible) level of output at which economic profits are maximised (and therefore, we assume, the level of output at which vessels will seek to operate if not constrained).

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27 The contents of the chapter is based on working papers carried out by: A. Hatcher (CEMARE, UK), F.C. Buisman, W.P. Davidse and E.W.J. Hoefnagel (LEI, Holland); and H. Frost and F. Jensen (SJFI and SDU, Denmark). The reports are mentioned in the references list. Aaron Hatcher is responsible for the use and interpretation of the working papers.

28 As compared to effort controls which attempt indirectly to regulate catches and therefore fishing mortality.

29 This will depend, Inter alia, upon the expected and actual distribution of catches across age classes in the fishery.
Otherwise the problem is trivial. The regulator is therefore faced with the task of restricting the output of at least some fishing vessels to below the level at which profits are maximised. It is axiomatic that these vessels will then have an incentive to evade such restrictions.

Viewed as an agency problem, with the regulator as principal and the fishing vessels as agents, we propose that the principal has a disutility for catches in excess of the TAC while the agents collectively have a utility for catches in excess of the TAC. A first-best (full information) solution for the principal is to impose an arbitrarily large penalty on the agents if they exceed the TAC, or, equivalently, to impose such a penalty on any individual agent who exceeds a given quota (a sub-division of the TAC). If the penalty in question is sufficiently large, no vessel will have an incentive to exceed their quota and the TAC will not be exceeded.

In the classic “hidden action” (or “moral hazard”) principal-agent problem (e.g. Holmström 1979) the principal is interested in the outcome of some unobservable action by the agent. The problem is characterised by the fact that the outcome is a stochastic function of the agent’s action (otherwise the principal could always infer the agent’s action from the outcome) and that the action is costly to the agent. The (second-best) solution to the problem is an incentive scheme that maximises the principal’s utility while satisfying two constraints; firstly, an “incentive compatibility” constraint that ensures that the interests of the agent are aligned with those of the principal, and secondly, a “participation” constraint that ensures the optimal incentive scheme (or contract) gives the agent at least his reservation level of utility (otherwise he would simply opt out of the contract).

We can see that the basic problem of quota regulation in fisheries is not a classic agency problem of this type. Firstly, the principal is only interested in the outcome per se and not in the agent’s actions. Secondly, as we have already suggested, the problem for the principal is trivial if the outcome can be observed. The fundamental real-world difficulty for the principal in the quota regulation problem is to observe the outcome. Otherwise, it could be argued, only a lack of political will would prevent the principal adopting a penalty scheme that would ensure that quotas were not exceeded.

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30 It is also necessary to assume “stochastic dominance” so that increasing the agent’s input (e.g. effort) increases the size of the expected outcome. However, the principal does not know the
Formally, the simple “full information” problem for the principal could be written

$$\min_{v, F(v)} u(v + F(v)) \quad \text{s.t.} \quad \pi'(v) = F'(v)$$

(5.1)

where $u(\bullet)$ is the principal’s disutility for a quota violation $v$, $(v)$ is the agent’s profit from a quota violation and $F(v)$ is the fine applied by the principal for violations (note that in the objective function we assume the principal does not value the resultant income). The constraint recognises that the agent will seek to maximise profits from $v$ if she can - this is the incentive compatibility constraint.\(^{31}\) Clearly it is possible for the principal to achieve a minimum (zero in fact) by ensuring that the constraint binds at all values of $v$, i.e. that there is no positive level of violation that is profitable.

Ensuring that

$$\pi'(v) = F'(v), \quad \forall v$$

(5.2)

however, would require a knowledge of the agent’s profit function, but the principal can achieve zero violations without the constraint ever binding. This simply requires that

$$\pi'(v) < F'(v), \quad \forall v$$

(5.3)

which can easily be assured if

$$F(v) = \begin{cases} 
0 & \text{if } v = 0 \\
\infty & \text{if } v > 0 
\end{cases}$$

(5.4)

as we suggested above.\(^{32}\)

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31 Note the omission of a participation constraint for the present. This constraint is discussed in 5.2.4.

32 The fine for a violation does not actually need to be infinite, just large enough to exceed any feasible marginal profit from violation. We could equally well propose an arbitrarily large reward for $v = 0$ if we allowed $F(v)$ to be negative.
It is not technically impossible for a vessel’s catches to be observed, but in most fisheries the cost of, say, a full-time observer on each and every vessel would be prohibitive. For this reason the first point of control in most fisheries is at the quayside where fish are landed. But even observing all landings is likely to be extremely costly, so most practical fishery monitoring systems involve a rationing of inspections both quantitatively (random inspections and/or targeted inspections) and qualitatively (from cursory to thorough).

If a violation is detected, the economics of the problem is straightforward, as we have seen. There is, however, now uncertainty about whether a given violation will be detected or not. This type of agency problem is most appropriately analysed through the economics of risk and expectations. A review of the economics of quota regulation is given in Chapter 2.

The general practical reliance on enforcing quota controls at the point of landing raises the issue of discarding. To a greater or lesser extent, discarding is an inevitable activity in all fisheries and will occur whenever the cost of retaining a particular part of the catch on board exceeds the benefit of landing it (see Pascoe 1997 for a review). As we see in the next Chapter, discarding because of quota controls means that quotas (and therefore the TAC) may be exceeded in terms of catches even if they are adhered to in terms of landings. Not only is discarding difficult to observe, however, in many quota management systems it is encouraged, even if only implicitly, in order to comply with quota regulations. The problem of discarding is considered further in 5.2.2.

5.2. Models of quota regulation

5.2.1. Introduction

In this Chapter we examine formally the economic incentives that appear when a fishing vessel, whose efficient operation is otherwise unconstrained, is subject to output regulations (quotas). We examine a number of cases with different assumptions, moving from the simplest model to models which more closely approach reality. The main distinction to be drawn is between fixed quotas and variable (transferable or tradeable) quotas, i.e. between quotas which cannot be varied in the short run, and quotas which, in theory, can (and which may therefore be treated as variable inputs).

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33 UK licence conditions, for example, refer to the amounts of fish “which may be retained on board, landed or transshipped”.
Throughout we treat the vessel as the decision-making unit or firm, and assume the objective of profit maximisation. 34

5.2.2. Fixed quota models

5.2.2.1. Deterministic; single product; single fixed quota (base-model)

The simplest case assumes that the vessel’s catch is a continuous deterministic function of effort and that there is a single homogeneous product. This implies, firstly, that the vessel can (precisely) choose its catch by choosing its level of effort, and secondly, that there is no qualitative variation in the catch and (hence) no variation in the output price. As a result there is no need to consider the problem of discarding in response to a quota constraint (catch and landings can be considered as synonymous) and there is also no incentive to discard low-value fish to replace them with fish of a higher value. 35

To keep the model simple, let a vessel’s short run profit per period be simply a function of composite “effort” (an input vector) $e$ and a parametric output price $p$. Then the profit function can be written

$$\pi(e; p) = pq(e) - c(e)$$

where $q(e)$ is catch (= landings) as a function of effort and $c(e)$ is the cost of effort (we will subsequently let the effort argument be implicit). In order to ensure an optimum, we assume non-increasing marginal returns to effort and increasing marginal cost of effort over the relevant range, i.e.

$q' > 0$, $q'' \leq 0$
$c' > 0$, $c'' > 0$

The vessel’s short run profit maximisation problem can be written

34 More strictly, we should assume maximisation of the utility of profits, to allow for the possibility of risk aversion (5.2.4) and non-monetary incentives (5.3.4).

35 In order to keep the arguments uncluttered we do not consider the possibility of a binding hold constraint (a physical constraint on the amount of fish that can be retained per period).
\[
\begin{align*}
\max_{e} \pi &= pq - c & \text{s.t.} & e \geq 0 \\
\text{and the first-order (Kuhn-Tucker) condition for an optimum at a positive level of effort is} & \\
\frac{c'}{q'} &= \frac{dc}{de} = \frac{dc}{dq} & (5.8) \\
\text{which is the usual equality of marginal revenue and marginal cost. Note that the choice variable here is } \text{effort, not catch, but that in our deterministic model} & \\
c' &= \frac{dc}{de} = \frac{dc}{dq} & (5.9) \\
\text{If we now introduce a fixed catch (landings) quota } Q \text{ as a constraint, then the problem becomes} & \\
\max_{e} \pi &= pq - c & \text{s.t.} & e \geq 0, \quad q \leq Q & (5.10) \\
\text{and the first-order condition (FOC) for a constrained optimum is now}^{36} & \\
\left( p - \lambda^* \right) &= \frac{c'}{q'} \Rightarrow \lambda^* = p - \frac{c'}{q'} & (5.11)
\end{align*}
\]

The Lagrange multiplier \(\lambda^*\) is the \textit{shadow value} or \textit{shadow price} of the quota at the optimum and is positive if the constraint is binding. The shadow price represents the marginal increment to profit from a marginal relaxation of the quota constraint (or the marginal loss in profit from a marginal tightening of the quota constraint). The term \((p - \lambda^*)\) in the first expression can be interpreted as the \textit{virtual price} (see Neary and

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36 The Kuhn-Tucker conditions are set out in full in Appendix 5.I, Section (i).
Roberts 1980) at which the unconstrained vessel would choose to produce at a level of output \( q = Q \). Clearly \( \lambda^* = 0 \) if the constraint is not binding, i.e. if we have an interior solution so that \( q(e^*) < Q \).

We can readily see that the shadow price is equivalent to the marginal tax (or fine) on over-quota landings that would have to be applied by an authority to induce firms to produce at a level of output \( q(e^*) = Q \).

We can incorporate the constraint (which in the real world clearly cannot be a constraint in the true sense of the word) into the objective function through a fine schedule as follows:

\[
\max \pi = pq - c - F \quad \text{where} \quad F = F(q - Q) \\
\begin{cases} 
F' > 0 & \text{if} \quad q > Q \\
F' = 0 & \text{if} \quad q \leq Q 
\end{cases}
\]

(5.12)

We assume in general that for all \( q > Q \),

\[
F' > 0, \quad F'' \geq 0
\]

(5.13)

i.e. that the fine is everywhere a non-decreasing function of over-quota landings.

The necessary FOC for an optimum is now

\[
\left( p - F' \right) q' = c' \quad \Rightarrow \quad p - F' = \frac{c'}{q'}
\]

(5.14)

In the real world, as we discussed previously, the problem for the authority is monitoring landings and hence detecting violations. Since in all practical cases the overall probability of inspection, detection, prosecution and sanction will be less than one, we

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37 This is exactly analogous to the use of a landings tax in order to regulate exploitation in a fishery.
need to model the objective function in terms of expected profits and the expected (subjective) probability of detection.

For a risk-neutral firm\(^{38}\) the problem now becomes

\[
\max_e E\pi = (1 - \phi)[pq - c] + \phi[pq - c - F]
\]

where \(\phi\) is the subjective probability of detection (which, we can assume, reflects the “true” probability of detection, i.e. the fisherman forms a reasonable estimate of his chances of being caught).

The FOC for an optimum is now

\[
(p - \phi F')q' = c' \quad \Rightarrow \quad p - \phi F' = \frac{c'}{q'}
\]

(5.16)

In words, a vessel facing a fixed quota will expand effort, and therefore output, until marginal cost just equates to marginal revenue net of the expected cost of a fine, given by the expected marginal fine multiplied by the expected probability of incurring that fine. Note that here we are assuming that the “fine” is not really punitive but is more like a tax (i.e. the vessel only pays for the over-quota landings). Nevertheless, it is clear that for the quota to be perfectly enforced, i.e. for \(q(e^*) = Q\), we must have

\[
\phi F' \geq p - \frac{c'}{q'}, \quad \forall q > Q
\]

(5.17)

i.e. for any level of catch above the quota limit, the expected marginal fine must be at least equal to the marginal profit. If the expected marginal fine is less than this, the (risk-neutral, profit-maximising) vessel will choose a level of output greater than the quota limit.\(^{39}\) This is a simple but fundamental result in the theoretical analysis of quota regulation.

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\(^{38}\) For a discussion of the implications of risk-aversion see 5.2.4.

\(^{39}\) As long as the expected marginal fine is greater than zero, however, output will still be less than it would be in the absence of any quota limit.
Now consider a vessel in a multispecies fishery catching \( m \) different species and facing \( m \) associated quotas. We assume for simplicity that the species are caught in a fixed proportion at all levels of effort.

Treating the quotas as constraints, but now allowing for the possibility of discarding (which for simplicity we will assume is costless), the vessel’s maximisation problem is

\[
\max_{e, d, j} \pi = \sum_j p_j (q_j - d_j) - c \quad \text{s.t.} \quad e \geq 0, \quad d_j \geq 0, \quad q_j - d_j \leq Q_j, \quad d_j \leq q_j
\]

(5.18)

which gives rise to the following FOCs

\[
\sum_j p_j \frac{q_j'}{q'} - \frac{c'}{q'} = \sum_j \left( \lambda_j - \sigma_j \right) \frac{q_j'}{q'}
\]

(5.19)

and

\[
p_j = \lambda_j - \sigma_j \quad \text{for} \quad d_j > 0
\]

(5.20)

where \( q = \sum_j q_j \) and \( q' = \sum_j q_j' \). The Lagrangian and Kuhn-Tucker conditions are set out in full in Appendix 5.I, Section (ii.a).

The Lagrange multiplier \( \lambda_j \) is the shadow price of the \( j \)th quota, equal to zero if the quota is non-binding. The multiplier \( \sigma_j \) on the other constraint (which, logically, prevents discards in excess of catches) equals zero for all \( q_j > d_j \) but can be positive where \( q_j = d_j \). It is apparent that this constraint will just bind (only) if a quota is set at zero, where the shadow price \( \sigma_j \) then has the trivial interpretation of the marginal benefit of relaxing the constraint (and so in effect preventing the quota constraint binding). Clearly a positive quota, no matter how small, means that this constraint cannot bind.

If the quotas are imposed in the same proportion as the different species appear in the vessel’s catch, then clearly all the quotas will bind at the same level of effort and there will be no incentive to discard.
If, on the other hand, the \( j \)th quota \( Q_j \) binds before the other quotas, which will occur if

\[
\frac{Q_j}{Q} \neq \frac{q_j}{q}
\]  

(5.21)

then \( \lambda_j \) becomes positive. Given the second of the two FOCs, however, it is only optimal to discard where the shadow price equals the market price. Otherwise it is optimal to retain the over-quota fish.

Again, we can model an enforcement system by replacing the quota constraints by fine schedules (and for simplicity omitting the discard constraint). This gives the FOCs 40

\[
\sum p_j \frac{q_j}{q'} - \frac{c'}{q'} = \sum F_j' \frac{q_j}{q'}
\]  

(5.22)

and

\[
p_j = F_j' \quad \text{for} \quad d_j* > 0
\]  

(5.23)

Now it is optimal to discard if the marginal fine from exceeding the quota for the \( j \)th species is equal to (or indeed greater than) the marginal revenue (given by \( p_j \)) otherwise it is optimal for the vessel not to discard fish of the \( j \)th species, even if the quota has been exceeded.

Allowing for imperfect enforcement of fines (with a subjective probability of detection) gives the equivalent conditions as

\[
\sum p_j \frac{q_j}{q'} - \frac{c'}{q'} = \phi \sum F_j' \frac{q_j}{q'}
\]  

(5.24)

and

\[
p_j = \phi F_j' \quad \text{for} \quad d_j* > 0
\]  

(5.25)

---

40 See Appendix 5.I, Section (ii.b).
In reality of course there is likely to be just a single fine schedule $F()$ where

$$F'_j = \frac{\partial F}{\partial q_j}, \quad > 0 \quad \text{if} \quad q_j > Q_j$$

(5.26)

and

$$F' = \frac{dF}{dq} = \frac{\partial F}{\partial q_1} + \frac{\partial F}{\partial q_2} + \ldots + \frac{\partial F}{\partial q_m} = \sum F'_j$$

(5.27)

If only the $j$th quota limit has been reached then clearly $F = F_j$.

If all quotas bind at the same level of effort, “perfect enforcement” requires, as before, that

$$\phi F' \geq \sum p_j \frac{q'_j}{q'} - \frac{c'}{q'}, \quad \forall q_j > Q_j$$

(5.28)

i.e. for any level of catch above the quota limit(s), the expected marginal fine must be at least equal to the marginal profit at that point.

If, however, one quota limit is reached before the others, “perfect enforcement” of this quota requires that

$$\phi F' \geq p_j, \quad \forall q_j > Q_j$$

(5.29)

as long as it is profitable for the vessel to continue to catch and retain fish of other species. While the quota has been enforced at the point of landing, however, it certainly has not been enforced at the point of capture - the vessel is simply discarding all fish of the $j$th species that are over the $j$th quota limit.\(^{41}\) The same will apply to the

\(^{41}\) Note that the discarding condition compares the expected marginal fine with marginal revenue (i.e. output price) not marginal profit. Once fish has been caught (which it clearly has to be be-
next quota to be reached, and so on, as long as it remains profitable to catch and retain fish of other species. Logically, it is possible that if the market price of the species subject to the least constraining quota were high enough, effort could continue to expand until all other species were being discarded. In this case only the least constraining quota in the overall quota package could (indirectly) be enforced at the point of capture.

5.2.2.3 Deterministic; heterogeneous product; single fixed quota

A case of particular interest is where the catch is differentiated qualitatively with a corresponding variation in the market price but where the entire catch is covered by a single quota. An obvious example is where fish of the same species but different size classes command different prices. Incorporating a fine schedule (rather than a constraint) from the outset and again assuming that discarding is costless, the objective function can now be written

$$\max_{e,d_j} \pi = \sum_{j} p_j \left(q_j - d_j\right) - c - F' = F \left(\sum_{j} \left(q_j - d_j\right) - Q\right)$$

s.t. \( e \geq 0, \quad d_j \geq 0 \)

(5.30)

where the subscript now refers to the \( j \)th size class.

The FOCs can be written

$$\sum_{j} p_j \frac{q_j'}{q'} - \frac{c'}{q'} = F'$$

and

$$p_j = F' \quad \text{for} \quad d_j > 0$$

(5.31) \hspace{1cm} (5.32)

If the quota is not exceeded \((F' = 0)\) it is not optimal to discard (unless, for example, a hold constraint binds). If the quota is exceeded, so that \(F' > 0\), then it is optimal to discard fish of size class \( j \) as long as the marginal fine is greater than or equal to the unit price for that size class, which is \( p_j \) (again, the cost of catching the fish has al-

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\(^{42}\) See Appendix 5.1, Section (iii).
ready been incurred). Provided the marginal fine is not very large the marginal conditions ensure that the lowest value size classes are discarded preferentially until $F'$ is just equal to the unit price of the lowest value size class retained. Effort will be expanded until the marginal profit from the retained portion of the catch is just equal to the marginal fine. In theory, it is possible that effort could be increased until all size classes apart from the most valuable are being entirely discarded and the optimal effort condition could then be written

$$p_m \frac{q'_m}{q'} - \frac{c'}{q'} = F'$$

(5.33)

where the subscript $m$ refers to the most valuable size class. There is no incentive to discard fish of this size class (if the marginal fine is just equal to the marginal profit from catching the most valuable size class and retaining only that size class it must be less than the unit price of that size class and so the discarding condition cannot hold).

It is not difficult to see that this model is identical to one in which a multispecies quota is applied in a fishery where (as is usually the case) different species command different market prices. If the marginal fine from exceeding the multispecies quota is greater than the marginal revenue from landing fish of species $j \neq m$ it will be optimal to discard fish of that species and to continue to catch and retain fish of a higher value (as long as the marginal revenue from the retained species in the catch exceeds the marginal cost of catching them and the marginal fine from landing those species). As before, depending on the shape of the fine schedule, relative prices and the cost of effort it is possible that fishing could continue for one species only, all catches of the lesser valued species being discarded.

Again, allowing for a probability of detection of less than one we can substitute the expected marginal fine throughout, i.e. $E(F') = \phi F'$ where $\phi$ is the subjective probability of incurring a fine.

5.2.2.4 Stochastic; single product; single fixed quota

In reality, a vessel’s catch is never a deterministic function of effort. Rather, catch is a random variable whose probability distribution is related to effort. The implications of this can be appreciated from a re-definition of the base model as a stochastic model.

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43 See Section 5.2.4.
Formally, catch is now a function of effort $e$ and a “state of the world” parameter $\theta$ over which, we assume, the fisherman has no influence.

$$q = q(e; \theta)$$

(5.34)

Catch $q$ and effort $e$ are now not related deterministically but by a probability distribution with the cumulative distribution function

$$F(q,e)$$

(5.35)

which is assumed to be convex in $e$ so that increasing effort has decreasing (expected) returns. For a given level of effort the expected catch is given by the integral of the density function over the range of feasible outcomes

$$E(q) = \int_0^{q_{\text{max}}} q f(q,e) \, dq$$

(5.36)

where $q_{\text{max}}$ is the upper bound to the distribution of $(q,e)$. This is the maximum catch that is feasible, set by the ecology of the species and/or the technology of the vessel. The lower bound is assumed to be zero.

The vessel’s profit function is given by

$$\pi(e, p) = p \left[ \int_0^{q_{\text{max}}} q f(q,e) \, dq - d \right] - c(e)$$

(5.37)

and the objective function is now

$$\max_{e,d} \pi = p \left[ \int_0^{q_{\text{max}}} q f(q,e) \, dq - d \right] - c \quad \text{s.t.} \quad e \geq 0, \quad \left[ \int_0^{q_{\text{max}}} q f(q,e) \, dq - d \right] \leq Q$$

(5.38)

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44 To avoid confusion, note that it is conventional to use $F()$ to designate a cumulative probability distribution and $f()$ to designate a probability density function, but elsewhere we have used $F()$ to describe the fine (penalty) function.
where we allow for discards since the vessel cannot now precisely determine its catch level by choosing the level of effort (the expected catch can only be known *ex post*).

The conditions for an optimum can be written

\[
(p - \lambda^*) = \frac{c'}{\int_0^{q_{\text{max}}} q f_e(q, e^*) dq}
\]

and

\[
p = \lambda^* \quad \text{for} \quad d^* > 0
\]

While replacing the quota constraint with an expected fine schedule gives the conditions

\[
p - \frac{c'}{\int_0^{q_{\text{max}}} q f_e(q, e^*) dq} = \phi F'
\]

and

\[
p = \phi F' \quad \text{for} \quad d^* > 0
\]

In practice the first condition is unlikely to be met exactly by adjusting effort. The vessel could either (a) expand effort until $\phi F'$ from the last haul just exceeds marginal profit and then discard according to the discarding condition if necessary (the cost of effort having already been incurred), or (b) expand effort until $\phi F'$ from the last haul just falls short of marginal profit (here there is no incentive to discard).

### 5.2.3. Variable quota models

#### 5.2.3.1. Deterministic; single homogenous product; single variable quota

We now let the per period quota be variable. The fisherman can choose not only the level of effort but also, *in the short run*, the amount of quota. We will assume that there exists a market for quota and, for the moment, that the vessel operates in a wide, competitive, quota market, so that we treat the quota price as parametric, i.e. it is exogenously determined.

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45 See Appendix 5.1, Section (iv).
The vessel’s profit maximisation problem with two choice variables (effort and quota) is now

$$\max_{e,Q} \pi = pq - c - rQ - F \quad \text{s.t.} \quad e \geq 0, \quad Q \geq 0, \quad q \geq Q$$

(5.43)

where, as before, $F = F(q - Q)$ and $r$ is the unit short run (rental) price of quota. The final constraint ensures full utilisation of quota and helps to derive a sufficient condition for violation of the quota level. Note that for simplicity we have again ignored the possibility of a hold constraint and assumed that there is no initial (free) endowment of quota. These simplifications do not substantially alter the results.

The necessary FOCs are

$$p - \frac{c'}{q'} = F'$$

and

$$r = F'$$

(5.44)

Or, equivalently, in terms of expected fines

$$p - \frac{c'}{q'} = \phi F'$$

and

$$r = \phi F'$$

(5.45)

The second condition is the condition for violation. Taken together, the two conditions imply that the vessel will optimise by equating marginal profit with either the quota price or the expected marginal fine, whichever is the smaller. In other words, if the quota price is less than the expected marginal fine from landing over-quota fish, then it is rational to buy more quota. If, on the other hand, the quota price is greater than the expected marginal fine, then it is rational to violate the quota limit. Section 5.2.5.3 considers the implications of endogenous, rather than exogenous, quota prices.

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46 See Appendix 5.1, Section (v).
5.2.3.2 Deterministic; joint products; multiple variable quotas

It is relatively straightforward to generalise the case of tradeable quotas to a multispecies fishery. The vessel’s maximisation problem can be written

$$\max_{e, Q_j, d_j} \pi = \sum p_j (q_j - d_j) - c - \sum r_j Q_j - F_j$$

s.t. \( e \geq 0, \quad Q \geq 0, \quad d_j \geq 0, \quad (q_j - d_j) \geq Q_j, \quad d_j \leq q_j \)  

(5.46)

where again we have modelled the fine schedule as an additive function of implicit fine schedules for each species, i.e. \( F = \sum F_j, \quad F_j = F_j(q_j - d_j - Q_j) \). The FOCs for optimal (positive) \( e, Q_j \) and \( d_j \) are, with a probability of detection \( \phi \)

$$\sum p_j \frac{q_j'}{q'} c' = \sum \phi F_j' \frac{q_j'}{q'},$$

(5.47)

$$r_j = \phi F_j'$$

(5.48)

and

$$p_j = \phi F_j'$$

(5.49)

The three marginal conditions can be interpreted as follows. Effort will expand until marginal revenue equals marginal cost, including the cost of the fish as an input (which it effectively is) - this is given by the marginal cost of quota (the quota price) or the expected marginal fine, whichever is the smaller. It is optimal to discard fish of species \( j \) if the market price is less than the expected marginal fine (and hence also, implicitly, the quota price).

5.2.3.2. Deterministic; heterogeneous product; single variable quota

Now we can examine the case of a single species tradeable quota where different size classes of that species command different prices. Incorporating a fine schedule \( F = F(\sum(q_j - d_j) - Q) \) and again assuming that discarding is costless, the objective function can be written

47 See Appendix 5.1, Section (vi).

48 A quota price in excess of the market price is conceivable as a very short term phenomenon, or where the quota price is determined in a wider market (as we have assumed here) and there is locally weak demand for a particular species. In most circumstances it is unlikely, however.
\[
\max_{e, Q, d_j} \pi = \sum p_j (q_j - d_j) - c - rQ - F
\]
\[
\text{s.t. } e \geq 0, \quad Q \geq 0, \quad d_j \geq 0, \quad \sum (q_j - d_j) - Q \geq 0, \quad d_j \leq q_j
\] (5.50)

where the subscript refers to the \(j\)th size class. The FOCs for optimal (positive) \(e\), \(Q\) and \(d_j\) are, with a probability of detection \(\phi^{49}\)

\[
\sum p_j \frac{q'_j}{q'} - \frac{c'}{q'} = \phi F',
\] (5.51)

\[
r = \phi F'
\] (5.52)

and

\[
p_j = \phi F'
\] (5.53)

It is optimal to discard fish of size class \(j\) as long as the market price is less than the expected marginal fine from retaining and landing that fish (and the quota price \(^{50}\)). Otherwise it is optimal to buy quota as long as the quota price is less than the expected marginal fine. A theoretical condition for discarding all but the highest value element of the catch would be that the expected marginal fine from exceeding the quota and the quota price both exceed the market price of all other size classes in the catch (given, of course, a positive expected net profit from catching and retaining only the most valuable size class).

### 5.2.4 Risk-aversion

In the foregoing we have assumed that fishermen are risk-neutral, that is, they are indifferent between the expected value of an uncertain outcome and its certain monetary equivalent. In terms of an outcome that involves the risk of a financial penalty, this implies that they evaluate an expected fine at its monetary value and that they are indifferent to the uncertainty itself. The wider issue of attitudes and influences that may make fishermen behave other than as strictly rational profit-maximising agents in their responses to rules, regulations or norms of behaviour imposed by an external au-

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49 See Appendix 5.1, Section (vii).

50 A quota price greater than the output price for some size grades is quite feasible where there is a wide disparity between the prices received for different size grades.
authority, their peers, or whoever, is considered in the following chapter. For the moment, we can model the consequences of risk-aversion (a preference for certainty over risk, a preference for less risk over more risk) by looking at the agent’s (the vessel operator’s) expected utility of profits instead of expected profits.

The simplest way to model risk-aversion in the present context is to assume a diminishing marginal utility of wealth or income. This implies that expected losses in income are more costly in utility terms than expected symmetric increases in income are of benefit. Formally, we assume that the utility of, say, profits from fishing exhibits the following:

\[ U(\pi) > 0, \quad U'(\pi) > 0, \quad U''(\pi) < 0 \]  
(5.54)

We can see the implications of risk aversion by returning to the simplest model of a fixed quota limit and a fine schedule and expressing the vessel’s objective function in terms of the expected utility of profits. Thus

\[
\max_{e} EU(\pi) = (1 - \phi)U(pq - c) + \phi U(pq - c - F) = F(q - Q) 
\]  
(5.55)

which gives the FOC

\[
(1 - \phi)U'(\pi_0)(pq' - c') + \phi U'(\pi_1)(pq' - c' - F'q') = 0 
\]  
(5.56)

where

\[ \pi_0 = pq - c \quad \text{and} \quad \pi_1 = pq - c - F \]  
(5.57)

This can be rearranged to give

\[ p - \frac{c'}{q'} = \frac{U'(\pi_1)}{(1 - \phi)U'(\pi_0) + \phi U'(\pi_1)} \phi F' \]  
(5.58)

which can be written (since the denominator on the RHS of the expression is simply the expected marginal utility of profits)
Risk aversion implies
\[ U'(\pi_1) > U'(\pi_0) \Rightarrow \frac{U'(\pi_1)}{EU'(\pi)} > 1 \]  

Thus the expected fine is weighted (effectively increased in “value”) according to the degree of risk-aversion exhibited. Note that assuming risk neutrality (here a constant marginal utility of income) collapses the condition to the expression previously derived. We have
\[ U'(\pi_1) = U'(\pi_0) \Rightarrow \frac{U'(\pi_1)}{EU'(\pi)} = 1 \]  

and hence the FOC is, as before
\[ p - \frac{c'}{q'} = \phi F' \]  

5.2.5. Some notes on the fine schedule

5.2.5.1 Continuous vs. discontinuous functions

In this chapter we have assumed, implicitly at least, that the fine schedule for exceeding a per period quota is a smooth continuous function of \([(q - Q) > 0]\) so that all the marginal conditions we have examined which include \(F'\) represent feasible optimum conditions for profit maximising at some positive level of violation \((q > Q)\). In effect, we have modelled the fine as a real-world expression of the shadow price in the simple constrained optimization problem.

Whether the marginal fine is constant \((F''' = 0)\) or increasing \((F''' > 0)\) will, depending on the parameters of the fine schedule, have implications for the level of the vessel’s output in relation to the quota limit, or, in the case of a tradeable quota, the amount of equilibrium output covered by quota.
As we suggested in Chapter 5.1, however, we could envisage a discontinuous fine schedule in which any detected quota infringement results in a lump sum fine. An *arbitrarily large* fine, which should in theory deter any violation as long as the risk of detection is positive, can be represented as

\[
F(q) = \begin{cases} 
\infty & \text{if } q > Q \\
0 & \text{if } q \leq Q 
\end{cases}
\]  
\tag{5.62}

If we had \( \phi F'(q > Q) = \infty \) then the marginal conditions would be impossible to solve. The objective function itself would show that the expected profit from violation would be vanishingly small. This would result in no incentive for a vessel to exceed a fixed quota or to avoid paying for tradeable quota. Note that incentives to discard in order to remain within quota limits or to “high-grade” within a quota would remain, however.

5.2.5.2 *Fine schedules and quota prices*

If, in a market for tradeable quota, the quota price is not somehow controlled by an external authority or determined in a wider market, as we assumed previously, it must be endogenous to the system of \( n \) vessels in the fishery. Standard analysis of equilibrium quota prices in compliant markets suggests that the market price for quota is determined *ceteris paribus* by vessel technology and the total supply of quota. The *inverse derived demand* for quota results from the willingness to pay for marginal quota units, and the maximum willingness to pay for a unit of quota will be set where vessels just cover their short run average costs after paying for quota (assuming a homogenous fleet). 51 This is the difference between the output price and the minimum of the average cost curve, thus

\[
r_{\text{max}} = p - \min \left[ \frac{c(e)}{q(e)} \right]  
\]  
\tag{5.63}

In a non-compliant market (by which we mean a market in which vessels will only purchase quota if it is less costly than incurring a penalty) the equilibrium price \( r^{*} \) will be determined by the parameters of the enforcement scheme as well as the ves-

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51 The question of which costs should be considered here is examined in the following section.
sels’ technology and the total supply of quota. Specifically, \( r^* \) cannot be greater than the expected marginal penalty \( \phi F' \) (otherwise vessels would simply choose to incur the fine instead); otherwise its upper bound will remain \( r_{\text{max}} \). Given our assumptions about vessel behaviour, the endogenous quota price will be determined by the fine schedule.

Formally, let the expected marginal fine for over-quota landings be a constant, \( \phi \tau \). Let the total supply of quota be \( \Sigma Q \). Let each of the \( n \) (identical) vessel’s output at \( p - \phi \tau = c'/q' \) be equal to \( q_i(\phi \tau) \) which is the \( i \)th vessel’s demand for quota at \( r \geq \phi \tau \). Then we can observe that

\[
\begin{align*}
\Sigma Q \leq \Sigma q_i(\phi \tau) & \Rightarrow r^* = \phi \tau \leq r_{\text{max}} \\
\Sigma Q > \Sigma q_i(\phi \tau) & \Rightarrow r^* < \phi \tau \\
\Sigma Q \geq \Sigma q_i(\phi \tau = 0) & \Rightarrow r^* = 0
\end{align*}
\]

i.e. if the total supply of quota is just equal to or less than the vessels’ demand for quota at \( (p - \phi \tau = c'/q') \) then the quota price will equal the marginal fine, while the quota price will be less than this if the total supply of quota is greater than the aggregate demand at \( (p - \phi \tau = c'/q') \). Assuming a perfectly functioning market it should, in fact, be bid up to the shadow price of each vessel’s share of the total quota. If the supply of quota is just equal to or exceeds the unconstrained demand (i.e. where \( \phi \tau = 0 \)), the quota price will be zero. An arbitrarily large marginal fine for violations will therefore result in a quota price anywhere between 0 and \( r_{\text{max}} \) depending on the total quota supply giving the (perfectly enforced) industry inverse demand curve for \( r = r(Q) \) with

\[
0 \leq r^* \leq r_{\text{max}}, \quad \frac{dr^*}{dQ} < 0
\]

If the expected marginal fine is an \textit{increasing} function of the violation size, i.e. \( F'' > 0 \), then the determination of the quota price will depend on the total supply of quota and the slope of the marginal fine. A very steep marginal fine function will return the (perfectly enforced) market clearing quota price, while a very shallow marginal fine function will represent a ceiling to the quota price as before.
In the case of a constant marginal fine, all vessels will land in excess of their quota holdings wherever $\Sigma Q < \Sigma q_i(\phi\tau)$ since $\Sigma q_i(\phi\tau)$ is the equilibrium output level. In the case of an increasing marginal fine, the proportion of landings not covered by quota will depend on the slope of the fine function and in particular the marginal fine for the first unit of illegal landings.

5.2.6. Sufficient conditions for viable operation
Establishing a marginal condition for short run profit maximisation under quota regulation does not in itself establish that the corresponding level of profit is viable, or indeed positive. We know that the minimum profitable (viable) short run level of output must be at a point where average revenue (the output price) at least equals average variable costs. Otherwise short run profit is negative. This implies that, given an average cost curve with a minimum at some positive level of output (as is usually assumed) and an output price that is not everywhere above the average variable cost curve, it is possible that a fixed quota may be small enough to represent a level of output that is not viable in the short run.

But even securing non-negative short run profits will not guarantee viable operation in the medium term since the vessel’s fixed costs have to be covered. Fixed costs would certainly include costs associated with the vessel, for example, which are incurred whether or not the vessel puts to sea. However, there may be other costs which, although normally considered as variable costs in economic analysis, may represent quasi-fixed costs to the vessel operator; labour for example. Although payments to crew may be based on a percentage of net revenues, medium term viability of the enterprise will likely depend upon a minimum level of crew remuneration required to keep them from seeking alternative employment. In any case, we can state that the minimum viable level of profit per period is equal to the periodised fixed (and maybe quasi-fixed) costs. This is equivalent to saying that the vessel must be operating at a level of output where the output price is on or above the average total cost curve for the period.\(^{52}\)

In terms of effort and assuming a constant (parametric) output price we can write this condition as

\(^{52}\) We are implicitly considering quota limits that will be (expected to be) repeated in future periods, otherwise we could assume that a vessel would expect to “catch up” with meeting deferred fixed costs in future periods.
where \( k \) is the vessel’s fixed costs per period and \( \phi F' \) is the expected marginal fine which constrains output. This states that net marginal revenue must equal marginal cost at a point on or above the average total cost curve. This condition can be thought of as equivalent to the participation constraint that we omitted for simplicity in 5.1. In essence, if the authority tries to reduce the output of a vessel to below the minimum viable level it is effectively trying to force the vessel out of business. In the following chapter we will consider the implications this may have for incentives to violate quota limits.

5.3. A summary of incentives in quota regulation

5.3.1. Introduction

This chapter draws from the analysis presented in the previous part of the chapter some basic propositions about incentives under different types of quota regulation and examines them from a practical policy perspective. The aim is to link the theoretical analysis of quota regulation with the analysis of national management systems in the following part of the chapter, by establishing the types of incentive structure which different real-world management systems are likely to produce.

5.3.2. Incentives under fixed quota systems

If a vessel’s profit-maximising level of output in any given period is greater than the fixed quota that is applied to that vessel for the same period, the vessel (if its operation is directed by a rational, profit-maximising agent) will have an economic incentive to exceed the fixed quota. It is not unreasonable to propose that the greater the difference between the quota and the profit-maximising level of output, the greater is the incentive to exceed the quota. This would follow directly if we take the measure of the incentive as the foregone profit at the constrained level of output. At the margin, however, the measure of importance is (for a risk-neutral agent) the marginal profit at the quota level of output. This is the shadow price derived in 5.2.2.1.\(^{53}\)

\(^{53}\) Only as long as marginal profit is decreasing in output will the shadow price increase as the quota becomes more constraining. Otherwise, the shadow price will not increase, and may decrease, even as the foregone profit (the area under the marginal profit curve) increases. Thus al-
We saw from 5.2.2.1 that in order to ensure that the vessel does not exceed the quota, the management authority would have to ensure that the expected marginal fine at the quota level of output is at least equal to the shadow price (marginal profit at that point). If the expected marginal fine is less than this, there will still be an incentive to exceed the quota. The vessel will then continue to expand output until marginal profit just equals the expected marginal fine. If the expected marginal fine at the quota limit were very large, however, we could guarantee that the quota would be respected by a rational agent.

This is true for single quotas in a single species fishery - and also for multiple quotas in a multispecies fishery, whether or not the quotas for individual species are fixed in the same proportion as the different species appear in the vessel’s catch. However, in the multispecies case the marginal profit from retaining, rather than discarding, fish of a species for which the quota has been filled is just equal to the market price, since the costs of fishing have already been incurred. If, as is often the case, quotas can only be enforced at the point of landing, the vessel then has the opportunity to discard fish at sea in order to avoid (or reduce) the expected fine for landing over-quota fish.

Given our simplifying assumptions, there is no incentive to discard in a single species fishery if (and only if) there is no price differential between different elements in the catch (commonly size classes, but there could be price differences between males and females, or between immature and gravid females, for example). If there are price differentials, there will be an incentive at or above the quota level of potential landings (i.e. landings in the absence of discarding) to discard any fish for which the expected marginal revenue (market price) is less than the expected marginal fine that would be incurred if they were retained and landed. At the same time, as long as the marginal profit from catching and retaining only a part of the catch exceeds the expected marginal fine from so doing it will be optimal to carry on fishing (see 5.2.2.3).

It would appear that the greater the expected marginal fine for exceeding the quota, the more likely it is at the margin that less valuable parts of the catch will be discarded in order to avoid the fine, but also the more likely it is that it will be optimal to stop fishing altogether at or near the quota limit. Even if the marginal fine is large enough to ensure no over-quota landings, however, it may still be optimal to carry on

though the shadow price is a critical incentive measure for marginal conditions, its magnitude is not necessarily an indication of the degree to which output is constrained.

54 We ignore “unintentional” quota overruns due to the stochastic nature of catches in the real world.
fishing once the quota has been filled in order to replace fish of low value with those of higher value. This is commonly referred to as “high-grading”. The marginal condition for this to be optimal would be the equality of marginal profit from the additional catch with the marginal profit forgone by discarding a unit of the least valuable part of the existing catch. Since the costs of effort have already been incurred, the latter is simply equal to the market price. In simple terms, it is profitable to high-grade as long as the marginal profit from an additional unit of effort is greater than the marginal loss from discarding.

In a multispecies fishery with multiple fixed quotas we have already proposed that each and all of the individual quotas can be enforced at the point of landing if the expected marginal fine for violation is sufficiently large. If the quotas are not in the same proportion as the species appear in the catch, however, there will be discarding of all species other than the species subject to the least constraining quotas as long as it is profitable to continue fishing for those species alone. In either case, if fish of a particular species command different market prices according to their size, then there may be incentives as above to high-grade within each respective quota.

In summary, fixed quotas give rise to incentives to land over quota fish if, as is usually the case, they represent a constraint on a vessel’s efficient operation. They can be enforced at the point of landing if the expected fine for violation is large enough, but not, in most realistic circumstances, at the point of capture. Incentives to discard are created by price differentials within a single species and by species quota combinations out of proportion to the species mix in the catch.

5.3.3. Incentives under tradeable quota systems
The significance of a market for quota is that the shadow price of quota can everywhere be compared with both the expected marginal fine and the market price for quota (which, as before, we will initially assume is parametric). The (rationally operated) vessel will optimise by equating the shadow price with either the expected marginal fine or the quota price, whichever is the smaller.

In the previous chapter we assumed, implicitly, that the marginal fine was a constant, like a flat-rate tax. If the expected (constant) marginal fine were less than the quota

55 This should include the cost of discarding, which we omitted earlier for simplicity: see, for example, Anderson (1994).
price, the rational vessel would buy no quota, while if the quota price were less than
the expected marginal fine, it would equate its quota holdings with its output (land-
ings). If the marginal fine were an increasing function of the violation size, however,
then for a given total supply of quota, depending on the shape of the penalty function
the optimal quota holding would be a percentage of landings. The steeper the penalty
function, the closer the quota holding will be to 100% of landings. At the same time,
with an increasing marginal penalty function, the percentage of landings covered by
quota will increase as the total supply of quota increases.

In a multispecies fishery, it will be optimal to buy quota wherever the expected mar-
ginal fine from landing the fish is greater than the quota price. Effort will expand until
marginal profit (the shadow price) equals the weighted average quota price 56 or the
expected marginal fine, whichever is the smaller. If the market price of a particular
species is less than both the expected marginal fine and the quota price, it will be op-
timal to discard, but in most practical circumstances this is unlikely. It is certainly
very unlikely if the quota price is endogenous to the fishery we are considering (see
below). Assuming a perfectly functioning quota market, we would therefore expect
the level of discarding because of quotas per se to be zero in most cases.

Tradeable quotas will not remove incentives to discard due to price differentials
within a species, however. Assuming that the fine schedule is such as to ensure that
quota holdings are equated with landings, it will be optimal to discard any element of
the catch for which the market price is less than the quota price. Where there is a very
wide price differential between fish of different sizes, for example, it is possible that
the market price for small fish may indeed be lower than the quota price.

On the other hand the commonly encountered assertion (often with reference to
Copes, 1986) that high-grading is a particular feature of tradeable individual quotas is
wrong. With tradeable quotas incentives to high-grade do not depend merely on mar-
ket price differentials, but on the existence of market prices below the quota price.
Otherwise it is optimal to expand output until marginal profit equals the quota price
(or the weighted-average quota price in a multispecies fishery), and it is optimal to
retain fish and land it as long as the market price exceeds the quota price. High-
grading is likely to be a significant problem if the real price of marginal quota units is
high, because of transaction costs for example, or if the total supply of quota becomes

56 The average of the quota price for each species, weighted according to the mix of species in the
marginal unit of the retained catch.
constraining so that it is not possible to buy additional quota. But the implication is then that the quotas are more like fixed rather than variable quotas.

More generally, our analysis of tradeable quotas has throughout assumed a perfectly functioning market for quota (which is unlikely in practice). In particular, the transaction costs of adjusting short-run quota holdings at the margin may indeed be high, so effectively increasing the quota price (which will increase incentives to high-grade and to land fish without quota). In some cases marginal adjustments may not be possible at all, so that per period quota holdings have to be decided in advance. Then the quotas will in the short run resemble fixed quotas. However, even if marginal adjustments are costly, the ability of vessels to adjust their permanent quota holdings means that incentives to land over-quota fish are likely to be reduced when compared with fixed quotas.

In 5.2.5.3 we briefly examined how the quota price is likely to be determined within a fishery depending, ceteris paribus, on the fine schedule and the total supply of quota. If the marginal fine for over-quota landings is large (i.e. a large constant marginal fine or a very steep increasing marginal fine function or a large lump sum fine) the quota price will be the shadow price of quota equalised across firms in the fishery. A moderate marginal fine will, however, provide a ceiling to the quota price. In a fishery the equilibrium quota price will depend inter alia upon the total supply of quota, the economic performance of the fleet and the degree of any market power enjoyed by some firms.57

Finally, our previous analysis focused only on the rental price of quota. In practice a significant amount of trade in quota may be in permanent holdings where the price will be the asset value i.e. the capitalisation of the rental value. The real capital value of quota will depend upon the usual parameters of asset pricing (discount rates, risk, etc.) as well as attributes such as option values, but there is likely to be particular uncertainty over future rents.58

57 See, for example, Anderson (1991).
5.3.4. Non-monetary incentives

In the previous chapter we considered risk-aversion as an example of how the expected utility of a quota violation could be reduced to below its monetary value, or, equivalently, how the expected value of a marginal fine could be increased above its monetary value in the decision-making process.

There may of course be a number of factors other than the expected financial penalty and the individual’s degree of risk aversion that determine compliance with fixed quotas, the percentage of landings covered by variable quotas, willingness to discard etc. Such factors might for example be normative (feelings of moral obligation, perceptions of regulatory legitimacy) or social instrumental (peer attitudes and pressures). The influence of these factors may be to reduce the utility of any violation so that there is a decision not to violate, rather than altering the marginal conditions which determine the extent of a violation once the decision to violate has been made.\(^{59}\)

While there is no conventional view in economics about how to deal with non-monetary influences, their effect can be thought of as reducing the expected utility of any violation. One possible simple model of moral influence, for example, is (for a violation level of profit \(\pi\) and a fine \(F\))

\[
EU(v) = m(M) \left[ (1 - \phi)U(\pi) + \phi U(\pi - F) \right]
\]

(5.69)

where \(m(M)\) is decreasing in \(M\) and takes values from 0 to 1. Large values of \(M\) (strong feelings of a moral obligation not to violate) produce values of \(m(M)\) close to zero and hence reduce the expected utility of a violation to almost nothing. Weak moral judgements, on the other hand, result in values of \(m(M)\) close to one and so hardly affect expected utility.\(^{60}\) In general we can envisage that the greater are the normative and social pressures to comply with quotas, the smaller is the expected utility of any feasible quota violation. Note that a model of this type does not alter our marginal conditions for a positive violation under any given set of beliefs or influences: the effect of, say, a moral judgement is assumed to be independent of any fi-

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59 It is important to distinguish between the level of expected utility and the marginal properties of the expected utility function (the “principal of marginal deterrence”). See, for example, Shavell 1992.

nancial penalty. The moral judgement, we assume, reduces the likelihood of a violation decision, but if a violation decision is made the usual optimising conditions will apply.

In the case of a vessel facing a fixed quota which represents less than its minimum viable level of output, we could envisage that the incentive to cheat would be increased, perhaps because of a relaxation of the influence of non-monetary factors, or a change in attitudes to risk.

5.4. An appraisal of quota management systems in Denmark, the United Kingdom and the Netherlands

5.4.1. Introduction
This chapter examines the quota management systems operated in Denmark, the United Kingdom and the Netherlands in order to identify the incentive structures that are likely to be presented to fishing vessel operators in those countries. The analysis draws on the detailed descriptions of the quota management systems contained in working papers from the project and only a brief summary of the key features of each of the national systems is given here.

5.4.2. Denmark
The Danish quota management system relies on an administrative allocation of periodic fixed quotas. Quotas are allocated on a short term basis (for a few weeks or months) or, in some fisheries, also as annual individual quotas (IQs), see also Section 3.2.5.

In the North Sea and Skagerrak cod fisheries bi-monthly quotas (“rations”) are allocated according to vessel length band. Catches up to 20% in excess of a two-month quota can be deducted from the following period’s quota (except in the final period of the year). Quota undershoots of up to 20% can be transferred forward only from the July-August quota allocation. In the small-scale Kattegat cod fishery there is a similar system but with two-week quotas set for vessels under and over 12 metres in length.

Vessels fishing for cod in the Baltic can opt either for rations or annual IQs (which are non-transferable). The rations are adjusted from time to time by the authorities according to the overall pattern of uptake. The allocation of annual quotas is based on the best of the vessel’s recorded landings during the previous two years. If landings
exceed 80% of the IQ by mid-June an additional allocation is granted, but if landings are less than 50% of the quota by this time the difference between the recorded landings and 50% of the quota is forfeited. A similar rule applies to a threshold of 80% of the quota by mid-October.

The herring/mackerel quotas in the North Sea are allocated as 85% annual IQs and 15% rations. The annual IQs are 50% based on the best of a vessel’s previous three years catches and 50% on length band (a small reduction is applied if a vessel did not land all its allocation in the previous year). IQs can be pooled (normally by up to 7 vessels) and vessels can apply to have their IQs for the next year adjusted as a result (in order to retain individual “track records”). If a vessel chooses to participate in one of the other pelagic fisheries it forfeits a part of its quota for each 15 days it spends in another fishery. The ration fishery is designed for smaller vessels that are highly mobile between different fisheries.

Herring fishing in the Kattegat is regulated using periodic rations based on vessel length band, as is the Baltic herring fishery, but here the rations are adjusted if a vessel also holds permits for other fisheries. If a vessel is fishing in both the Baltic and Kattegat a single series of common rations are allocated. The North Sea sprat fishery also uses length-banded periodic rations.

5.4.3. United Kingdom

Until quite recently (1999) quota management in the UK was based upon a system of allocations made according to vessels’ immediate past history of landings (“track records”) but since then all allocations have been fixed. Prior to 1999 annual quota allocations were made to three sectoral groups on a percentage basis according to the groups’ aggregate track records over the previous three years (or two years in the case of some pelagic stocks). The three groups were the producers’ organisations (POs) who each received an allocation in respect of their member vessels over 10 metres in length, the so-called “non-sector” i.e. those over 10 metre vessels not in membership of a PO, and the inshore (10 metre and under) sector (whether or not those vessels belonged to a PO). Since individual records are not kept on 10 metre and under vessels, the allocation for this group was essentially just the residual. Since 1999, however, the quota allocations have been fixed on a percentage basis, each over 10 metre vessel receiving a fixed number of quota “units” which were equivalent to 100kg in 1999 but now rise or fall in value (weight) depending on movements in the size of national quotas.
The individual allocations carried by each over 10 metre vessel are used to calculate the annual group allocations to each of the POs and to the non-sector. For many vessels their individual allocations are entirely notional i.e. they are only used to calculate a group allocation, but for some they represent an individual quota (IQ). IQs are allocated directly by the Government in a few cases, to a small number of larger firms and vessels in the pelagic and distant water fisheries, but for the most part IQs are implemented only by the POs. The POs can more or less freely choose how to manage their quota allocations and while some operate a quota pool, rationing quotas over the year by means of monthly limits, others operate internal IQ systems for some or all of the stocks for which they hold quotas.

The quota shares allocated to the (now small) non-sector are managed directly by the Government using a system of monthly landings limits which are varied throughout the year depending on the observed pattern of uptake. The uptake of the quota shares reserved for the inshore (10 metre and under) sector has historically not been regulated unless the level of estimated landings dictated an early fishery closure but more recently temporary stops, and lately monthly limits (in the *Nephrops* fishery), have been imposed for some stocks in order to spread a fishery over 12 months.

In the UK quota is not officially tradeable and no person holds a legal title to any share of the national quotas (the quota management system is an entirely informal arrangement operated by agreement between Government and industry). Nevertheless there is an increasing trade in quota. Quota units are attached to licences, and licences can be bought and sold, and by employing various administrative mechanisms it is possible to move units between licences when they are traded. Licences can be aggregated under the “capacity unit” system in order to licence a larger vessel and this results in the aggregation of quota units. The main developments in quota trading, however, have taken place between vessels within the same PO or in different POs without any adjustments to the numbers of quota units attached to their licences. Quota is exchanged between vessels either on a once off basis (an annual quota lease) or on a continuous basis (a quota sale). In the case of vessels in different POs this necessitates a transfer or exchange of quota between the POs, which is allowed by the system. Since the new fixed allocation system does not (yet?) permit annual adjustments to vessels’ units, permanent quota “sales” involve annual transfers in perpetuity. It is apparent that there is no incentive for an individual vessel belonging to a PO which op-
erates a pooled quota system to buy quota\textsuperscript{61} (and vessels in the non-sector have no means of doing so). Some of the POs operating pooled quotas have, however, collectively purchased quota by various means in order to enhance the size of their quota pool (the extra quota is held on a “dummy vessel”).

5.4.4. Netherlands
Quota management in the Netherlands is now almost entirely based on a system of individual transferable quotas (ITQs) which are determined as a percentage of the national quotas i.e. they rise and fall in weight value with changes in national quotas. Only the distant water fishery for blue whiting is outside the ITQ system, although beam trawlers holding only sole and plaice ITQs are still allocated by-catch allowances (as flat-rate monthly limits) for cod and whiting.

There are permanent and lease markets for ITQs and these are regulated in various ways. For example ITQs must be held for all related species (i.e. species which are caught together); ITQs must be held on a vessel (although there are allowances for delays in vessel replacements); a vessel cannot normally divest itself of its entire quota holdings unless it is retiring from fishing; and part holdings of sole and plaice or cod and whiting quotas can only be sold to vessels already holding quota for the same species. Otherwise, there is considerable freedom to trade in quota which has developed in response to pressure from fishermen, the appearance of “grey” markets for quota and apparent enforcement problems resulting, in part at least, from trade restrictions.

A significant feature of the Dutch ITQ system is the formation of “co-management” Groups which was initiated in 1993. These are associations of ITQ owners which are legally distinct from the POs (although on the whole the Groups and POs coincide). They introduce a degree of collective responsibility for managing the uptake of ITQs, including responsibility for monitoring landings and penalising infringements, and facilitate the quota trade both within and between Groups. Membership of a Group is encouraged through relaxed rules on quota trading (and additional fishing days allowances). In addition, Group members’ days-at-sea allowances (based on engine power) are pooled. Although the total fishing time for the Group is restricted, therefore, it is

\textsuperscript{61} There are limited exceptions. A few POs operate a “pool-plus” system whereby a vessel can enhance its pool share with quota leased or bought from another vessel.
possible for individual allowances to be more flexibly determined according to levels of quota use.

5.4.5. Summary and discussion
Comparing the three national quota management systems described above, we can see that the Danish and Dutch systems provide examples of quite different approaches to the allocation of national quotas among the fishing fleets. The Danish system involves an allocation of quotas determined almost entirely by the management authorities, whereas under the Dutch system quota allocations are almost entirely determined by the quota market. The UK system falls somewhere in-between; quota allocations are determined under an administrative system, but there is a partial market for quota which results in a degree of effective quota re-allocation within some parts of the national fleet.

An administrative (as opposed to market) allocation of quotas will produce fixed vessel quotas per period, whether the period in question is short (e.g. one month) or longer (annual). The simplest allocation of this type is an equal sharing of the quota amongst all vessels in the fishery irrespective of their individual characteristics. This method of allocation may be chosen for its simplicity, but also because it is perceived to be equitable, either by the management authority or by the industry itself (in which case the allocation might become politically less contentious and therefore less costly for the authority to implement). Since national quotas are set on an annual basis, the authority may determine short-period quotas according to historical patterns of uptake by the fleet as a whole and then adjust these throughout the year according to the current pattern of uptake. This approach to quota allocation is observed in the Danish and UK systems. In the UK the “ration” system (as it is known in Denmark) is used both by the Government (for the non-PO over 10 metre sector) and as an internal allocation system by a number of the POs for their own group allocations.

Given an administrative approach to quota allocation, from an economic perspective we might expect that the authority should make some attempt to allocate quota in such a way that the shadow value of the quota constraint is equalised across all vessels, so that the allocation is as efficient as possible (in effect mimicking the allocation that a perfectly functioning quota market would achieve through the quota price). Attempting a near equalisation of shadow prices (i.e. minimising the variance of shadow prices across firms) could reduce enforcement problems to the extent that
with a moderate expected marginal penalty the number of firms for which the net incentive to cheat\textsuperscript{62} is positive is likely to decrease.

The practical problem for the authority if it seeks to achieve an efficient allocation is that of knowing the characteristics of each vessel’s technology in each quota allocation period. This is clearly a formidable information requirement and for all practical purposes would be impossible to achieve. A second-best strategy for the authority is to allocate per period quotas according to some proxy for vessel capacity, such as vessel size. This is done in Denmark in most of the ration fisheries and was also the norm in the UK before the PO allocations represented as large a proportion of the national quotas as they now do.\textsuperscript{63} While we might expect the allocation of quotas to be improved under such a system, there are likely to be incentives at the margins of the vessel size bands to, for example, lengthen existing vessels or build longer new vessels in order to receive larger quota allowances.\textsuperscript{64}

An alternative strategy is to base quota allocations on recorded landings in a previous period, or on the average recorded landings over a number of previous periods. This is done in the case of Iqs in Denmark and until quite recently was the method used for calculating all sectoral allocations in the UK. While the attractions of this method for the authority are understandable, there is some logical inconsistency in the methodology and also potentially serious information problems. The logical inconsistency arises from the fact that the landings recorded in the previous period are not necessarily the actual landings but the declared legal landings (given that a vessel is unlikely to declare an illegal level of landings). Thus vessels for which previous allocations gave rise to significant incentives to land over-quota fish will continue to receive the same allocations, all else being equal. Also, the system may provide incentives for mis-reporting, particularly in multi-species (or more strictly multi-stock) fisheries where effort can be distributed in many different ways between fisheries. There may be incentives to declare landings larger than actual landings in order to provide options for flexibility of effort in subsequent periods, for example, to establish an his-

\textsuperscript{62} i.e. the difference between the shadow price and the expected marginal fine at the quota limit

\textsuperscript{63} One or two of the UK POs still determine their members’ monthly landings allowances according to vessel size.

\textsuperscript{64} In the UK the absence of individual quota controls for vessels of 10 metres or less has resulted, within the rules of the capacity licensing system, in a relative concentration of vessels of exactly (or just under) 10 metres in length but with disproportionately large physical capacity (GT) and engine power.
torical track record in a fishery or to increase the sale value of a licence (as was possible in the UK). The system of “track record” based allocations in the UK was ended largely because of alleged mis-reporting, often over-reporting, of landings. In most cases this was apparently caused by a desire among the POs to protect and enhance their quota “portfolios” relative to other POs and to the non-sector. PO member vessels and potential member vessels had an incentive to declare landings up to the allowed quota limits in order to achieve “good” track records.

One of the problems we would expect with fixed quotas in a multi-species fishery is that of quota-related discarding due to the likely inequality between the species ratio in the catch and that in the vessel’s mix of per period quota limits. Basing allocations on past landings would be expected to ameliorate this problem to some extent but given the likely discrepancies between actual and reported landings as discussed above, together with changes from year to year in the relative abundance of different species and in the market prices for different species, as well as changes in a vessel’s technological characteristics, the problem is likely to remain. Related to this, but at the international level, the allocation of national quotas based on shares agreed many years ago (the principle of “relative stability”) can give rise to chronic quota imbalances which no national quota allocation system can resolve.65

Highgrading, we have argued, is a problem associated principally with individual quotas per se and will occur to a greater or lesser extent wherever there are significant price variations within a species. A near-efficient quota allocation based on the approaches discussed is likely to reduce incentives to highgrade compared with a less efficient allocation.

In theory, a market for quota should, if it functions properly, result in an allocation of quota that is efficient. Given an enforcement scheme that effectively deters landings without quota, the equilibrium quota price will be determined by the equalisation of shadow prices across firms. We saw in Chapter 5.2 that the formation of the equilibrium quota price will depend on enforcement. If expected marginal penalties for landing fish without quota are low, the quota price may be depressed, as in the case of a constant marginal fine.

65 In the UK, for example, the national quota for North Sea saithe (Pollachius virens) is small compared to its recent relative abundance on the grounds and reports of significant discards of saithe are common in the UK fishing press.
Earlier, it was argued that where it was difficult (costly) for vessels to adjust their per period quota holdings at the margin, in the short run tradeable quotas would resemble fixed quotas and would result in the incentive problems associated with fixed quotas. In the UK there is some market allocation of quota but trade is confined to some parts of the fleet only and the transaction costs are likely to be large, since much of the trade involves movements of quota between POs, backed up by complex legal agreements between vessel owners (and, in some cases, their POs). Unlike in the Netherlands, where the system facilitates quota trade in the short-run, in the UK short-run adjustments are difficult except within the POs which operate internal ITQ systems.

Table 5.1 gives some idea of the recent levels of quota prices in the Netherlands and the UK. The prices obtained are selling prices (i.e. for permanent quota holdings) averaged over the year. The UK prices are those recorded by a vessel management company which is mainly involved in broking quota deals between Anglo-Dutch vessels and other vessels in the UK fleet. The marked differences between UK and Dutch quota prices for North Sea sole and plaice may have a number of causes, but such significant differences are unlikely to be due to differences in output prices or vessel technology. Much of the UK production of sole and plaice is landed into Dutch ports and the principal buyers of North Sea sole and plaice quota in the UK are the Anglo-Dutch vessels which are very similar to the Dutch-registered vessels targeting the same stocks (beam trawlers). It is likely that the observed price differences to a great extent reflect (a) the supply of quota relative to demand, and (b) the structure of quota markets in the UK and the Netherlands. Whereas the quota market in the Netherlands is formal and organised, the quota market in the UK is informal and organised on a very ad hoc basis. Of course the structure of the market will in turn have an influence on both the supply of, and demand for, quota, so the two factors are necessarily interlinked. The quota prices may also be affected by differences in the quality of enforcement and levels of compliance in each country.

66 Vessels registered in the UK and fishing against UK quotas but having Dutch owners and predominantly landing their catches into Dutch ports.
### Table 5.1. Mean UK and Dutch quota prices 1996-2000 (£ per tonne)

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<tbody>
<tr>
<td>North Sea plaice (UK)</td>
<td>£1,800</td>
<td>£2,000</td>
<td>£1,800</td>
<td>£1,500</td>
<td>£1,800</td>
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<tr>
<td>North Sea plaice (NL)*</td>
<td>£4,100</td>
<td>£4,300</td>
<td>£4,900</td>
<td>£3,900</td>
<td>n/a</td>
</tr>
<tr>
<td>North Sea sole (UK)</td>
<td>£10,000</td>
<td>£10,000</td>
<td>£8,000</td>
<td>£8,000</td>
<td>£10,000</td>
</tr>
<tr>
<td>North Sea sole (NL)*</td>
<td>£30,000</td>
<td>£24,800</td>
<td>£21,400</td>
<td>£16,400</td>
<td>n/a</td>
</tr>
<tr>
<td>Area VII hake (UK)</td>
<td>n/a</td>
<td>n/a</td>
<td>£2,500</td>
<td>£3,500</td>
<td>£4,500</td>
</tr>
<tr>
<td>Area VII anglerfish (UK)</td>
<td>n/a</td>
<td>n/a</td>
<td>£2,500</td>
<td>£3,500</td>
<td>£5,000</td>
</tr>
</tbody>
</table>

* converted from Dutch Guilders at average current rates; n/a - no data available. Sources: Danbrit Ship Management Ltd (UK prices); LEI-DLO (Dutch prices).

The difficulty of obtaining reliable data on discards and on over-quota landings meant that the extent of these problems could not be assessed empirically for each country. It was also not possible to conduct surveys of compliance and enforcement. These issues have been the subject of other EC-funded studies. A recent study of enforcement in the UK, Denmark and the Netherlands found positive levels of quota violation in all countries but the lowest levels in the Netherlands. It appeared that in many cases expected penalties were rarely high enough to deter quota infringements on their own, and that the social responsibility engendered by the Dutch “Group” system, together with the flexibility afforded by ITQ’s, was a significant factor in producing high levels of compliance in the Netherlands. Another study found evidence in the UK that normative and social influences were significant in determining compliance with quotas, although so were the level and probability of financial penalties.

### 5.5. Discussion and conclusions

#### 5.5.1. Incentive problems

Given a fishery quota that is less than the total economic capacity of the fleet, it is axiomatic that there will be incentives to exceed any individual quotas which are applied by the management authority. The magnitude of individual incentives will be determined by the total quota size and by the distribution of quotas among vessels in the fleet. An efficient allocation (the allocation which, in theory, a quota market would produce) equalises the shadow value of quota across firms and will secure the highest economic profits. For a given fine schedule, reducing the variance of quota shadow prices can reduce the likelihood of any vessel having a net incentive to cheat.

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(land over-quota fish). In the case of tradeable quotas, the nature of the fine schedule will influence the equilibrium quota price in the fishery.

If the expected marginal fine for landing over-quota fish is large enough, it is possible to achieve total compliance with quota limits, however they are allocated. The difficulty (cost) of monitoring activities at sea means that in many fisheries it is only possible to enforce at the point of landing. Therefore, even if perfect enforcement can be achieved at the point of landing there may be discards due to quotas. Incentives to discard are created by species quota combinations that do not match the pattern of catches in a multispecies fishery, and by price differentials within a single quota (high-grading). Incentives for both types of discarding can be reduced by having variable (tradeable) rather than fixed quotas. High-grading is a product of individual quotas per se and the problem is likely to be exacerbated with fixed quotas rather than tradeable quotas, but it may be a significant problem where the market structure results in tradeable quotas being effectively fixed in the short run.

5.5.2. Changing the incentive structure

5.5.2.1 Over-quota landings

It is clearly possible in theory to ensure that there are no over-quota catches, but in practice the cost is likely to be prohibitive. Analysis of the incentives to exceed quotas at the point of landing shows that the expected marginal fine for landings in excess of a quota should be at least as large as the marginal profit, i.e. the shadow price, at that level of output. This is ensured if the expected marginal fine is very large. Since the expected fine is a function of the fisherman’s subjective probability of detection and the anticipated fine the management authority can choose the most cost-effective combination of penalty and inspection probability. Inspections need not be random but can be targeted in some way. This is the conventional enforcement solution, but it is nevertheless an-incentive based approach.

We can argue, and we know from empirical evidence, that non-monetary incentives can reduce violation levels. Management structures, institutions and instruments that command the support and respect of fishermen and engender normative and social-instrumental incentives to comply can reduce the expected utility of violations and hence the overall level of violation. It is unlikely, however, that external enforcement

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69 See, for example, Sutinen and Andersen (1985), Mazany (1993).
can be entirely replaced, especially since it appears that enforcement itself is important in producing respect for regulations. Also we should not expect vessels operating with less than a minimum viable level of quota voluntarily to respect a quota limit however it is decided.

It is worth noting that a tax on all landings would reduce the marginal profit at all levels of output and so reduce incentives to exceed quotas.

It is difficult to envisage a workable system of positive payments to fishermen in order to achieve compliance with quota limits, even if the necessary public expenditure were considered justified by the potential stock benefits or could be recouped from the industry in some way. It would, for example, be possible to reward vessels for presenting their landings for inspection, but there would then be an incentive to present a legal level of landings in order to receive a premium and to then land the illegal element of the catch elsewhere. We could also envisage that fishermen could be required to deposit a refundable bond with the authority at the start of each year, receiving repayments for inspected landings. Again, however, there would be incentives to collect the repayments and to land illegal catches elsewhere. In either case there would be increased demands on the authority’s inspection effort, and certainly no possibility of replacing the enforcement system.

Finally, it is apparent that for a given total quota incentives to exceed quotas will be reduced for all vessels if the total capacity of the fleet is reduced. For any total quota size there will be a level of fleet capacity at which each and every vessel could operate efficiently without constraints.

5.5.2.2 Discarding

Discarding is a feature of all practical quota management systems where quotas can only be enforced at the point of landing. With individual quota limits, incentives to discard are only absent in a single species fishery where there is a uniform price for all elements of the catch. There will also be no quota-related incentives to discard if a quota is applied globally and the entire fishery is closed when one or more of the species quotas have been reached.

Incentives to discard because of inappropriate multispecies quota combinations can be reduced if the fleet capacity is reduced, or if quotas can be traded, particularly at the
short run margin. If the national quotas do not match overall patterns of catches, however, these incentives cannot be eliminated for all vessels.

If transactions costs make marginal quota trading difficult, or quota prices are inflated because of a short term reduction in the supply of rental quota, it might be possible for retrospective trading to be undertaken at a later date in order to adjust quota holdings to the species mix in the landings. There might be problems, however, if at the year end there was insufficient spare quota to cover vessels’ excess landings.

If discarding is costly (morally if not financially) there may be incentives for vessels to alter their technology (gear) in order to change the pattern of their catches. Otherwise, it would be possible for authorities to provide payments in order to give vessels incentives to change their gear. Similarly it is possible that discarding could be reduced if vessels had an incentive to change their normal patterns of fishing time or place. In most cases however deviations from normal activity are inherently less efficient and the loss in efficiency as well as the cost of additional regulation and/or a subsidy would have to be weighed against the possible benefits.

Incentives to high-grade should be significantly reduced if quotas can be traded at the margin, as compared to fixed quotas, but since high-grading depends upon price differentials it is possible to use selective taxes or subsidies in order to remove these differentials. It is also possible, in theory at least, to introduce quotas for each and every size grade, for example, in order to remove the incentives to high-grade. This would then be analogous to the case of multiple quotas in a multi-species fishery. There would be problems in setting the overall quota ratios, since there are likely to be significant variations in the catch size composition from area to area, season to season, boat to boat and day to day. Overall, the level of high-grading would be expected to decrease, but the management and monitoring costs might be high.

It is of course possible to make discarding an illegal activity, but the problem is then to have an enforcement system that is effective in deterring discards. This is really the same as arguing for quota enforcement to be at the point of catching rather than landing. It is also possible to provide incentives for vessels to land, rather than discard, over-quota catches. This requires, however, that the net value of the over-quota catch must be exactly zero to the vessel. If it is positive then an incentive is created to exceed the quota limit(s). If it is negative, on the other hand, then the vessel will simply

70 See Anderson (1994).
discard as before. A similar approach is the “deemed value” scheme developed for the New Zealand ITQ system\textsuperscript{71} in order to discourage the discarding of catches for which a vessel is unable to obtain quota. The basic idea is to tax over quota landings without implying any illegality on behalf of the vessel operator. The value charged to the fishermen should be greater than the short-run quota price (otherwise the vessel would opt to pay the tax instead of attempting to acquire quota) but not so great as to discourage landing. Needless to say, the problems in setting the correct rate are considerable and the monitoring requirements are at least as onerous as for straightforward enforcement.

Other potential economic solutions to quota-related discarding include quota substitution and value-based quotas. The former involves establishing quota substitution rates in multispecies fisheries which will encourage vessels to use spare quota to cover over-quota landings of a different species. The key is to set a substitution rate that will provide incentives to substitute quota in order to cover incidental quota overruns without providing incentives to deliberately target the other species using substituted quota rather than purchasing additional quota for the targeted species. This requires the rate to be set so that the shadow value (opportunity cost) of the substituted quota is greater than the rental price of the other quota but less than the net market price for the species which would otherwise be discarded. Quota substitution has been used in Iceland.\textsuperscript{72}

Value-based quotas have been proposed in order to eliminate incentives to high-grade as well as quota-related discarding in multi-species fisheries.\textsuperscript{73} The idea is to remove all incentives to increase the value of output so that a vessel is left only with incentives to minimise costs. Potential problems with value-based quotas include achieving the correct total quota targets, because of the difficulty of converting quantities to values on the basis of prices which are fluctuating and which depend (still) on the price/size differentials for a given species, as well as the unpredictable targeting of different species.

\textsuperscript{71} See Baulch and Pascoe (1992), Pascoe (1997).
\textsuperscript{72} See Pascoe et al (1994).
\textsuperscript{73} Turner (1996), Wilmann (1996).
5.5.3. Conclusions

Whenever quotas are constraining in a fishery, there will be economic incentives for vessels to exceed the quotas. The net economic incentive to violate a quota can be reduced to zero if the enforcement scheme is such that the expected penalty makes a potential violation unprofitable, but any positive expected marginal penalty will reduce output to below the unconstrained level. We might expect that if a vessel were subject to a quota representing a level of output below that necessary for medium term viability of the firm, its incentive to violate the quota limit could be greater than predicted by the (short-run) shadow value of the quota. Otherwise, quotas represent reduced positive profits and reduced levels of efficiency in the fleet, but not necessarily a threat to the viability of all firms. This would depend upon the profitability of the fleet at any point in time.

If quotas can be traded, and if the enforcement scheme ensures that quota holdings are equated with output, the distribution of quota should be efficient but there will still be constraints on vessels’ operation and hence (gross) incentives to exceed quotas. Provided there is heterogeneity in the fleet, however, ITQ systems should provide incentives for some downward adjustment of total fleet capacity\textsuperscript{74} and hence an overall reduction in incentives to violate.

The only real practical solutions to the problem of discarding are provided by tradeable quota systems, but there will always be some residual incentives to discard marketable fish. Reductions in incentives to discard from tradeable quotas will be severely compromised if it is difficult and costly to adjust quota holdings in the short run.

The importance of non-monetary incentives is recognised and emphasised. The utility of a quota violation can be reduced, possibly to zero, if there are normative or social incentives to comply. Aspects of the overall management system which engender or strengthen non-monetary incentives to comply are important to consider. Linked to this, the asset value acquired by ITQs may considerably influence compliance decisions, particularly where the fishery is organised in such a way that compliance is observed by other fishermen.

\textsuperscript{74} See, for example, Arnason (1990), Anderson (1995).
References to Chapter 5


**Reference list of project papers for Chapter 5**

Hatcher Aaron (1998): Incentives in quota management systems: an agency perspective

Hatcher Aaron (1998a): Quota management in the United Kingdom


Appendix 5.I: Kuhn-Tucker conditions for constrained optima in Chapter 5.2

i) Deterministic; single product; single fixed quota

\[ L = pq - c + \lambda(Q - q) \]
\[ L_e = pq' - c' - \lambda^* q' \leq 0, \quad e^* \geq 0, \quad L_e e^* = 0 \]
\[ L_{\lambda^*} = Q - q \geq 0, \quad \lambda^* \geq 0, \quad L_{\lambda^*} \lambda^* = 0 \]

(ii) Deterministic; joint products; multiple fixed quotas

(a)

\[ L = \sum p_j(q_j - d_j) - c + \sum \lambda_j (Q_j - q_j + d_j) + \sum \sigma_j (q_j - d_j) \]
\[ L_e = \sum p_j q'_j - c' - \sum \lambda_j * q'_j + \sum \sigma_j * q'_j \leq 0, \quad e^* \geq 0, \quad L_e e^* = 0 \]
\[ L_{d_j^*} = -p_j + \lambda_j * - \sigma_j * \leq 0, \quad d_j^* \geq 0, \quad L_{d_j^*} d_j^* = 0 \]
\[ L_{\lambda_j^*} = Q_j - q_j + d_j^* \geq 0, \quad \lambda_j^* \geq 0, \quad L_{\lambda_j^*} \lambda_j^* = 0 \]
\[ L_{\sigma_j^*} = q_j - d_j^* \geq 0, \quad \sigma_j^* \geq 0, \quad L_{\sigma_j^*} \sigma_j^* = 0 \]

(b)

\[ L = \sum p_j(q_j - d_j) - \sum F_j - c \]
\[ L_e = \sum p_j q'_j - \sum F_j q'_j - c' \leq 0, \quad e^* \geq 0, \quad L_e e^* = 0 \]
\[ L_{d_j^*} = -p_j + F_j^* \leq 0, \quad d_j^* \geq 0, \quad L_{d_j^*} d_j^* = 0 \]
(iii) Deterministic; heterogeneous product; single fixed quota

\[ L = \sum p_j (q_j - d_j) - c - F + \sum \sigma_j (q_j - d_j) \]
\[ L_e = \sum p_j q'_j - c' - F' \sum q'_j + \sum \sigma_j q'_j \leq 0, \quad e^* \geq 0, \quad L_e e^* = 0 \]
\[ L_{d_j} = -p_j + F' - \sigma_j q'_j \leq 0, \quad d_j^* \geq 0, \quad L_{d_j} d_j^* = 0 \]
\[ L_{\sigma_j} = q_j - d_j^* \geq 0, \quad \sigma_j^* \geq 0, \quad L_{\sigma_j} \sigma_j^* = 0 \]

(iv) Stochastic; single product; single fixed quota

\[ L = p \left[ \int_0^{q_{\text{max}}} q f(q,e) dq - d \right] - c + \lambda \left( Q - \int_0^{q_{\text{max}}} q f(q,e) dq + d \right) \]
\[ L_e = p \int_0^{q_{\text{max}}} q f'(q,e^*) dq - c' - \lambda \int_0^{q_{\text{max}}} q f'(q,e^*) dq \leq 0, \quad e^* \geq 0, \quad e^* L_e = 0 \]
\[ L_d = -p + \lambda s^* \leq 0, \quad d^* \geq 0, \quad d^* L_d = 0 \]
\[ L_{\lambda} = Q - \int_0^{q_{\text{max}}} q f(q,e) dq + d^* \geq 0, \quad \lambda^* \geq 0, \quad \lambda^* L_{\lambda} = 0 \]

(v) Deterministic; single homogenous product; single variable quota

\[ L = pq - c - qQ - F + \mu (q - Q) \]
\[ L_e = pq' - c' - F' q' + \mu q' \leq 0, \quad e^* \geq 0, \quad L_e e^* = 0 \]
\[ L_Q = -r + F' - \mu q \leq 0, \quad Q^* \geq 0, \quad L_Q Q^* = 0 \]
\[ L_{\mu} = q - Q^* \geq 0, \quad \mu^* \geq 0, \quad L_{\mu} \mu^* = 0 \]
(vi) Deterministic; joint products; multiple variable quotas

\[ L = \sum p_j (q_j - d_j) - c - r_j Q_j - \sum F_j + \sum \mu_j (q_j - d_j - Q_j) + \sum \sigma_j (q_j - d_j) \]

\[ L_e = \sum p_j q'_j - c' - \sum F'_j q'_j + \sum \mu_j^* q'_j + \sum \sigma_j^* q'_j \leq 0, \quad e^* \geq 0, \quad L_e e^* = 0 \]

\[ L_{Q_j} = -r_j + F'_j - \mu_j^* \leq 0, \quad Q_j^* \geq 0, \quad L_{Q_j} Q_j^* = 0 \]

\[ L_{d_j} = -p_j + F'_j - \mu_j^* - \sigma_j^* \leq 0, \quad d_j^* \geq 0, \quad L_{d_j} d_j^* = 0 \]

\[ L_{\mu_j} = q_j - d_j^* - Q_j^* \geq 0, \quad \mu_j^* \geq 0, \quad L_{\mu_j} \mu_j^* = 0 \]

\[ L_{\sigma_j} = q_j - d_j^* \geq 0, \quad \sigma_j^* \geq 0, \quad L_{\sigma_j} \sigma_j^* = 0 \]

(vii) Deterministic; heterogenous product; single variable quota

\[ L = \sum p_j (q_j - d_j) - c - rQ - F + \mu \left[ \sum (q_j - d_j) - Q \right] + \sum \sigma_j (q_j - d_j) \]

\[ L_e = \sum p_j q'_j - c' - F' \sum q'_j + \mu \sum q'_j + \sum \sigma_j^* q'_j \leq 0, \quad e^* \geq 0, \quad L_e e^* = 0 \]

\[ L_Q = -r + F' - \mu^* \leq 0, \quad Q^* \geq 0, \quad L_Q Q^* = 0 \]

\[ L_{d_j} = -p_j + F' - \mu^* - \sigma_j^* \leq 0, \quad d_j^* \geq 0, \quad L_{d_j} d_j^* = 0 \]

\[ L_{\mu} = \sum (q_j - d_j) - Q^* \geq 0, \quad \mu^* \geq 0, \quad L_{\mu} \mu^* = 0 \]

\[ L_{\sigma_j} = q_j - d_j^* \geq 0, \quad \sigma_j^* \geq 0, \quad L_{\sigma_j} \sigma_j^* = 0 \]
6. General discussion

While case specific discussions and conclusions are found in chapter 3-5, more general viewpoints are forwarded in this Chapter. Information problems in fisheries from a theoretical point of view have played an important role in the study.

While the identification of economic incentives and the disparity between fishermen’s objectives and society’s objectives has been subject for numerous studies where often full information is assumed, the use of the principal-agent method is rather novel in fisheries economics. The principal-agent method is, however, well known from studies in environmental economics that has strong resemblance with fisheries economics.

It could be argued that the principal-agent approach is not applicable to fisheries because although the fish resources are common property and owned so to speak by the public, the public, materialised by the Government, does not pay the fishermen to exploit the fish resource in the same way as an owner of a property pays a person to exploit it. It is rather the other way round, which makes the principal-agent problem in fisheries non-intuitive. The intuitively clear cases are the cases of decommissioning of capacity, and the cases of temporary effort reduction by use of laying-up premiums.

While the principal-agent methodology constitutes a contractual framework for agreements, it is necessary to be clear about the underlying conditions for the agreements be it full information or imperfect information. With full information the principal could induce the agent to undertake the activity the principal wants, or the principal could impose a corrective tax/subsidy scheme that “guides” the agent to do what the principal wants as long as the same (profit maximizing) behaviour of the principal and the agent leads to different outcome from the principals point of view if the principal does not interfere. With full information, there is no problem literally speaking because the principal may impose taxes or subsidies that solves the problem. In the literature this problem solution is often considered a matter of fixing Pigouvian taxes rather than a principal-agent problem which requires that imperfect information is present. Some authors, as mentioned in Chapter two, consider areas where someone wants to persuade someone else to act in a certain way a principal-agent problem irrespective the type of information.

In fisheries however, asymmetric information is prevalent, and it has been an important task in the project to study the management aspects in view of the fact that the
fishermen normally possess better information about the fishing activities than the managers (society), which is asymmetric information from the viewpoint of the manager. And the asymmetric information problem is in the literature often associated with the principal-agent method.

It has been observed that the management solutions arrived at under full information do not apply in a system with asymmetric information if the aim is to arrive at economic efficiency. Under full information an economic efficient solution in the exploitation of a resource, be it fish stock or a piece of land, that is not owned by the exploiter would be to pay the agent to fish, and the agent could then deliver the fish to the principal to be sold on the market. With asymmetric information this solution would not lead to economic efficiency. The solution leading to economic efficiency is profit sharing (risk sharing). Basically this is how fisheries management is designed currently. The fishermen are given incentives to fish by granting them some of the profit that should be extracted by society.

There are several sources for asymmetric information in fisheries. Although all three cases: Effort management, capacity adjustment, and quota management include elements of hidden information and hidden action, the dominant type of asymmetric information in effort management and capacity adjustment is hidden information (adverse selection), while hidden action (moral hazard) dominates quota management. This is partly due to what is observable. Once observable quotas are distributed to the fishermen, the problem is that the action of the fishermen is not observable which is a problem with respect to excess quota landings and discarding. Quotas are meant to protect the fish stocks by controlling catches, but catches are more difficult to observe and control by the principal as opposed to landings of fish.

Effort regulation in terms of limited number of fishing days, although not applied to any large extent in the EU, uses among other variables fishing days as the most important observable variable. It is comparatively easier to control the number of fishing days than to control the catches, but it is difficult to estimate the number of fishing days that is in accordance with fish stock protection unless the fishermen reveal information about the catching power. Finally, capacity adjustment depends more on information about the characteristics of the more or less observable capacity rather than the (change in) action of the owner of the capacity before and after the agreement about capacity adjustment has been reached.
The focus and the solution to the problems are different depending on the type of asymmetric information. Quota and effort management is from an asymmetric point of view different in terms of what is the target (stock protection), what is the observable management variable, what is the type of information the agent (fisherman) reveals, and what is his action.

The often-suggested individual transferable quota system (ITQ) does not solve the problem with asymmetric information, at least entirely, in terms of stock protection, because the system is dependant on reliable information about catches, and the hidden action problem is not solved with ITQ. Although economic efficiency in a full information, perfectly functioning ITQ market eventually could be obtained, the capital-stock and the fish-stock relationship is not by itself moving towards an efficient state because the hidden action incentives are not removed. This could be done, however, by appropriate (and costly) monitoring and control measures or by correcting taxes or subsidies.

On the other hand, while there are no incentives to mis-reporting catches in an effort regulation system because catches are not the monitoring subject, there is a strong incentive to conceal information. This incentive is reduced somewhat if effort (i.e. operationally fishing days) is made subject to trade, but the incentive to try to expand the effort on the behalf of stock preservation still remains, and quite a lot of information is required to solve that problem.

The study does not solely apply the principal-agent approach but includes various other methods. The dominant model type in the case of quota management is qualitative bioeconomic models in which the type and magnitude of incentives are detected and the solution with respect to correcting incentives are taxes according to shadow prices, and this solution is confronted with e.g. ITQ or monitoring, control, and punishment.

While qualitative models are used in the quota management case, in the effort regulation case quantitative optimization models are used to calculate shadow prices as indications of the economic incentives to circumvent restrictions. Because effort limitation is not applied directly but rather in association with temporary quotas the shadow prices of the quota restriction are calculated as well, and it could be argued as to whether in practical management, emphasis is put on quota management or effort management.
However, the principal-agent approach in effort management is used to show that the initial allocation of fishing days from a point of view of economic efficiency, including assumptions about the optimal size of the fish stocks, is dependant on the fishermen’s willingness to inform about their catch per unit effort and their cost structure. Because of the imposed restriction on effort the system needs monitoring and control to function properly. Alternatively, efficient temporary effort limitation could be obtained by subsidies, but this is also dependant on the fishermen’s willingness to reveal information. The information that could be extracted from the market or the fishermen’s records are not enough because there is a disparity between the real preferences including expectations of the fishermen and the economic information recorded in the books. The study has shown ways to extract the necessary information from the fishermen.

The model in the capacity adjustment case is an investment model which is used quantitatively to determine the subsidy that is required to make the fisherman decide to withdraw rather than to continue fishing. This is put in perspective in a discussion about the information that is provided from the calculation relative to the fisherman’s actual preferences that are not known. Methods to make the fishermen reveal their true preferences are discussed e.g. auctioning in various forms. In a principal-agent context, the problem could be addressed theoretically by granting information rent to the agent because the agent cannot even in an auctioning system be expected to reveal his true preferences.
7. General conclusions

The general conclusion that may be drawn from the study is that new insight in the management problem could be gained by use of the economic theory of information. The management measures that support economic efficiency are not the same in a system with full information as in a system with asymmetric information. Although the principal-agent approach at first glance may not seem the most obvious method to use partly because it is based on some sort of contract between the principal and the agent and partly because it involves transfer payments between the contractors, it is considered a useful path that could be pursued further with respect to obtain a better understanding of the Common Fisheries Policy of the European Union. This study has shed light on that, and there are several reasons.

First, it is notable that in fisheries asymmetric information is rather the rule than the exception. Secondly, the regulatory measures prescribed are not quite the same as in full information cases that hitherto have dominated the literature within fisheries economics. Thirdly, at least within the EU, long traditions for transfer payments and hence taxes exist not least within agriculture and the environmental area which are both closely connected with fisheries. Fourthly, the struggle within the EU to make the Common Fisheries Policy function in a system with many Member States advocating for the relative stability in allocation of fishing rights seems to be better supported by research that takes into account explicitly strategic behaviour together with profit (or rather welfare) maximizing behaviour rather than research that is based solely on profit maximising behaviour.

While the principal-agent approach includes maximisation of a welfare-function subject to two constraints: An incentive compatibility constraint (sometimes also referred to as a self selective constraint) and a participation constraint in fisheries a third restriction: The resource restriction need be included. To a large extent these three restrictions are already included in the CFP of the EU. However, a clear understanding of the interaction between these constraints and the impact on the optimal solution of the welfare-function would add to the understanding of the way the CFP is functioning and how it could be improved. With reference to the specific conclusions in Chapter 3-5, the direct or implicit inclusion of the type of information problem (hidden action or hidden information), and the consequences for the solutions of the inclusion of the 3 constraints mentioned in this paragraph it is important with differentiated subsidy rates to identify what type the agent is (the self selection restriction) in effort.
management and capacity reduction. To avoid hidden action in e.g. quota management a detailed system with tax/subsidies could solve the problem. However, some of the rather comprehensive information requirements could be solved by working on homogeneous fleet segments and with respect to avoid e.g. excess quota catches and discarding a tax/subsidy as a function of the size of the fish stock could be implemented. The fish stock is monitored and assessed biologically in some areas of the EU already, and the stock size could be used as a proxy for the real catches that very often cannot be observed.

Hence, a number of improvements could be made to the CFP of the EU, first of all attempting to correct the economic incentives of the fishermen. The wrong incentives are caused partly by market failures and partly by the way restrictions are imposed onto the system with the aim to protect fish stocks from overexploitation. It seems clear, however, that incentive correcting measures such as individual transferable quotas and taxes or subsidies will not solve the problems unless the information problems are solved as well. Therefore it is important with further investigations directed towards how could information be revealed, and what type of information is needed in an imperfect world to make the management function better.
Appendices introduction

At the beginning of the project period much effort was used to acquire the fundamental idea of the importance of imperfect information, how to define the principal-agent relationships, and how to design systems that could be used for numerical calculations. Only very few articles exist about application of the principal-agent method to fisheries. The formal analyses of principal-agent topics are based on work carried out in a Ph.D. study by Jensen (2001) parallel to this project.

In appendix A, the full information case is described, and the solution to the problem of fish stock exploitation is similar to the results in what could be named traditional economic analyses of fish stock exploitation e.g. Clark (1985).

In appendix B, the case with hidden information (adverse selection) is analysed. In fisheries the case refers to the situations where the manager does not have full information about the marginal profit of the fisherman, which is important if catch quotas or number of fishing days, or decommissioning grants must be allocated to the fishermen.

Finally, in appendix C, the case with hidden action (moral hazard) is analysed. The hidden actions of the fishermen constitute a problem in cases where the allocation of quotas, fishing days, or decommissioning grants have been made, and there is an incentive for the fisherman to act differently after the allocation compared to before the allocation.
Appendix A: Full Information

In a common property fishery, society is the owner of the fish stocks. For simplicity, in a principal-agent context the problem could be viewed as if society collects the revenue generated by fishermen, but pays a subsidy to the fishermen to make them fish. The fishermen bear the costs associated with the fishery, but receive the payment from the society.

Assume that society wants to control how much fishing effort is exerted. The output could also be chosen as a control variable. Let \( e_i \) be the effort of fisherman \( i \) and \( x \) the stock size. The output from fisherman \( i \) (a production function) is denoted \( g_i(x, e_i) \). The maximisation problem of fisherman \( i \) is:

\[
\text{Max}(s_i(e_i) - c_i(e_i)) \tag{1}
\]

The first order condition for fisherman \( i \) is:

\[
s_i'(e_i) - c_i'(e_i) = 0 \tag{2}
\]

Where:

\( s_i(e_i) \) is the payment from society (the subsidy) to the fisherman \( i \).
\( c_i(e_i) \) is the cost function of fisherman \( i \).

Society wishes to maximize long run economic yield and for simplicity discounting is disregarded. Society then has to include a resource restriction and it is assumed that society wants a steady-state equilibrium where the natural growth of the fish stock is equal to catches. With \( n \) fishermen, the maximisation problem of the society is:

\[
\text{Max} \sum_{i=1}^{n} pg_i(x, e_i) - s_i(e_i) \tag{3}
\]

s.t.

\[
f(x) - \sum_{i=1}^{n} g_i(x, e_i) = 0 \tag{4}
\]

\[s_i(e_i) - c_i(e_i) \geq 0 \text{ for all } i = 1, \ldots, n \tag{5}\]
Where:

\[ p \] is the price of fish

\[ f(x) \] is the natural growth of the fish stock

Expression (4) is the resource restriction and (5) is the participation restriction which expresses that every fisherman must earn at least the reservation utility in order to participate. In this case the reservation utility is fixed at zero but it could enter with a positive value. This restriction is always binding because the payment enters with negative weight in the objective function. Therefore the equality sign holds, and the fishermen only earn the reservation utility. By substituting the binding restriction into the objective function, a Lagrange function could be constructed. The first order condition for \( e_i \) expresses that:

\[
p \frac{\delta g_i}{\delta e_i} - c_i'(e_i) - \lambda \frac{\delta g_i}{\delta e_i} = 0
\]

where \( \lambda > 0 \) is a Lagrange multiplier and \( \lambda \frac{\delta g_i}{\delta e_i} \) is the user cost of the fish stock. Equation (6) expresses that the marginal benefit \((p \frac{\delta g_i}{\delta e_i})\) must equal the marginal social cost of fishing \((c_i'(e_i))\) plus the cost of using (diminish/increase) the fish stock \((\lambda \frac{\delta g_i}{\delta e_i})\) from the point of view of the society.

With full information the society knows the user cost of the fish stock and could determine the optimal effort, and hence the payment \( s_i \) to each fisherman. The optimal payment is obtained by equating (2) and (6):

\[
s_i'(e_i) = p \frac{\delta g_i}{\delta e_i} - \lambda \frac{\delta g_i}{\delta e_i}
\]

It is seen from (7) that the optimal payment is smaller than the marginal revenue to the fisherman from fishing. This difference embodies the seed to information problems.
Appendix B: Adverse Selection

In cases where adverse selection could be applied society has imperfect information about e.g. the fisherman’s cost function or production function. The fisherman knows his cost function or production function, which implies asymmetric information in the principal-agent case. Let the i agents of type 2 have high costs \(c_{i2}(e)\) and the i agents of type 1 have low costs \(c_{i1}(e)\), with \(c_{i2}(e) > c_{i1}(e)\) for all \(e\).

Society does not know which type the agent is but knows a probability \(\pi_1\) for type 1 and \(\pi_2\) for type 1. It is useful to make another assumption about the cost function. It is assumed that single crossing property is fulfilled such that \(c_{i2}'(e) > c_{i1}'(e)\) for all \(e\). In other words, the fishermen that have highest total costs also have highest marginal costs.

The problem is that the low cost agent may pretend to be a high cost agent. If \(e_{i1}\) is the effort level society wishes the fishermen to choose, society must structure the pay- ment so that type 1’s utility of choosing \(e_{i1}\) is greater than the utility of choosing \(e_{i2}\). The same applies to type 2 in the opposite direction. These restrictions are often called self-selection restrictions or sometimes incentive compatibility restrictions. Given these observations, society’s maximisation problem may be written as:

\[
\text{Max } \sum_{i=1}^{n} \left[ \pi_1 (pg_{i1} (e_{i1}, x) - s_{i1} (e_{i1})) + \pi_2 (pg_{i2} (e_{i2}, x) - s_{i2} (e_{i2})) \right] \quad (8)
\]

s.t.

\[
f(x) - \sum_{i=1}^{n} \left[ \pi_1 g_{i1} (x, e_{i1}) + \pi_2 g_{i2} (x, e_{i2}) \right] = 0 \quad (9)
\]

\[
s_{i1} (e_{i1}) - c_{i1} (e_{i1}) \geq 0 \quad \text{for all low cost fishermen} \quad (10)
\]

\[
s_{i2} (e_{i2}) - c_{i2} (e_{i2}) \geq 0 \quad \text{for all high cost fishermen} \quad (11)
\]

\[
s_{i1} (e_{i1}) - c_{i1} (e_{i1}) \geq s_{i2} (e_{i2}) - c_{i2} (e_{i2}) \quad \text{for all low cost fishermen} \quad (12)
\]

\[
s_{i2} (e_{i2}) - c_{i2} (e_{i2}) \geq s_{i1} (e_{i1}) - c_{i1} (e_{i1}) \quad \text{for all high cost fishermen} \quad (13)
\]

The inequalities (12) and (13) represent the self-selection restrictions that secure that the payments to the fishermen are determined in such a way that the correct type is
revealed. By manipulating the restrictions (Jensen and Vestergaard 1999) it can be shown that (11) and (12) are binding, which yields:

\[ s_{i2}(e_{i2}) = c_{i2}(e_{i2}) \quad \text{for all high costs fishermen} \quad (14) \]
\[ s_{i1}(e_{i1}) = c_{i1}(e_{i1}) + (c_{i2}(e_{i2}) - c_{i1}(e_{i2})) \quad \text{for all low cost fishermen} \quad (15) \]

The binding restrictions of the expressions (10) to (13) could also be derived intuitively. The low cost fishermen demand a smaller payment than the high cost fishermen to fish. If the high cost fishermen are granted a payment equal to the low cost fishermen (13) still holds while (11) does not. Therefore (11) is binding for the high cost fishermen. For the low cost fishermen a payment equal to the one of the high cost fishermen and an effort equal to the high cost fishermen will yield a profit to the low cost fishermen, which means that (10) is not binding at that effort level. Because the low cost fishermen will receive a lower payment per unit of effort, (12) will be binding at \( e^2 \) effort because at that level the right hand side will be greater than the left hand side.

From (14) and (15) it is seen that the high cost agent receives a payment that makes him indifferent between participating and not participating while the low cost agent receives an information rent. This rent is precisely the amount that induces the agent to reveal his true type. By substituting (14) and (15) into (8), and by inclusion of (9), a Lagrange function can be set up. The first order condition for \( e_{i1} \) and \( e_{i2} \) is:

\[ p \frac{\delta g_{i1}}{\delta e_{i1}} - c_{i1}(e_{i1}) - \lambda \frac{\delta g_{i1}}{\delta e_{i1}} = 0 \quad (16) \]
\[ p \frac{\delta g_{i2}}{\delta e_{i2}} - \frac{\delta c_{i2}}{\delta e_{i2}} + \pi_1 \left( \frac{\delta c_{i1}}{\delta e_{i2}} - \frac{\delta c_{i2}}{\delta e_{i2}} \right) - \lambda \frac{\delta g_{i2}}{\delta e_{i2}} = 0 \quad (17) \]

For type 1, the expected marginal benefit is set equal to the marginal costs as (16) shows. For type 2 there is an extra cost. Because type 1 is present and must be given an incentive to reveal his type correctly and an incentive cost arises for type 2, repre-
sensed by the element \((\pi_1/\pi_2(\delta c_{i1}/\delta e_{i2} - \delta c_{i2}/\delta e_{i2}))\) which is negative as the marginal cost for type 2 is higher than for type 1.

The optimal payment from the principal to the fisherman of type 1 and 2 respectively is obtained by equating (2) with (16) and (17), and the following marginal subsidies are calculated:

\[
s_{i1}'(e_{i1}) = p \frac{\delta g_{i1}}{\delta e_{i1}} - \lambda \frac{\delta g_{i1}}{\delta e_{i1}} \tag{18}
\]

\[
s_{i2}'(e_{i2}) = p \frac{\delta g_{i2}}{\delta e_{i2}} + \frac{\pi_1}{\pi_2} \left( \frac{\delta c_{i1}}{\delta e_{i2}} - \frac{\delta c_{i2}}{\delta e_{i2}} \right) - \lambda \frac{\delta g_{i2}}{\delta e_{i2}} \tag{19}
\]

First, from (18) it appears that the payment to the low cost fishermen is the same as in the situation with full information. But this is not the case for the high cost fishermen. The optimal allocation of effort and hence the payment to the type 2 fishermen is smaller than it would have been had type 1 not been present in the fishery. The reduction in payment to type 2 is furthermore dependant on the probability of being type 1 relative to type 2 \((\pi_1/\pi_2)\). If a fisherman claims to be of type 2, but the probability of being type 2 is small, the optimal allocation of effort and hence payment to the fisherman should be reduced further, relative to the situation where the fisherman claims to be type 2 and the probability of being type 2 is high. If certain vessel characteristics are observable and are highly correlated with the (unknown) type, estimates of the probability could be determined from that information.
Appendix C: Moral Hazard

Finally a case with moral hazard (hidden action) is analysed. In fisheries it could be argued that moral hazard problems arise in particular within quota management because of illegal landings and discarding of fish, which is more difficult to observe than e.g. the number of fishing days in effort regulation, or whether or not a fishing vessel is actually continuing fishing after the owner has received decommissioning grant.

The problem with moral hazard is addressed for the quota regulation area in such a way that the incentive to discard is minimised by use of variables that could be observed or estimated and that are affected by the discard level. Such a variable could be the size of the fish stock. The fishermen’s incentive to discard or land illegally could then be corrected by implementation of a stock tax. The analysed tax mechanism is:

\[ T_i(x) = t_i(x^* - x) \]  

(20)

Where:

- \( t_i \) is a variable tax rate
- \( x \) is the actual stock size
- \( x^* \) is the optimal stock size
- \( T_i(x) \) is the total tax payment

It is seen that if \( x^* > x \) the fishermen pays a tax, while the fishermen receives a subsidy \( (T_i(x) < 0) \), if \( x^* < x \). Now the aim is to calculate \( t_i \) in such a way that free riding is eliminated in the sense that the fisherman is made responsible for the change in the fish stock.

In order to do that a model for society’s selection of individual catches and a model for fisherman behaviour is necessary. From society’s point of view individual catches are unobservable due to illegal landings and discards, therefore an expectation operator \( (E(.)) \) is defined. It is assumed that society maximises expected long-run economic rent in steady-state. Therefore:

\[ \text{Max } E(ph_i - c_i(h_i, x)) \]  

(21)

s.t.
\[ f(x) - \sum_{i=1}^{n} h_i = 0 \]  \tag{22}

where:

- \( h_i \) is the catch of fisherman \( i \)
- \( c_i(x, h_i) \) is the cost function for fisherman \( i \)

If (22) is solved for \( x \) it yields:

\[ x = m(h_i, h_{-i}) \]  \tag{23}

where:

- \( h_i \) is a vector of catches of all other fishermen than \( i \)
- \( m(.) \) is a function that expresses how the steady-state stock size responds to changes in catches

The following first-order condition for catches is obtained by substituting (23) into (21):

\[ E\left( p - \frac{\partial c_i}{\partial h_i} - \frac{\partial c_i}{\partial m} \frac{\partial m}{\partial h_i} - \sum_{j \neq i} \frac{\partial c_j}{\partial m} \frac{\partial m}{\partial h_i} \right) = 0 \]  \tag{24}

The expected user cost of the fish stock is \( E(\delta c_i/\delta m * \delta m/\delta h_i + \Sigma \delta c_j/\delta m * \delta m/\delta h_i) \) and from society’s viewpoint (24) expresses that the marginal benefit is equal to the marginal social cost. The expression includes the marginal costs of all other fishermen \( j \) from the change in stock size inflicted by fisherman \( i \).

With regard to fisherman \( i \), it is assumed that he reacts to the stock tax by applying some resource conservation measures. In the model this is captured by \( x = n(h_i, h_{-i}) \) and is a restriction on the maximization problem. Further it is assumed that fisherman \( i \) has an incentive to fish illegally and the tax payment is then \( T_i(x) = t_i x^* - t_i x \). The tax payment enters into the objective function of the fisherman \( i \) and his maximisation problem is:

\[ \text{Max } [ph_i - c_i(h_i, x) - t_i x^* + t_i x] \]  \tag{25}
By substituting (26) into (25), the following first-order condition is reached for optimal catches with Cournot-Nash expectations:

\[ p - \frac{\delta c_i}{\delta h_i} - \frac{\delta c_i}{\delta n_i} \frac{\delta n_i}{\delta h_i} + t_i \frac{\delta n_i}{\delta h_i} = 0 \]  

(27)

The fisherman’s perception of the user cost of the fish stock is \( \frac{\delta c_i}{\delta n_i} * \frac{\delta n_i}{\delta h_i} \) and (27) captures that the marginal benefit is set equal to the marginal private costs.

By equating the optimal conditions for society and fisherman i (24) with (27), the following expression is reached for the variable tax rate:

\[ t_i = \frac{\frac{\delta c_i}{\delta h_i} + \frac{\delta c_i}{\delta n_i} \frac{\delta n_i}{\delta h_i} - E(\frac{\delta c_i}{\delta h_i}) - E(\frac{\delta c_i}{\delta m} \frac{\delta m}{\delta h_i}) + \sum_{j \neq i} \frac{\delta c_j}{\delta m} \frac{\delta m}{\delta h_i}}{\frac{\delta n_i}{\delta h_i}} } \]  

(28)

The two first elements in the numerator (28) express the effects on the marginal costs and the user cost of fisherman i from his own viewpoint. The variable tax rate contains two further expectation components (E-components). First the principal’s (society’s) expectations with respect to marginal costs of fisherman i are included and, secondly, society’s user cost are included. Because the fisherman pays the tax on basis of the full marginal costs that illegal landings or discards generate, free riding is eliminated.
References to the Appendices


Discussion and working papers from the project


7. Frost, Hans (1998): The design of the Danish management system and the implementation


24. Buisman et. al. (2000): Economic incentives and effort regulation


**Contract information FAIR CT97 3936**

“The Significance of Economic Incentives in Fisheries Management under the CFP.”

Final Report

(December 2000)

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*) Became responsible after change of position of the original coordinator Hans Frost who, however, continued on the project from the new position:

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