A study on overcapacity in the Dutch flatfish sector

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This report addresses the important issue of overcapacity in the fishery sector. The main objectives of the research were to estimate: 1) current incomes and costs in the Dutch flatfish sector, and 2) future fishing capacity under various scenarios. Whereas the flatfish sector is at break-even at the moment, we believe that it is possible for the sector to make more profit in the future. Of the current capacity operating in the Dutch flatfish sector, only around half will be needed to exploit the plaice and sole populations sustainably. Withdrawing vessels from service will lead to increased profits for the remaining vessels.

In dit rapport wordt gekeken naar het probleem van overcapaciteit in de Nederlandse vloot. Het doel van deze studie is: 1) het berekenen van de huidige inkomens en kosten in de platvisvisserij en het bepalen van de aanwezige overcapaciteit in de huidige vloot, 2) het berekenen van de optimale vlootcapaciteit in verschillende toekomstscenario's. De platvissector opereert op het moment op breakevenomzet, berekeningen laten zien dat de sector meer winst zou kunnen behalen in de toekomst. Ongeveer de helft van de huidige vlootcapaciteit is slechts nodig om de toekomstige bestanden van tong en schol op een duurzame wijze te exploiteren. Het verkleinen van de vloot zal winst opleveren voor de overblijvende schepen.

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Preface

Overcapacity is seen as one of the main problems in the management of marine fisheries. Overcapacity means that the fleet has the potential to catch more fish than is sustainable. We were asked by LNV to take a closer look at the overcapacity issue in the Dutch flatfish sector in the North Sea.

On behalf of M.J.W Traa, LNV, we estimated how many vessels will be needed given expectations regarding future fish stocks and technological developments. As the problem of overcapacity in the Dutch fleet remains despite many policy initiatives to solve it, Traa suggested that we look at the problem from a new angle. Therefore, instead of applying existing models, we projected future harvests by looking at stock sizes and then estimated the economic implications for the sector.

Although the estimates given in this report are preliminary (several assumptions needed to be made about the future catchability of the fleet), this report presents an interesting and new way of looking at the optimal fleet size and the potential profit for a smaller fleet.

Prof. Dr R.B.M. Huirne
Managing Director LEI

Summary

This report addresses the issue overcapacity of the Dutch flatfish sector fleet. The main objectives of our research were to find: 1) current incomes and costs in the Dutch flatfish sector, and 2) future fishing capacity under various scenarios concerning the fish stocks and technological developments.

We show that at present the Dutch flatfish sector is at break-even, implying that the sector does not make any profit. More precisely, the total revenue is estimated to be slightly lower than break-even revenue for both efficient and non-efficient vessels. Although the landings of plaice and sole have decreased in recent years, it is expected that the landings will remain constant at their current levels in the near future. Moreover, if less plaice and sole is harvested in the near future and thus the stock is allowed to grow, we may see increased landings in the medium or long term.

In 2008, 308 vessels caught (predominantly) flatfish. Scenario analyses show that the minimum number of vessels needed to exploit these stocks sustainably in the future can be 100-200 vessels, implying a reduction of 100-200 vessels. As a consequence of removing vessels, the remaining ones can increase their incomes as fixed costs in the sector will fall and more will be harvested by the remaining vessels. We calculated extra profits of between €50,000 and €350,000 for each of the remaining vessels. The exact sum will depend on fish stock sizes and technological developments.

Finally, we estimated the maximum number of vessels in the future if the aim were to reach break-even instead of maximum profits. Assuming that the cost structure will be equal in the future to what it was in the past, it is estimated that the sector can involve around 300-360 vessels.

Samenvatting

In deze studie wordt nader gekeken naar het overcapaciteitsprobleem in de Nederlandse platvisvisserij. Het doel van deze studie is: 1) het berekenen van de huidige inkomens en kosten in de platvisvisserij en het bepalen van de aanwezige overcapaciteit in de huidige vloot, 2) het berekenen van de optimale vlootcapaciteit voor de komende 25 jaar op basis van verschillende scenario's van de bestands- en technologieontwikkelingen.

We laten zien dat de huidige platvissector al enige jaren opereert op breakevenomzet. Dit houdt in dat er geen winst wordt gemaakt door de sector. Een analyse laat zien dat zowel efficiënte als niet-efficiënte schepen op of net onder de breakevenomzet opereren. Hoewel de totale aanlandingen van tong en schol de laatste jaren zijn afgenomen, kan verwacht worden dat in de nabije toekomst de aanlandingen op het huidige niveau kunnen blijven. Indien de visserij in de nabije toekomst tijdelijk minder zou vangen, is het zelfs goed mogelijk dat de stock zich zodanig hersteld dat de aanlandingen flink omhoog kunnen op de middellange termijn.

In 2008 vingen 308 schepen (voornamelijk) platvis. Scenarioanalyses laten zien dat er mogelijk slechts 100 tot 200 schepen nodig zullen zijn in de toekomst om de platvisbestanden op een duurzame wijze te exploiteren. Dit impliceert een reductie van 100-200 schepen. De overgebleven schepen zouden dan € 50.000 tot € 350.000 meer winst kunnen maken dan de huidige schepen doen waardoor zij boven de breakevenomzet zouden kunnen opereren.

Ook is er tot slot gekeken naar de maximale hoeveelheid schepen die met de verwachte bestanden op een breakevenomzet zouden kunnen vissen. Aangenomen dat de kostenstructuur constant blijft in de toekomstige jaren dan zou er ruimte zijn voor maximaal 300 tot 360 schepen in de vloot.

1 Introduction

Overcapacity of the fishing fleets is seen as one of the main problems in the management of marine fisheries (Beddington et al., 2007). We therefore researched the fishing capacity in the Dutch flatfish sector in the North Sea. The two main objectives were to estimate 1) current incomes and costs in the Dutch flatfish sector, and 2) future fishing capacity under various scenarios concerning stock sizes and technological developments.

After an introduction we provide some general information about the issue of fishing capacity by means of a literature review. We then introduce the Dutch flatfish sector and provide estimates of costs and revenues in the past and present for the Dutch flatfish sector. The fishing vessels are divided into more efficient and less efficient vessels for comparison purposes. Then seven scenarios about future sole and plaice landings are identified for the years 2008-2025, based on a study conducted by IMARES. Moreover, past and future price developments related to plaice and sole landings are combined with estimated landings in order to project future values of the flatfish landed by the Dutch fleet. Based on this, and on assumptions about how much harvest one vessel can have in the future, the number of vessels in the sector are estimated under various different scenarios. This is further linked to potential profits made by the remaining vessels. We also estimate the maximum number of vessels that could be involved to achieve a break-even situation in the future. Finally, we discuss possibilities for follow-up research.

2 Fishing capacity

2.1 Defining fishing capacity

Fishing capacity can be expressed as the maximum amount of fish over a period of time (year, season) that can be produced by a fishing fleet if fully utilised, given the biomass, age structure of the fish stock and the current state of technology (Grébroval, 2003, p. 4). Capacity utilisation is essentially a short-term concept, and can be defined as the ratio of actual output (catch, landings) to some measure of potential output (capacity output) for a given fleet and biomass level (ibid.). Capacity indicators include measures such as gross tonnage (a measure of the volume of the vessel), engine power and the number of boats (Pascoe and Grébroval, 2003). Overcapacity and overcapitalisation can have the same meaning (Monro, 1998). However, it is specified that overcapacity can be defined as a situation in which capacity output is greater than target output, while overcapitalisation refers to situation in which the actual capital stock is greater than the optimal capital stock required to produce the output target. The 'optimum' can be defined in a technical manner (i.e. determined by the production technology) as the minimum capital stock required, or in an economic manner as the capital stock that will minimise the cost of the producing the target output (Grébroval, 2003, p. 5).

In principle, having the right capacity should be sufficient to maintain yields while avoiding over-exploitation (Arrizabalaga et al., 2009). Management of fishing capacity is a key to successful fisheries management because overcapacity can lead to stock collapse (Hennesay and Healy, 2000). With good management, fish stocks have the potential to generate substantial economic benefit in the form of resource rent (Gordon, 1954). However, without effective management, resource rent acts as pure economic profits for fishermen, and the fishery will attract excess capacity until this resource rent is fully dissipated. In an unregulated open access fishery, the fish stocks will be at a lower level than what is biologically and economically optimal. Thus, without management, fish stocks are effectively a common pool resource, and are thereby subject to the tragedy of the commons (Hardin, 1968).

Since the 1950s, some form of regulation has been introduced into most fisheries to limit either catch or fishing effort by identifying catch target. With a correctly set total allowable catch (TAC), fish stocks can be prevented from being biologically overfished. However, TACs alone do not solve the economic problem in fisheries management because they do not change the economic incentives of the fishermen (Asche et al., 2008). Instead, incentives are created for fishermen to maximise their share of the catch, which leads to overcapacity in the harvesting sector as fishermen increase their use of unregulated inputs (Munro and Scott, 1985). Furthermore, compared to an unregulated fishery, the TAC regulations can make the overcapacity problem even more urgent because of the incentives created to race to fish (Rijnsdorp et al., 2008).

2.2 Problems related to overcapacity

Overcapacity of the fishing fleets is seen as the main problem in the management of marine fisheries (Beddington et al., 2007). There is an urgent need to develop legally enforceable and tested harvest strategies, coupled with appropriate right-based incentives for the fishing community. However, in reality, it is very difficult to restrict the fishing efforts.

For instance, despite the attempts to reduce fishing capacity in the North Atlantic in recent years in various jurisdictions, it has continued to expand (Johnsen, 2005). This has been explained in the Norwegian fisheries by the ways political, economic and technological forces continue to fuel capacity expansion within the fishing sector. The collapse of the Norwegian Northern Cod stock and the sudden halt that occurred in the fishery in 1988/89 was partly unexpected. Despite many attempt to reduce capacity in the fishery sector in the subsequent years, involving the introduction of quotas, capacity is in practice enhanced by the financial mechanisms that are available to increase capitalisation and profitability with more effective machines, better gear, boats and equipment that allow the processes to go faster, and the increasing economic value of the catch. In practice, the vacuum created by those who leave the fishery sector is filled by enhanced technological capture capacity. As in other North Atlantic states, pressures to modernise and increase technical and economic efficiency have become increasingly important in Norwegian fisheries.

Eigaard (2009) analysed the electronic equipment on board Danish trawlers and gill-netters. He shows that newer, larger vessels have a significantly higher technological level than older, smaller vessels. As a consequence, the capacity reduction programmes that target smaller and older vessels undermine the nominal capacity reduction in fleet level that is based on total fleet tonnage, because of the increase in individual vessel fishing power.

Flaaten and Wallis (2000) argue that the main difficulties in reducing the overcapacity in the fishing fleets are related to the technological changes, price changes, lack of well-defined property rights and user rights, subsidies and management failures, and that all these factors have contributed to over-exploited fish resources. The particular effect that governmental transfer has on the sector depends on the type of transfer. It has been estimated that for OECD countries in 1997, a total of 78% of the governmental transfer was general services, including research, infrastructure, etc., and that 22% went on revenue-enhancing and cost-reducing transfers (ibid.).

Mardle and Pascoe (2002) explain that a main reason that the overcapacity problem is so difficult is related to the relatively high level of scientific uncertainty about fish stocks. As a consequence, a short-term perspective is mostly taken when formulating policy objectives, which are intended to preserve employment and regional income by increasing the fishing effort. However, long-term ecological and economic benefits require a reduction in the fishing effort. It has been estimated that short-term solutions result in higher benefits and higher employment, and that this will lead to a considerable loss in terms of long-term profitability. The most politically acceptable solution is to balance the two approaches.

Another main reason for the difficulties in reducing fishing capacity is the fishermen's incentives to maximise their incomes. Obviously, increased profitability can be obtained by increased capacity, but also by reducing costs.

Marchal et al. (2006) observed the improved fishing efficiency of a number of Danish, French and Basque fleets, including the appearance of twin trawls and trammel nets, and an increase in the polyvalence (i.e. involvement in more than one fishery by means of individual vessel diversification). On the basis of in-depth interviews with fishermen, they found that catch rates depend on fishing effort descriptors that are not traditionally considered useful; these include gear type, ground rope type, length of net used per day, headline length, crew size and number of winch net drums. They suggest that fishing effort may be explained by such terms to improve the understanding of fishing mortality.

The over-exploitation of fish resources worldwide has been caused not only by the commercial fishery sector, but also by the recreational fishery sector. Coleman et al. (2004) evaluated the commercial and the recreational fisheries in the last 22 years in the South Atlantic and the Gulf of Mexico. Fish species like red drum, bocaccio and red snapper that are the most valuable overfished species, are taken primarily in the recreational fishery.

One of the most successful experiences that is frequently referred to when addressing the problem of overcapacity is New Zeeland, where a quota management system (QMS) was implemented in 1986. This QMS aimed at dealing with the perception that most of the inshore fish stocks were suffering from high levels of over-exploitation. Most of the major fish stocks are now said to have been replenished (Annala, 1996). In 1994, eight years after the implementation of the QMS, it was estimated that of a total of 179 fish stocks, only 13 were reported to be overfished (below BMSY). Transferability of individual quotas provides incentives for efficient harvesters to acquire quotas from less efficient harvesters, leading to a reduction in harvesting capacity (ibid.). In this way, the overall harvesting efficiency in the fishery improves and generates rent. In principle, a well-designed individual transferable quota (ITQ) system allows resource rents to be generated through a reduction in excess capacity arising from quota trading, although there is also evidence that this is a long-term process that may take substantial time.

According to Beddington and colleagues (2007), it is necessary to analyse the capacity and incentives of the fishing community and the management authorities, as well as other stakeholders, including environmental NGOs. TAC, restrictions on fishing gear, fishing seasons and fishing areas are useful, but if they are not adequately enforced, illegal fishing can occur. In many TAC-regulated fisheries, there has been an unexpected increase in fishing capacity. Management approaches are the most successful when rights-based systems - which create incentives for fishermen to operate efficiently and with long-term sustainability in mind - are combined with a strong legal structure (ibid.).

2.3 Estimates of overcapacity

There are many ways to assess fishing capacity. Asche and colleagues (2008) estimated the overcapacity of the major fishing fleets in Sweden, Denmark, the UK, Iceland and Norway by applying an optimisation problem that maximised profits and minimised costs given a quota. This allowed them to compare actual and optimal harvest levels, revenues, costs and profits. The optimisation problem estimates potential harvest level, revenue, costs and economic profits based on the standard Gordon-Schaefer model, with biomass (X) as stock size and a standard cost function with constant average cost per unit effort. An equilibrium is achieved when the total cost is equal to total revenue and no excess profits are generated. In this equilibrium, all rents are dissipated, and the economic waste, from a social point of view, is even greater in the regulated open access than in the open access equilibrium because of the increase in redundant capacity. Optimal level of output and minimum average cost per unit of output is the point at which the marginal cost is equal to the average cost. The number of vessels necessary to take the TAC can be estimated by dividing the TAC by the optimal harvest level. In all countries, fisheries are managed by an individual vessel quota (IVQ), and only in Iceland is the quota transferable (ITQ). They found that, given current capacities of the fleets, Iceland could harvest almost 2 times more than they land today, Norway almost 3 times more, Denmark around 4 times more, and Sweden and the UK almost 5 times more (tonnes). Moreover, they estimated that reductions in fleet capacity given estimated potential resource rents were 50%, 65%, 67%, 50% and 79% for the 5 countries, respectively.

Krikley and Squires (2003) refer to the concept of excess capacity, which refers to the excess use of inputs, including labour and capital, to produce a potential output, and thus differ from the definition of overcapacity, which refers to excess use of only capital. Based on the concept of excess capacity, a distinction is made between output- and input-oriented approaches. Excess capacity in an output-oriented approach can be defined as the difference between capacity outputs and desired or target level of capacity output, such as the TAC. Excess capacity in an input-oriented approach, however, starts with the TAC and determines how many of each vessel type would catch this TAC, then compares to current fleet size, given full utilisation of the variable inputs and the resource stock. The maximum that a given fleet could potentially catch divided by the target TAC is a measure of excess capacity.

According to Pascoe and Grébroval (2003), two methods are more promising for widespread, tractable application that corresponds to the technological-economic definition focusing on capacity output and does not require cost data. These output-oriented approaches are the so-called data envelopment analysis (DEA) of Färe and colleagues (1989) and the peak-to-peak method of Klein (1960).

The peak-to-peak is best suited when the data are limited to, for example, catch and vessel numbers. The approach can determine capacity output and potential level of capacity to be reduced for decommissioning schemes, but it cannot provide information to indicate the actual operating units to be decommissioned. The peak-to-peak method (which is also called trend lines through peaks) defines capacity by estimating the relation between catch and fleet size. Periods with the highest ratio of catch to the capital stock provide measures of full capacity. Estimates of the maximum attainable outputs for the most recent years are obtained by extrapolating the most recent output capital peak and multiplying it by the capital stock in the selected recent years. The capacity output is compared with actual output levels in various time periods to give measures of capacity unit. Catch levels in all years can be adjusted for productivity levels. The method is seriously limited by the ignorance of the economic inputs as well as differences across gear types, as the method only applies vessel tonnage or numbers, which are only rough numbers of capital stock.

DEA is based on an output orientation, as the maximum output or capacity corresponds to the output that could be produced given full and efficient utilisation of variable inputs, but constrained by the fixed factors, the state of technology and possibly the resource stock (see Appendix 1). Several studies have assessed the capacity utilisation of the Dutch fishing fleet using the DEA approach (including Van Hoof and De Wilde, 2005; Bartelings and Buisman, in press). DEA is an output-oriented approach that applies a linear programming technique that is used to compare a vessel's inputs and outputs with a best practice front. The best practice front constitutes the maximum obtainable output for a vessel with a fixed amount of inputs. A vessel's efficiency index is defined as the vessel's share of obtainable outcome. The DEA allows the assessment of the efficiency of a technology relative to a best-practice frontier technology formed as non-parametric, piece-wise linear combination of best practice activities (Coelli et al., 1999; Lindebo, 2005). The frontier envelops the observations that are not best practices (i.e. not operating at full technical efficiency) and allows for the calculation of technical efficiency scores for each observation based on its distance from the frontier.

An ecosystem approach is emphasised by Piet and colleagues (2006), who address the importance of indicators of fishing pressure to fisheries management. The Dutch beam trawl fleet in the North Sea is used as an example to show pressure indicators. The pressure indicators include: 1) fleet capacity, namely number of vessels, 2) fishing effort expressed in hours of fishing or days at sea, 3) fishing parameters such as time spent fishing, fishing speed, gear characteristics, and 4) fishing mortality.

Other input-oriented measures are presented in Pascoe and Gréboval (2003). They include, for example, marine fisheries statistical data that are described together with fishing capacity measures such as total number of fishing vessels, total engine power and total tonnage (Zhou et al., 2003). Here, catch per unit effort (CPUE) is a core measurement indicator for comparisons. Correcting parameters can also be included in the analysis, for example for fishing power, fishing time and gear improvements, and aggregative weighted indexes can be formulated in a linear regression as a function of fishing time and number of vessels (see Zhou et al., 2003). Ernesto (2003) applied an input-oriented model to find fleet carrying capacity. This can be estimated by including fishing mortality and fleet-dependent catchability coefficient. Also included in this model are functions for yield and stock size. O'Brian and colleagues (2003) looked at the relation between CPUE and stock abundance, and also at the relation between the nominal fishing mortality and fishing effort. This can be used to investigate temporal dynamics in fishing power.

2.4 Overcapacity in the EU fleet

An Annual Economic Report (AER) on the EU fishing fleet provides the most recent statistics on the economic performance of Member States' fishing fleets (STECF, 2009). The framework of the Data Collection Regulation (DCR) was applied as a framework for the data collection over the years 2002-2007. The national fishing fleet overviews provide information about selected economic indicators and capacity indicators, and average characteristics of the vessels. The economic indicators include income, value added, cash flow and profits, as well as employment, investment and effort days. The capacity indicators include weights of landings, number of vessels, GT and KW. Not only the totals are provided, but so too are average GT, KW and age of the vessels.

A model called EIAA (Economic Interpretation of Advisory Committee for Fisheries Management (ACFM) advice) has been used to calculate the economic repercussions of the ACFM advice for TAC/quota and spawning stock biomass (SSB). The model covers 25 quota species distributed over 113 quota-management areas and the projections are based on known information about costs and earnings and fleet structure (base years) (STECF, 2009). The predictions made for the Dutch beam trawl >40 metres with this model show perhaps overly optimistic scenarios for 2008 and 2009, because the model does not take into account recent important developments such as decommissioning, sudden price changes and policy changes (e.g. effort reduction schemes).

The profits of the EU fleet increased in the period 2002-2006. Profitability, cash flow and value added have all improved, and the fleet incomes have slightly increased (STECF, 2009). While the number of vessels decreased in most countries during in the period 2002-2007, the fleet capacity, measured in kW and GT, did not decrease to the same degree. Employment and days at sea also decreased during this period. However, the Netherlands does not fit into this main EU trend (ibid.) because the weight of landings, as well as the number of vessels, increased by 4% between 2002 and 2007, while in terms of GT and kW, the capacity decreased by 10% and 25%, respectively. Looking at the data on the development of fishermen's incomes in the Netherlands, we see that, in the cutter fishery sector, salaries have increased by around 30% per person since 1980 (Taal et al., 2008).

The EU capacity problem has received specific attention in the last two decades through the implementation of capacity adjustment programmes, namely the Multi-annual Guidance Programmes (MAGPs). The main aim of the MAGPs is to reduce the fishing effort (including fleet capacity) to a level that will ensure a long-term balance between fishing activities and resources. This adjustment was initiated because of the need to ensure the survival of a sector that is seriously under threat from over-exploitation of fisheries resources ('too much fishing') and that must therefore be restructured (EU, 1997). Under the programme, the Member States' fleets were divided into segments on the basis of length categories, fisheries and/or gear used by the vessels. Annual objectives in terms of tonnage (GRT, then GT) and power (kW) were then set for each segment. All EU fishing vessels had to be registered in the Community Fishing Fleet Register to allow for close monitoring and follow up of programmes. As a result of the MAGP, the EU fleet has shrunk by 20% over the last two decades in terms of vessel tonnage and engine power, although to a highly variable extent across fleet segments and Member States.

Andersen and colleagues (2009) analysed the extent to which it is possible to achieve specialisation gains by liberalising access to fishing quotas within the European Union. Fishing quotas are currently exchanged between Member States at a rate of 4% of total turnover in EU fisheries; the countries most actively involved in this are Germany, Belgium, Denmark and the Netherlands. It was found that there are only some specialisation gains in the EU, and that these gains could be increased by liberalising access to fishing quotas and allowing the transferability of quotas between countries on a permanent basis.

The economic performance of the EU fleet is likely to deteriorate as a result of three main factors (STECF, 2009): 1) the fuel crisis in 2008 increased operational costs and raised the concern of whether EU vessels are fuel efficient, 2) reduction for a number of key stocks, which will limit the earnings potential of a large part of the EU fleet, and 3) the global economic crisis in 2009 is affecting the demand for seafood and thus affecting fish prices.

3 The Dutch flatfish sector

3.1 Fisheries management of the Dutch flatfish sector

The Dutch demersal North Sea fishery (i.e. the cutter fishery) comprised 610 vessels in 1974 (Smit, 2001). Most were owned by single-family companies, but in several cases family firms owned four vessels. The vessels varied a lot in size and gear. Restricted fishing effort and/or restricted output did not exist before 1975, except for some technical measures like mesh size and minimum landing.

The tradition was to land fish at auction prices. However, since 1976 the Dutch fishing sector has been governed under the umbrella of the Common Fisheries Policy, which is still the framework for fisheries management in the EU. The flatfish sector was the first fishery to be regulated due to overfishing. Sole and plaice were the two main flatfish species targeted by the twin-beam fleet, and were managed by vessel quotas. The individual quotas (IQs) in a period of nine months consisted of 42% of the highest landings of sole, and 45% of the highest landings of plaice, during the years 1972, 1973 or 1974. Initially, the IQs could not be sold, leased or used as collateral. 'Track-records' were estimated for each vessel for each species based on highest landings in 1972-74. The Agricultural Inspection Service checked harvests to prevent overfishing.

When the IQ system was implemented there were several problems to deal with. For example, there was insufficient information about the relation between effort and landings, especially with the new investments in large vessels. Moreover, it was difficult to estimate capacity on the basis of HPs and effort on the basis of HP days. The quota targeted not multiple species but individual species, resulting in extensive discards and black markets. As the IQ system was expected to result in a 'race for fish' and in heavy competition, individual harvesting rights, individual fishing capacity and fishing effort were introduced in 1976.

A main problem after the quota system was implemented was related to the track records of new vessels and traded old vessels. Especially the gear, fishing capacity and landings of the larger vessels differed. It was a problem that some people fished more than their quota, which resulted in others not having the chance to get theirs. In 1977, the track records included 50% of real historical landings and 50% of theoretical landings. This allocation system is still used. The Dutch fishing board handed responsibility back to the government because it was difficult to administer as there were many stakeholders and interests involved.

An official system of ITQ trade was implemented in 1987, after a period of many 'unofficial' transfers. This system is managed by a co-management framework with fishermen being responsible for the industry, organised by groups of fishing firms since 1992. Fishermen in each group are in charge of controlling ITQ transfers, and controlling between members on a permanent basis (buying/selling), or on an annual basis (leasing), using agreed transfer prices.

Co-management groups have pooled the quota (ITQs) since 1993, including eight different management groups, whereby the board of each group is responsible for compliance with the group quota. The ownership of the rights remains with the individual holders. These groups facilitate trading, hiring and renting of the ITQs between their members, and these activities make the system flexible. The ITQs also serve as security for banks if a loan is required to, for example, finance a vessel. The value of harvesting rights increased 30 times per vessel between 1983 and 1998; thus, the high prices of the ITQs have become an important production factor for the firms. The ITQs of sole and plaice have contributed most to this increase in value. Apart from the ITQs, the Dutch right-based fisheries management consists of a number of other individual rights, namely: 1) transferable rights, or licences, expressed in quantities of engine power per vessel, aimed at limiting the total engine power of the sea going fleet under the EU's Multi-annual Guidance Programme (MAGP) implemented in 1985, 2) entitlement to fish in the coastal zone, which may also be transferred, and 3) limitation of gross tonnage (GT) of each vessel, implemented in 1998, under the MAGP that covered the years 1997-2001, which has led to rising values for transferable GT licences.

During the period 1983-1998, the number of vessels decreased and the fleet composition changed (Taal et al., 2008). The segments of medium-sized vessels almost disappeared and the Euro cutters and the large beam trawlers now count for 90% of the fleet's engine power. While the engine power capacity of the fleet decreased (13%), the number of sea days increased. Another important change is that the number of vessels less than 10 years old decreased from 39% to 23%, and the number of vessels older than 20 years rose from 33% to 41% over these years. The changes in the fleet capacity are due to many factors, including the EU's Common Fisheries Policy, TAC limitation and the horsepower licence system, as well as to stringent enforcement through the ITQ systems. Moreover, economic performance allowance of fiscal investments and the high prices of fishing rights were of importance.

The lower capacity of the demersal North Sea fleet has many consequences. One is the overall increase in profitability of the cutters. For example, the sector has been profitable, or at break-even, since 1991, after some years of adverse results. In addition, employment decreased from 2,750 crew members in 1983 to 1,920 in 1997. The fishing communities in the Netherlands have declined and the proportion of large beam trawlers in the fleet has increased, which again has affected the productivity of the sectors. Finally, because of the reduction in the numbers of days at sea under the MAGP, it has become difficult to catch the full quota. Note that through the decrease in quota of, for example, plaice, the prices have increased.

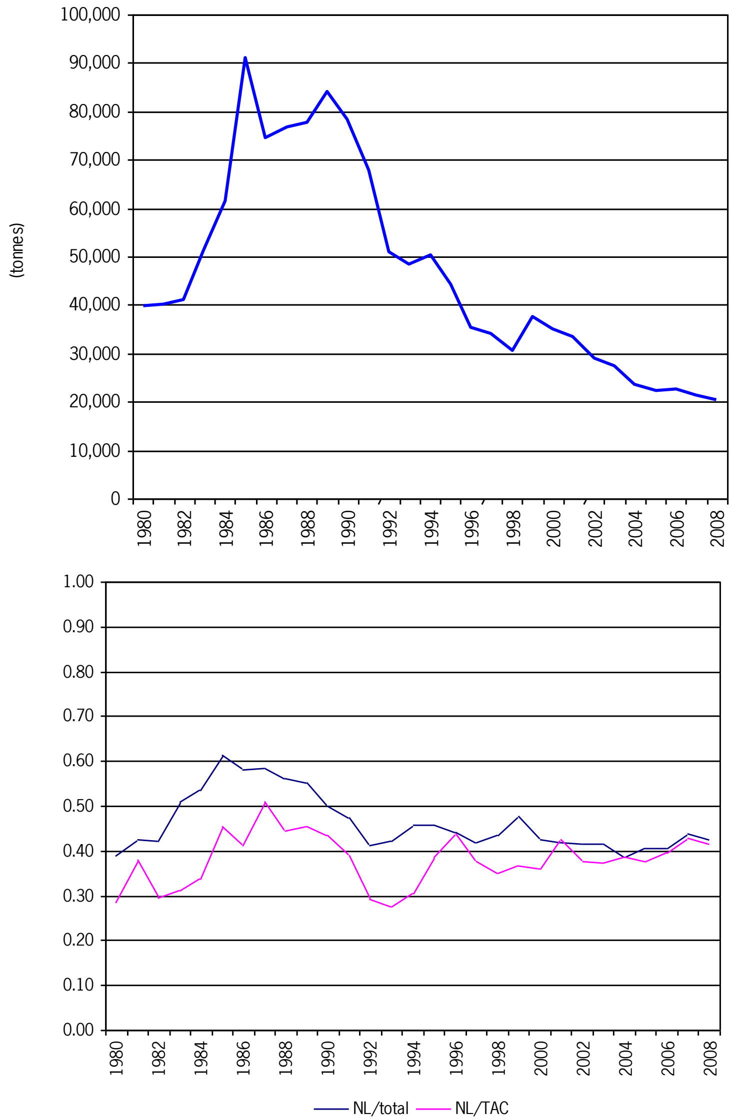
An overview of the main trends of fishing capacity of the whole fishing sector in the Netherlands during the period 1990-2005 is provided by Bartelings and colleagues (2007). It shows that between 1990 and 2005, the total number of active vessels decreased from over 600 to fewer than 500, the number of crew decreased from over 3000 to around 2300, and the total engine power decreased from almost 700,000 hp to about 500,000 hp. The investments in the fishery have reached a very low level in recent years, but note that the largest investments in the period 1990-2005 were made in the largest fleet with the highest technology levels in 2000. Except for the years 1997-2001, when there was a slight increase in total income, the overall trend during this period is that income decreased.

3.2 Sole and plaice in the Dutch flatfish fleet in the North Sea

Sole *(Solea solea)* and plaice *(Pleuronectus platessa)* are taken by the beam trawlers in a mixed fishery using 80 mm mesh in the southern part of the North Sea. In addition, plaice is harvested by a directed fishery with seines and in a mixed otter trawl fishery, and some sole is harvested along the Danish coast in a directed gill net fishery. According to the International Council for the Exploitation of the Sea (ICES), the stocks were harvested outside safe biological limits until 2007. In 2007 ICES reported that plaice is recruited with average strength, but that sole still has reduced reproduction capacity and is at risk of being harvested unsustainably (ICES, 2009).

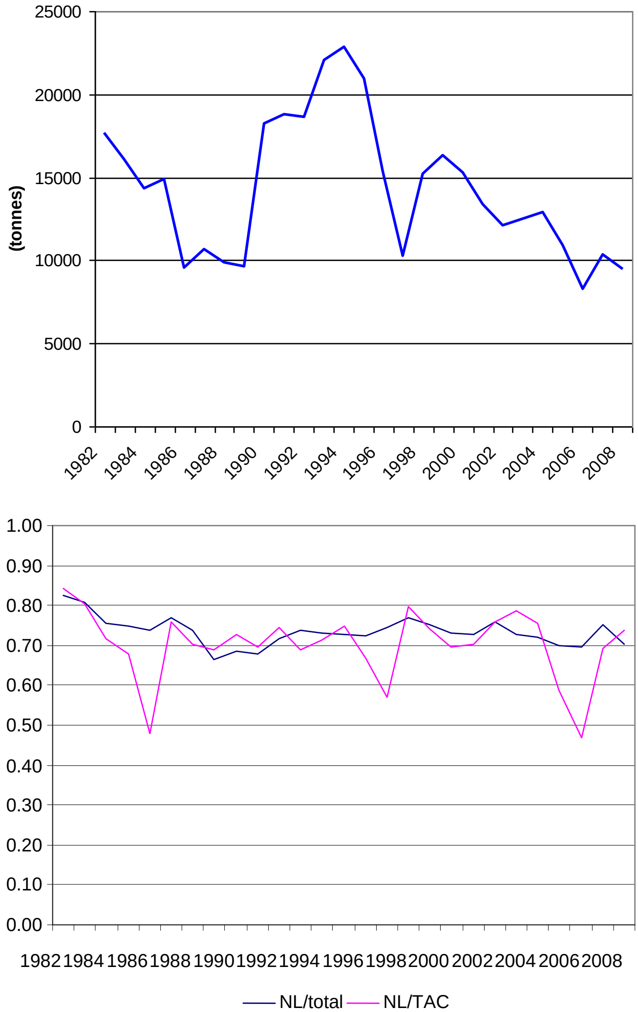
In Figures 3.1 and 3.2 we provide the trends of Dutch landings of plaice and sole in weights, as well as their share of the total landings and TACs set in the North Sea over the years 1980 to 2008.

Figure 3.1	Total landings of plaice by Dutch fleet in the North Sea (tonnes/share of TAC)



Source: ICES (2009).

Figure 3.2 **Total landings of sole by Dutch fleet in the North Sea (tonnes/share of TAC)**

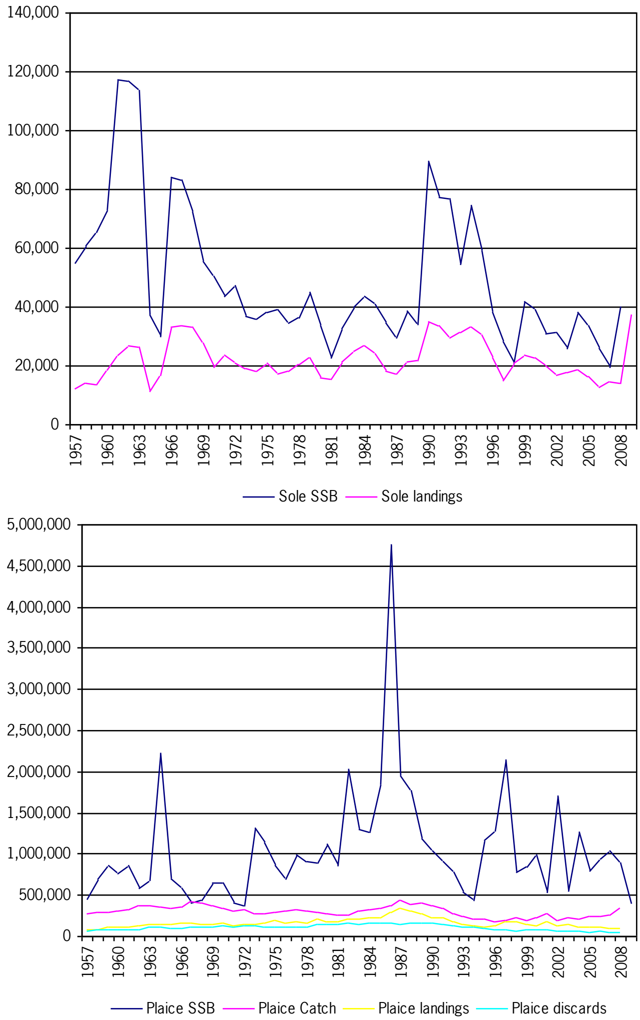


Source: ICES (2009).

The figures show downward trends in landings of both plaice and sole. Looking at Dutch harvest compared with the TACs and the landings set for all countries in the North Sea, we can see that the trend is that the Netherlands is taking a higher share. For sole, however, the landings have fluctuated.

In Figure 3.3, the SSB (spawning stock biomass) and the landings are shown for the years 1957 to 2008 for sole and plaice. For plaice, data also shows the pattern of catch and discards during these years.

Figure 3.3	Estimated SSB and the landings of sole and plaice in the North Sea, 1957-2008



Source: ICES (2009).

4 Current capacity of the Dutch flatfish fleet

4.1 Introduction

This section concerns the first objective, namely to estimate current incomes and costs in the Dutch flatfish sector and to determine the efficiency of the current flatfish sector. To determine the efficiency of the Dutch flatfish sector we used the DEA analysis presented in Appendix 1.

We estimated the capital utilisation using length and age of the hull as fixed input; gear cost, fuel costs and personnel costs as variable inputs, and sole, plaice, other species with a low price and other species with a high price as outputs. These variables were chosen because of their strong link to profits and investments. The net profit was optimised in the model, thus revenue minus variable costs was maximised. Vessels with high capital utilisation will thus have relatively high landing value and or combined with low variable costs.

Although there is some autocorrelation and heteroscedasticity between the variables used, especially between length and employment, data envelopment analysis is not affected by this. Research has shown that DEA-based estimators (i.e. data envelopment analysis are the best estimators of efficient output under heteroscedasticity (Banker et al., 2003) (see more information about the DEA analysis in Appendix 1).

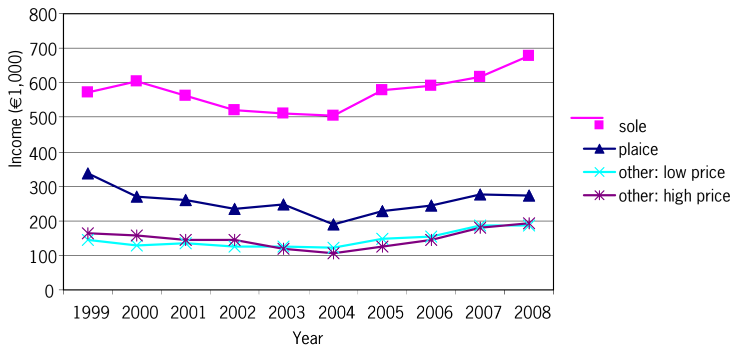
The models were applied only to the beam trawl and demersal fleet. To ensure that vessels were comparable in terms of catch composition, we selected only vessels that catch at least 5 tonnes of sole and plaice per year. This means that vessels that target only shrimp were left out of the analysis as these are significantly different from the other vessels.

4.2 Data

The LEI panel data was used as source for the estimates, including costs and income of around one third of the total Dutch fleet.

Figure 4.1 shows the average value of landings of the four outputs for the vessels in the LEI panel during the period 1999-2008. Whereas the average landings decreased (not shown in the graph), the average income was rather stable.

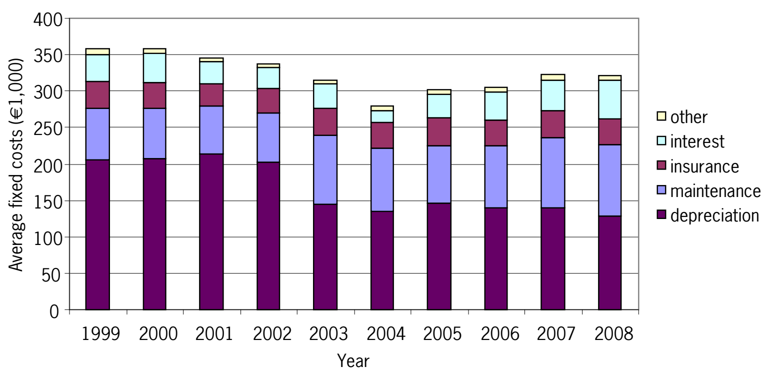
Figure 4.1 **Total revenue per species in the period 1999-2008 for the selected part of the demersal and beam trawl fleet**



Source: LEI survey.

Figure 4.2 gives an overview of the development of fixed costs in the period 1999-2008. Because the vessels in the fleet became older, the depreciation costs dropped. The striking change in depreciation costs between 2002 and 2003 can be explained by changes in the reporting methods of the depreciation costs. The maintenance costs increased as the vessels became older.

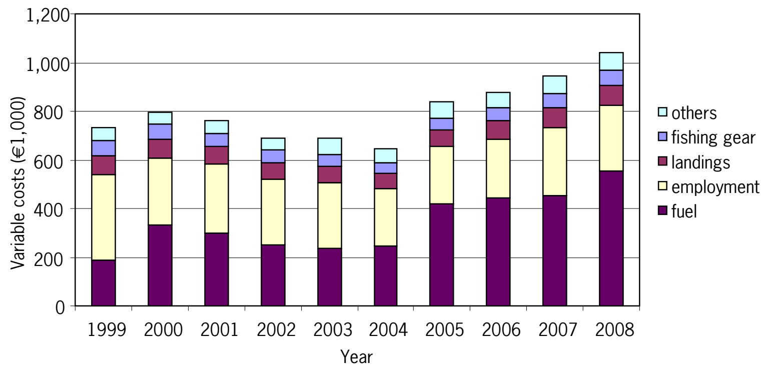
Figure 4.2 **Average fixed costs per vessel selected beam trawl and demersal fleet in the period 1999-2008**

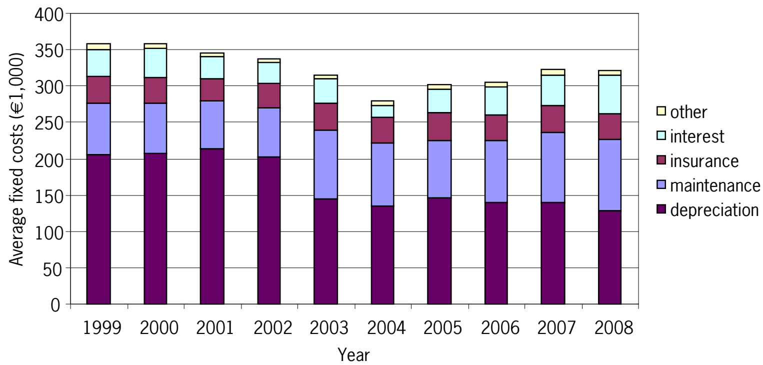


Source: LEI survey.

Figure 4.3 gives an overview of the variable costs during the period 1999-2008. Due to the pressure of the high oil prices, the fuel costs increased a lot, although the use of fuel decreased. The negative results in the fishery sector resulted in pressure on the employment costs, which are reduced in terms of costs and employment (in FTE). The other variable costs show less variation.

Figure 4.3 **Average variable costs per vessel selected beam trawl and demersal fleet in the period 1999-2008**





Source: LEI survey.

4.3 Capital utilisation of the Dutch flatfish sector

We estimated the overall capital utilisation of the Dutch flatfish sector by applying the DEA model as described in Appendix 1. The results of this model are shown in Table 4.1. In 2008 the average mean economic capital utilisation was 0.79. That means that vessels could earn 21% short-term profit if capital was fully utilised. The average capitalisation score became higher over the years, as Table 4.1 shows. This indicates that efficient and less efficient vessels became more similar and thus overall the fleet became more efficient.

Table 4.1 Average economic capital utilisation of Dutch flatfish sector

	Mean	Minimum	Maximum	Std Deviation	Count
1999	0.70	0.02	1.04	0.26	77
2000	0.62	0.04	1.06	0.29	81
2001	0.66	0.02	1.00	0.28	73
2002	0.73	0.04	1.05	0.28	68
2003	0.69	0.03	1.04	0.30	65
2004	0.74	0.04	1.03	0.29	56
2005	0.75	0.02	1.14	0.30	62
2006	0.70	0.13	1.15	0.32	53
2007	0.78	0.12	1.19	0.29	49
2008	0.79	0.09	1.16	0.29	43

Source: Results DEA model based on LEI survey.

4.4 Characteristics of efficient and less efficient vessels

The data presented in the previous section was used to estimate the break-even revenue, which is defined as the income that is necessary to cover both the variable and the fixed costs.

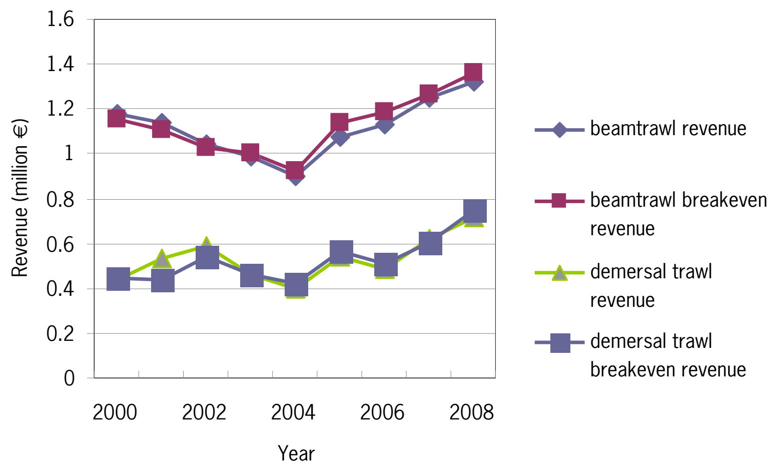
Figure 4.4 shows how the average break-even revenue relates to the actual income obtained by the whole fleet. It is notable that until 2003 the average total income was higher than the break-even revenue. After 2003, however, the total income was lower than the break-even income, and on average, the income is thus not high enough to cover the total fixed and variable costs.

Figure 4.4 **Average income and break-even revenue of beam trawl and demersal fleet in the period 1999-2008**

Source: LEI survey.

Figure 4.5 splits the results into the beam trawler fleet and the demersal fleet. It is notable that although the average income of a vessel in the demersal fleet was lower than that of a vessel in the beam trawl fleet, it is closer to the break-even revenue in comparison.

Figure 4.5 **Average revenue and break-even revenue of beam trawl and demersal vessel, 2000-2008**

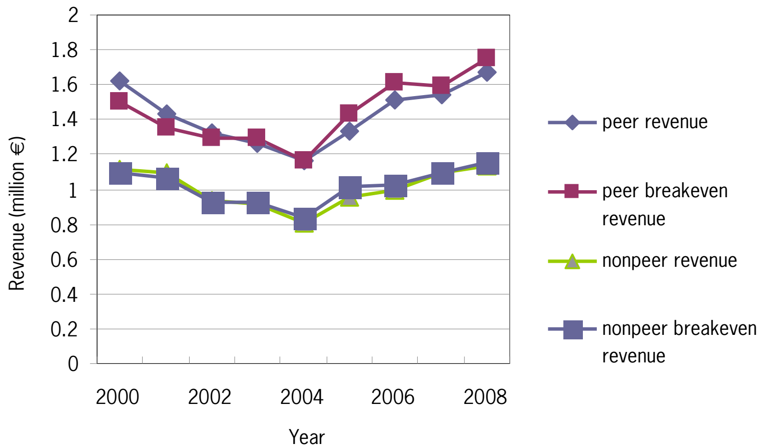


Source: LEI survey.

The economic efficiency levels of the vessels were calculated by applying a DEA analysis. The economic efficient vessels gain higher turnover with the use of less production factors than the less efficient vessels. Note that we particularly looked at the extent to which they can maximise their capital utilisation. More details of the DEA analysis can be found in Appendix 1.

The differences between the break-even revenue of the efficient vessels and of the less efficient vessels are presented in Figure 4.6. The economic efficient vessels had higher incomes than the less efficient vessels. Moreover, the efficient vessels had a relatively larger difference between break-even revenue and total income. This is because these vessels were newer and therefore had higher depreciation and interest costs. This implies that they had to catch relatively more fish than the older vessels to be able to cover total fixed and variable costs.

Figure 4.6	Average revenue and break-even revenue efficient and less efficient vessels, 2000-2008

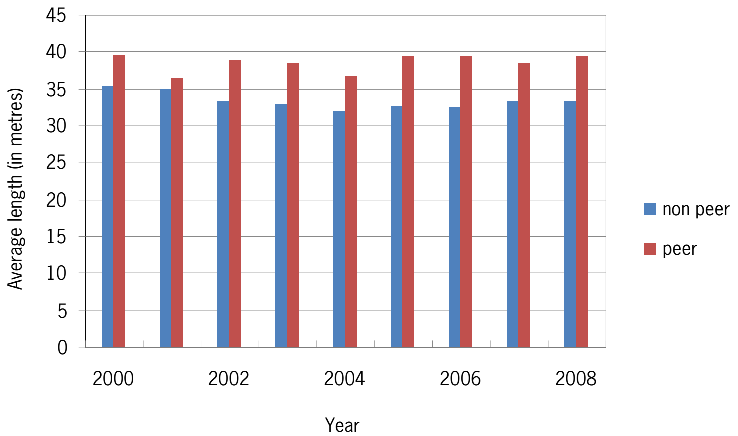


Source: Results based on LEI survey.

Although the DEA analysis does not provide exact estimates of how the variables affect the results, the individual effect of the variables can be further explored by looking at how peer vessels and non-peer vessels score on the different vessels.

The efficient vessels (i.e. the vessels that maximise their capital use) were on average larger than the less efficient vessels. This is shown in Figure 4.7.

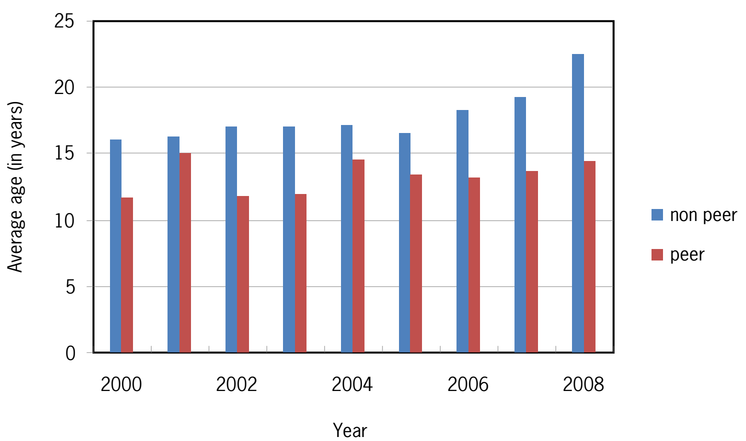
Figure 4.7 **Average length of peer and non-peer vessels in the period 2000-2008**



Source: Results DEA model based on LEI survey.

Figure 4.8 shows that the efficient vessels on average are newer than the less efficient vessels, although the age overall is rather high.

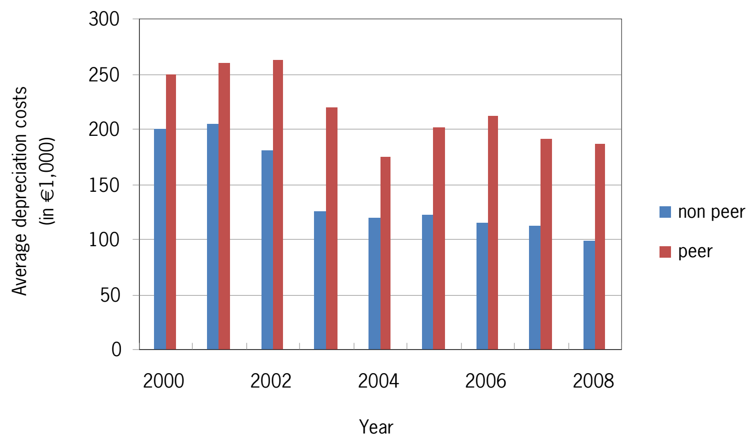
Figure 4.8 **Average age of peer and non-peer vessels in the period 2000-2008**



Source: Results DEA model based on LEI survey.

Given the younger age of the efficient vessels, the average depreciation costs for this group are somewhat higher than for the less efficient vessels (Figure 4.9).

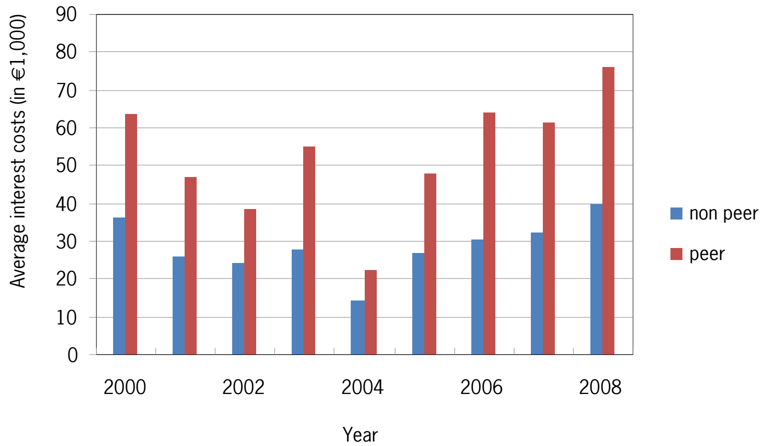
Figure 4.9	**Average depreciation costs of peer and non-peer vessels in the period 2000-2008**



Source: Results DEA model based on LEI survey.

The large investments in vessels resulted in higher interest costs for the efficient vessel category, as shown in Figure 4.10.

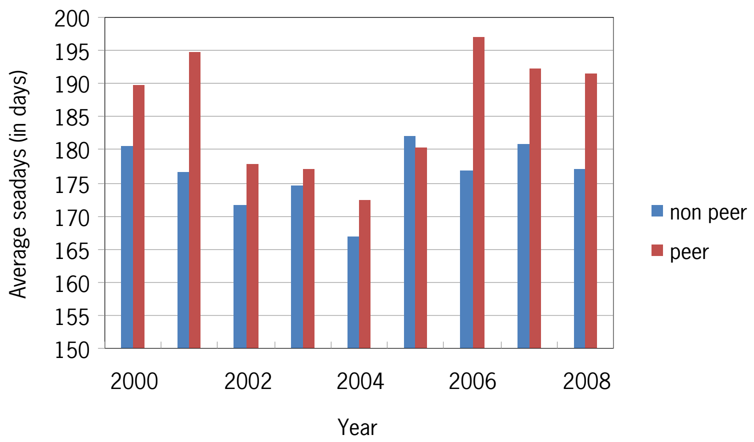
Figure 4.10 **Average interest costs of peer and non-peer vessels in the period 2000-2008**



Source: Results DEA model based on LEI survey.

Finally, Figure 4.11 compares the number of days at sea used by efficient and less efficient vessels. The efficient vessels are on average at sea longer than the less efficient vessels. In particular, a clear difference can be seen in 2006-2008.

Figure 4.11 **Average number of sea days of peer and non-peer vessels in the period 2000-2008**



Source: Results DEA model based on LEI survey.

4.5 Cost structure differences between efficient and less efficient vessels

On average, the total costs comprised about 25% fixed costs and about 75% variable costs. Whereas fuel and labour costs are the most important variable costs, maintenance and depreciation costs are the most important fixed costs categories. Although around 25% of the total costs of both the efficient and the less efficient vessels are fixed costs, the cost structures differ: the efficient vessels spend a larger share on interest and depreciation, while the less efficient vessels spend more on maintenance.

Table 4.1 gives an overview of the average cost of efficient and less efficient vessels.

Table 4.1	Cost structure 2006-2008			
	Efficient vessels		**Less efficient vessels**	
	average cost	**%**	**average cost**	**%**
Total fixed costs	426,970	26	264,939	24
- maintenance	108,867	7	85,356	8
- depreciation	196,047	12	108,201	10
- interest	67,262	4	34,216	3
- insurance	47,603	3	30,885	3
- other	7,192	0	6,281	1
Total variable costs	1,226,664	74	826,702	76
- fishing gear	85,570	5	43,891	4
- fuel	620,164	38	418,060	38
- landing	102,123	6	67,490	6
- employment	331,144	20	235,226	22
- others	87,663	5	62,035	6

Source: Results DEA model based on LEI survey.

4.6 Discussion

The data shows that the current fleet operates at break-even revenue or just below and has been operating on the break-even revenue for quite some time.

We calculated the efficiency of the current Dutch flatfish sector by applying a DEA analysis. The average capital utilisation was 79% in 2008. By increasing the capital utilisation of the fleet, short-term profits could potentially increase by 21%. The efficient vessels generate more short-term profit than the less efficient vessels. The efficient vessels are in general younger, larger and use more sea days than the less efficient vessels.

The cost structure of the efficient vessels is also quite different from that of the less efficient vessels. Efficient vessels spend on average a large percentage on depreciation and interest cost, while less efficient vessels spend more on reparation costs.

The overall profit of the fleet could be higher if the less efficient vessels became more like the efficient vessels or if the overcapacity of the fleet was reduced by reducing the number of inefficient vessels.

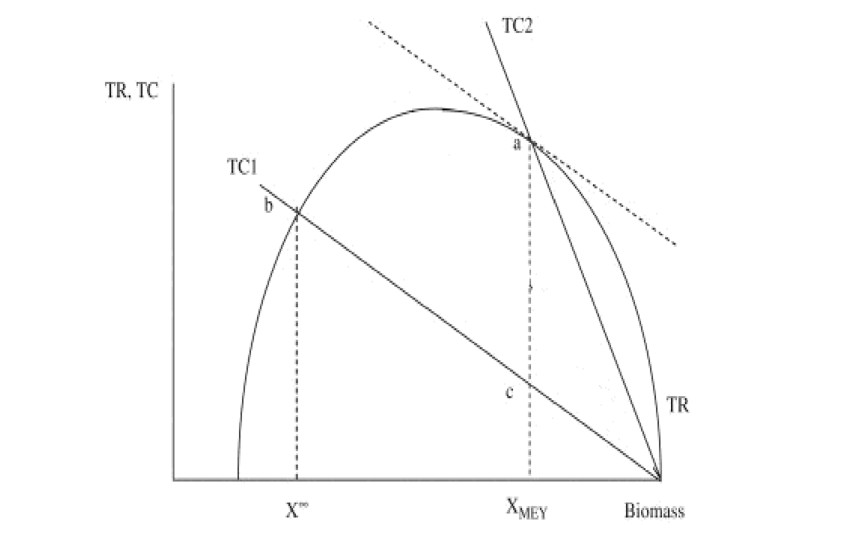
5 Future capacity of the Dutch flatfish fleet

5.1 Introduction

In this section we address the second main objective of this study: to estimate the future fishing capacity under various scenarios. But first we provide relevant background information.

According to the theory about effort, the fishery sector can search for a maximum resource rent position and thus increase its overall profitability with less effort as indicated by X_{MEY}a in Figure 5.1, where the distance between effort costs and income of landings is at its greatest.

Figure 5.1 **Regulated open access and rent (for explanation see text)**



Source: Asche et al. (2008).

However, in a regulated open access fishery, the harvest is restricted by a TAC and the length of the fishing season is restricted in order to achieve the desired TAC (see Figure 5.1, Asche et al., 2008). Access to the resource during the open season, however, is effectively unlimited and if this regulation is successful, stock size will be larger than under unregulated open access. Let it be assumed that the stock has been biologically well-managed by the regulators so that it corresponds to X_{MEY}. Whereas a regulated open access reinforces the problem of overcapacity, a 'successful' regulated open access regime leads to substantially greater overcapacity than the standard open access regime (Homans and Wilen, 1997). This is because the increased stock results in higher revenue and short-term economic profits, which continue to attract investments that comply with regulations. That could involve investment in bigger or faster boats, increasing the cost of fishing and shifting the cost function from TC1 to TC2. A new equilibrium is achieved when the total cost is equal to total revenue and no excess profits are generated (point a, Figure 5.1). All rents are dissipated, and the economic waste, from a social point of view, is even greater in the regulated open access than in the open access equilibrium because of the increase in redundant capacity. Note that in an open access situation, variable costs are more likely to be higher than the fixed costs, whilst in a restricted regulated access this is reversed.

Although Figure 5.1 suggests a theoretical equilibrium situation, it is probable that the Dutch flatfish fishery is closer to a maximum sustainable yield (MSY) situation than an MEY situation. This is in accordance with the EU policy that is aimed at creating an MSY situation in the European fisheries. Today the Dutch fleet is restricted by the EU's Common Fisheries Policy and the limits set on days at sea, by the horsepower licence system and by stringent enforcement through the TAC/ITQ system. Due to the horsepower licence restriction, new vessels can enter only if they replace vessels that are leaving the sector. As we saw in the estimates in section 4, the cutter fishery sector is at break-even with a small overall economic loss (-€2m in 2008). Whereas in practice no profit is observed, this would imply that theoretically the Dutch sector situation would be between the TC1 and TC2 in Figure 5.1. Given EU restrictions, investments can still go on by improving fishing techniques and renewing vessels, and thus increase the fixed costs in the sector until total costs equals total revenues. Thus, the costs have increased compared with an open access situation also in the Dutch sector.

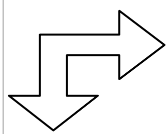
In this study we were interested in establishing the number of vessels that will be needed to harvest future landings. Hence, we estimated the following (in a rather hypothetical manner, as many assumptions had to be made):

1. The minimum number of vessels needed to harvest future landings.
2. The potential gains in profits to the sector with a reduced number of vessels as overall fixed costs will be reduced.
3. The potential gains in profits to the remaining vessels as fixed costs and profits of the withdrawn vessels will be replaced.

In addition, we wanted to find out how many vessels would fit into the sector at a break-even situation in the future, in other words:

4. The maximum number of vessels that will be able to harvest future landings at break-even.

Before addressing these four issues, we provide some background information about how we estimated future landings, future prices and future incomes for the Dutch flatfish sector. However, before we continue we first provide an overview of the various scenarios that were applied as a basis for the estimates. A summary of the scenarios is provided in Table 5.1. This is done to facilitate the readings, as the scenarios combine different options (A, B and C are combined with 3, 4 and 7).

Table 5.1	**Scenario assumptions**			
		Total landing projections, plaice and sole *(based on section 5.2)*		
	Assumptions: 	3: Fleet will go on fishing until the last of the two TACs is fished while discarding/ misreporting the over-quota catch of the other species	4: Fleet will fish up both TACs while avoiding catching over-quota fish	7: Fleet will go on fishing until the last of the two TACs is fished while discarding/ misreporting the over-quota catch of the other species. Shape differs from other scenarios because of different assumptions made about stock dynamics
Maximum tonnes catch per vessel *(based on observed harvest in the past)*	A: Stable future catches of around a maximum of 200 tonnes per vessel	Scenario A3	Scenario A4	Scenario A7
	B: Slight increase in landings from 200 tonnes per vessel in 2009 to around 230 tonnes per vessel in 2025	Scenario B3	Scenario B4	Scenario B7
	C: A large increase in maximum harvest from around 200 tonnes per vessel in 2009 to around 560 tonnes per vessel in 2025	Scenario C3	Scenario C4	Scenario C7

Source: Adapted from Machiels et al. (2009), ICES (2009).

Whereas the three assumptions about the projected landings for the whole fleet are based on Machiels and colleagues (2009) (see background in the following section), the assumptions of the maximum catch per vessel are based on observations made of harvests per vessel in the past (back to 1990).

5.2 Background - assumptions set for scenarios

Expected landings of sole and plaice

Machiels and colleagues (2008) identified seven scenarios of TACs and landings of plaice and sole in the North Sea in the years 2009-2026 (see Table 5.2), and estimated the efforts needed to yield the plaice TAC and the sole TAC.

The simulation model they used consists of three modules: 1) an operating module, 2) a stock assessment module and 3) a management module. Whereas the operating module simulates the true stock and dynamics of the fishing fleet, the stock assessment module explicitly includes information about or perception of the stock's status. In the management module of the model, the perceived fishing mortality (F), which is equal to the assessment estimate, and conservation target reference points from the management agreement are used as input to simulate a harvest control rule (HCR) and formulate advice for setting the TACs and intended fishing mortality.

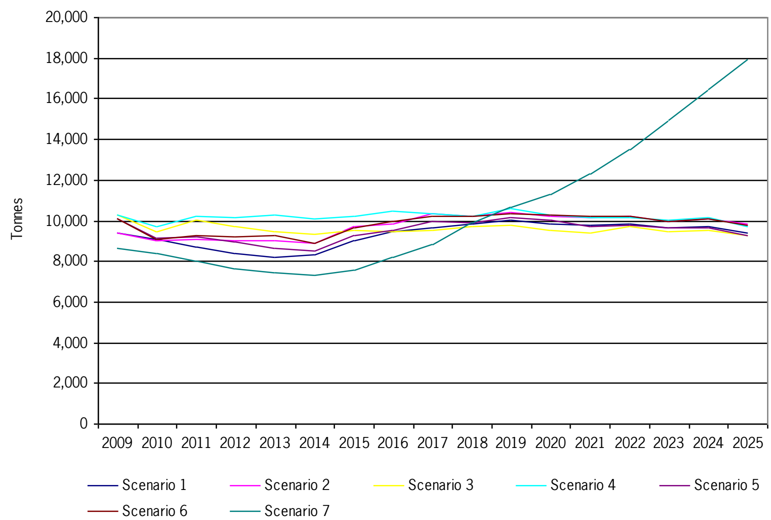
A number of simplifications and assumptions were made in the simulation model. It was assumed that fishing continues until both TACs are caught, so that the maximum of the estimated level of fishing days at sea available for the relevant fleets (i.e. efforts) was selected. This estimate is the effort used in the simulated year of the TAC's application. In case the TAC for a species is lower than the simulated landing, under scenario 1 the surplus is to be regarded as over-quota catch. As an alternative in scenario 2, the surplus catch is avoided and the estimated over-quota is added to the stocks. The management measure in the agreement is a reduction of fishing mortality, which is partly implemented as a TAC reduction. The mortality reduction is achieved via the adjustment of the effort (days at sea), which is based on a forecast of the maximum level of fishing effort necessary to land the TACs established. In practice, effort will probably not restrict the fisheries, and therefore the simulation study did not implement limiting effort levels below the 2006 level. Moreover, spatial and seasonal differentiation in stock abundance and fleet effort allocation were not included. Also, the fleet structure was simplified. The annual variations in TACs are kept within limits (15% up or down).

Table 5.2	Seven scenarios of future TACs and landings in the Netherlands with different constraints to the model and assumption of fishing behaviour		
Constraints to model / **Assumed fishing behaviours**	Fishing mortality reduction assumed to be relatively large (by applying a single multiplier)	Fishing mortality reduction assumed to be relatively small (by applying a double multiplier)	A TAC constraint was applied instead of a multiplier
Fleet will go on fishing until the last of the two TACs is fished while discarding/ misreporting the over-quota catch of the other species	Scenario 1/7 a)	Scenario 3	Scenario 5
Fleet will fish up both TACs while avoiding catching over-quota fish	Scenario 2	Scenario 4	Scenario 6

a) Scenarios 1 and 7 are similar, but different assumptions have been made on stock dynamics.
Source: Machiels et al. (2008).

Seven scenarios of the estimated Dutch fleet catch of plaice and sole are shown in the figures bellow. Total catches for the Dutch fleet were based on the share in the EU TAC - estimated as an average over the last 27 years. In order to find the Dutch share of this total catch, we based our estimates on ICES (2009 a and b) to find the average Dutch share of the total TACs and landings in the North Sea in the last 27 years. The average Dutch share of the total landings was 46% for plaice and for 73% sole. Based on the data estimated with the model of Machiels and colleagues (2008), the seven options were adapted to the Dutch catch, as shown in Figures 5.2 and 5.3.

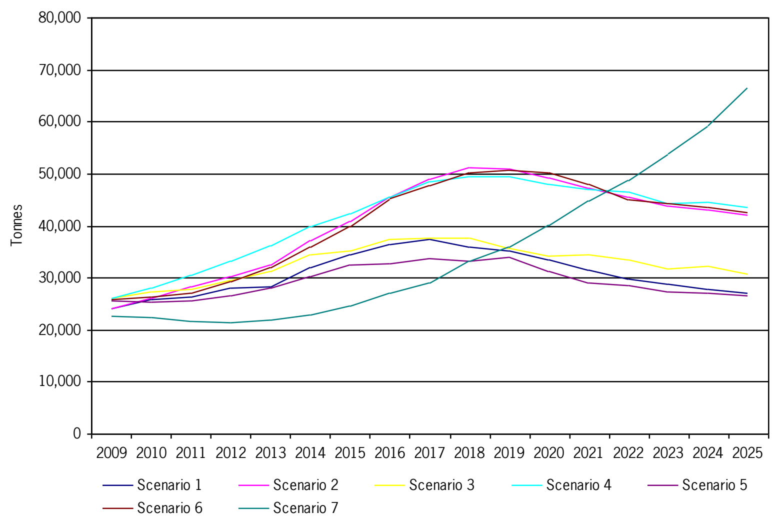
Figure 5.2 **Estimated sole landings for the Dutch flatfish sector under seven scenarios in the years 2009-2025**



Source: Machiels et al. (2008).

The simulated Dutch sole landings are expected to be stable or to increase. In Figure 5.2 we do not see large differences in the simulation of scenarios 1-6, implying that the three constraints to the model specified in Table 5.2 did not have an impact, and also that the assumed fishing behaviours with respect to discards did not have an impact. Only when different assumptions were set on stock dynamics in scenario 7 is a different pattern observed, namely an increase in landings in the long term as a consequence of low harvests in the near future.

Figure 5.3	Estimated plaice landings of the Dutch flatfish sector under seven scenarios in the years 2009-2025



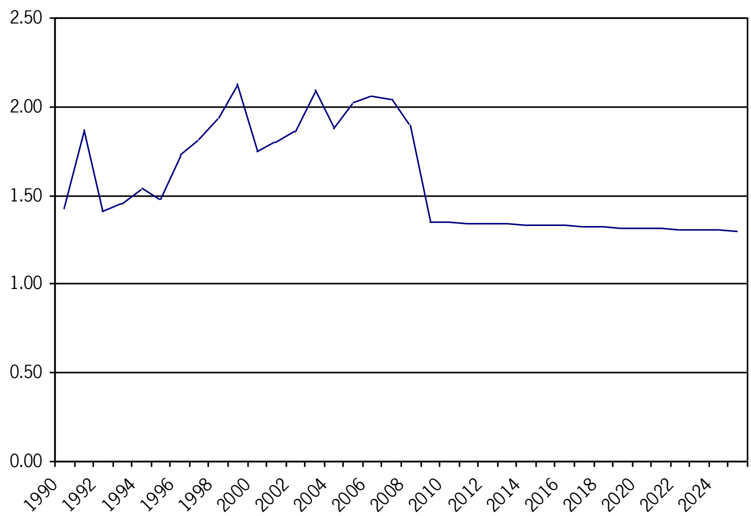
Source: Machiels et al. (2008).

Whereas the projected Dutch plaice landings show an expected increase in the short term, a decrease is seen in the longer term. In Figure 5.3 differences are seen in the simulation of the scenarios when different assumptions are set for fishing behaviour with respect to discards. While in scenarios 2, 4 and 6 the fleet is assumed to avoid catching over-quota fish, resulting in higher landings, in scenarios 1, 3 and 5 lower levels of landings are simulated when it is assumed that the fleet will go on fishing until the last of the sole or plaice TACs are harvested while discarding/misreporting the over-quota catch of other species. Similar to the simulations of sole, an increase in landings of plaice is observed in the long term if less is caught in the short term - when different assumptions are set on stock dynamics in scenario 7.

Expected prices of sole and plaice

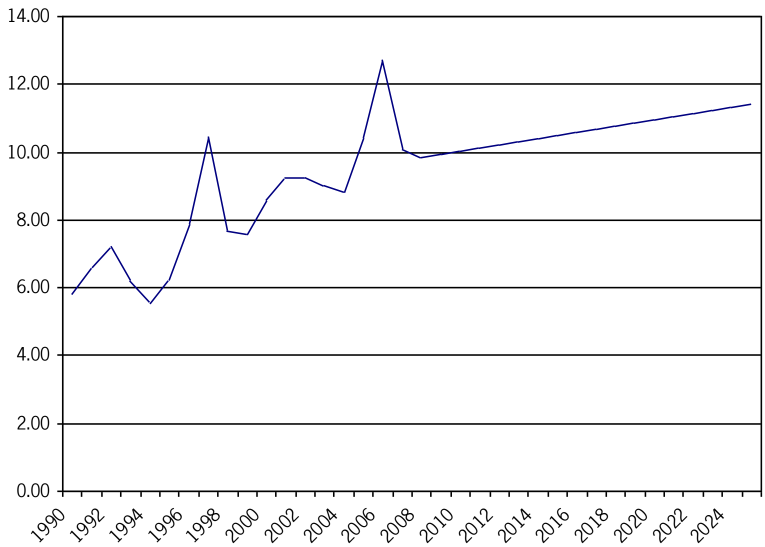
We estimated the expected price trends of plaice and sole based on price trends over the years 1990-2009 (LEI, 2009) and on expert insight into future expectations. The trends are shown in Figures 5.4 and 5.5. Because of the current substitutes for plaice, and a relatively very low price in 2009 at €1.35/kg, it is expected that the trend will be a slight decrease in price over the coming years to €1.30/kg in 2025. This implies a small average decrease in the price of plaice per year of -€0.003/kg. For sole, the price is expected to increase to a little less than €12.00/kg in 2024, implying an average increase of €0.09/kg per year. Note that this is projected as a trend and does not include any price flexibility, as that would involve more assumptions and model specifications.

Figure 5.4 **Price scenario of plaice until 2025**



Source: LEI, Aquatic resources, Taal et al. (2009).

Figure 5.5 **Price scenario of sole until 2025**

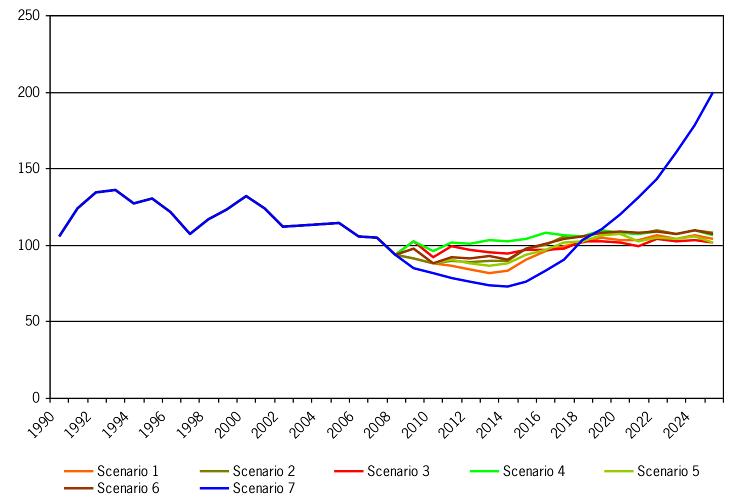


Source: LEI, Aquatic resources, Taal et al. (2009).

Expected incomes from sole and plaice

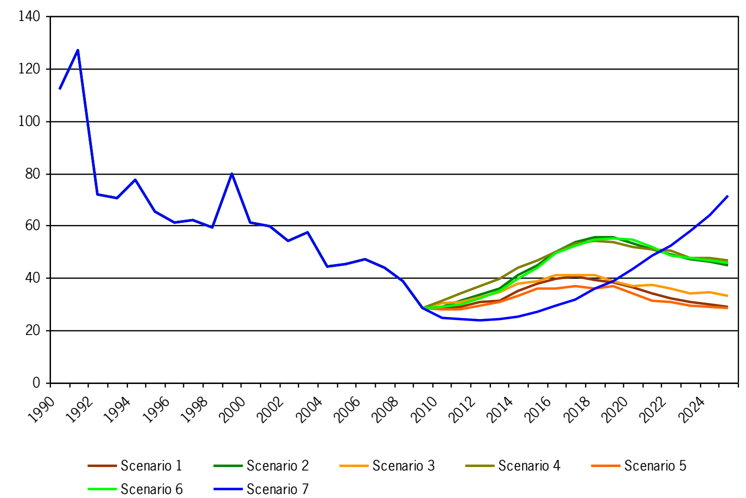
The values of future Dutch landings were estimated based on the projected prices and quotas of plaice and sole until 2025. They are shown in Figures 5.6 and 5.7. The past is also included in the two tables. This is because the future can best be seen in the context of the past (and also because we use the previous harvests when we suggest possible harvests per vessel in the following section).

Figure 5.6	Past and future values (€m) of sole until 2025 a)



a) Note that in scenario 7, the value increased a lot more than presented and we assumed that with such an increase in supply, there would be an impact on price flexibility. We therefore implemented a price elasticity of 0.7 in this scenario only.
Source: Based on data provided in Figures 3.1, 5.2 and 5.5.

Figure 5.7	Past and future values of plaice (€m) until 2025



Source: Based on data provided in Figures 3.2, 5.3 and 5.4 and ICES (2009).

As we can see in Figure 5.7 it can be expected that the total value of landings of plaice will increase in the short term, with a probable reduction in value after 2015 or 2020. However, if less is harvested in the coming years, an increase may take place in the long term if stocks are allowed to expand. For sole, the differences are smaller in the various scenarios (Figure 5.6), and no reductions in values are projected. However, if the landings are reduced in the very short term, it is possible that the fish stocks will recover and ensure a high value in the longer term.

We can see that the values of plaice landings were a lot higher in the past because of larger catches, but the values of sole landings have been more stable.

Projected landings per vessel of sole and plaice

The maximum future landings per vessel (max zt) were set to be the same as the maximum historic landings per vessel. They were obtained by dividing the landings presented in Figures 5.6 and 5.7 by the total number of vessels harvesting sole and plaice. Looking at the historical data of landings per vessel in 1990-2008 we can see that landings decreased from 184 tonnes per vessel in 1990, to below 100 tonnes per vessel since 2004.

The underlying assumption for this statement is that both future SSB and future catchability will be at least as much as in the most productive period over the recent decades. This assumption for similar SSB is supported by the fact that in the simulations of Machiels et al. predicted biomass of both plaice and sole are in the same order of magnitude when MSY is reached as the maximum during the last decades. For sole the SSB for 2020 is predicted to be around 80,000 tonnes in most scenarios, around the same as the maximum SSB in the early nineties and late sixties (ICES, 2010). The 2008 SSB of 359,000 tonnes for plaice was only slightly lower than the SSB in 1990 (ICES, 2010). Recently, the maximum SSB for plaice has been increasing and is estimated to reach around 600,000 tonnes in 2020, which is around 50% higher than the maximum SSB from recent history.

The other assumption is that the fishing power in the future fleet is similar to the fleet during the maximum landings. The flatfish vessels that we included consists of different hp classes, Whereas the share of the 250-300 hp class was 40% in 1990-94, it increased in 2005-08 to 65% (see Table 5.3). Thus, overall, the average size of the vessels in terms of engine power has decreased by around 20%. Although the relative catching power of a beam trawl vessel is decreasing with increasing engine power (Rijnsdorp et al. 2000), this decrease in catching power would be around 18%, if there would not have been any technological improvements. However, Rijnsdorp et al (2006) showed that during the period from 1990 to 2003 the efficiency of the fleet has increased irrespective of the engine power. To enable an increase of 18% in 20 years would require less than 1% per year which is below many estimates of technical creep in literature.

Therefore, given that the vessels stay about the same size the coming years, implying that the share of hp classes of 250-300 hp remains around 65% as it was in 2005-2008 (Table 5.3), although with some technological improvements in terms of catchability, it is realistic to assume that the maximum landings per vessel will be greater in the future than they were in 1990. Only in near future, the potential catches per vessel for sole are overestimated because of the current relatively low SSB for this species.

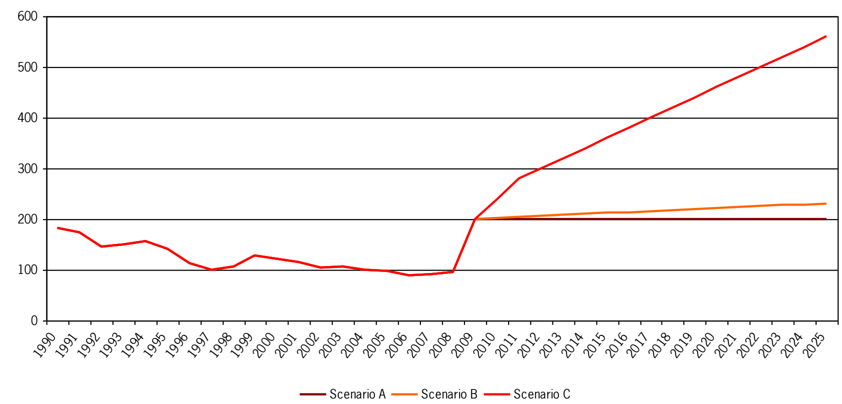
Table 5.3	**The share of hp classes of the cutters over the years 1990-2008**			
Engine power	**1990-94**	**1995-99**	**2002-04**	**2005-08**
250-300 hp	249	234	235	220
1,800-2,000 hp	249	196	158	122
SUM	498	430	393	342
Share of 250-300 hp	0.50	0.54	0.60	0.65

Source: Taal et al. (2009).

The assumptions about landings per vessel introduced in Table 5.3 are also presented in the following (see Figure 5.8). We identified one option with stable catches of around a maximum of 200 tonnes per vessel (A), and one with a slightly increase from 200 tonnes per vessel in 2009 to around 230 tonnes per vessel in 2025 (B). Note that this situation might result from both increased availability of fish and/or more efficient fishing technology. A third option suggests a large impact of technological improvements and/or larger stock sizes, resulting in a maximum harvest from around 200 tonnes per vessel in 2009 to around 560 tonnes per vessel in 2025 (C). The extent to which one option is more realistic than the others are discussed later.

The negative slope of the harvest per vessel in 1990-2008 in Figure 5.8 can be explained by three main factors; 1) the TAC, 2) restrictions on days at sea, and 3) the size of the spawning biomass in the sea of the two species. Note that if the simulations of the expected landings in Figures 5.2 and 5.3 were restricted by a total number of sea days per vessel, the scenarios of future maximum landings per vessel in the coming years would be wrong. However, as the number of sea days used in the simulations in Figures 5.2 and 5.3 were calculated as what would be needed to harvest TAC, they are not set as a restriction in the estimations. The main restrictions are therefore the TACs and the size of the spawning biomass.

Figure 5.8 **Average landings of plaice and sole per vessel (tonnes) in 1990-2008 and three projected maximum landings per vessel (A, B and C)**



Source: Adapted from ICES (2009).

5.3 Estimated minimum number of vessels in the sector

In this section, we look at the minimum number of vessels that will be needed in the coming years to harvest the expected landings of sole and plaice. The logic behind the formulas presented here is that, given that vessels are withdrawn from the sector, the fixed costs that are linked to the withdrawn vessels are thus also withdrawn from the sector. However, the variable costs, which are linked to the amount harvested, will remain in the sector and have to be paid by the remaining vessel owners. This implies that, as the sector has to pay less fixed costs because of the withdrawn vessels, but still harvests the same amount of fish and hence earn the same amount of money, the withdrawn fixed costs will be experienced as an overall profit for the remaining sector. Later on we show how this extra profit for the sector will also result in increased overall profits to be made by the remaining vessel owners. First, however, we show how much one vessel can harvest at a maximum, which enabled us to estimate the minimum number of vessels needed to harvest the projected future landings. To do so, we used the following formula (4.1):

$$\text{Min } \Sigma X_t = Y_t \,/\, \max z_t \qquad \text{(Formula 4.1)}$$

Where:

- Min ΣX_t is the minimum number of vessels needed to harvest the projected future landings,
- Y_t is the total landings of the sector
- max z_t is the maximum landings per vessel.

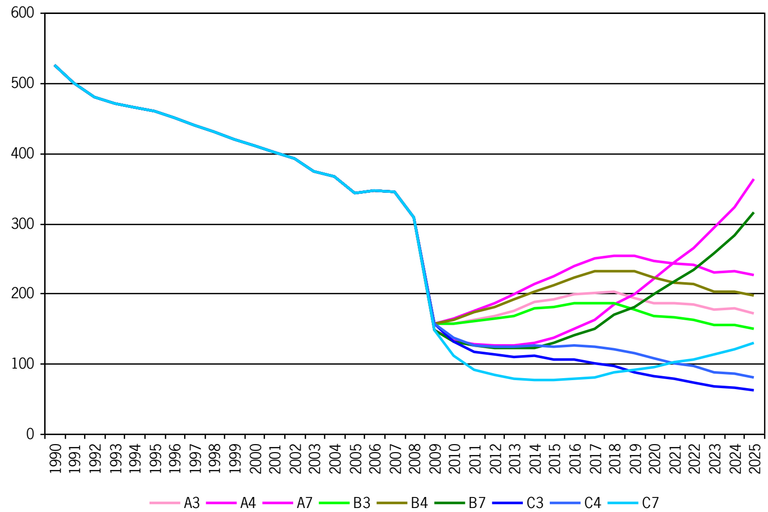
The total landings of sector (Y_t) are based on the values of the landings presented in Figures 5.2 and 5.3, where the tonnes of expected catches of sole and plaice are estimated by the simulation model presented in section 5.2.

The minimum number of vessels needed to harvest the projected future landings (Min ΣX_t) is based on estimates of the selected projected future landings (3, 4 and 7) and the three options for maximum landings of the vessels (A, B and C) (formula 4.1).

The big jump from 2008 to 2009 is explained by the current overcapacity for plaice and sole, as it was assumed that in 2009 each vessel should be able to catch about the same amount of these species as in 1990. As argued before, this is probably an overestimate of the overcapacity, because in 2009 sole SSB is still lower than in the early 1990's but in the consecutive years this bias is expected to decrease.

As Figure 5.9 shows, before 2021, the number of vessels for all scenarios presented in Table 5.1 will be less than 244. Moreover, if the future provides fish stocks and vessels that can result in around 230 tonnes per vessel, the total number of vessels will be only 150-250 vessels (scenarios B3 and B4). With very technologically efficient vessels and larger stocks in the near future providing the potential to harvest up to 540 tonnes per vessel in 2024, the minimum number of vessels will be between 60-130 vessels (C3, C4 and C7). This is a lot fewer than in the past. In 2022 onwards, it is estimated for two scenarios, with stock dynamics assumed to be different, that the number of vessels needed will be more than 244 (A7 and B7). However, this is most unlikely, as in these scenarios fish biomass of both stocks will increase tremendously allowing for much higher catches per seaday.

Figure 5.9	Minimum number of vessels needed to harvest the estimated future landings a)



a) A, B and C are possible total landings per vessel in the future. The numbers 3, 4 and 7 refer to three selected scenarios of future total landings of sole and plaice (see section 5.2).
Source: Adapted from Machiels et al. (2009) and ICES (2009).

The main reason for a rapid reduction after 2008 in Figure 5.9 is that we argue that the number of vessels needed for the total landings in 1990 would be sufficient also in 2009. As Figure 5.9 shows, before 2021, the number of vessels for all scenarios presented in Table 5.1 will be less than 244. Moreover, if the future provides fish stocks and vessels that can result in around 230 tonnes per vessel, the total number of vessels will be only 150-250 vessels (scenarios B3 and B4). With very technologically efficient vessels and larger stocks in the near future providing the potential to harvest up to 540 tonnes per vessel in 2024, the minimum number of vessels will be between 60-130 vessels (C3, C4 and C7). This is a lot fewer than in the past. In 2022 onwards, it is estimated for two scenarios, with stock dynamics assumed to be different, that the number of vessels needed will be more than 244 (A7 and B7). This will of course be possible only if less is harvested in the short term.

5.4 Potential overall gains for the sector by withdrawing vessels

In this section we look at the potential gains for the sector resulting from a reduction in the number of vessels. This gain is assumed to be related to the fixed costs that will follow the withdrawn vessels, and therefore contribute as profits for the remaining sector. Hence, we estimated what the potential gains in profits for the sector with a reduced number of vessels as overall fixed costs will be reduced. We solved this by using the following formula (4.2):

$$\Pi_t = (\Sigma X_{2008} - \text{Min } \Sigma X_t) * f_t \qquad \text{(formula 4.2)}$$

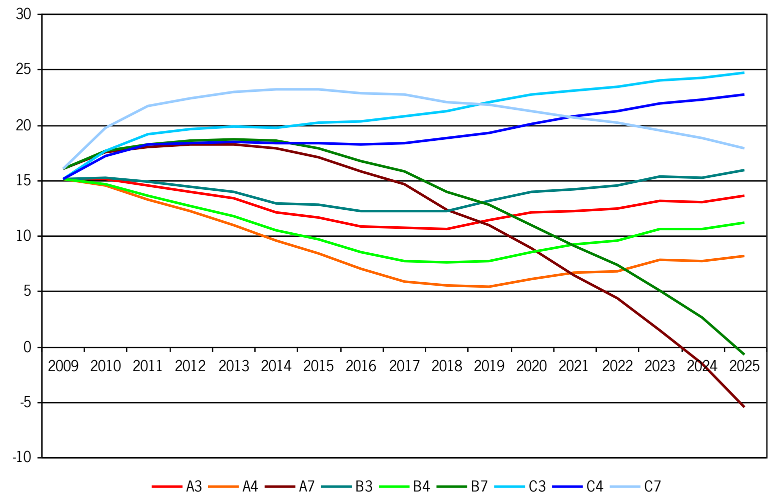
Where:

- Π_t is the potential overall gain in profits for the sector
- ΣX_{2008} is the current number of vessels (=308)
- Min ΣX_t is the minimum number of vessels needed to harvest the projected future landings
- f_t is the fixed costs per vessel.

First we found the potential removal of vessels under various scenarios, namely the difference between the current (2008) number of vessels (ΣX_{2008} = 308) and the minimum number of vessels needed to harvest the expected landings in various scenarios (Min ΣX_t). The numbers of vessels that in theory can be withdrawn under various scenarios are shown in 5.10, including the scenarios presented above (A3, A4, A7, B3, B4, B7, C3, C4, C7).

As shown in Figure 5.10, the highest removal of vessels is with the C options, where it is assumed that the vessels can land a lot more than they do at present. In the A and B options, however, the landings per vessel are assumed to be slightly above the level in 1990, namely around 200 tonnes per vessel. Whereas reductions are suggested in the range of 54 (A4) to 186 (B7) vessels, it is also estimated that after 2022 it might be possible that only a few vessels fewer than the current level will be needed (A7 and B7), depending on whether the stock dynamics of this scenario (7) is more likely than what is assumed for the others (3 and 4) (see section 5.2).

Figure 5.10	Reduction potentials of vessels with various options for projected landings (3, 4 and 7), as well as the potential harvest per vessel (A, B and C)



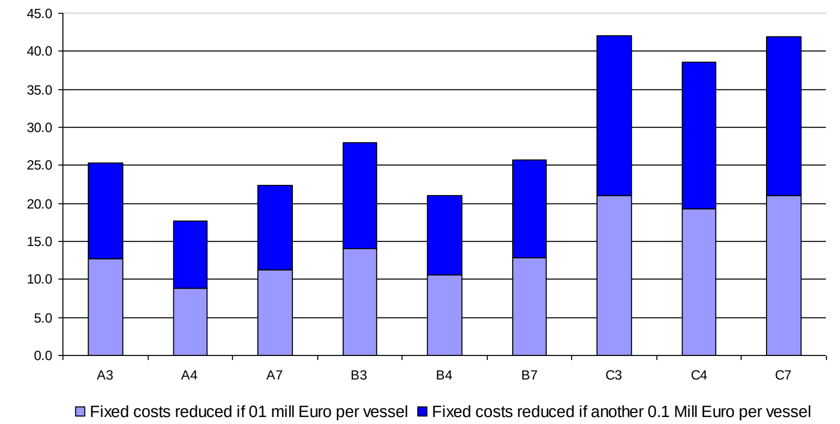
Source: Adapted from Machiels et al. (2009) and ICES (2009).

The total fixed costs for the flatfish sector in the Netherlands are estimated for 1990-2008 in €m (f_t). When total fixed costs are divided by the number of vessels operating each year, the average fixed costs are €0.2m per vessel in 1990-2005, and €0.1m per vessel in 2006-2008. Thus, in the following we apply fixed costs per vessel of €0.2m and of €0.1m for comparison. The fixed costs include those for insurance, interest and amortisation, as well as 50% of the maintenance costs.

First, we assumed that fixed costs will be €0.1m or €0.2m per vessel in the future (Figure 5.11). By simply multiplying the fixed costs per vessel by the proposed reduction in numbers of vessels in the various scenarios, we found total fixed costs to be withdrawn from the sector together with the potential removal of vessels in the various scenarios. Figure 5.11 presents the average yearly reduction potentials of fixed costs with the various scenarios in 2009-2025.

When assuming that total landings per vessel would be 200-230 tonnes in accordance with the A and B options, six scenarios suggest an average annual reduction from the sector of fixed costs of around €9-14m assuming that fixed costs per vessel are €0.1m, and of around €18-28m assuming that fixed costs per vessel are €0.2m. Moreover, if it is assumed that catchability improves a lot in the future, according to the C options, the gain to the sector can be around €20m assuming €0.1m fixed costs per vessel, and €40m assuming that fixed costs per vessel are €0.2m. Only two of the scenarios (A7 and B7) suggest that there might be less reduction of fixed costs in the long term.

Figure 5.11 **Average reduction potentials per year (2009-2025) of total fixed costs (€m) from the sector with possible removal of vessels in various scenarios (A3, A4, A7, B3, B4, B7, C3, C4, C7). Fixed costs at €0.1m and €0.2m per vessel are included for comparison**



Source: Adapted from Machiels et al. (2009), ICES (2009) and Taal et al. (2009).

5.5 Potential gains for the remaining vessels

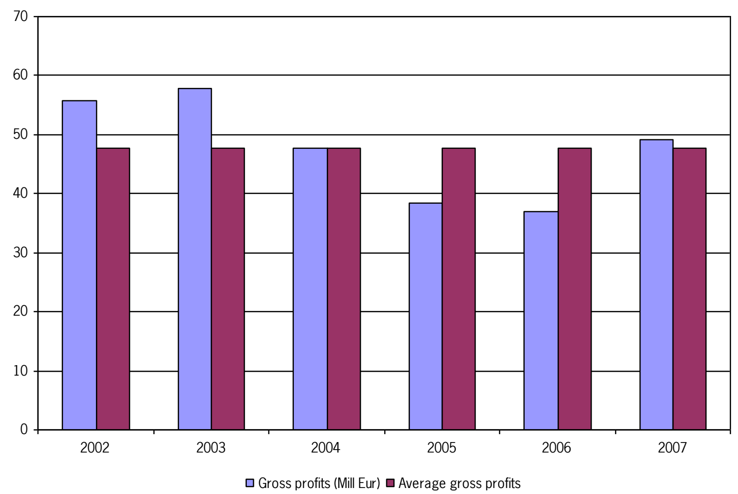
If a fishery sector has a positive gross profit, it is reasonable to think that if vessels were withdrawn, the profits earlier made by withdrawn vessels would be transferred to the remaining vessels. Thus, instead of looking at what happens to the sector with withdrawn vessels, we now look at what happens at vessel owner level. The gross profits are defined as total revenue minus total variable cost; in other words, profits plus fixed costs. The gross benefits of the withdrawn vessels will be experienced as extra profits for the remaining vessels. Hence, potential gains in profits per remaining vessel would be equal to formula (4.3):

$$\Pi_t / \text{Min}\ \Sigma X_t = [(\Sigma X_{2008} - \text{Min}\ \Sigma X_t) * (f_t + \pi_t)] / \text{Min}\ \Sigma X_t \qquad \text{(formula 4.3)}$$

Where:
- Π_t is the potential overall gains in gross profits of the sector
- ΣX_{2008} is the current number of vessels (=308)
- Min ΣX_t is the minimum number of vessels needed to harvest the projected future landings
- f_t is the fixed costs per vessel
- π_t is profits per vessel

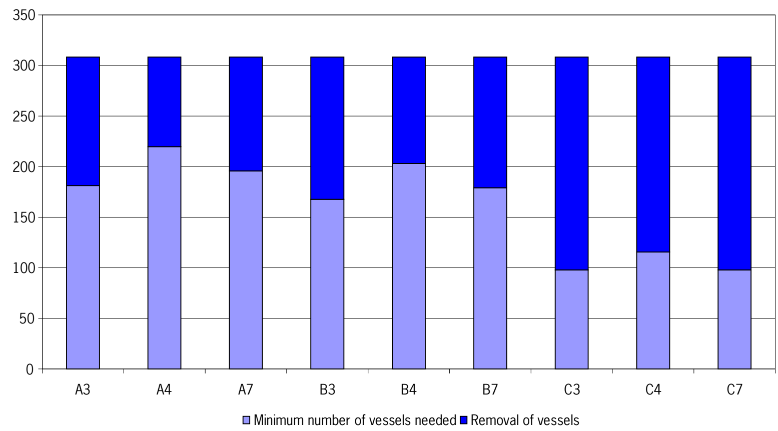
As shown in Figure 5.12, the average gross profits of the sector in the years 2002-2008 was €48m.

Figure 5.12	**Gross profits of the cutter fishery sector in the Netherlands in the years 2002-2008**



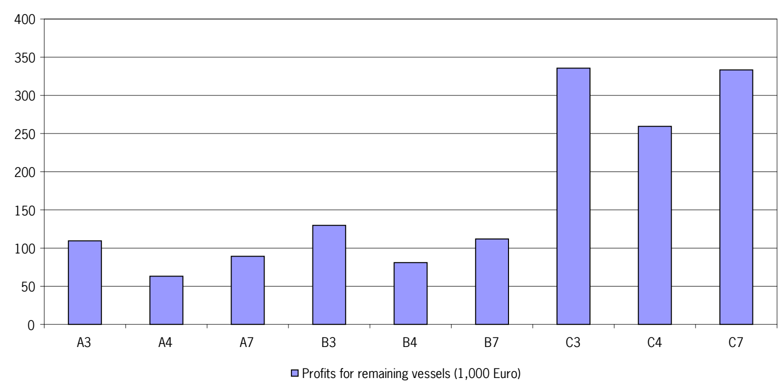
Source: Taal et al. (2009).

Figure 5.13	Average reduction potentials per year (2009-2025) of vessels as well as average minimum number of vessels needed in the sector under various scenarios (A3, A4, A7, B3, B4, B7, C3, C4, C7)



Source: Adapted from Machiels et al. (2009), ICES (2009) and Taal et al. (2009).

Figure 5.14	Earning potentials per remaining vessel as an average (2009-2025) under various scenarios (A3, A4, A7, B3, B4, B7, C3, C4, C7) (€1,000)



Source: Adapted from Machiels et al. (2009), ICES (2009) and Taal et al. (2009).

In the following we make some simplifications in order to arrive at an estimate of potential earnings for remaining vessels in the sector if vessels are withdrawn in accordance with the various scenarios. First, we assume that in the future there will be a net gross benefit of €48m, as this was the average over the years 2002-2007. The average gross benefit divided on the current level of 308 vessels gives a total of €0.16m per vessel.

In Figure 5.13 we show how many vessels would be needed to harvest the landings potentials as a yearly average under the various scenarios. In scenarios A3, A4, A7, B3, B4 and B7, it is suggested that around 200 vessels will be sufficient as an average over the years 2009-2025. In scenarios C3, C4, C7, however, it is suggested that even fewer vessels are needed: about 100 as an average over the years. It should be noted that the trends in the various scenarios over these years follow the trends in Figure 5.13, and that we here look at an average over the years.

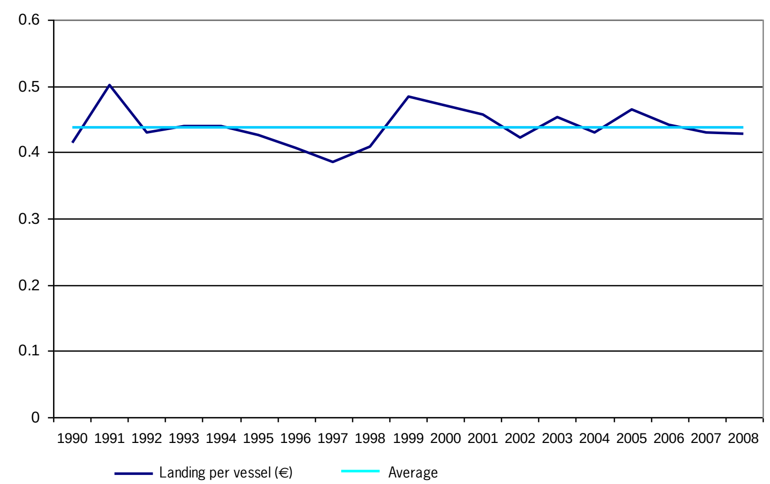
Figure 5.14 shows the average earnings over the years 2009-2025 for the remaining vessels under the various scenarios. As there are more vessels left in the first six scenarios (A3, A4, A7, B3, B4 and B7), the potential average earnings per vessel per year is lower than for the last three scenarios (C3, C4, C7). Whilst for the first six scenarios the potential earnings per vessel per year would be between €70,000 and €140,000, the potential average yearly earnings for the last three scenarios would be between €250,000 and €350,000 per vessel.

5.6 Future number of vessels at break-even

In this section we want to find out how many vessels could be involved at a maximum, given that the sector is at break-even, implying that total costs equal the value of the projected future landings. This is relevant information if the political aim is to preserve employment in the sector, or to make use of existing vessels that cannot be used otherwise and at the same time advance the sector with new vessels that have improved fishing technology. Then the policy makers will know, for example, whether it is relevant to support the sector by facilitating new investments. It can also be relevant information as it shows what could happen in the future without any policy interventions, comparable to an open access situation.

In this exercise, we start by looking at the value of total landings in the past (see section 5.2), which were shown to be close to a break-even situation in section 4. We divide the value of total landings by the existing vessel in the past to find the value of landings per vessel. This is shown in Figure 5.15, along with the average landings per vessel during these years, which was €438,000 per vessel.

Figure 5.15	Value of landings of plaice and sole (€m) per vessel in the years 1990-2008, as well as the average of these values of landings



Source: Taal et al. (2009).

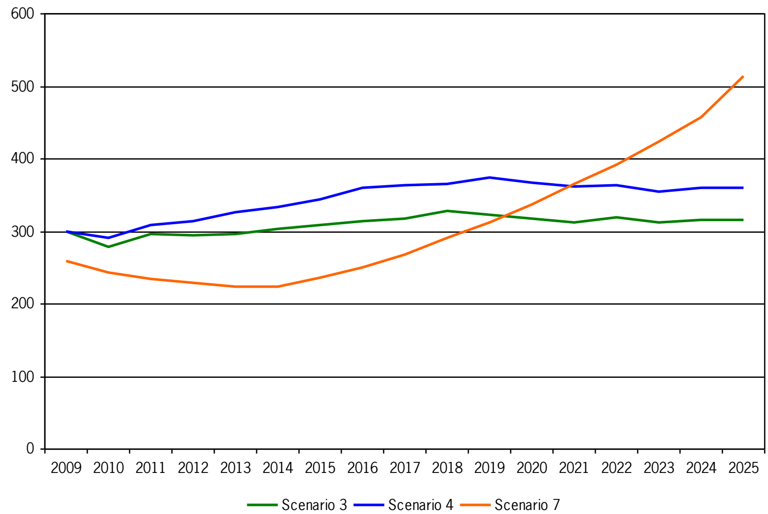
We now want to find the maximum number of vessels that can operate at break-even in the future, based on what we have observed in the past. Thus, the maximum number of vessels can be found by the following formula 4.4:

$$\text{Max } \Sigma X_t = V_t / v_t \qquad \text{(Formula 4.4)}$$

Where:

- Max ΣX_t is the maximum number of vessels at break-even to harvest the projected future landings;
- V_t is the projected future landings, based on section 5.2;
- v_t is the projected future landings per vessel at break-even, which are based on observations made in the past (v_t=0.44, see Figure 5.15).

Figure 5.16 **The maximum number of vessels to reach break-even in the future, given that the cost structure is similar to that in the past**



Source: Taal et al. (2009).

Based on the three selected scenarios about projected future landings of plaice and sole, and estimated values of these landings, we can see in Figure 5.16 that a maximum number of vessels at break-even will in options 3 and 4 be around 300 to as many as 360 vessels, whereas in option 7, with different assumptions about stock dynamics, it is possible to have more than 360 vessels after 2021. However, this will mean that the catches in the years 2009-2020 will need to be reduced to allow the stocks to grow.

Note that it is assumed here that the cost structure will be similar to what it was in the past, and this may not be the case. For example, if the fuel price increases a lot, fewer vessels than what we estimated in Figure 5.16 will be able to continue at break-even.

5.7 Summary

In this section, we addressed the second main objective of this study, namely to estimate future fishing capacity under various scenarios. After providing relevant background information, we addressed four research questions.

1. What is the minimum number of vessels needed to harvest projected future landings? We have shown that the total number of vessels needed to harvest future stocks of plaice and sole will most likely be only about 150-250 vessels. With very technologically efficient vessels and larger stocks providing the potential for more than doubling the harvest per vessel in 2024, the minimum number of vessels will be 60-130 vessels - a lot fewer than in the past.
2. What are the potential gains in profits for the sector with a reduced number of vessels, as overall fixed costs will be reduced? A reduction of the fleet to 150-250 vessels will imply an average yearly reduction of fixed costs of around €9m - €14m (assuming that fixed costs per vessel are €0.1m).
3. What are potential gains in profits for the remaining vessels, as the fixed costs and profits of the withdrawn vessels will be replaced? The potential earnings per vessel per year will be between €70,000 and €140,000 over the years 2009-2025.
4. What is the maximum number of vessels required to harvest projected future landings at break-even? Under the scenarios with the most probable assumptions about stock dynamics, we have estimated that the maximum number of vessels needed will be around 300 to as many as 360 vessels.

6 Future research

This study provides a first step in thinking about the optimal size of the Dutch fleet and the economic gain a reduction of the fleet will have for the remaining vessels, which could be considerable as this research shows. The assumptions set in this exercise on prices, fish stocks and technology development are basic to the various scenarios. Because of all these assumptions, this study must be seen as a theoretical exercise which is primarily focusing on long term trends. The exercises show some indications to be considered in future research, although more research would be needed for specific policy advice. Based on this first step, there are many possible directions for future research.

First of all the relationship between the status of the stocks and the fishing opportunities was assessed in a rather simplistic manner, by means of three different scenarios: constant landings per vessel, slightly increased landings per vessel and highly increased landings per vessel. As stated, these increases in maximum landings are driven by both the developments in fish biomass and fishing technology. Although it has been stated that some of the scenarios were less probable than others, because of predicted developments in fish stocks, the relationship could be worked out further. With respect to fishing technology, many developments have seen the light in recent years, as the fishery sector is now faced with large challenges related to the increase in fuel prices, decreases in fish prices and the pressure from NGOs to switch to less bottom-damaging fishing methods. Scenarios with relevant different vessel sizes and technologies would therefore be of interest to involve in follow-up studies. While we looked at possibilities for catchability linked with technology levels assuming a relative distribution of vessels similar to the current one, this could be specified for which gear types the technological developments would be relevant. Such specific information would involve more details about future technology development for specific gears and would require more research.

The scope of this study was limited by only looking at plaice and sole as target species for the beam trawl fisheries. Although these species are very important for this fishery, their importance has decreased because of changes in targeting behavior. Because of the decreasing TACs fishermen have increasingly sought other fishing opportunities and found these in non-quota species like mullet and gurnard. Thus, in order to obtain better estimates of the optimal fleet size, the fishing opportunities for these species could also be taken into account, probably increasing the number of vessels needed.

Although we applied the DEA analysis in parts of this study, more possibilities exist. For example, we could link the removal of vessels to the efficiency scores obtained as a part of the DEA analysis. By removing less efficient vessels from the fleet, it may be possible that the stock can be caught with even fewer vessels than stated in this study. Introducing a link between the DEA analysis and the fleet calculations would certainly be relevant for future studies.

The DEA results could also help to include differences in cost structures between vessels. Older vessels, for example, have on average more maintenance costs while younger vessels have more depreciation and interest costs. Reducing the number of older vessels will change the cost structure of the fleet and thus perhaps the potential profits.

Also, more focus could be given to the uncertainties that may influence future prices of sole and plaice, including the appearance of cheaper competeing aquaculture species in the sole and plaice markets. In addition, there are many uncertainties regarding climate change and acidification of the seas. If conditions for the fish species worsen and fewer fish become available, the future prices may increase.

Although the estimates of vessel withdrawals in this study can be seen as a theoretical exercise, we have illustrated that optimal future capacity level is much lower than the current level.

An issue not addressed in this study relates to the structural adjustment process that would be needed to make the suggested changes in the sector. In practice, if a restriction were set on the number of vessels in the fishery sector, the remaining vessels would soon develop the technology required to harvest larger amounts per vessel, and the result could be just as much technological capacity as possessed by the current number of vessels, although it would be distributed among fewer vessels.

An important question is: what kind of fishery do we want in the future? Is it optimal from political and social point of views to develop a sector with only a few, efficient vessels? If so, we would possibly be faced with a problem of malleability, namely that the existing vessels and the related investments would be lost for those vessels leaving the sector, as this technology cannot be easily adapted to other sectors. Moreover, fishermen invest money not only to earn a living, but also to maintain their lifestyle. To move capacity out of the fishing sector into other (maritime) sectors would be a real challenge.

These factors might be seen as limited short-term problems, but they will require the long-term development plan to be clear and optimal from environmental, technological, economic and social perspectives, as large structural changes will be costly in the short term. It would be relevant to do a stakeholder survey about what the current perceptions of a future fishery sector are in the Netherlands. Moreover, it would be interesting to estimate total costs related to possible structural changes of the sector.

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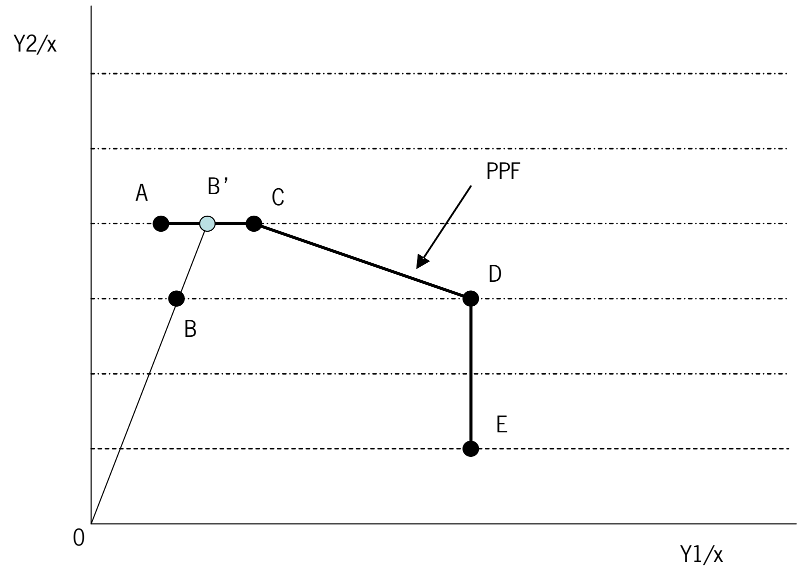
Appendix 1

The DEA Analysis

In section 4 we applied a standard tool for evaluating the available capacity and potential output in the fleet is data envelopment analysis (DEA). DEA methodology uses information on physical inputs to provide multi-output distance functions/frontiers to determine how these inputs relate to the capacity level of output. With the help of a DEA analysis it can be determined what the overall efficiency level of the fleet is and what factors contribute to a less than optimal production.

DEA estimates the degree to which vessels are performing relative to other vessels using similar amounts of inputs. The capacity of a vessel can thus be determined as the maximum level of output that could be expected under normal circumstances. A vessel operating below its capacity level, due to an underutilisation of fixed inputs, inefficient use of its variable inputs or a combination of these two, can be considered technically inefficient. Differences in efficiency levels may be caused by the skipper effect, age of vessel, differences in navigational aids, et cetera.

Figure A1.1	Production frontier in a two output example



Source: Coelli et al. (1999).

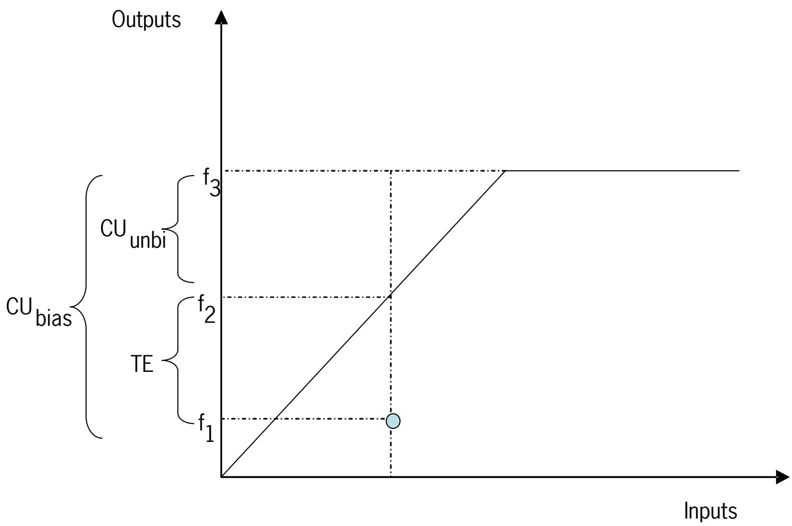
Figure A1.1 shows the idea behind DEA. Consider an example with two output y1 and y2 and one input x. In this example there are 5 firms, A to E. Firms A, C, D, E are considered efficient firms; the output of these firms forms the production possibility curve (PPF). Firm B is inefficient; its output could be increased to B' given its input of x. In this case, firm B is compared to both firm A and firm C; these firms are considered to be the peers of firm B.

The distance between B and B' is a measure of the technical inefficiency of firm B., that is, the amount by which the output of firm B can be increased without requiring extra input. Coelli and colleagues (1999) define the technical efficiency score of an output-oriented DEA model as the ratio 0B/0B'. For example, an efficiency score of 0.80 indicates that outputs could be increased by 25% (1/0.80) whilst keeping the inputs at their current level. An efficiency score of 1 represents a firm that is technically efficient and thus on the production possibility frontier.

Technical efficiency and capital utilisation

There are basically two measures: technical efficiency and capital utilisation. The measure calculated depends on whether it is assumed that variable inputs are fixed or allowed to vary in the model. The concept and difference between technical efficiency and capital utilisation is further explained in Figure A1.2. Consider a firm that is producing inefficiently. If the inputs were kept constant at their current level, this firm could produce f_2 outputs instead of f_1. However, by increasing its variable inputs, the firm could actually increase its output to f_3. The technical efficiency in this case would be equal to f_1/f_2 since the inputs are kept constant. The capital utilisation would be equal to f_1/f_3, namely the ratio between actual and maximum obtainable catches. The unbiased capital utilisation measures only how much the output can increase if the inputs are used in a technically efficient manner and are calculated by f_2/f_3.

Figure A1.2 **Technical efficiency and capital utilisation**



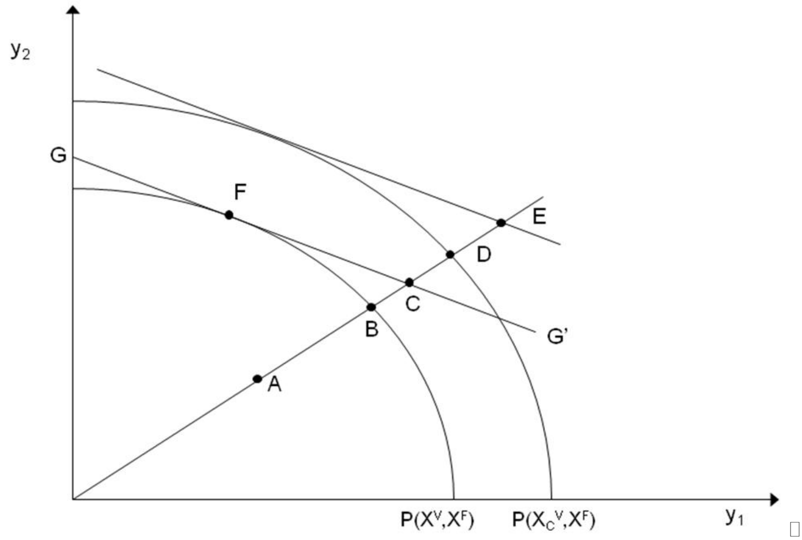
Source: Coelli et al. (2002).

Efficiency scores and idleness

There are two dominant approaches to defining the potential output: the technological approach (as explained above) and the economic approach. The economic approach is based on the concept that the maximum potential output should take into account maximising profits, as fully using available capital will not necessarily lead to maximum profits. Coelli and colleagues (2002) showed that it is almost always optimal for firms to have some idle capacity. Idle capacity in general can arise because of indivisibilities in inputs (i.e. fixed inputs), a fluctuating demand for an existing product or uncertainties in the expected demand for an existing product. Idle capacity is of great importance to investment decisions as a large amount of existing idle capacity can be used to diversify in other products, without investing in new capital.

Simple two-output example of the economic efficiency measures
Suppose there are m firms that produce two outputs y1 and y2. $P(x_v,x_f)$ illustrates the production curve if vessels are operating on a technically efficient level. The technical efficiency indicates whether vessels are producing optimally with both keeping fixed inputs and variable inputs at their current levels. $P(x_c^v, x_f)$ illustrates the production curve if vessels are operating on capital utilisation maximising level, which indicates whether a vessel is operating at full capacity while only keeping its fixed inputs at its current level. Vessel A produces a level of output y1 and y2 that is clearly inefficient. This vessel should be able to produce at a level B is it was operating at a technically efficient level. If vessel A was maximising its capital utilisation it would even be able to produce at level D. To test whether a vessel is operating on the economic efficient level we need to determine whether the vessel is maximising the short-term profit. To do this we add a slope determined by the prices of the two outputs G' (-p1/p2) to Figure A1.3. Point F represents the point where a vessel is operating in a technically efficient manner and is also maximising its short-term profits. However the output mix is changed at point F. If it is assumed that the two outputs are linked and the outputs can only be radially expanded, the economic efficient technical output would be equal to point C. The same analysis can be done for the capital utilisation. A vessel maximising short-term profit and operating at capital utilisation level would be able to produce at level E. Point E represents the economic capital utilisation. In the remainder of this paper this will be shortened to economic capital utilisation.

Figure A1.3	A two-output example of efficiency scores



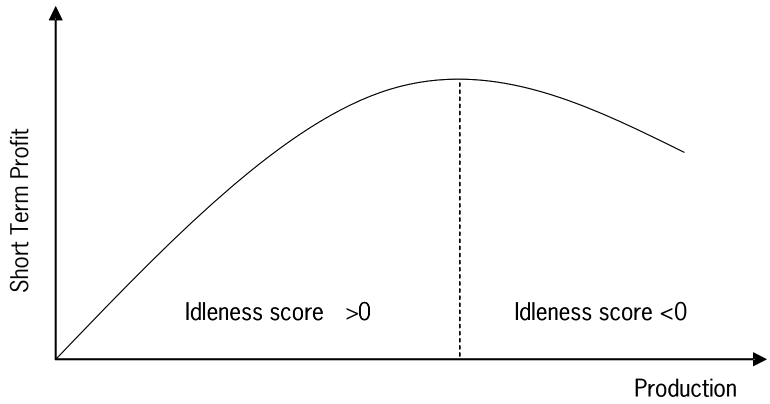
Source: Coelli et al. (2002).

Optimal level of idleness

The idea of optimal idleness of capital is hinged on the idea that the short-term profit curve is downward sloping. Up till a certain point it will no longer be beneficial to increase production as the marginal costs of producing an extra product exceed the profit gained from it. This idea is shown in Figure A1.4.

A firm with an idleness score of unity should use its capital to the fullest extent. A firm with an idleness score of less than unity will earn more short-term profit by decreasing production.

Figure A1.4 **An illustration of idleness scores**



The optimal level of idleness is defined as the ratio between the optimal production considering economic capital utilisation and the optimal production considering capital utilisation.

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